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CHAPTER 27

Measuring the educational effects of problem- and place-based research education programs: The student survey

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Introduction

The evaluation the effectiveness of a research education program is vital to ensure its success. Although some valuable feedback can be obtained through discussions with participating students and faculty mentors, it is crucial to empirically evaluate the impact of the program to clarify and document the contribution that it is making to the achievement of educational goals (Fien, Scott, and Tilbury, 2001). This study examined the educational and learning effects of the program based on the results of a survey of 56 participating students.

The main purpose of the survey was to address the following questions:

(1) Does the 2-week research trip to the Netherlands significantly increase students' general knowledge of flood risk?

(2) Does the multidisciplinary approach of the program have a significant impact on changing and diversifying students' perspectives?

A total of 56[a] students (21 undergraduate and 35 graduates) responded to the questionnaire comprising of both structured and open-ended questions. The survey is designed to quantify how well the program is achieving its goal and consists of 23 items asking about students' flood risk perception, knowledge, and feedback on the program itself. Six items were constructed to measure the degree of flood-related knowledge of the students and how diverse perspectives lead to different problem-solving approaches. Using a pretest-posttest design, student learning over the 2-week research trip in the Netherlands was tracked and analyzed quantitatively to see whether the program led to significant differences in knowledge level and perspectives of the students.

[a] A total of 58 students have participated in the program but the data of two students were dropped because they were not able to complete the program.

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The results show that the 2-week long problem- and place-based research education program does increase the level of knowledge of the participating students in general. The results also indicate the students acquired a perspective transformation.

The following section briefly reviews literature that contributed to the fundamental concepts of the program: transformative learning and authentic learning. Next, we describe the method used in the study including survey data description and analysis. Then, we report on the statistical results of paired *t*-tests assessing changes in knowledge and perspectives of the students. This chapter concludes with implications of our findings in terms of improving research education programs for authentic and transformative learning experiences at the university level.

Transformative and authentic learning and education

Transformative learning and education

Transformative learning (TL) can be defined as a process of change in a frame of reference, achieved when the transformation occurs as a result of experience or by acquiring a new perspective (Mezirow, 1997, 2003; Strange & Gibson, 2017). In Mezirow's Transformative Learning Theory (Mezirow, 1997), "frames of reference" is defined as the structure of assumptions that constitutes a person's cognitive habits and points of view. These fixed assumptions form a set of codes that can be influenced by the cultural, social, and educational environment of individuals. TL aims to encourage learners to question and transform these assumptions, the ways they see and think about the problem, and enable them to deepen their understanding of that particular topic (UNESCO, 2017).

In higher education, TL is considered as a primary objective and important outcome that enables students to think critically and analytically, while enhancing communication and collaboration skills, and global understanding (Calleja, 2014; Nichols, Choudhary, and Standring, 2020; Strange & Gibson, 2017). Furthermore, students are encouraged to create new meanings of a problem from an altered view and identity. The importance of TL is widely recognized in various areas and United Nations Educational, Scientific, and Cultural Organization (UNESCO) designated TL as a key element of learning approaches for the 2030 sustainable development agenda (Harder, Dike, Firoozmand, Des Bouvrie, and Masika, 2021; UNESCO, 2017). The pivotal role of TL is getting more attention as the importance of multidisciplinary approaches to address complex natural and societal challenges grows. In this sense, TL should be properly incorporated when designing an international multidisciplinary research and education program to provide students with an opportunity to recognize various perspectives in approaching a complex problem such as flooding.

When implementing TL, students should be presented with a challenging problem in an unfamiliar environment with other students they can relate with in the same process and educators or lecturers should challenge them to discuss with their peers (Christie, Carey, Robertson, and Grainger, 2015). This approach may evoke a process of seeing, acting, or thinking outside their comfort zone (Perry III, 2011). Since a shift of perspective can be achieved by changing culturally entrenched meaning structures, even short-term foreign experiences—combined with strong academic content—can lead to transformation (Bell, Gibson, Tarrant, Perry III, and Stoner, 2016). Furthermore, a direct teacher intervention may occur to ensure changing frames of reference to help students develop insights about different perspectives and to encourage participation in critical dialectical discourse. These attributes are crucial for constructing a new perspective (Mezirow, 2003).

Authentic problem- and place-based learning and education

Authentic learning is widely recognized as an effective approach based on real-world problems that are closely related to a specific field (Herrington, Reeves, & Oliver, 2014). This approach enables students to constantly experience and engage with interdisciplinary problems in a real-world situation, using active learning pedagogies such as fieldwork, group work, and rigorous discourse, in a way that emphasizes the complexities of tackling challenging problems (Cross & Congreve, 2020). Debate is also considered an essential feature of authentic learning environments because it enables students to construct hypotheses, test them against what they think is true, and view knowledge and information from multiple perspectives.

In authentic learning environments, the role of the teacher changes from information provider and test maker to learning guide and problem presenter by demonstrating "care" or "passion" for a subject and by motivating students to care as well. Because students regulate this learning process themselves, they are encouraged to think, discover, and become more reflective practitioners (Cross & Congreve, 2020; Duignan, 2012). This kind of learning, presented as an iterative discovery process around an authentic task, enables students to conceptualize the nature of a complex problem and allows students to develop solution-focused thinking, problem-solving skills, and confidence in their own learning ability.

One of the best ways to implement authentic learning is the use of problem-based learning (PBL) techniques. In PBL, students are presented with a challenging problem and required to analyze and find solutions to the problem (Zamroni, Hambali, & Taufiq, 2020). In this process, a team of students shares the problem with the aim of solving it collectively, leading to a greater level of responsibility, competence, and learning outcomes (Donnelly, 2006; Friedman & Deek, 2002). A key point of PBL is linking theoretical knowledge to practical application by working together in mixed disciplinary groups in which students decide for themselves what to learn.

To combine authentic learning and PBL, a problem can be presented in a case study setting that invites students to investigate, analyze, and solve problems in collaborative groups (Cockrell, Caplow, and Donaldson, 2000). Some notable features of such case studies make them an ideal strategy to facilitate authentic learning. First, a case is based on a real situation or event that forces students to think through problems they may encounter in the workplace. Second, the case study is designed and developed through careful research and study involving local experts and stakeholders. Third, and most importantly, a case provides learning opportunities at different levels for both those involved in designing the case and those who may be involved with the case (Wallace, 2001).

Another key application of authentic learning is the use of place-based learning. Place-based education is based on the principles of authentic learning and applies them to a particular spatial environment, for example, a floodplain or vulnerable community. Collaborative learning is then tailored to the local context in which 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 ability to produce rather than consume, teachers act as guides rather than just instructors, and groups work together to develop a set of strategies to address a real problem (Smith, 2000).

Methods

This study uses a pretest-posttest research design to measure and explain the changes in knowledge and perspectives of 56 participating students of the program from 2016 to 2019. Comparing pre- and postintervention student survey responses is the most common evaluative approach for an education program assessment (Carleton-Hug & Hug, 2010; Stern, Powell, and Hill, 2014). The data were collected using student surveys, conducted before and after the 2-week research trip in the Netherlands. A pretrip questionnaire was given to the students on the plane going to the Netherlands, where no Internet access was available; the posttrip survey was administered right after the last group meeting of the research trip and students were instructed not to use any resources while they answered the questionnaire. The total of 56 students consisted of 21 undergraduate, 12 Master's, and 23 PhD students, with an age ranging from 20 to 52 years old. Respondents came from five different US institutions and diverse disciplines, such as engineering (25), social science (12), natural science (9), and architecture/urban planning (10). The students had a variety of educational and professional backgrounds.

The educational objectives of the research trip in the Netherlands are to provide students with:

(1) A comprehensive and integrative research and education experience to produce a diverse generation of researchers and practitioners equipped to solve societal challenges of increasing flood hazards.

(2) A deep understanding of the necessary connections between different disciplines and the ability to approach an issue with a varied and holistic perspective.

In general, the effectiveness of environmental education programs can be measured by changes in students' knowledge, skills, awareness, attitudes, and behavior (Stern, Powell, and Hill, 2014). For this study, change in students' perspectives on flood issues was measured along with increases in baseline flooding knowledge. We measured each student's knowledge level by including quiz type of questions related to general and specific flood issues in the pretrip and posttrip surveys and a scoring rubric was created to grade the responses. The score of baseline knowledge was calculated by aggregating the points given to the answers according to the rubric. The questions asked students if they can list or address any examples of flood mitigation strategies, the main differences of flood risk mitigation between the United States and the Netherlands, and the major drivers of flood risk in two countries. Each mitigation example was given up to three points if a student had provided specific information (name and location of the mitigation example). For the question about the differences in risk mitigation approach between two countries, the answer was given up to four points if a student had clearly stated and explained the differences using proper examples. Additionally, students were asked to suggest flood risk mitigation ideas for each case study area in both countries according to its flood risk drivers. Not only was the knowledge measured, but also the comprehensiveness of students' perspectives was assessed using the mitigation ideas they had suggested. We measured the degree to which their approaches to solving flood problems were integrative based on the number and scope of mitigation responses: if a respondent proposed more than three mitigation strategies that included both nonstructural and structural or both engineering and nonengineering approach (e.g., Flood risk drivers: storm surge and land use pattern; Mitigation ideas: building a storm surge barrier and adopting a zoning system), the answer would get the highest possible score (see Appendix for the questionnaire used for analysis and employed rubric to score them).

Participation in the program requires a case study research proposal addressing a specific issue related to flood risk reduction. Students are advised to revise and update their research plan by completing a literature review during the pretrip period. Thus, it was expected that students develop a baseline knowledge level prior to traveling to the Netherlands.

As the same questions were asked before and after the research trip to the Netherlands, we used a paired *t*-test of means to assess the change in the average score of students' responses between the pretrip and posttrip survey. A paired *t*-test is also called a repeated-measures *t*-test since it is used to measure one group of people at two different points in time in order to determine the mean difference between the two sets of observations (Acock, 2008).

Results

Improved knowledge. Based on the results reported in Table 1, students' knowledge level showed significant change comparing the means of the pretrip (pretest) and posttrip (posttest) scores. The total average score of the flood-related knowledge of the students changed from 42.90[b] to 51.61, a statistically significant 16.88% increase ($P < 0.01$). This result provides an initial indication of the educational effects of the 2-week long research trip to the Netherlands on individual levels of flood-related knowledge. The results of paired *t*-test of each component of the knowledge questions follow.

Major flood risk drivers of case study areas: Students were asked to select two major drivers (among "rainfall," "storm surge," "subsidence," "sea level rise," "land use patterns," "social vulnerability," and "climate change") of flood risk in case study areas (Houston-Galveston metropolitan area and the Netherlands). This question was intended to measure students' basic understanding of the "problem" (floods) in the "place" (case study areas) that the program is based on. We expected the posttrip score would be higher than pretrip, however, the analysis did not show any significant change. There was a slight increase in the average score of the drivers of the Netherlands but not statistically significant.

Differences in flood risk mitigation approach between the United States and the Netherlands: The second component was an open-ended question that asked students if they could address any differences between the two countries when it comes to flood risk mitigation

Table 1 The paired t-tests of pretrip and posttrip survey.

Variable	Pre-test (Mean)	Post-test (Mean)	*t*-value	*P*-value
Total average score	42.95	51.61	−3.63	0.0006
Knowledge				
Flood risk drivers (US)	45.76	41.52	1.21	0.23
Flood risk drivers (Dutch)	30.58	33.06	−0.67	0.51
Differences in mitigation approach (US and Dutch)	61.16	68.30	−2.37	0.02
Flood mitigation examples	53.57	51.61	0.69	0.49
Flood mitigation ideas	39.05	51.24	−3.69	0.0005
Perspective				
Integrative mitigation ideas	18.17	34.95	−4.70	0.0000
Self-assessed knowledge				
Knowledge level	4.21	5.34	−7.80	0.0000

[b] Highest possible score for the knowledge level was 69 for the 2016 and 2017 cohort, and 62 for 2018 and 2019 cohort. Each respondent's score was divided by the highest possible score and multiplied by 100 for generalization.

approach. The results showed 11.67% increase ($P < 0.05$) in the score, which indicates that the research and learning activities in the Netherlands for 2 weeks were informative and enabled students to realize that two different countries would take a different approach to mitigate flood risk.

Mitigation examples: Another open-ended question asked students to list five examples of flood risk mitigation strategies and the result showed a statistically significant increase in the score of this item. This question did not restrict areas or types of mitigation measures, so students were able to freely list any mitigation examples no matter where they are located or how they mitigate the flood risk. However, surprisingly, there was no statistically significant knowledge change on this component.

Mitigation ideas according to the major drivers in the area: The last component of the questions attempted to measure students' ability to connect the problems of places (flood risk drivers of each case study area) and possible solutions (flood mitigation ideas). The score showed a clear increase of 32.14% ($P < 0.001$) on this question, indicating the positive educational effects of the problem- and place-based research education program.

Changed perspectives: Comprehensive and integrative problem-solving approach. Flood mitigation ideas addressed by students were graded to see if students' perspectives had changed to more integrative or perspective after participating in the research trip to the Netherlands. A response with more than three mitigation ideas that include both structural and nonstructural or both engineering and nonengineering approaches received the highest possible score. The average score for this item has increased by 93.15% ($P < 0.001$).

Other findings: Self-reported knowledge level and the most helpful program features. In addition to the questions about the knowledge and perspective, students were asked to self-measure their current knowledge level on the flood-related topics and answer from 1, meaning "very low," to 7, meaning "very high." The result shows a statistically significant 27% ($P < 0.001$) increase in the score, meaning students feel that they have a better understanding of the topic after the program, no matter how much their actual knowledge has increased. Also, we asked students to rank the program components ("field trips," "connecting to experts," "literature review," "lectures," "breakfast meetings," "individual research time," and "free time") based on how much they can contribute (pretrip)/how much they actually contributed (posttrip) to their knowledge about flood risk reduction. The majority of the students selected "field trips" and "connecting to experts" for the most helpful components before and after the trip. In total, 17 students ranked the field trips the first, and 16 students ranked the second for the pretrip survey, and the number slightly increased after the trip to 18, and 19 students ranked the field trips first and the second. Regarding connecting to experts, 25 students ranked it the first and 16 students the second. After the trip, it also shows a negligible increase to 27 and 18 students. This descriptive analysis implies that the program has met the students' expectations of the place-based and authentic learning approach.

Discussion

All survey responses, except ones asking about major flood risk drivers and the examples of flood mitigation, showed a clear improvement after the research trip. The most notable change was found in mitigation ideas, suggesting a substantial increase in flood-related knowledge. It is important to note that this question measured not only students' understanding of major drivers of flood risk in each case study area, but also their ability to come up with mitigation ideas to alleviate the food risk. It requires students to have contextual knowledge of the place and the ability to think comprehensively to present the solutions accordingly. This result implies that the transformative and immersive characteristics of the program helped students to approach a problem with a more comprehensive and integrative perspective that is beyond their own academic discipline by communicating closely with people with diverse backgrounds: other students, faculty, Dutch experts, and Dutch local stakeholders.

Another noteworthy finding is from the results of descriptive analysis. Students reported that the "field trips" and "connecting to experts" were the most helpful components of the program, which indicates the distinguished effects of a place-based and authentic learning approach in comparison with a traditional in-class approach in which learning opportunities like visiting actual places and talking with Dutch experts in person cannot be offered.

By completing a 2-week long problem- and place-based program, students became more knowledgeable and their approach to the problem became more integrative as well. This result shows a clear contrast with the result of the item that asked students to list general flood mitigation examples without any limitation of location or types. Although the results indicate that the students learned thoroughly about local specific flood issues and to suggest its associated possible solutions, there was no statistically significant improved knowledge on the universal flood mitigation measures. This might imply that when it comes to designing a problem- and place-based program, it is important to incorporate a way to guide students to see a problem not only in a horizontally diverse perspective—multidisciplinary approach, but also in a vertically diverse perspective—in a different scale: local, regional, national, and global level.

Conclusions

The results of this study suggest that a problem- and place-based research education program offering immersive and transformative training could significantly improve students' knowledge and help students to approach a problem with a more integrative and holistic perspective in only 2 weeks if the program is properly designed. Findings support that the activities of the 2-week long research trip such as field trips, lectures, and a series of immersive discourses with other students from a variety of disciplines, led by a multidisciplinary group of faculty mentors could offer substantial knowledge increases and an opportunity to learn how to approach a problem with different perspectives. Another notable finding that the analysis offers concerns the students' self-assessed level of knowledge on flood risk. The result of the pretest-posttest analysis shows that students think their knowledge has increased significantly after the 2-week long research trip to the Netherlands. This finding might be considered more important than the actual knowledge score increase because it indicates that in 2 weeks, students have gained not only knowledge but also confidence in having a broad base of experience, which gives them more room for academic growth in the future.

Future studies should include an untreated control group (traditional in-class, lecture and reading focused learning group) for analysis to have a better understanding of the educational effects of this program, as the actual differences between the study group and the control group can thus be assessed. On top of that, a follow-up study after a certain time that has elapsed can be conducted by tracking down students' career paths and see if the program has any substantial impacts on their capability to deal with real-world problems in a professional or academic setting. Furthermore, within this program, supporting faculty members gathered multiple times to discuss the effectiveness of the diverse program items and methods. This was done in group meetings during and after the research trip to the Netherlands. To be able to further evaluate and standardize this valuable information, future studies could include a survey for supporting faculty mentors to inquire about their experience and insights into students' learning progress and processes, methods and other relevant issues concerning the effectiveness of the program.

Appendix: Scoring Rubric for NSF PIRE CFRRP Student Survey[c]

Question 3. What are the primary drivers of flood risk in the Houston-Galveston region? (1: least important ∼7: most important) [2 points total]

Criteria:

- Allow 2 points if the student places "Rainfall" and "Land Use Patterns" in 5, 6, or 7 (most important).
- Allow 1 point if only one of them (Rainfall or Land Use Patterns) is placed in 5, 6, or 7.

No credit if "Rainfall" or "Land Use Patterns" is placed in 1, 2, or 3.

[c] This rubric was created using an example rubric provided by New York State Alternative Assessment in Science Project (NYSED, n.d.). Retrieved from https://pals.sri.com/tasks/9-12/Testdrug/rubric.html.

Question 3-1. Do you think there are any others? [2 points total]

Criteria:

- Allow 2 points if the student states two or more other drivers.
- Allow 1 point if the student states only one other driver.
- No credit if the student does not answer or states something completely irrelevant.

Question 4. What are the primary drivers of flood risk in the Netherlands? [2 points total]

Criteria:

- Allow 2 points if the student places "Rainfall" and "Storm Surge" in 5, 6, or 7 (most important).
- Allow 1 point if only one of them (Rainfall or Storm Surge) is placed in 5, 6, or 7.
- No credit if "Rainfall" or "Storm Surge" is placed in 1, 2, or 3.

Question 4-1. Do you think there are any others? [2 points total]

Criteria:

- Allow 2 points if the student states two or more other drivers.
- Allow 1 point if the student states only one other driver.
- No credit if the student does not answer or states something completely irrelevant.

Question 5. What in your opinions are the main differences between Dutch and American flood risk mitigation? [4 points total]

Criteria:

- Allow 4 points for clearly stating and describing the differences between two countries with examples or detailed explanations.
- Allow 3 points for clearly stating and describing the difference between two countries without examples or detailed explanations.
- Allow 2 points for simply listing examples of different approaches between two countries without explanations.
- Allow 1 point if the student vaguely or unclearly states differences between two countries (or guessing).
- No credit if the student does not answer or states something completely irrelevant.

Question 6. List 5 examples of mitigation strategies that are innovative and where they have been applied (not limited to the United States or the Netherlands). **[15 points total—3 per example]**

Criteria:

- Allow 3 points if the student states a specific mitigation example and its location (e.g., Maeslant barrier, Rotterdam).
- Allow 2 points if the student states a somewhat general example and its location (e.g., storm surge barrier, the Netherlands).

- Allow 1 point if the student states an example but missing its location (e.g., Maeslant barrier/storm surge barrier).
- No credit if the student does not answer or states something completely irrelevant.

Question 7. As part of NSF PIRE CFRRP, we have identified 5 or 6 case study areas: 2 or 3 in the United States and 2, 3, or 4 in the Netherlands. Based on your *existing* knowledge of each area, please list what you view as the primary driver of flood risk. List two to three ideas for mitigation in each area. [25–30 points total—5 point per case]

Criteria:

- Allow 5 points if the student states two or more primary drivers and two or more mitigation ideas that can mitigate the stated drivers—the drivers and mitigation ideas are matched (e.g., Drivers: storm surge; Mitigation idea: building a storm surge barrier/ Drivers: land use pattern; Mitigation idea: adopting a zoning system).
- Allow 4 points if the student states:
  - Two or more primary drivers and two or more mitigation ideas but they are randomly listed—the drivers and mitigation ideas are not matched (e.g., Drivers: land use pattern; Mitigation idea: building a storm surge barrier); **or**
  - Two or more drivers with only one matching mitigation idea.
- Allow 3 points if the student states one primary driver and two or more mitigation ideas that can mitigate the stated drivers—the drivers and mitigation ideas are matched.
- Allow 2 points if the student states:
  - One or more primary driver and one or more mitigation ideas but they are randomly listed—the driver and mitigation idea are not matched;

    or
  - One primary driver with only one matching mitigation idea
- Allow 1 point if the student states either primary drivers or mitigation ideas, but not both.
- No credit if the student does not answer or states something completely irrelevant.

<Mitigation ideas> [10–12 points total]

- Allow 2 points if the student states three or more mitigation ideas that include both nonstructural and structural or both engineering and plan/policy approaches.
- Allow 1 point if the student state two mitigation ideas that include both nonstructural and structural or both engineering and plan/policy approaches.
- No credit if the mitigation idea(s) are solely nonstructural, structural, engineering or plan/policy-based, or no mitigation ideas are mentioned.

Highest possible score 62 points (2019/2018); **69 points (2017/2016**)

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