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CHAPTER 26

How to design a successful international integrative research and education program

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Introduction

The integration of multiple disciplines in research and education is becoming an important subject in higher education, combined with an increasing emphasis on multidisciplinary approaches and international collaborations in research projects. In a traditional university setting, a discipline-based organizational structure makes it hard for students to have a chance to learn how to communicate, collaborate, and interact with other students or faculty from different disciplines. In addition, students are not adequately provided with opportunities for international research or learning experiences due to lack of funding or nonexistent systemic programs. To remedy this gap, funding agencies and universities extended efforts to provide students and faculty with international multidisciplinary research and education experiences. However, there are not many existing studies that discuss how to design such programs to ensure the successful learning outcomes of participating students. This chapter explains the program design process, as well as reflections and lessons, acquired from developing and implementing 4 years of student research and education that involves international research trips and interdisciplinary collaboration. Having a set of guidelines for a program design based on concrete experiences would benefit researchers and faculty who intend to create a similar program in the future.

The Partnership for International Research and Education (PIRE) is a National Science Foundation (NSF)-wide program that supports high-quality international multidisciplinary projects to facilitate the development of a diverse and globally committed scientific and engineering workforce. The NSF PIRE Coastal Flood Risk Reduction Program (CFRRP) was initiated under the PIRE in 2015 as an international integrative research and education project to address flood risk. This multiyear binational program includes a synergetic set of faculty, researchers, experts, and students with different

Coastal Flood Risk Reduction
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academic backgrounds, such as engineering, hydrology, landscape architecture, economics, and planning. The program aims to contribute to flood risk reduction in the United States, especially along the Upper Texas coast by benchmarking successful cases in the Netherlands, a country known for effective flood mitigation practices. It has become clear that the rising costs of flooding are not just a function of changing weather patterns or a problem that can be solved with technical solutions alone. Flood risks and associated losses can only be understood and ultimately reduced through integrated research across multiple disciplines, cultures, and international borders. The approach of this program, therefore, involves combining physical and social science data, research methods, and analytical techniques to form a more comprehensive understanding of flood risks.

An integral part of the CFRRP is the educational component where teams of students from different academic and cultural backgrounds conduct problem- and place-based research with the guidance of a multidisciplinary team of faculty mentors. The primary goal of the education component of the program is to provide "transformational learning experiences" for participating students by creating "authentic learning environments" that both support and benefit from the research components.[a]

This chapter describes the design and implementation of the educational aspects of the CFRRP. First, a brief review of theories and concepts applied to the program design is addressed, followed by a detailed description of the design process including a discussion on how to incorporate convergence into the program components. The chapter concludes with reflections and lessons learned that could help other researchers or educators in higher education who intend to create an international integrative research education program.

Background theories and concepts of the program design

The design of the education component of the program embraces convergence, an expanded concept of interdisciplinary research (NRC, 2014). The NSF identified "convergent research" as one of the main paths the organization should pursue. Convergence in research is defined as the deep integration of knowledge, tools, expertise, and ways of thinking and communication from multiple fields to form a comprehensive framework for addressing scientific and societal challenges (Herr et al., 2019; Kitney et al., 2017).

With the inevitable increasing interactions among various academic disciplines in research projects dealing with societal challenges, convergence has become an opportunity for the education communities. The integration of crosscutting core knowledge and concepts requires a perspective shift from "what is taught" to "how is it taught" (Kitney et al., 2017).

[a] For more details about the background theories and concepts of transformative education, authentic learning, and problem- and place-based learning, see Chapter 5.30.

The NSF PIRE CFRRP is an international research education program in which students conduct case study research focusing on flood-related problems. Due to the increasing complexity of flood impacts and associated losses, integrative efforts to tackle the problem across disciplines is essential for both faculty and students participating in the project. To create a convergent setting that facilitates a holistic approach to the problem in a research education program, integration across disciplines should be incorporated into educational and training strategies as well (Herr et al., 2019).

Many factors affect the success of integrative research education, and the most important ingredient is the physical incorporation of classroom and field by forming a multidisciplinary team that focuses on a particular overarching research question and problem solving. This approach helps students overcome fragmented perceptions and realize connections among different discipline domains as well as across participants' experiences gained in various academic and cultural contexts (Booth, 2011; Clapton et al., 2008; Kulasegaram, Martimianakis, Mylopoulos, Whitehead, & Woods, 2013). Jamison, Kolmos, and Holgaard (2014) described the educational effects of the integrative setting in engineering education. They stated that the integrative approach allows students to grasp the connections between the theoretical and practical aspects of engineering work, broadening their cultural and social understanding to more effectively deal with real-life problems. In this way, integrative convergent education trains students to grow into professionals with enhanced communication skills through interacting and building a network with other students and faculty from various disciplines (Herr et al., 2019).

Another pivotal factor for convergent research and education is the diversity that takes multiple forms. The National Research Council (2014) suggests two types of diversity that are needed to secure innovation in convergent research: functional and identity. Functional diversity refers to the range of approaches to problem solving; identity diversity is the variance in demographic, cultural, and ethnic characteristics within a research team. Indeed, previous studies showed that groups of individuals with various perspectives generate more innovative solutions to complex problems than do groups comprised of individuals with similar perspectives (Hong & Page, 2004). In addition, vertical diversity in education levels (e.g., bachelor's, master's, and PhD), as well as horizontal diversity (variations in disciplines), are also pivotal features in achieving the goal of convergent education. Bolli, Renold, and Wörter (2018) found that vertical educational diversity significantly enhances innovation, particularly in the invention phase of a new product. This is because different levels of education accompanied by different insights and experiences of participants might create various interpretations of problems which can lead to a wider spectrum of possible solutions. Further, the diversity in convergence is generally more inclusive than in interdisciplinary research because the cross-fertilization of knowledge, ideas, and experiences occur not only among different academic disciplines but also with stakeholders, partners, and policymakers outside academia (NRC, 2014).

While physical integration and diversity are the factors needed at the initial stage of the program design, creating an open and inclusive learning environment that allows students to freely represent their thoughts on issues is essential at the implementation phase. A high level of integration requires one to move beyond their own expert language to be able to communicate across disciplines and build a common understanding of the shared problem solving and goals (NRC, 2014). This is where transformative learning occurs through immersive discourses guided by faculty and researchers from various disciplines.

Tables 1–3 show the program timeline along with expected educational effects and organizational tasks objectives of each phase in chronological order: pretrip (Table 1), on-trip (Table 2), and posttrip (Table 3). These tables have been adopted and modified from Lee, Kothuis, Sebastian, and Brody (2019).

Program design incorporating convergence

Integrative case study research design

Every year, the first and most important step of the program design process is to configure the case studies that will be investigated by the cohort of students. The overarching research theme of these case studies is flood risk reduction (problem-based) and the cases are located in the Netherlands (place-based). Fig. 1 shows the map of the case study areas of the 2019 program (case study locations change every year).

How to present the case study areas with relevant local flood-related issues is crucial for integrative group formation because students who apply for the program are required to write a case study research proposal based on the information provided. One of the most important tasks of the program managers and faculty mentors is to set up the case study presentation properly so it can attract students from various disciplines and academic levels.

A brief description of the regional context addressing local problems and issues concerning the flood risk of the area is provided with an example of a set of research questions (see e.g., Fig. 2). Suggested research questions are developed based on the local context embracing various disciplines. To the students who intend to apply for the program, this array of multidisciplinary research questions acts as a guide providing a hint for how to come up with a research question(s) for application based on their major or research focus. For example, an undergraduate student majoring in urban planning or architecture could choose "Focus area 1: City of Vlissingen" and "RQ1: What is a flood resilient building code in Vlissingen and how can this be applied in the United States?" and a civil engineering PhD student whose research focus is infrastructure resilience could write a research proposal for application around "Focus area 2: Vlissingen Port" and "RQ4: What are the impacts of climate change or extreme weather on the area, especially infrastructure networks?" or formulate their own research question.

Table 1 Pretrip.

Phase	Timeline	Phases	Educational aspects	Organizational aspects
Pretrip Application and orientation	Sep–Nov	Application Phase #1	• Writing skills: LOI • Knowledge increase: Get acquainted with study areas and local flood risk related issues	• Design case studies • Organize mentor teams • Publish application information online • Select 25 students and notify them to submit a full proposal
	Dec–Jan	Application Phase #2	• Writing skills: full research proposal • Knowledge increase: Obtain a better understanding of a specific flood risk related issue in a specific case study area	• Select 16 students and announce selection • Organize accommodations and other logistic arrangements
	Feb–Mar	Application Phase #3	• Writing skills: revise and update the proposal based on the comments from the review committee • Knowledge increase: international field work travel preparation	• Scoping trip to case study locations for arranging fieldtrips, lectures, and expert meetings • Prepare the orientation • Travel arrangements for students and faculty
	Mar	Orientation Phase #1	• Presentation skills: first presentation to a multidisciplinary group (mentors and students) • Collaboration skills: meet with peers and discuss different ways of approaching the topic within a multidisciplinary team	• Orientation day • Review the updated proposals and guide students in how to do a literature review

Continued

Table 1 Pretrip—cont'd

Phase	Timeline	Phases	Educational aspects	Organizational aspects
	Apr–May	Orientation Phase #2	• Knowledge increase: General overview of the flood risk issues and cultural differences in both countries • Knowledge increase: individual literature review • Collaboration skills: virtual meetings with the team members, share the research proposal development process and combine individual literature reviews into one paper for the case study team	• Finalize day-to-day schedule of the research trip • Give final comments on the updated proposals

At this stage, a team of multidisciplinary faculty mentors and researchers provide input on the proposed case study descriptions and research questions to provide students with proper guidance throughout the program. An integrative case study design is a part of the foundational work that enables students to implement interdisciplinary research activities through problem- and place-based learning. Every year a program announcement with a description of case study areas and research questions is published online and advertised through campus emails, social media, and presentations in classes to recruit students.[b]

Student recruitment and application review for securing diversity

Student recruitment emphasizes attracting underrepresented groups in science and engineering and integrating all relevant disciplines to form a diverse multidisciplinary cohort of students. So far, the program has been successful in both functional (various disciplines) and identity (demographic, cultural, and ethnic characteristics) diversity, which resulted in a 72% underrepresented minority (Black, Hispanic women) participation in this STEM-intensive program between 2016 and 2020. Additionally, the program drew on the extensive experience in undergraduate and graduate student recruitment and retention offered by a historically Black college and university (HBCU) collaborating institution.

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

Table 2 On-trip.

Phase	Timeline	Phases	Educational aspects
On-trip	May	Group Field visits (2–3 days)	• Knowledge increase: Firsthand experience of the Dutch flood risk approach (see and hear) • place-based learning: – Field visits to all the case study locations – Meet with local experts and stakeholders (lectures/discussion)
		Research meeting #1 and #2 (half day each)	• Presentation skills: second presentation to a multidisciplinary audience (mentors and students) • Problem-based learning: Various approaches to a problem (flood risk reduction) • Transformative learning: multidisciplinary perspectives on multiple cases
		Research time #1 and 2 (4 days each)	• Place-based research: Individual field visit to a case study location • Authentic learning: individual meetings and discussions with local experts and stakeholders • Knowledge increase: deep understanding of the issues and the study area from meetings with local stakeholders and experts and desk research on individual research case study • Writing skills: start writing a research paper
		Bi-national multidisciplinary design studio (full day)	• Knowledge increase: lectures by local experts and stakeholders, description of the area • Place-and-problem-based research: field visit to the location, discussions with local experts and stakeholders • Collaboration skills: interaction within an international multidisciplinary team for the assignment • Presentation skills: group presentation of the final outcome to the jury consisting of academic experts and local stakeholders
		Research meeting #3 (half day)	• Presentation skills: fourth and final presentation to audience with various backgrounds (PIRE mentors and cohort students plus local experts and stakeholders, host university faculty, and students)

Table 3 Posttrip.

Phase	Timeline	Phases	Educational aspects
Posttrip	Jul–Aug September 1	Finalize	• Knowledge increase: finalize desk research • Writing skills: Write a research paper • Presentation skills: Produce a poster Students submit paper and poster

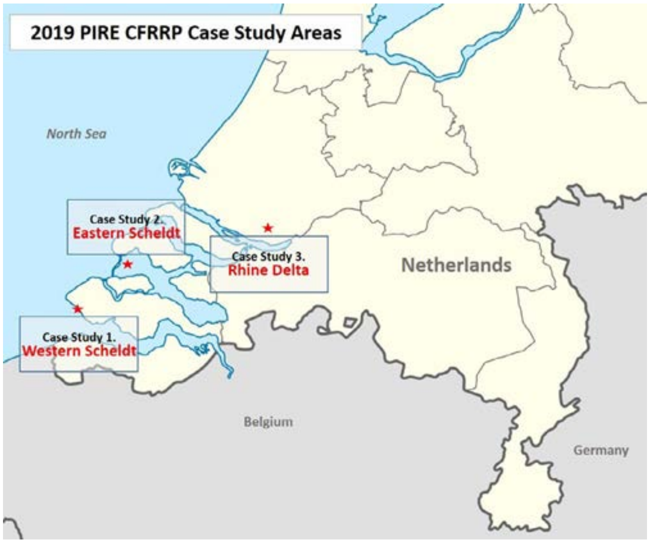

Fig. 1 2019 program case study areas.

Each year, participants are chosen from all applicants through a rigorous two-step selection process. The two steps include submission of a preproposal in the form of a letter of intent (LOI) and a full proposal by a narrowed-down group of candidates in the form of a more detailed research plan. In the LOI, students are asked to describe their project preference, their preliminary research question(s), how their background and research interests contribute to the overall place-based flood resilience research, and how they expect this program to influence their current research or future career. Applicants are also required to submit their resume or CV along with the LOI as supporting evidence of their background and research focus.

The faculty mentors review all applications based on the following assessment rubric. The reviewers score each subcriteria from 0, meaning "not at all," to 5, meaning "definitely yes."

Case Study #1: Western Scheldt

The Western Scheldt region is an intertidal area vulnerable to storm sure and riverine flooding. While a critical navigational channel to Antwerp, Belgium, this area experiences declining development, making it an interesting case for examining the role of restoring natural functions for flood mitigation. Due to its special geographic location and integral functions, regular dredging is required to secure safe navigation to the port of Antwerp and it has caused several environmental and intergovernmental issues that need attention. Vlissingen is a coastal city located in Western Scheldt region, and well-known for its comprehensive flood risk reduction strategies. With its critical location between the Scheldt and the North Sea, Vlissingen has played a pivotal role as a harbor for centuries.

Focus areas	**Examples of local issues and topics**
1. City of Vlissingen	- Multipurpose flood defenses - Land use plan for flood risk reduction - Dike in dune constructions - Flood resilient building code - Flood resilient housing policy for socio-economically vulnerable population
2. Vlissingen port	• Vulnerable infrastructure protection: - Nuclear power plant protection (critical infra) - Above ground Storage Tanks (AST) protection
3. Ship channel	• Environmental and social-political issues: - Dredging - Intergovernmental management/collaboration
4. Coastal inlet	- Morphology of multiple channel tidal inlet systems - Oyster reef protection

Examples of Research Questions

RQ 1: What is a flood resilient building code in Vlissingen and how can this be applied in the U.S?
RQ 2: How can land use plans incoporate flood risk reduction and are they effective in reducing losses?
RQ 3: How can a local governments produce housing policies that promote the flood safety of socioecoimically vulnerable populations?
RQ 4: What are the impacts of climate change or extreme weather on the area, especially infrastructure networks?
RQ 5: How do the Netherlands and Texas differ in dredging methods and practices?
RQ 6: How can multiple local governments or agencies collaborate to secure the ship chanel safety/ecosystm protection?
RQ 7: How do the Netherlands and Texas differ in flood risk perception and how does this influence their mitigation approach?

Fig. 2 Case study area description with examples of multidisciplinary research questions.

(1) Quality of the LOI/research plan
- *Research question*: Is/are the research question(s) in the LOI/research plan well reasoned and relevant to the issues of the preferred case?
- *Motivation*: Does the LOI/research plan describe the motivation for the preferred case study and is the motivation a likely basis for a good research project?

(2) Scientific approach
- *Scientific contribution*: Is the proposed research project a significant contribution to the field of study?

- *Feasibility*: Will the proposed research project be feasible as part of the preferred case; can the necessary data be collected and the report written within the research time frame?
- *Disciplinary contribution*: Is the proposed research project a potential contribution from a multidisciplinary perspective to the group?

(3) Applicant's background
- *Cultural diversity*: Does the applicant contribute to the overall diversity of the program or this year's class?
- *Academic diversity*: Will the background and research interests of the candidate contribute to the preferred case study?
- *Potential for success*: Does the applicant's educational background, previous coursework, and/or GPA indicate that the applicant will succeed?

(4) Quality of presentation
- *Presentation*: Does the presentation of the LOI/research plan satisfactorily show overall quality? Are all fields in the application form filled in correctly? Is the text of the LOI/research plan well written?

After the review of the LOIs, around 30 undergraduate and graduate students are selected to submit a 900–1000-word research plan and two reference letters from their academic advisors. The same rubric is used for the second-round review of the research plans, but in the Scientific Approach category, reviewers focus more on whether the following factors are identified: (1) specifics on methodology to answer the proposed research questions, (2) data sets needed and how they are to be used, (3) possible sources for those data, and (4) opportunities to apply the expected results in the United States for flood resilience. The final review results in the selection of 16 students per year (8 undergraduate and 8 graduate) to participate in the program.

It is important to note that the application review process is systemically devised to secure multidisciplinarity and diversity among participating students, not only academically but also demographically.

Open and inclusive learning environment

Group research meetings and presentations

Throughout the program, students are placed in situations where they have to present their research plan, process, and results to a group of people with diverse cultural and academic backgrounds. The main audience is their cohorts and faculty mentors, but Dutch experts and stakeholders also attend these meetings to give students feedback and local knowledge on their case study research. While they prepare for the meetings and presentations, students learn how to make their research comprehensible for a diverse audience and also learn how other people look at the same problem from different perspectives. This is where transformative learning occurs through a frame of reference moving away from ethnocentrism and dualistic epistemologies and acquiring a new perspective with which to approach the problem (Bell, Gibson, Tarrant, Perry III, & Stoner, 2016).

During these group meetings and presentations, students go through comprehensive immersive discourses on their research, guided by faculty mentors, researchers, and Dutch experts. Open discourse is important not only for convergent research and education by providing a variety of intellectual viewpoints on a certain issue but is also an essential feature of authentic learning environments that the curriculum aims to provide throughout the program because it helps students construct hypotheses to test (Duignan, 2012). In addition, the debates and brainstorming that occur in the discourse encourage students to talk, think, and explore their research topics in a stereoscopic way. Faculty mentors play a role here as guides rather than just "information providers," leading students to the path but not directly indicating the destination. In addition, the mentors focus on creating an open and inclusive atmosphere helping students feel free to talk about their research or comment on somebody else's work.

Multidisciplinary design workshop

The design workshop is a 1-day long integrative research activity held at the actual project location of an innovative flood protection project along the Dutch coast.[c] Participating students from US institutions collaborate with a group of 10–15 multidisciplinary students from several Dutch universities. The workshop starts with talks by local stakeholders and experts. Then, the students are split into multidisciplinary binational teams consisting of 5–6 members and collaborate on envisioning a design to address the complex flood-related local problems. The workshop provides an authentic learning environment given existing flood issues in the local area and a collaborative problem-solving process. Two extra learning aspects are included in the workshop: (1) students are introduced to a Dutch-specific design-concept called Building-with-Nature, which they must incorporate into their design. This change of perspective stimulates transformative learning (Mezirow, 1997); (2) students learn about the different roles of experts representing diverse disciplines and get a chance to conduct a self-assessment to discover which role fits them best. During the workshop, they practice various roles and experience culturally different interpretations of these roles.

The on-site execution of the workshop offers students a more conducive learning environment. In addition, allowing Dutch and US students to collaborate in producing an actual design enables them to acknowledge cultural differences in approaching problems. On top of that, this collaboration facilitates the development of a potential international professional network for both the United States and Dutch students.

[c] See also Chapter 27, "Measuring the educational effects of problem- and place-based research education programs: The student survey".

The design workshop is an effective educational tool to help student participants learn about and experience convergent research. Not only do US students get to interact with international students and faculty, but they also communicate with stakeholders, including local residents, authorities, and private sectors, for problem solving.

Lessons learned

To date, four of the seven planned research trips have been completed and each year, significant improvements are made to different parts of the program based on lessons learned from previous years.

First, there was a need for a major improvement in the application and review system. For the first 2 years of the program, there was no rubric for the evaluation of applications. The committee assessed the applications based on their own judgment without clear rating criteria. On top of that, the committee had to review, all at once, a 30-page application packet of each applicant that included a research proposal and other supplemental documents, which resulted in an overwhelming review process that made it hard for the committee to evaluate the applications from various aspects. To address these issues, the application was changed to a two-step process, which allowed the reviewers to spend more time on each application. In addition, we developed and refined a review system equipped with clear criteria that specifically reflects the multidisciplinarity and diversity of the applications and applicants on top of measuring the systemic quality of the research proposal. This modification of the application and review system played a pivotal role in increasing the number of underrepresented participants and the inclusion of students from a wider variety of disciplines.

Second, the case studies, which change each year, have become more integrative. We found that students from certain disciplines tended to concentrate on specific case studies, which hinders the convergent research and transformative learning effects among students. To avoid this problem, the description of the case study areas is presented more inclusively and more broadly so it can cover a wider range of local issues and research topics that can be approached by various disciplines.

Third, the program struggled with some students who lost interest in finishing their research work after coming back from the Netherlands. The final product required is the submission of a report and a poster, which students work on for 3 months after the research trip. Since this program is not an actual course for which they get credit or has other consequences, some (but not many) students were reluctant to finalize their work. To fix this problem, additional resources have been allocated to implement a "carrot-and-stick" strategy. The stick is to hold an annual student research symposium where students are required to present their work to receive a certificate of program completion. The carrot is to fund six top-performing students to attend an international conference to present their work. We hope this strategy will encourage students to engage even more in the later phase of the program and improve the quality of their final work.

Conclusions

Convergent research and education through transformative and authentic learning can be successfully implemented if it is carefully designed by incorporating the integration of students from various disciplines, ensuring diversity, and creating an open and inclusive learning atmosphere. Well-structured international integrative research and education programs could significantly benefit students by providing career-transforming insights, resources, and connections that go far beyond regular classroom teaching. This chapter describes the design process of the NSF PIRE CFRR Program as a vehicle for offering transformative education to students through problem- and place-based learning in authentic learning environments. Built on our 4 years of experience, we have been continuously improving and modifying the contents of the program to provide the best learning opportunities to participating students. The program has demonstrated how to break down existing disciplinary silos and develop the skillsets needed to address growing flood risks through convergent research and education. Upon completion of the program, participating students will have obtained a deep understanding of necessary connections between different disciplines to address major societal challenges, which will make them valuable future research leaders and practitioners with a global perspective on problem solving.

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