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Facilitating Interdisciplinary Problem-Solving among Pre-Collegiate Engineering Students via Materials Science Principles

Dr. Denia Djokic, University of California, Berkeley

Denia Djokic is a postdoctoral researcher in nuclear engineering at the University of California, Berkeley. Dr. Djokic received her PhD in nuclear engineering from UC Berkeley in 2013 as a graduate fellow of the Department of Energy's Office of Civilian Radioactive Waste Management. She also received her MS from UC Berkeley in 2007 and her BS in Physics from Carnegie Mellon University in 2005. Her academic interests range from radioactive waste management, advanced nuclear fuel cycle systems, and nuclear security policy to energy science and technology, energy sustainability, engineering ethics, and engineering education. She is a national member of the American Nuclear Society and a founding member of Nuclear Pride.

Prof. Wil V. Srubar III, University of Colorado Boulder

Wil V. Srubar III is an assistant professor of civil, environmental, and architectural engineering at the University of Colorado Boulder. Prof. Srubar received his PhD in structural engineering and materials science from Stanford University in 2013. He received his bachelors degree in civil engineering and architectural history from Texas A&M University in 2006 and his masters degree in civil, architectural, and environmental engineering from The University of Texas at Austin in 2008. His research interests include sustainable materials science, interdisciplinary engineering education, and the retention of underrepresented groups in engineering. He is an active member of the American Society of Civil Engineers, the Architectural Engineering Institute, and the American Concrete Institute, and he is affiliated with the United States Green Building Council.

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Abstract

Given that fundamental materials science principles transcend traditional disciplinary boundaries, a grand opportunity exists to leverage materials science concepts to facilitate multidisciplinary teaching and learning. This paper presents the development and implementation of a three-phase teaching module designed to foster organic, cross-disciplinary discourse and learning among pre-collegiate engineering students. Thirty domestic and international high school students were selected for an introductory four-week summer course in engineering. The students were divided into two classes, either civil engineering or nuclear engineering, according to their disciplinary preferences. In Phase I of the interdisciplinary module, the students were taught fundamental discipline-specific concepts in separate classrooms by their respective instructor (e.g., static equilibrium, nuclear reactor physics) over the course of one week. In Phase II, a joint lecture on diffusion, a materials science topic of mutual importance to both disciplines, was given to all students and facilitated by both instructors. In Phase III, the students worked in mixed, interdisciplinary teams in a structured problem-solving session in which they were asked to apply their knowledge of static equilibrium, diffusion, and nuclear principles to solve engineering design problems regarding reactor pressure vessels and radioactive waste casks.

The effectiveness of this collaborative module in promoting cross-disciplinary learning was assessed through an analysis of student responses to an anonymous survey. The results show that the module was effective in (a) teaching students the fundamental principles of diffusion, (b) fostering peer-to-peer teaching and learning, and (c) emphasizing the importance of teamwork and problem-solving across disciplines. The results also indicate that students developed a broader view regarding the applicability of their knowledge beyond their own disciplinary boundaries. Given its universality, this materials-focused teaching module has the potential to serve as an effective model to foster interdisciplinary teaching and learning between other engineering disciplines.

Introduction

Engineers must gain the ability to communicate and collaborate across disciplines in addition to gaining a deep technical disciplinary knowledge. This is increasingly true in modern society in which scientists and engineers must address complex, interdisciplinary challenges on a global scale. While current efforts at teaching interdisciplinary problem-solving at the collegiate-level (e.g., class projects, capstone courses) exist, the effectiveness of many of these approaches are ineffective in achieving interdisciplinary learning objectives. Richter and Paretti (2009) identified two main learning barriers to common interdisciplinary approaches: (1) students are unable to identify the relationship between their own discipline and an interdisciplinary subject; and (2) students are unable to identify and value the contributions of multiple technical and non-technical fields to a given interdisciplinary problem.

While more recent studies have included assessment components (and have been successful in achieving learning objectives), it remains that current interdisciplinary learning efforts (and associated assessment research efforts) are highly concentrated at the collegiate level, while efforts at achieving and assessing *interdisciplinary* learning objectives at the pre-collegiate level have not yet been thoroughly investigated.

Recent studies have sought to identify a common vision, which is currently lacking, for pre-collegiate engineering education. Most authors agree that, currently, there is a lack of systemic infrastructure and support mechanisms for pre-engineering programs and that there is not a common, agreed-upon definition of a body of engineering knowledge that are appropriate at the pre-collegiate level (Chandler, et al. 2011). Marshall and Berland (2012) posited that the primary goal of any pre-collegiate engineering programs should be to develop a command of the engineering design process that transcends traditional mathematics and science curriculum goals. In a more multi-dimensional study, Moore, et al. (2014) proposed a framework and identified twelve key indicators for describing and designing effective K-12 engineering programs. These indicators include (a) applying concepts in science, engineering, and mathematics and (b) conceptualizing the engineering profession. The authors state that educators can achieve these two objectives by emphasizing this interdisciplinary nature of engineering and include the integration and understanding of multidisciplinary engineering concepts. To this end, however, Stohlmann, et al. (2012) argues that, while teaching integrated STEM principles across disciplinary boundaries is effective in making learning more relevant to students, there is a need for further research and discussion on the knowledge, experiences, and background that teachers need to effectively teach integrated concepts.

Scope of Work

In this work, an interdisciplinary mixed-classroom module was designed, implemented, and preliminarily assessed during a four-week summer course for pre-collegiate engineering students. The hypothesis of this study was that, independent of engineering discipline, fundamental principles of materials science govern certain classes of problems in the design and analysis of engineering solutions and that there is a common materials-based discourse that can be leveraged to promote interdisciplinary teaching and learning in the pre-collegiate engineering classroom. The specific objectives of this study were:

(1) To value their specific expertise and acknowledge their individual contribution to an interdisciplinary problem;
(2) To appreciate the interdisciplinary effort of a multi-disciplinary team;
(3) To cross-communicate and teach each other discipline-specific concepts;
(4) To provide a replicable interdisciplinary framework for pre-collegiate programs and collegiate-level interdisciplinary programs.

To achieve these objectives, two separate groups of students were separately taught either principles of civil engineering (e.g., statics) or nuclear engineering (e.g., reactor physics) by two instructors. The students were then brought together and taught how a certain materials phenomenon (diffusion) applied to both disciplines. The students then participated in an interdisciplinary, team-based problem-solving session that was designed to facilitate peer-to-peer teaching and learning. The effectiveness of the module was assessed by an anonymous survey. The individual responses were analyzed and general observations were made based on the preliminary results.

Disciplinary Course Descriptions and Multidisciplinary Classroom Module

In the summer of 2014, 30 high school students were admitted to a four-week introductory engineering course at a college campus. They were allowed to choose, based on their interests, a section of the course that would focus on either (a) Civil Engineering or (b) Nuclear Engineering. The students were divided according to their preferences. As part of the program, these students experienced a unique residential setting, sharing close living quarters and participating in daily social events, fostering a strong sense of academic cohort comraderie.

Introduction to Nuclear Engineering: Course Objectives and Components

The Introduction to Nuclear Engineering course exposed students to a variety of topics in the field of nuclear engineering, including the social and historical context of nuclear issues. The specific course objectives were designed so that by the end of the course the students would (1) understand the technical foundations and interdisciplinary nature of the nuclear engineering field; (2) comprehend the current and historical controversies surrounding nuclear energy; and (3) be able to read any news article related to nuclear energy or nuclear security and explain it from a technical perspective.

Specific course topics included: nuclear physics and interactions of radiation with matter, reactor design, reactor safety and reactor accidents (Three Mile Island, Chernobyl, and Fukushima), risk assessment, the nuclear fuel cycle, radioactive waste management, nuclear energy in the context of climate change, dosimetry and health physics, medical applications, nuclear weapons and nuclear non-proliferation. The theoretical parts of the course were supplemented by relevant field trips, film screenings, a debate, and a capstone project of the students' choosing.

During this course, the students developed an understanding of not only the basic principles of nuclear technology, but also the costs and benefits of nuclear energy and other energy sources. They appreciated the complexities of the field, the physics and chemistry behind it, and the sociopolitical issues surrounding it. They demonstrated critical thinking, learned how to question and verify sources of information, and practiced their independent research skills and resourcefulness. At the end of the course, the students walked away with knowledge and skills that has solidly contributed to their preparation for a university-level engineering class.

Introduction to Civil Engineering: Course Objectives and Components

The Introduction to Civil Engineering course exposed student to both the art and the science of engineered structures. Using principles of math and physics (e.g., static equilibrium), the students analyzed towers, buildings, and bridges, including historic monuments such as the Eiffel Tower and the Golden Gate Bridge.

Upon completion of the course, successful students were able (1) to understand the influence of materials like concrete and steel on structural engineering; (2) to calculate the efficiency of structures using physics-based principles; (3) to evaluate the life-cycle impact and sustainability of materials and structures; (4) to design a bridge using a computer program and predict its load-carrying capacity; (5) to communicate effectively about different issues pertaining to engineering structures; (6) to see (in person) modern engineering marvels.

The principles of structural engineering and calculations of efficiency and safety were presented through the use of structural case studies. Homework assignments, laboratories, and hands-on design projects were designed to emphasize structural analysis for columns, towers, buildings, trusses, and arch structures. This course included field trips to relevant local landmarks, documentaries, structural analysis using computer modeling software, and hands-on learning by building and testing domes and a model bridge. In addition to technical calculations, this course emphasized the importance of effective communication in the field of engineering through student presentations and written reports.

Multidisciplinary Module: Structure, Lesson Plan, Assignment

Structure of the Multidisciplinary Module

The framework implemented in the multidisciplinary module is illustrated in Figure 1. The module was divided into three distinct phases. In Phase I, the two instructors taught fundamental disciplinary principles to students in their respective courses, as elaborated in the course descriptions above. For example, the civil engineering instructor taught the principles of static equilibrium, structural design, and environmental impact of construction materials to the civil engineering students. The nuclear engineering instructor taught the principles of reactor physics, nuclear waste, and containment to the nuclear engineering students. In Phase II, the students from both courses were combined into one large lecture classroom. The instructors co-taught a lecture on materials and transport phenomena with a primary focus on diffusion. In Phase III, the students were paired into multidisciplinary teams to complete an assignment that required disciplinary expertise. The assignment was designed to facilitate organic cross-disciplinary discourse and learning through structured problem-solving. Details on the combined lecture lesson plans and the combined team assignment are discussed below.

Lesson Plan for the Multidisciplinary Lecture (Phase II)

Recent research has shown both advantages and disadvantages to mixed classrooms. According to Jones and Harris (2012), advantages (such as variety of teaching style, expertise) are maximized and disadvantages (such as adjustment to teaching styles, communication difficulties) are minimized when instructors interact and collaborate in class in multidisciplinary courses are in courses with multiple instructors. The combined multidisciplinary lecture on materials and transport phenomena was divided into three parts: (A) a mini-lecture on diffusion in civil engineering, (B) a mini-lecture on diffusion in nuclear engineering, and (C) a discussion of real-world problems in which both civil and nuclear engineering professional expertise is required.

Part A: Diffusion in Civil Engineering

The instructors led with a discussion on diffusion in civil engineering because students were most likely familiar with real-world examples of materials in civil engineering (e.g., buildings, bridges, pavements). The pre-existing familiarity provided a common discourse for all students to engage. The lecture on the importance of diffusion in civil engineering included topics to answer the following questions:

(a) What are common materials used in civil engineering? This topic provided definitions and common terminology of building materials (e.g., steel, wood, reinforced concrete).

(b) What are the primary causes and mechanisms of deterioration? This topic introduced the concept of water and ion (e.g., chloride) diffusion in reinforced concrete.

(c) What effect does chloride ions have on reinforced concrete? This topic showcased the mechanisms of chloride-induced corrosion in reinforced concrete.

(d) What is a diffusion coefficient and how is it measured? This topic introduced the students to rate processes of materials and methods by which diffusion coefficients are quantified.

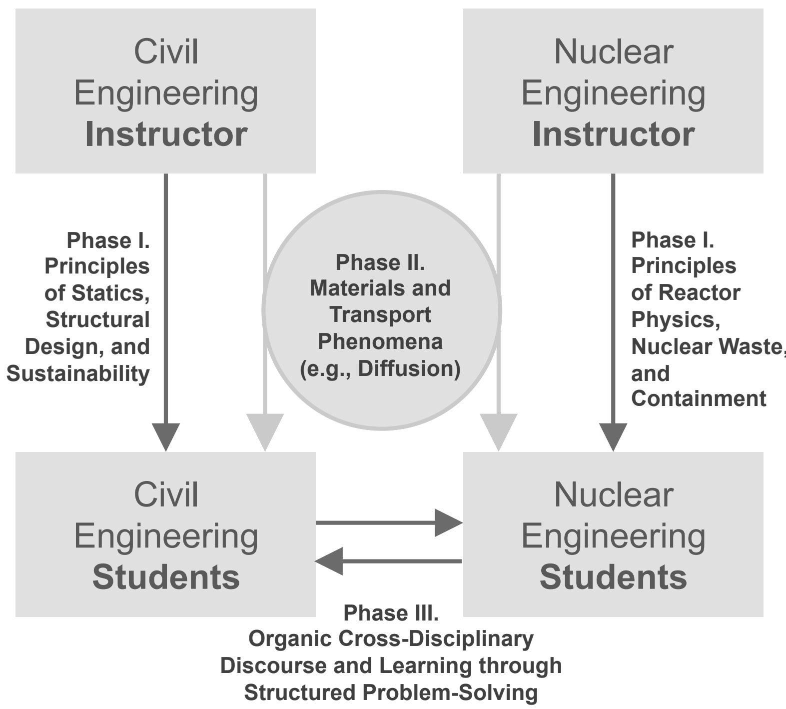

Figure 1: Multidisciplinary framework to facilitate cross-disciplinary discourse and learning through materials science principles.

Part B: Diffusion in Nuclear Engineering

The instructors then led a discussion on diffusion in nuclear engineering. The lecture was intended to provide sufficient details on the background of radionuclides and answers to the following questions:

(a) How do we model radionuclide migration in geologic media? This topic was introduced by using some of the same language that was used in the previous discussion on diffusion in civil engineering.

(b) How is neutron transport modeled? The variables used in transport modeling, as well as the complexity in measuring and modeling the process, were highlighted.

Part C: Discussion of the Intersection of Civil and Nuclear Engineering

The instructors then led a group discussion on the intersection of civil and nuclear engineering. The students were asked a series of leading questions that were designed to solicit answers from students in both engineering disciplines:

(a) What materials are used to construct nuclear facilities and repositories?
(b) What factors do civil and nuclear engineers consider in design?
(c) What are the differences in the mathematical principles in each field? The main objective of this discussion series was to highlight that the mathematical principles to model diffusion processes are fundamentally the same regardless of discipline.

Assignment for the Multidisciplinary Lecture (Phase III)

After the two-hour lecture, the students were divided into groups of four. Two civil engineering students and two nuclear engineering students comprised each team. The students were then asked to complete the following team-based assignment. The assignment required the use of discipline-specific and interdisciplinary concepts.

Preliminary Results and Discussion

The survey questions and general observations from preliminary responses are presented below. Out of the 29 students surveyed, 10 students submitted responses. Three responses were from the nuclear engineering students and seven were from the civil engineering students. The survey was conducted six weeks after the end of the summer program.

In recognition that the data from survey responses is limited, below are some first-order observations and key trends of the students' responses. Full responses are shown in Appendix B.

1. How did you feel about your ***individual*** performance in the context of (i) the pressure vessel and (ii) the diffusion problem?

   Observation*: Generally, every student felt confident in their performance, though about half of the students said that they performed better in one area than another. This is likely due to the recognition that their discipline-specific knowledge, while helpful, is also limited in solving complex problems.*

2. How did you feel about your ***group's*** performance in the context of (i) the pressure vessel and (ii) the diffusion problem?

   Observation*: All students felt like their group performed effectively to solve the problems, and emphasized the value and importance of communication (and that their group did it well). All agreed on the value of bringing different strengths and skill sets together to solve a common problem.*

3. What information did you rely on to solve the diffusion problem?

   Observation*: The students noted that they relied on the data that was given, the equations that were given in lectures, and their group members. This is indicative of the teams evoking the strengths of team-based problem solving.*

4. What did you learn during the group assignment that you didn't already know?

Observation*: The answers given varied from the conceptual understanding of diffusion to learning how diffusion is applicable to many disciplines. Others noted that the assignment required a high degree of communication and that communication is needed across disciplines. Others mentioned that they learned what other disciplines were, and others identified more skills-based knowledge that they had acquired (e.g., "… how to use Microsoft Excel").*

5. Describe how and what you communicated to your peers regarding your own disciplinary perspective before, during, and after the diffusion day.

Observation*: Generally, the responses indicated that the amount or quality of the communication did not change as a result of the mixed classroom module, because the students communicated frequently since they were sharing a common residence. This data suggests that the shared residence further enhanced cross-communication and interdisciplinary teaching and learning.*

6. In general (throughout the whole course), how did you interface with other students in an unstructured environment outside of class? Did you teach each other disciplinary concepts?

Observation*: (See question 5) Results indicate that communication outside of class was ongoing. Most students described talking about general disciplinary concepts with their peers, but not really formally teaching anything. However, many emphasized that the general exchange of ideas was fun and important and facilitated by being housed together in the same building.*

Y / N Did teaching other students what you already knew solidify your knowledge of those concepts?

Observation: All students answered yes to this question.

Y / N Did learning about diffusion help you understand the broader applications of your field?

Observation: All students answered yes to this question.

Y / N Do you feel that this interdisciplinary experience added to or took away from your learning process? Please elaborate on ideas you have to strengthen this interdisciplinary module.

Observation*: This free response was the most beneficial in assessing the success of the interdisciplinary module. One student responded:*

"I think this experience added to my learning process because it showed me how my discipline related to and was vital for the discipline. In other words, it showed how the two disciplines overlapped and how they were somewhat dependent on one another."

Another student noted:

"Yes, the interdisciplinary experience definitely added to the learning experience. We were able to see the real life applications of many of the topics we learned in class, such as the design of a nuclear reactor. Working with those from other

classes helped us consolidate our knowledge, as we had to teach some of the topics learned to others. Through this teaching process and exchange of ideas, we were able to strengthen our own knowledge."

Future Work

This work represents a first step in assessing the effectiveness of interdisciplinary modules at the pre-collegiate engineering level. Limitations in the acquired data set make it difficult to draw firm conclusions. The authors have plans to collect additional data from pre-collegiate students after implementing this approach. Some of the main questions that still remain include the extension and applicability of this materials-based education framework to other peer-to-peer contexts not only at the K-12 level, but also at the collegiate level. This framework could be evaluated in peer-to-peer undergraduate materials laboratory contexts. The authors have current plans to implement and assess the effectiveness of versions of this framework in collaboration with educational researchers at the graduate-undergraduate level in a combined problem-solving session.

Conclusions

The effectiveness of an interdisciplinary module based on the principles of materials science was assessed at the pre-collegiate level via anonymous student surveys. The objectives of the module were (1) to value their specific expertise and acknowledge their individual contribution to an interdisciplinary problem; (2) to appreciate the interdisciplinary effort of a multiple discipline team; (3) to cross-communicate and teach each other discipline-specific concepts; and (4) to provide a replicable interdisciplinary framework for pre-collegiate programs and collegiate-level interdisciplinary programs. The preliminary results suggest that the materials-based framework was effective in achieving the objectives. However, the limited data that was collected requires further investigation on the generality and applicability of the framework to other interdisciplinary contexts (e.g., peer-to-peer, graduate-undergraduate laboratories).

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Dr. Wil V. Srubar III, University of Colorado Boulder

Wil V. Srubar III is an assistant professor of civil, environmental, and architectural engineering at the University of Colorado Boulder. Prof. Srubar received his PhD in structural engineering and materials science from Stanford University in 2013. He received his BS in civil engineering and architectural history from Texas A&M University in 2006 and his MS in civil, architectural, and environmental engineering from The University of Texas at Austin in 2008. His research interests include sustainable materials science and the retention of underrepresented groups, namely LGBT students, in undergraduate engineering programs. He is an active member of the American Society of Civil Engineers, the Architectural Engineering Institute, and the American Concrete Institute, and he is affiliated with the United States Green Building Council.

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Appendix A: Multidisciplinary Assignment of Phase III

Problem I. Reactor Design Problem

Consider the following dimensions, pressures, and factor of safety.

1. Calculate the thickness required to construct a ***safe*** (a) spherical and (b) cylindrical pressure vessel out of the following materials. Calculate the total volume, total cost, and total carbon needed to construct each.
2. Which of the designs is most favorable according to these considerations? ***Why***?
3. We actually construct cylindrical vessels for nuclear reactors. ***Why***?

Length:	**11**	**m**
Internal Radius:	**1.5**	**m**
Pressure:	**15.5**	**MPa**
Factor of Safety:	**10**	

Material	Tensile Strength (MPa)	Cost ($/kg)	Carbon (kg CO_2-eq/kg)	Density (kg/m3)
Stainless Steel	520	$4.00	6.15	8000
Aluminum	440	$1.70	9.20	2700
Steel	250	$2.00	1.46	8050
Copper	70	$7.00	2.70	8960
Cast Iron	130	$1.50	1.46	7870
Concrete	3	$0.85	0.11	2000

Problem II. Design of Dry-Cask Storage of Nuclear Waste

Calculate the thickness of concrete needed to resist the diffusion of each radionuclide through the cask walls. (a) Consider diffusion at a global temperature equal to room temperature and (b) consider diffusion at a temperature increase 30 C due to global warming effects that will have occurred in 1,000,000 years.

Limit Conc. (c/c_0)	**1.0**	
Total time	**1,000,000**	**Years**

Radionuclides	D_0 (m^2/s)	E_a (J/mol)
Technetium 99	1.95E+00	56000
Cesium	5.50E-02	49000
Iodine 129	4.03E-03	42000
Uranium 238	5.68E-02	53000
Neptunium	1.12E-07	30000
Plutonium	1.06E-05	45000

Appendix B: Student Responses (Full)

Which class were you in -- nuclear or civil engineering?	How did you feel about your *individual* performance in the context of (i) the pressure vessel and (ii) the diffusion problem?
Nuclear	I contributed a lot
Civil	I think that I learned a lot from both parts of the problem presented because of how much our group used excel in our calculations.
Civil	I feel that I did better in the pressure vessel problem than in the diffusion problem.
Nuclear	I felt as if I performed very well in both problems and knew exactly what to do to solve them.
Civil	I think that I definitely played my role in both the pressure vessel and the diffusion problem. I helped with the calculation, and I also shared what I learned in the civil engineering class with my group members.
Civil	In pressure vessels I was helpful to my group and I understood it. The diffusion problems I really did not understand much of what was going on, only had limited knowledge.
Civil	i) I was pretty confident in this part of the assignment because I was already familiar to the formula needed to solve the problem. What I liked was that the problem was also challenging because we needed to know which value to multiply with which value, and so on. On the other hand, in part 3, I was pretty stumped because I did not know why cylindrical vessels are used in nuclear reactors. ii) This part was easier, compared to the part i. The formula was given to us during the presentation, so it was pretty straightforward, just that we had to watch out for the input of the calculations into Excel.
Civil	I felt prepared to answer the questions regarding the physical structure really well, but I was unable to solve the problems including nuclear aspects on my own.
Civil	I think I did well (from what I can remember)
Nuclear	I feel like I contributed the best I could towards solving both problems. I was able to bring different perspectives from other classes as the group was split between the two classes. I was able to provide a particular nuclear perspective and apply the knowledge that I learned that others in the group may not have been able to do.

Which class were you in -- nuclear or civil engineering?	How did you feel about your *group's* performance in the context of (i) the pressure vessel and (ii) the diffusion problem?
Nuclear	We split up - the nuclear kids did the nuclear problem and the civil kids did the other. We finished the nuclear problem first, the other half of the group were the last to finish because they did it manually
Civil	Exchange of ideas and explanations were clear and plentiful!
Civil	I think that my group consisting of nuclear and civil students was able to work in a timely and accurate fashion.
Nuclear	My group worked extremely efficiently on both problems and thus performed very well.
Civil	They were absolutely helpful. They figured out how to used excel for calculation, and we together got the spreadsheet done.
Civil	As a group I think that we did well since we were able to help each other out. Our knowledge put together allowed us to learn and finish the task.
Civil	What we did for both parts was that we calculated the problems simultaneously and then compared the formulas and the calculations we used in the case of any discrepancies in the answer. The pressure vessel problem was more complicated because the civil and the nuclear students knew part of the answer, but they had to communicate with each other to get the full answer. However, I think that it worked out pretty fine, and in the end, we could agree on a correct solution for both parts.
Civil	My group performance was great. Our different strengths allowed us to come together and solve a problem.
Civil	I think we did well, from what I can remember)
Nuclear	I felt like my group performed very well on both problems. As solving the pressure vessel and diffusion problems involved aspects from both classes, good communication was incredibly important. Sometimes, Nuclear could supply information that the Structural class lacked and vice versa. Only by working cohesively as a team, were we successful in solving the problems.

Which class were you in -- nuclear or civil engineering?	What information did you rely on to solve the diffusion problem?
Nuclear	N/A
Civil	radionuclide and material properties that were specified online/in the problem
Civil	diffusion equation, diffusion constants for each material, strength of different materials, and equations about pressure and force
Nuclear	The data given to the students in the problem, such as the coefficient of diffusion.
Civil	I relied on the equations given in the lecture as well as my previous learning in my civil engineering class.
Civil	I relied on my group members to help me understand what was going on.
Civil	To solve the diffusion problem, we primarily relied on the formula given to us during the class. In addition to that, we used the example problem in class to give us an idea on how to go about solving these problems.
Civil	I don't remember. Sorry!
Civil	Info from class, info from my partner, and info from the Internet and other groups
Nuclear	The information we had to rely on came both from the Nuclear and Structural classes. For example, sometimes Nuclear students had to explain some concepts of decay, while Structural students provided some support with equations and calculations.

Which class were you in -- nuclear or civil engineering?	What did you learn during the group assignment that you didn't already know?
Nuclear	How to apply the formula
Civil	how the heck diffusion works and the math behind it
Civil	The amount of cooperation required for different disciplines of engineering to make a single decision where both disciplines have their own criteria for what the best decision is.
Nuclear	How important diffusion was to understanding so many engineering problems.
Civil	I figured out how to use excel to do estimations.
Civil	I learned more about diffusion and also how different engineering paths mix in order to work at a specific goal.
Civil	I did know that spherical vessels are safer than cylindrical ones with the same thickness. I did not know that one can quantify this 'safety' into the thickness of the concrete needed. Second, I learned that cylindrical vessels are used in nuclear reactors to maximize the space for the rods. Most importantly, I learned how different engineers work together to solve a problem. To solve these problems, I noticed that civil and nuclear students had learned different things, but if one combines the knowledge of both, then one can solve more advanced problems like these.
Civil	The walls would have to be really thick!
Civil	I don't remember
Nuclear	I not only learned about the new topic of diffusion, I also got a better feel for what students in other classes were learning. I gained a better view of what the structural class pursued and learned about each day in class.

Which class were you in -- nuclear or civil engineering?	Describe how and what you communicated to your peers regarding your own disciplinary perspective before, during, and after the diffusion day.
Nuclear	N/A
Civil	I didn't really think that civil and nuclear would do something together, so working with the other class was pretty interesting. Communication didn't change, since the people in our group already got along pretty well.
Civil	For the most part, I communicated the same amount of information before and after the diffusion day. I would just converse with them about the topics learned in class that day, but would not try to teach them the topics unless asked.
Nuclear	I communicated my love of physics to everyone throughout the course (by talking to them)!
Civil	Basically, I would just talk to them directly for questions or comments, and the subjects of conversations were mostly academic.
Civil	Before: helping understand what the basic ideas behind a pressure valve is During: helped work problems out and what they meant After: Don't remember
Civil	I told my peers about the safety factor of structures and the formulas to calculate the thickness of the concrete of a sphere and a cylinder from a given safety factor.
Civil	I shared my knowledge and I learned a lot about theirs. (PS- I'm not quite sure what this question is asking)
Civil	I shared what I knew and stuff
Nuclear	The extent to which we communicated with our peers didn't change too much in comparison to before and after the diffusion day. However this was only because we consistently communicated with one another throughout the entire course.

Which class were you in -- nuclear or civil engineering?	**In general (throughout the whole course), how did you interface with other students in an unstructured environment outside of class? Did you teach each other disciplinary concepts?**
Nuclear	N/A
Civil	I mingled with other classes, as everyone else did. Inside the civil engineering group, we referenced facts as inside jokes to everyone, but rarely taught others in earnest (unless someone asked for help).
Civil	For the most part, I just told the other students, in basic terms, what we learned and did in class, but did not go into great detail or try to teach them the concepts I was learning.
Nuclear	Yes I aimed to spread my knowledge and ideas to all of my friends and help inspire them as much as possible about the topics I am interested in.
Civil	For most of the times we would share and discuss what we learned in classes with each other. By doing that, we knowed more about different subjects of areas.
Civil	N/A
Civil	Because all of the engineering students were housed in one building, this allowed us to build friendships across our disciplines and not be confined to one. This offered many insights into what other students were doing and what they learned. For example, I saw energy students working on their reports or using electromagnetism to make a generator. On the other hand, when I was working on something, many would become interested, and I had the chance to tell them about what I learned.
Civil	I do. I love learning from people that are taking different classes than I am, and collaboration is usually easy and productive.
Civil	We shared the stuff we learned about, if that's what you're asking
Nuclear	Outside the classroom, we would often compare what we learned in class with each other. Although there was little clear cut teaching, we discussed ideas (often even in a somewhat competitive tone). This casual discussion of ideas led to the general exchange of some concepts.

Which class were you in -- nuclear or civil engineering?	Did teaching other students what you already knew solidify your knowledge of those concepts?	Did learning about diffusion help you understand the broader applications of your field?
Nuclear	Yes	Yes
Civil	yes	yes
Civil	yes	yes
Nuclear	Yes	Yes
Civil	Yes	Yes
Civil	Yes	Yes- used in chemical, but also structural engineers also look at diffusion
Civil	Yes	Yes
Civil	Yes. Definitely.	Yes. It was essential in doing so.
Civil	Yes	Yes
Nuclear	Yes	Yes

Which class were you in -- nuclear or civil engineering?	**Do you feel that this interdisciplinary experience added to or took away from your learning process? Please elaborate on ideas you have to strengthen this interdisciplinary module.**
Nuclear	Added to
Civil	It was interesting. I think that it added to my learning process. I would suggest a tutorial on excel, but for us, asking for help just fostered more positive communication.
Civil	I think this experience added to my learning process because it showed me how my discipline related to and was vital for the discipline. In other words, it showed how the two disciplines overlapped and how they were somewhat dependent on one another.
Nuclear	I feel strongly that it added to my learning process throughout the camp's duration, as it put into context many key engineering issues and problems that not only nuclear engineers face, but a whole host of other engineering professions as well. I don't think that this module could have been any better in truth, however the problems we worked on could probably have been slightly more challenging in my opinion!
Civil	I think that the diffusion day surely added to my learning process. When we civil engineering students thought about building reactors, we generally would not consider nuclear factors. But after the diffusion day, I knew that there are much more points to consider.
Civil	It added to my learning process as it broadened what I knew at applied it to other fields in engineering.
Civil	This interdisciplinary experience definitely added to my learning process. I did not necessarily learn something about nuclear engineering, but I definitely got the chance to gain an insight into how engineers function in the real world and how they work together to solve problems. To strengthen this module, I would limit the group size to 2 because in my group, there were two civil engineering students, so while one was explaining the concept to the nuclear engineering student, the other would sit out and not participate.
Civil	It definitely added to the experience. Interdisciplinary modules are always the most fun and applicable.
Civil	It added, it was nice to work in groups and learn some of the stuff that the other classes were learning.
Nuclear	Yes, the interdisciplinary experience definitely added to the learning experience. We were able to see the real life applications of many of the topics we learned in class, such as the design of a nuclear reactor. Working with those from other classes, helped us consolidate our knowledge as we had to teach some of the topics learned to others. Through this teaching process and exchange of ideas, we were able to strengthen our own knowledge.

For the nuclear students only: Compare and contrast diffusion day to the morning that you taught nuclear engineering concepts to the energy engineering class. Was this a learning process for you? Which did you enjoy more, and why? Which process of information transfer would you say was more effective, and why? Any thoughts on the contrast of the two very different styles of teaching/learning are welcome here.
I found both really helpful in solidifying my learning, however i enjoyed and learned more through diffusion day
I would say both days were extremely instructive for my own perspective, especially the teaching day as this forced to step slightly out of my comfort zone and at the same time clearly and accurately relay complex information that I had synthesised during the course to the energy class. I thoroughly enjoyed both days, even though the teaching does come out slightly on top. I would also say that the diffusion day might have been more helpful in terms of transferring information to the energy engineering class, as during our teaching session, information was relayed quite sporadically, which almost certainly made it harder for them to understand the fundamental concepts that we were trying to get across than if they had been taught by two amazing teachers! Thank you for the great and informative survey :)
The learning process was definitely different in some ways. In the Nuclear class we often engaged in more light-hearted discussion, which I felt added to our learning experience. The mood lead students to be more comfortable and more receptive to new ideas.