Design of Transformative Education and Authentic Learning Projects: Experiences and Lessons Learned from an International Multidisciplinary Research and Education Program on Flood Risk Reduction

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Abstract:

As there is increasing emphasis on transformative education and authentic learning in interdisciplinary research projects, it is meaningful to investigate how to effectively design a multidisciplinary research and education program to ensure beneficial outcomes for participating students. This is especially important for ocean and coastal engineering programs that are likely the most multidisciplinary engineering programs.

The *NSF PIRE Coastal Flood Risk Reduction Program* is an international place and problem-based research education program in which students conduct case studies across the Houston-Galveston metropolitan area in the U.S. and in the Netherlands. There are three to four designated case studies (place-based) annually in each country, covering both surge-based and precipitation-driven flood problems (problem-based). From 2016 to 2018, there were three student research trips to the Netherlands (one each year, after the spring semesters). A total of 42 U.S. students, graduate and undergraduate were selected from four participating U.S. campuses apply for a designated Dutch case study. The three to four case studies change every year. Students from diverse disciplines, including engineering, planning, economics, hydrology, biology, architecture, geography, communications, and computational hydraulics, interested in flood risk reduction can apply. Those accepted into the Program are placed in interdisciplinary research teams composed of 5-6 students: 1-2 PhD, 2-3 Masters, and 2-3 undergraduate students. The teams are guided by project faculty mentors from both U.S. and Dutch partner institutions. A two-week long research trip to the Netherlands provides transformative education and an authentic learning environment through field trips, meetings with Dutch flood experts, lectures, and participation in design workshops. Students are required to present their research work three times while they are in the Netherlands: 5-minute research plan; 10-minute research progress; and 15-minute final presentation. By preparing these presentations, students learn how to collect data, interview stakeholders, lead/participate in brain-storming discussions, and adjust/improve their research products. Students also learn how to interact with people from different disciplines and look at the issues from diverse perspectives.

This article describes the design process of the Program, from initial development through implementation. Reflections and lessons learned from the first three years of the Program are shared.

Introduction

As integrating research and education takes on increased importance in interdisciplinary research projects, it is vital to have better guidance on designing such programs, grounded in actual experiences. The Partnership for International Research and Education (PIRE) is an NSF-wide program that supports high quality international multidisciplinary projects to facilitate development of a diverse and globally-engaged science and engineering workforce. International collaboration is inevitable to advance both research and education together.

Sponsored by NSF, PIRE Coastal Flood Risk Reduction Program is one such international multidisciplinary research and education project. This 5-year binational study – between the U.S. and The Netherlands – involves a synergistic set of different academic backgrounds and techniques such as engineering, hydrology, landscape architecture, economics, and planning, to mitigate flood risk in the U.S., especially in the Houston-Galveston metropolitan region in Texas, by benchmarking successful cases in the Netherlands in which there are some of the worlds' best practices for flood mitigation strategies. Since it has become clear that the rising cost of floods is not solely a function of changing weather patterns or a problem that can be solved through engineering solutions alone, flood risk and associated losses can only be understood and eventually reduced through integrated investigation across multiple disciplines, cultures, and international boundaries. Thus, the approach of this program entails combining physical and social science data, methods, and analytical techniques to form a more comprehensive understanding of flood risk. An integral part of the Program is the educational component: integrating research and education, where interdisciplinary teams of students with diverse academic and cultural backgrounds conduct problem-and-place-based research within designated case studies related to flood risk reduction. The primary goal of the Program is offering "transformative education" to the participating students by creating "authentic learning environments" that both support and benefit from the research components.

This article describes the process of designing the educational component of the Program, including its development and implementation. Reflections and lessons learned from three out of five years of experiences (2015-2018) are shared.

Literature review

1. Transformative learning and education

Transformative learning is understood as a process of change in a frame of reference and it is achieved when the transformation occurs as a result of experience or through a perspective transformation (Mezirow, 1997, 2003; Strange & Gibson, 2017). According to Mezirow (1997), frames of reference indicates the structure of assumptions which forms one's habits of mind and a point of view - perspectives. These fixed assumptions constitute a set of codes that can be influenced by cultural, social, and educational environment of individuals. In this sense, transformative learning is vital in the applied field of ocean and coastal engineering education to make students have various perspectives to see a real-world problem such as flooding. In addition, by changing students' frame of reference, transformative learning allows them to grow core competencies such as analytical thinking, communication skills, collaborative work, and global understanding (Strange & Gibson, 2017).

One way of providing a transformative learning opportunity for students is to present them with a challenging problem in an unfamiliar environment that can provoke unusual process of seeing, doing, or thinking out of their comfort zone (Perry III, 2011). Since a perspective transformation is achieved through altering meaning structures that are culturally required, even short-term abroad experiences can result in transformation when combined with strong academic content (Bell, Gibson, Tarrant, Perry III, & Stoner, 2016). Another premise to ensure changes frames of reference is direct intervention of educators to help students develop insights on the different perspectives and encourage participation in a critical-dialectical discourse. These attributes are crucial to constructing a new perspective (Mezirow, 2003).

The importance of transformative learning in education is gaining more support with the increasing importance of multidisciplinary approaches to address natural and societal challenges, such as flood risk reduction that cannot be solved solely by single engineering solutions alone.

2. Authentic, problem-and-place-based learning

Authentic learning exposes students to multidisciplinary problem solving and critical thinking, which are necessary skills to becoming a proficient researcher or expert.

Traditional classroom environments have been criticized for not providing essential contextual features that enable students to understand and apply information (Schmidt, 1993). As a response to these

criticisms, a new form of education called “authentic learning” is gaining prominence (Nicaise, Gibney, & Crane, 2000). Authentic learning involves learning based on real-world problems that are closely related to a specific field of study (Herrington, Reeves, & Oliver, 2014). This approach to education is grounded in the notion that learning occurs when students are presented with problems and situations that represent genuine complexity. In turn, students with their experiences are better prepared to solve real-world problems once they leave the classroom environment and enter professional arenas.

Unlike conventional educational approaches where students are told what they need to know, authentic learning occurs when students learn through inquiry and discovery. Learning in this case is presented as an iterative process of discovery around an authentic task so that students gain problem-solving skills and confidence in their own learning abilities. Discourse is an essential feature of authentic learning environments because it helps students to construct hypotheses and test them against what they believe to be true. Debate and collaborative problem solving enable students to view knowledge and information from multiple perspectives. Furthermore, in authentic learning environments the role of the teacher changes from information provider and test-creator to learning guide and problem presenter. Because students regulate this process of learning internally, they are encouraged to think, explore, and become more reflective practitioners (Duignan, 2012).

A key application of an authentic learning environment is the use of problem-based learning (PBL) techniques. A greater level of responsibility, competency, and learning results when an authentic problem is shared by a team of students, and the goal of the course is to solve the problem collectively (Donnelly, 2006; Friedman & Deek, 2002). A central premise of PBL is linking theoretical knowledge to practical application through the use of collaborative groups in which students are responsible for deciding what is to be learned. The rationale for instructional strategies that encourage cooperation among learners is that such strategies more closely approximate the real world than traditional didactic approaches (Cockrell, Caplow, & Donaldson, 2000; Gallagher & Gallagher, 2013). Research on PBL has indicated that collaborative groups are associated with higher levels of student learning and critical reasoning capabilities. PBL provides constant, iterative practice of a logical, analytical, and scientific approaches to problem solving that yields effective reasoning skills. Foremost, PBL promotes the idea that nothing is ever learned to finality, that interdisciplinary learning coincides with solving complex interrelated problems, that there exists too much for any one person to learn, and that tasks need to be shared among students (Allen, Donham, & Bernhardt, 2011).

A major element of authentic learning and PBL is the use of collaborative groups to explore, analyze, and solve problems presented in case form (Cockrell et al., 2000). Three main characteristics of case studies make them an ideal strategy to facilitate authentic learning. First, a case is based on a real situation or event forcing students to think through problems they may encounter in the work place. Second, the case study is developed through careful research and study. Third, and most important, a case provides learning opportunities at various levels for those involved in the construction of the case as well as for those who may interact with the case (Wallace, 2001). In general, a well-crafted case anticipates scenarios that a learner might eventually face in situations that do not allow time for careful deliberation (Coppola, 1996).

PBL is unique because of its connection to place and the analysis of case studies. Place-based education uses the principles of authentic learning and applies them to a particular spatial setting such as a floodplain or vulnerable community. Collaborative learning is geared to the local context where students can experience a specific problem first hand, how it affects their own lives, and the actions needed to address the problem. In these situations, students have the opportunity to produce rather than consume, teachers act as guides instead of solely instructors, and groups work together to develop a set of strategies for addressing an actual problem (Smith, 2000).

The principles of authentic learning have gained support not only in the academic education literature, but also in the national agenda on science education and research. In their report to the National Research Council entitled How People Learn, Bransford et al. (1999) lay out a design for effective learning environments comprised of four overlapping themes: learner-centered, knowledge-centered, assessment of support, and community-centered. These themes advocate educational programs where students are agents of knowledge, solvers of real-world problems, exposed to constant feedback from teachers, and develop a sense of community or place. The authors also recommend an educational approach that prepares a new generation of learning scientists by supporting interdisciplinary training where students and scientists work together. This collaboration between researchers, teachers, and students is critical to developing authentic learning environments and preparing future scholars and decision makers to address problems associated with pressing societal problems, such as flood hazards.

International multidisciplinary research education program design

1. Student field research travel

The NSF PIRE Coastal Flood Risk Reduction Program is a problem-and-place-based research education program designed to provide an authentic learning environment in which students find solutions to flood-related problems facing both the Netherlands and the Houston-Galveston metropolitan area in the U.S. In each year of the Program, there are six to seven designated sub-case studies (place-based), covering both surge-based and precipitation-driven flood problems (problem-based) in the two countries.

Each summer, the Program provides funding[1] for between 12 and 16 students to conduct intensive case study research in the Netherlands. Between 2016 and 2018, 42 U.S.- based students participated in the Program. Each year, 12 to 16 graduate and undergraduate students from participating U.S. campuses are chosen from a diverse applicant pool. Students backgrounds cover a variety of disciplines, including engineering, planning, economics, hydrology, biology, architecture, and computational hydraulics. Participating students are placed in interdisciplinary research teams composed of 5-6 students: 1-2 PhD, 2-3 Masters, and 2-3 undergraduate students, guided by project faculty from both U.S. and the Dutch partner institutions. Each research team is focused on once case study, which are varied from year to year. These annual two-week long research trips to the Netherlands provide authentic learning environments through field trips, meeting with Dutch flood experts, lectures, and design workshops. During the trips, students are required to present their research to the rest of the students and faculty mentors three times: 5-minute research plan; 10-minute research progress; and 15-minute final presentation. In preparing these presentations, they learn how to collect data, interview, lead/participate in brain storming discussion, and adjust/improve their research work.

Although when viewed from the outside, the Program may be considered as a short-term study abroad program, it is distinguished from other general study abroad programs with its own unique features. First, although participating students stay in the Netherlands for only two weeks, the entire program takes approximately 10 months to complete from application (pre-travel) to final paper and poster submission (post-trip). Table 1-3 shows the program timeline along with educational and organizational objectives. The detailed program contents will be addressed in the following section.

[1] Funding covers one round-trip flight and accommodation, meals, and transportation in the Netherlands. The expense information is available from author by request.

Table 1. Pre-Trip

Phase	Timeline	Phases	Educational Aspects	Organizational aspects
Pre-trip Application & Orientation	Sep - Nov	Application Phase #1	• Writing skills: one pager research-intention + CV • Knowledge increase: Get acquainted with general research location and local flood risk related issues	• Choose and describe case studies • Organize mentor team • Publish application information online • Select 25 students to write full proposal
	Dec - Jan	Application Phase #2	• Writing skills: full research proposal + letters from mentors • Knowledge increase: Get acquainted with specific case study location and local flood risk related issues	• Announce selected students • Organize accommodation and other local arrangements • Select final 16 students
	Feb - Mar	Application Phase #3	• Knowledge increase: international field work travel preparation	• Announce selected students • Scoping trip by mentors to case study locations: organize fieldtrips & experts, stakeholders, local partner institutions • Prepare student Orientation Day • Prepare mentor & student travel arrangements (tickets, visa)
	Mar	Orientation Phase #1	• Presentation skills: 1st individual presentation to multidisciplinary public (PIRE mentors and students) • Collaboration skills: meet with case study team, discuss different disciplinary case approaches • Knowledge increase: General overview of case study flood risk issues and cultural differences	• Student Orientation Day • Prepare students content wise, travel wise and culture wise for field research visit • Start full group- and case study team-bonding process
	Apr -May	Orientation Phase #2	• Knowledge increase: individual literature review • Collaboration skills: combine team literature reviews into one case study literature review	• Finalize travel preparations • Asses literature reviews

Table 2. On-Trip

Phase	Timeline	Phases	Educational Aspects
On-trip	May	Group Field visits (2 days)	• Knowledge increase: Firsthand experience Dutch flood risk approach (see & hear) • Practice place based research: Group field visits to all case study locations • Practice place based research: Meet, presentations & discussions with local experts and stakeholders
		Research meeting #1 (half day)	• Presentation skills: 2nd individual presentation to multidisciplinary public (PIRE mentors and students) • Knowledge increase: multidisciplinary perspectives on multiple cases
		Research time #1 (4 days)	• Practice place based research: Individual field visit to case study location • Practice place based research: Individual meetings & discussions with local experts and stakeholders • Knowledge increase: local & experts knowledge, desk research on research case study

		Bi-national multidisciplinary design studio (full day)	• Knowledge increase: presentation by local experts & stakeholders, design options • Practice place based research: field visit to design-assignment location, discussions with local experts and stakeholders • Collaboration skills: multidisciplinary team design assignment in bi-national student team • Presentation skills: group presentation of final design to jury of academic experts and local stakeholders
		Research meeting #2 (half day)	• Presentation skills: 3rd individual presentation to multidisciplinary public (PIRE mentors and students) • Knowledge increase: multidisciplinary perspectives on multiple cases
		Research time #2 (4 days)	• Practice place based research: Individual field visit to case study location • Practice place based research: Individual meetings & discussions with local experts and stakeholders • Knowledge increase: local & experts knowledge, desk research on research case study • Writing skills: Start writing research paper
		Research meeting #3 (half day)	• Presentation skills: 4th and final individual presentation to multidisciplinary group (PIRE students + local invitee experts and stakeholders, host university faculty and students) • Knowledge increase: multidisciplinary perspectives on multiple cases

Table 3. Post-Trip

Phase	Timeline	Phases	Educational Aspects
After-trip	July - August	Finalize	• Knowledge increase: finish desk research • Writing skills: Write research paper • Presentation skills: Produce poster
	September 1st		Students send in paper and poster

Second, the Program is distinctively customized to help participating students conduct individual research. Almost one third of the Netherlands experience is designated as “Research Time”, which refers to the time that should be spent for any research activities needed. The way this time is used varies for each student depending on the research focus and methods employed to answer their questions. Students may have meetings with Dutch experts, interview local stakeholders, collect observational data, discuss findings with their group members or faculty mentors, or just reflect and re-shape their research plans. Although students in one group work on the same case study area, each student examines the case through their own research lens to produce an individual report. In this sense, the Program is designed for students to conduct individual research, but in a group project setting. This technique gives them opportunities to learn from group members, not only to gain additional knowledge of the case study, but also experience a set of diverse disciplinary approaches to solving problems. This is where transformative learning occurs in the Program because it allows students

to develop their understanding of various issues with different perspectives and frames of references (Strange & Gibson, 2017). The transformative learning process is takes place when students prepare and present their research progress in aforementioned three research meetings throughout the trip.

2. Design process of the Program

To ensure the Program yields the most beneficial outcomes for participating students, it must be designed carefully with in-depth understanding of research topics and case study areas, as well as research education components. Also, determining how to effectively coordinate and organize content is one of the most important factors to achieve the educational goals of the Program. In this sense, the logistics part of the program design process is crucial to guarantee the best learning outcome.

In this section, the detailed design process of the Program is described in chronological order: Pre-trip, On-trip, and Post-trip, accompanied with expected research educational effects and organizational tasks of each stage.

2.1 Pre-trip

Case study selection and program announcement

As shown in Table 1, the program design for the upcoming summer begins by selecting three to four Dutch case study areas in September, followed by the program announcement which provides the information of these areas with related local issues and examples of flood risk reduction research topics and questions. At this stage, faculty mentors within the different participating disciplines (e.g., engineering, social science, hydrology, landscape

cdesign) participate to make sure their expertise and research interests are reflected within the suggested research topics and questions.

Once the application is published online[2], program coordinators advertise it through various routes: campus emails, social media, and presentations in classes. The application process is designed to encourage students to read the description of the case study areas carefully and investigate the case on which they intend to work, and to be able to write a letter of intent (LOI) and research plan. In this way, students become acquainted with the general research location and local flood risk-related issues at an early stage of the Program.

[2] http://www.tamug.edu/ctbs/PIRE/application.html

Two phases of application process and review standards

The application submission to the Program is similar to that of many competitive NSF grant proposals: Submission of LOI (pre-proposal) and research plan (full proposal). In writing their LOI, students are asked to describe why they prefer a given case study, what their research questions are, how their background and research interests can contribute to the case they intend to work on, and how they expect this program influences their current research or future career.

Applicants are also required to submit their resume or CV along with the LOI as supporting evidence for their research focus. During the review of LOI, program coordinators may redirect promising applicant to work on another case study or ask them to modify their research questions if needed.

Based on the LOI, the review committee consisting of senior faculty participants from each institution and the program coordinators selects 25-30 students. The selection of the first phase of application is announced around the end of fall semester (mid-December). Selected students are then asked to submit a 900 to 1,000-word Research Plan. Typically, they have at least one month to complete and submit their full research plan.

For the second-round review of the 25-30 research plans, reviewers focus more on whether following factors are identified: specifics on methodology to answer the proposed research questions; data sets needed and how they are to be used; possible sources for those data; and chances to apply the expected results in the United States for flood risk reduction (i.e., potential for translational research). At the same time, coordinators start to plan how to best support these students, such as exploring experts and organizations according to the research questions.

Once the final review is completed by the committee, program coordinators rank research plans and sort them by academic levels (undergraduate, Masters, and PhD). As for the final selection of 16 students, the balance among disciplines and institutions as well as recommendation letters are also considered.

Over approximately four months (from program announcement in October to research plan submission in January) of application process, students are expected to receive some educational benefits even though not every applicant end up being accepted. First, students are exposed to the information of case study areas in the Netherlands. We found some of our previous participating students had not even been aware of flood risk issues in the Netherlands or even if they had known or heard of, never looked into it closely before until they learned the Program. Second, students acquire a certain level of writing

skills when they prepare LOI and research plan. Most of the undergraduate students have no experience writing an LOI or research plan (proposal). In addition, few, if any, undergraduate students have experience conducting research and this lack of experience makes them struggle to articulate the intention of their research. To overcome this issue, students look for information how to write LOI and research plan through meetings with their advisors or mentors, visiting school writing center, or getting help from editors. Unsuccessful applicants are encouraged to apply the following year again. Often, there are considerable improvements between their first and second applications.

When the selection process is finalized, the program coordinators carry out a scoping trip to the Netherlands in early March to visit case study areas and have meetings with partner experts and organizations. The ideas and plans for field trips and lectures are discussed to ensure students get proper support for their research in the Netherlands. Also, we found that the preparatory meetings on scoping trips help to make the actual student visit in May more effective. During the scoping trip, program coordinators finalize the details of the daily schedule for the two weeks of the research trip and make plans of who, what, and how each student's individual research can be assisted based on the information contained in their research plan.

Program orientation

The final selection is announced around mid-February and the program orientation is typically scheduled for mid-March. Attendance is mandatory for all participating students. It is stated on the application form that program orientation is an essential part of the research travel and everyone is required to attend once selected. The program orientation is critical in that it includes not only information on logistics but also provides students with the chance of in-person meeting with their cohort, faculty mentors, and program coordinators. Throughout the orientation, students get information on research topics and disciplinary expertise from others, which facilitates future research collaboration. In this sense, the orientation is considered as the first step of group research activities by getting familiar with other participants.

A day-long orientation covers several important topics that participating students must be aware of before the actual trip: roundtable introduction with each participant's research topic and group discussion; introduction of case study areas and flood risk reduction in the Netherlands; travel logistics; daily schedule of two weeks in the Netherlands; and a short lecture to help students understand cultural differences the Netherlands.

After the orientation and before they leave for the Netherlands, students are required to submit a literature review and an updated research plan. Also, we ask PhD students to host virtual group meetings with available faculty mentors to regularly update the group members' research progress. In this way, students maintain research activities during the two months between the orientation and the actual research travel. In addition, students are expected to look for Dutch experts or organizations with whom they hope to meet on-site. Program coordinators provide email templates that students can use to contact the experts.

While preparing their literature review, students also identify experts and institutions that they may want to engage with and learn how to contact them in a proper way. Also, as the orientation offers chances to communicate with the cohort and mentors through virtual meetings, students are encouraged to interact with each other and brainstorm on their common case study area. In addition, PhD students get a chance to guide the masters and undergraduate students in their group as a group leader. For example, PhD students organize virtual group meetings and share key literature with other students. Masters and undergraduate students learn how to find relevant literature effectively and how to write a literature review for their research.

2.2 On-trip

Field trips and lectures

Field trips and lectures are usually scheduled for first two to three days of the travel to provide students with an opportunity to observe actual Dutch flood risk reduction strategies in person and to give some time to get adjusted overcoming jet-lag, icebreaking with the cohort, program coordinators, and faculty mentors. Field trips include visits to not only given case study areas but also representative Dutch flood prevention structures, research sites, and organizations such as storm surge barriers, Sand Engine, Waternet, and Rijkwaterstaat. At each field trip location, students get chances to listen to Dutch experts on topics ranging from a short introduction of the area to full lectures of general Dutch flood risk reduction strategies.

As noted in the National Research Council report (2014), the Dutch are considered the world leaders in flood risk research, education, and mitigation strategies. Through these field trips and lectures, students personally experience what they have read or heard of so far. They learn from Dutch experts and local stakeholders who are at the heart of the matter in the Netherlands. Students start to realize how Dutch and U.S. flood risk reduction strategies are different. This is where a frame of reference begins to be

created by moving from ethnocentrism and dualistic epistemologies and learning a new perspective to approach the issue (Bell et al., 2016).

Three research meetings and presentations

Initial research meeting: Field trips and accompanied lectures give students an authentic and place-based impression of Dutch flood risk reduction strategies. They are challenged to implement this new information in their research plans that were made up initially, and sharing their new insights with their fellow students during research meetings. The first research meeting occurs on the 3rd or the 4th day after field trips. The entire group including students, faculty mentors, and program coordinators as well as available Dutch experts attend this meeting and students introduce their updated research plan in five minutes, no presentation slides or graphics required. Students address their research questions and why those research questions are meaningful. The main purpose of this meeting is to help students narrow down their research questions to be answerable and feasible to be examined within limited time frame. At this stage of the Program, not many students have specific ideas for methodology or data to use for their research. By sharing the initial research plan, mentors and program coordinators can guide them to be on the right track and students themselves make their research questions clear. Based on the discussion from the initial research meeting, program coordinators and attending Dutch experts come up with names of professionals or organizations that can provide advice or data for students.

Through the initial research meeting, students learn and practice how to be succinct introducing their research plans without visual aids and present them in a comprehensible way for people who have different academic levels and disciplines than themselves.

Research progress meeting: The research progress meeting is scheduled in the middle of the trip. Students present their adapted research question and plan, including the plans for the final week in the Netherlands. The purpose of this meeting is to see whether the students' work is on the right track and to help if they have any problems and concerns continuing their research. We found that this meeting works as a tipping point to accelerate research development through intensive brainstorming and discussion with the cohort and guidance from the mentors and experts. The major educational goal here is to make students clearly understand and address "what is your research question (problem statement); why is your research important or meaningful (significance of the research), how to answer these questions (methodology)" in ten minutes with no more than five presentation slides.

We have observed many students struggle addressing their research questions properly at the early stage of the Program. There are three common issues students have as for research questions: 1) They suggest too broad or vague research questions; 2) address too many and too much diverging research questions to be answered within the given time; and 3) construe research questions in a declarative sentence. The first issue occurs more often among undergraduate students while the second one is for graduate students. The last one is a common issue for both undergraduate and graduate students. It is speculated that many students, even the PhD's, have not had a chance to properly learn what a research question is. It was a contentious topic among faculty mentors and program coordinators whether we should give students a lecture regarding conducting research at the orientation to save their time to figure out the way to conduct research effectively. However, we have reached a consensus that this struggle is also a part of their learning process. We therefore intend to guide students to find their own ways to get to the 'A-ha' moment through intensive discourse led by faculty mentors in the research progress meeting. According to Duignan (2012), discourse is an essential feature of authentic learning environments because it helps students to construct hypotheses to test. Also, through debate and brainstorm that occur in the discourse, students are encouraged to talk, think, and explore their research topics. Faculty mentors play an important role here as a guide rather than a simple information provider, leading students to the path but not directly indicating the destination. In addition, not only faculty mentors and experts guide students but also peer students are great teachers to each other. Due to the group setting based on case study areas, students interact with their group members more often than with students in the other groups. However, in these research meetings, students are exposed to what other groups work on and get a chance to learn diverse perspectives from the other multidisciplinary groups. Students then share information and ideas that can help the other students' research. Through this process, students get inspired by their peers and learn from each other.

Although every student moves forward with different speed, most of them manage to figure out one specific research question in the research progress meeting with the help of discourse with faculty mentors and other students. Through the research progress meeting, students learn what a research question is and how to make it specific and articulate to be able to answer it. Based on that, they concrete the plan to answer those questions – methodology part. Mentors can suggest additional relevant literature, certain data and data sources, analytic models and programs, or meeting with specific experts. The majority of students answered in the after–program survey that they find the research progress meeting significantly helpful to make their research specified. We have observed this

meeting clearly plays an important role to make students delve into their research in the latter part of the research travel.

Final presentation: The final presentation is the last official schedule of the Program in the Netherlands. Students are supposed to present for twelve minutes. The presentation includes a problem statement, research question(s), methodology, and analysis if they have done any, research activities and progress made while they were in the Netherlands, and the plan for research completion for three months before submission. As mentioned earlier, students are required to finish their research work and submit a report and poster by the end of summer, August 31st (the research travel is completed at the end of May). In this sense, the final presentation is not for presenting their final results but it can be considered as a follow-up of the second research progress meeting to get comments and advice for the rest of the research. Just like the research progress meeting, faculty mentors give students guidance indicating a certain direction and, if needed, narrowing down the scope of the research so students can complete their work in time. The final presentation is held in the form of more a more official event compared to the two preceding meetings. Students are encouraged to invite all the experts, stakeholders, students, and others they have communicated with in the Netherlands in the two weeks before. Program coordinators issue an official invitation to pertinent people and organizations. This way, students get comments and advice from diverse perspectives, and their effort and commitment is appreciated by a larger audience as well. It is essential to ensure that students feel they have accomplished and achieved goals at the end of the research travel in the Netherlands.

Through the final presentation and its preparation, students learn and practice how to present their research work concisely within a given time to a group of people with diverse cultural and educational background. This process also helps students cultivate the right attitude as a researcher, being open to different opinions than their own and accepting constructive criticism since the final presentation is an assessment for their work in a way. This characteristic of the final presentation influences their work ethic and motivation.

Research Time

After the initial research meeting, students get “Research Time” in the schedule on multiple days throughout the travel. The research time takes up more than one third of the time spent in the Netherlands. Students are to use this time for any activity needed for their research with a certain level of leeway. Students use this time for shaping up their research plan based on the comments and advice

that they get from the initial and progress meeting. Some students have meetings with experts or visit case study sites individually for additional observation. This time can be also used for data collection and meetings with stakeholders, faculty mentors, or group members - basically any activities needed to further develop their research project. With this autonomy, each student ends up having a different schedule during the research time in the Netherlands. They are required to share their individual schedule with everyone using an online spreadsheet, so that program coordinators can secure students' safety by being aware of each student's location and on the other hand, students check each other's schedule and may team up for site visit or meetings with experts. Besides, students feel obliged to use this research time more effectively when they find the other students do so.

The research time is essential part of the Program to give students opportunities to immerse themselves in their research. We have observed that the research time between the initial and progress meeting is mainly used for meetings with experts, interviewing stakeholders, and case study site revisit, while the research time between the progress meeting and final presentation is for data collection, meeting with faculty mentors, and desk work to organize information and knowledge they have acquired so far for the final presentation. Also, the research progress that students make in the latter time is significantly greater than the former one. There can be multiple different factors causing this difference and it is speculated that the intensive discourse which occurs in the research progress meeting helps students expedite the process of moving forward significantly.

Multidisciplinary design workshop and meeting with Dutch students

Collaborative design workshop is a one-day long multidisciplinary research activity taken place on the actual project location of innovative flood protection projects on the Dutch coast. The U.S. student group collaborates with 10 to 15 students from several Dutch universities representing multiple disciplines. The design workshop starts with consultation with local stakeholders and local experts. Thereafter the students are split into a couple of multidisciplinary bi-national teams consisting of 5 to 6 members to collaborate on an actual design to address the complex flood risk related problems presented to them. The workshop provides an authentic learning environment to the students with given existing flood issues in the local area and collaborative problem-solving process. Two extra learning aspects are included in the workshop: 1) The students get introduced to the typical Dutch approach – a specific design-concept (Building-with-Nature), which they are required to incorporate in their design. This change of perspective stimulates transformative learning (Mezirow, 1997); 2) The students learn about different roles of experts representing diverse disciplines. They are informed about

four different roles and find out which role the most fits them thtough a self-assessment. During the workshop, they practice various roles and experience the culturally different interpretation of these roles with Dutch and U.S. participants.

One of the learning points from the design workshop is that on-site execution provides a more conducive learning environment. The other point is that mixing Dutch and U.S. students and have them collaborate to make an actual design enable them to acknowledge the cultural difference in problem-approach and solving. In addition, this collaboration between Dutch and U.S. students creates an international professional network that some students will use for their individual research project and informal international social network as well.

2.3 Post-trip

Final research report and poster submission

After the research trip, students have approximately three months to complete their research work before submission. Most of the students can acquire requisite data during the time in the Netherlands with the help of Dutch experts and the program liaison. However, in some cases, students have to wait for a while to finally receive the data or documents because certain types of data need a paper work to be released and some documents are only available in Dutch that have to be translated to English. Even if data collection, documents acquisition or interviews are completed in the Netherlands, two weeks is fairly short time for data analysis and interpretation. Thus, students should be allowed to have enough time to finalize their research work. During this time, students can contact faculty mentors and program coordinators for additional assistance.

The final report must be written in the form of a journal paper with a maximum of 2,500 word, following one of common reference styles in their field or discipline. Thus, students learn how to write a journal paper in a proper manner while they finish up the final report.

3 Evaluation of the Program

To assess the educational effects of the Program, a student survey is conducted twice throughout the Program each year. Both surveys are taken without any notification during the flight (on the way to the Netherlands and back to the States) when the students do not have access to the internet. The survey consists of questions to assess personal flood risk perception, interests and knowledge about flood risk issues and mitigation in both U.S. and the Netherlands, expectation from the Program for their current

research or school work as well as future career plans. The survey also includes questions about experiences of any international multidisciplinary research project participation in the past, and other questions related to design workshop.

As for the survey after the research trip, students are supposed to answer the same questions regarding flood risk perception, interests and knowledge about flood risk issues and mitigation to see whether the Program actually has changed or increased their perception and knowledge on the issue. In addition, the questionnaire also examines whether their initial expectations of the research trip have been met properly. The final question asks students to tell program coordinators anything they desire to share about the Program.

Most of the students feel frustrated and agitated when they get handed the survey without any notice especially when they cannot get access to any references. Some students get overwhelmed by the survey taking it like a test. Nevertheless, the pre-trip survey gives the students a certain picture of what they are going to experience and learn from the research trip. The program coordinators, on the other hand, can see the baseline of students' knowledge and perception. As for the post-trip research, students still feel disconcerted when they find out they have another questionnaire to answer because by that time they think all the work is done. By filling out the post-trip survey, students recap on what they have learned and see how much their knowledge has increased through the Program. The survey shows the educational effects of the Program and suggests where the room for improvement is in the following years.

Since this paper mainly focuses on how to design a multidisciplinary research and education program, the survey analysis part has been saved for a separate article which will look into this more closely. However, the survey outcomes clearly show that problem-and-place-based research education program in an international multidisciplinary setting has significant positive influence on students' research education and future career through authentic and transformative learning process.

Lessons learned

To date, three research trips out of five have been completed, and each year, significant improvements are made to different parts of the Program.

First, the application and review process has been modified each year due to increasing number of applications and the need for clear criteria for scoring applications. During the first and the second year, we required an application packet, which consists of application form with personal information, Curriculum Vitae/Resume, full research plan, and recommendation letters. Not only were applicants overwhelmed but it also took a significant amount of time to review all the attached documents. For these reasons, the application was changed to two-step process beginning in the second year. By asking applicants to submit research abstract rather than full research plan for the first phase, the reviewers were able to reduce the applicant pool at an earlier staging, allowing more time to be spent reviewing the final research proposals. Note, in the third year of the Program (2018), the research abstract requirement was changed to a slightly longer LOI to see potential of students. Moreover, in the first two years of the Program, the review committee ranked or scored the applications using somewhat vague criteria such as “quality of the research proposal”. Beginning in 2018, a clear criteria for scoring system was developed based on what was found to be most important in predicting a successful candidate. Thus, a rubric has been created to facilitate the assessment of the LOI and Research Proposals (scoring rubric is available from author by request).

Second, the method of designing case studies, which change each year, was modified. The Program is a multidisciplinary program, however, students from certain disciplines tend to concentrate around specific case studies, which can hinder transformative learning effects among students. To avoid this, the case study descriptions were altered to include a wider range of local issues and research topics that can be approached by various disciplines. In addition, the faculty mentors assigned to each case study also represent various disciplines to try and guarantee the best outcome of multidisciplinary research activities.

Third, though it is rare, we acknowledge the need for consequences or penalty for students who fail to complete the requirements of the Program (e.g., final report or poster). While we hope that through improvements to the application and evaluation process, we can identify students who are self-motivated and will be successful, we have not yet found ways to address students who fail to complete the Program, and it can be considered as a weakness of this program.

Conclusion

This article addresses the design process of an international multidisciplinary research and education program that offers transformative education to the participating students by problem-and-place-based learning in authentic learning environments. Transformative education through authentic learning environments is vital for ocean and coastal engineering programs that are likely have to deal with the most multidisciplinary challenges. With an effectively designed international multidisciplinary research and education program, ocean and coastal engineering students will be able to learn how to approach real-life problems with a different frame of reference and communicate with others with different cultural and academic backgrounds.

To ensure beneficial outcomes for participating students, the Program must be designed with a careful selection of case studies and related research topics, then provide proper assistance and guidance with customized contents that can help students conduct individual research in a collaborative research setting. In addition, it should be noted that this is not a two-week study abroad program but nine-month problem-and-place-based research education program that includes international research travel for authentic learning.

While this article is one of few papers describing how to design such a program in extenso, it should be considered only an initial step that is based on three years of experience and lessons. Two more years are to come to adding to the portfolio. Future study should analyze the educational effects of the Program quantitively based on accumulated students survey outcomes. In addition, in-depth comparative studies among similar research education programs should be conducted.

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