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Online Interdisciplinary STEM Education: A Case of Co-teaching for Social Justice

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**ABSTRACT**

This paper presents the process two professors engaged in to develop a co-taught model for two online graduate courses taught concurrently as part of a justice-oriented STEM education curriculum. Students in the courses, who are k-12 teachers, contributed to the development of the courses across iterations through feedback and discussions with the professors. Our previous co-teaching experiences in face-to-face courses supported by literature on co-teaching in higher education online environments were instrumental in preparing for the initial semester and ongoing development of these two co-taught courses. Development of the courses also relied on extensive cogenerative dialogue that resulted in a merged calendar tool and revised discussion assignment strategies. Integration of content across STEM disciplines was enacted and modeled in both courses, in part through assignments that were connected across the two courses.

*Keywords:* STEM, online education, social justice, ecojustice, co-teaching, interdisciplinary learning

The University of West Georgia is a large producer of education graduate degrees in the state and serves as a leader in many other areas of interest. We are located in a relatively suburban area, with close access to two major cities in the southeast; as with most institutions, especially after COVID-19, graduate programs are offered primarily online with little to no on-campus expectations. As with many graduate programs that are housed online, we tend to serve students throughout the state. Our department within the College of Education offers several different types of degrees at the graduate level along with several endorsements of interest to the k-12 classroom teacher and administrator. We developed two courses in different, related content areas which we have taught collaboratively through shared goals and related readings, activities, and assessments for three years within a STEM Education Endorsement. The endorsement is the product of our combined specialties and a mission of a department that includes others who are directly invested in STEM education for a more socially just society. Table 1 presents the course descriptions for our two courses.

The STEM Education Endorsement was designed to immerse teachers in STEM issues relating to social justice, as evidenced in the course descriptions above. Graduate-level students who hold a teaching certificate are eligible to enroll in the endorsement, which consists of a series of four courses taken over a calendar year with common goals, readings, activities, and assignments.
designed to meet the specific content and relate to STEM and social/ecojustice. We share readings and activities, in the appendix, that are established in research-based literature as directly related to social-justice, but there are many others that could also be used in courses such as these that are subjective to the instructor perspective. Students take a summer introductory course focused on STEM in the community prior to our co-taught science for ecojustice and math for social justice courses. The final course, what is considered a capstone, ties together concepts addressed in each of the previous semester syllabi into a community-based effort to bring meaningful STEM to others. The information detailed in this manuscript is intended to illustrate how we adapted two online courses in an effort to model content integration and simultaneously address integrative co-planning and implementation of a justice-oriented STEM curriculum.

Table 1  
Course Descriptions

<table>
<thead>
<tr>
<th>Science for Ecojustice</th>
<th>Math for Social Justice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will be introduced to research in science education that promotes awareness for multiple perspectives and considers diverse aspects of STEM efforts within the community. Through a focus on ecojustice issues, the student will develop skills necessary to contextualize science instruction for effective community-based STEM initiatives as well as the dispositions, knowledge, and skills needed to teach integrated STEM lessons to students in P-12.</td>
<td>Concepts and materials which are appropriate for mathematics education integrated with science, technology, and engineering for P-12 children will be investigated. In addition, STEM education is considered through the lens of social justice, equity, and community-based learning. This course is a prerequisite for Designing Community-Based STEM Education.</td>
</tr>
</tbody>
</table>

Literature on STEM Education

As part of the process of developing courses and key assessments for the STEM Education Endorsement, we focused on an interdisciplinary approach to STEM, as defined by Vasquez (2014): “Students learn concepts and skills from two or more disciplines that are tightly linked so as to deepen knowledge and skills” (p. 13). This is a challenge that k-12 STEM teachers are called to meet: to implement a STEM curriculum integrated across content areas with rich tasks that address real-world concerns. STEM teachers may find that their backgrounds in only one or two content areas have left them underprepared for integrative planning (Al Salami et al., 2017; Radloff & Guzey, 2016). Indeed, many never experience a truly interdisciplinary course as a student in a college setting during their teacher preparation training (Nowikowski, 2017). We realized if we wanted our students to truly understand the interdisciplinary approach to STEM teaching and learning, they would need to experience it first-hand in our classes. This led to our initial discussions of integrating the two courses so that our candidates would develop a more comprehensive understanding of STEM as a truly integrative discipline. Our preparatory research indicated that many people talk about the importance of STEM education, but few actually address it holistically or address the balance of the individual disciplines within the framework of justice (Bybee, 2010; Garibay, 2015; Hudley & Mallinson, 2017). Breiner and his colleagues (2012) found that many university educators viewed STEM in terms of separate content areas without
connections. We knew planning for the integration of our course content would necessitate that we first overcome our own internal notions on siloed content before assisting our students in overcoming this struggle.

To design our co-taught online courses, we relied on our own experiences co-teaching outside of online environments as a starting point in addition to guidance found in the literature (Ericksson et al., 2020; Harter & Jacobi, 2018; Moore, 2016), and we turned to the literature for guidance on co-teaching in online environments (Heath & White, 2013; Morelock et al., 2017; Pharo et al., 2012, Tobin, 2006). While there is not a great amount of literature on co-teaching in post-secondary environments, some pointed to important themes and aspects of co-teaching in university settings that provided guidance as we built our courses. Harter and Jacobi (2018) found in their quasi-experimental study of two undergraduate communications courses, one co-taught and one not co-taught, that students believed they benefited from co-teachers’ differing perspectives on content topics and different teaching methods and styles. On the other hand, students reported that the course structure was sometimes confusing and some were uncomfortable with a departure from a traditionally structured class. From the perspective of the instructors, one advantage of co-teaching includes the potential for each instructor to focus on different areas of expertise. Shared planning, which brings the strengths of two instructors to the process, is also a positive aspect of co-teaching; however, this is balanced by the disadvantage that this type of co-planning is time-consuming (Ericksson et al., 2020, Morelock et al., 2017). In a large-scale teacher network formed to co-teach college courses focused on an interdisciplinary environmental topic, Pharo and her colleagues (2012) found that co-teaching created an enhanced sense of community in those online courses but that it required additional workload for the instructors to collaborate. Among the collaborative tasks required of those co-teaching online are planning for assessment in a way that is consistent between the two instructors, discussing assignment expectations and building rubrics during the planning phase, sharing comments between co-teachers before sharing with students, and making content or assessment revisions during the course (Heath & White, 2013, Tobin, 2006). Moore (2016) emphasized that students in online classes in particular, whether those classes are co-taught or not, need a sense that their instructors are present and engaged in the online class environment in a way that scaffolds student experiences but does not interfere with the self-directed nature of online learning. Being explicit about email response time expectations, including technology intentionally in course assignments, and creating student/student and student/instructor interaction opportunities are some of the methods that contribute to student perceptions of instructor engagement in online classes (Moore, 2016).

As mentioned in distance education literature, there is a heavy emphasis on maintaining a presence in the online class for the teacher as well as encouraging student participation (Moore, 2016). Our planning and course-coordination needed to be transparent for ourselves, but also for the students so that they would see an equitable partnership for instruction that was fully-integrated and inclusive. In the process of planning and implementing these two, integrated online courses we discovered that communication was the essential element, including open dialogue between professor and professor, students and professors, and students and students.

**Framing Methodology**

Through the use of cogenerative dialogue, the researchers were able to read, reflect, discuss, and navigate a more seamless way of teaching diverse courses with similar intended outcomes. We ascribe to the approach defined by Tobin (2006) where cogenerative dialogue is the shared
process of identifying outcomes and working together to attain common goals. Obviously, communication is a large component of cogeneration and allowed a better iteration of the courses over semesters as we gained feedback from our students but also from each other. An additional benefit of cogenerative dialogue is that our students were aware of the constant communication between us as professors and this, in-turn, demonstrated value in collaboration and positioned each content area as equally meaningful. Admittedly, one of the professors works from a big-picture perspective and has lofty ideas that may not always seem completely attainable; the other tends toward being systematic and intentional in her actions, with goals that are more explicit and easier to explain. Together, through self-analysis and constant communication regarding completed student work and feedback, we were able to develop a co-taught pair of courses that were truly co-created andcollaborative in content and goals, while expressing the directive that STEM is not dependent on any “one” area more than another. The material presented in this manuscript has the benefit of going through three iterations; we have successfully taught our respective courses for three years. While the notion of success is subjective, we deem success as student feedback provided throughout the semester as well as evidence of student application of concepts covered in the courses, while in the courses and after. We viewed success as students’ abilities to create authentic assignments that connected multiple STEM components while considering community and justice-based issues. Examples within this set of courses include identifying a local or relevant current issue and the aspects of Science Technology Engineering and Mathematics involved, identifying the social implications of how that impacts a community, and developing approaches to teaching STEM through that lens. Student “success” is also examined in the capstone course as the students are required to enact a community-based project with their k-12 students. Specific examples include projects that established a food pantry for their community, created blankets from plastic bags to distribute to local homeless populations, and developed school-based gardens that could supply fresh produce to families in need.

At the beginning of each semester before the courses, we have open and extensive dialogue regarding what worked for us and the students and what changes need to be implemented. This process includes our students’ perspectives as their feedback and understanding is, and should be, what drives our instructional practice. What we present relies heavily on how we began the structure that enabled our current approach to interdisciplinary STEM education, an approach that respects the function of all integrated content and aligns with issues of justice. Since one of the professors teaches the capstone course, we utilize examples from that course as well as feedback from students that has been included on the course evaluations to help refine the courses so they become more focused on approaching STEM education through a justice-focused lens.

**Design and Planning**

The professors met several times prior to the first fall semester to develop a plan of action, outline course assignments, and to establish a list of key articles and activities that would be required to satisfy their original course syllabi and common objectives for the two courses. Since the first iteration of the courses, we have been able to negotiate assignments that aligned with both of our respective course expectations while maintaining a focus on STEM for social justice. In developing these two online content-specific STEM methods courses (Math for Social Justice and STEM for Ecojustice) for the endorsement, the conversation was extended to make sure that readings did not overlap and students did not have repetitive assignments. We believe that the result was an intense “course” that addressed what we perceived as the larger goal revealed in the
literature. We deemed the larger goal as one contextualizing the role of STEM in disenfranchising people and places; our responsibility became one of helping our students make better decisions in how they teach concepts and for what purpose instruction exists. Both courses included a common set of objectives, a sample of which are included in Table 2.

Table 2

<table>
<thead>
<tr>
<th>Common Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>The candidates will demonstrate the ability to engage students in STEM reasoning that reveals how STEM professionals think and solve problems.</td>
</tr>
<tr>
<td>The candidates will demonstrate the ability to effectively engage students in engineering design processes to solve open-ended problems or complete design challenges.</td>
</tr>
<tr>
<td>The candidates will demonstrate the ability to effectively engage students in fostering a learning environment which encourages risk taking, innovation, and creativity.</td>
</tr>
<tr>
<td>The candidates will demonstrate the ability to effectively engage students in facilitating student-led learning.</td>
</tr>
<tr>
<td>The candidates will demonstrate the ability to effectively engage students in applying skills to novel, relevant, and authentic situations.</td>
</tr>
</tbody>
</table>

We settled on the idea that our two courses, covering different content areas, should be taught concurrently and intertwined as one online class within the STEM Education Endorsement. The very intentional decision to join our content was beneficial to our students, but even more so to our individual growth as professional academics. The context of our collaboration is critical, with a math educator who is highly linear in thinking, and a science educator who works with a much more abstract approach, both with a background and passion for sociocultural issues. Our combined voice was instrumental in helping the students navigate the role of “justice” in STEM education and more importantly, the value of their own voice in community-based issues that impact the disenfranchised. We dedicated our instruction to teaching processes, with the integration of readings that placed justice as the context for change and knowledge building in the area of STEM education. A partial readings list is included in the Appendix.

Planning to Co-teach

The online nature of these courses required us to consider the organization of our learning platform, the type of assignments and discussions which would take place, as well as the frequency of interactions that would be mandatory between teacher and student. We felt that a more hands-on approach would be beneficial in the beginning, not knowing the experiences of our students, who were working teachers, enrolled in the courses. Both of us were familiar with online learning and had taught courses before that required us to develop weekly/bi-weekly “modules” as a way to organize material and help students navigate the resources. With this fall grouping, we followed
our experience and developed learning “arrays” as a way of structuring student thinking and to bring in terminology that would connect content across both classes. As we planned for the first iteration of the course series, we focused on a common calendar, discussion expectations, and assignments that were integrated into each course with common goals and expectations.

Common Calendar

It was decided that a working calendar would be most effective in helping us, as well as the students, maintain organization and equitable inclusion of content in assignments across the courses. After several iterations of the course series (Figure 1), we have altered the structure of the calendar (Figure 2) but remain true to the original goal of equitable representation of content. These calendars represent, for the students, how each course builds on the other and integrates STEM across math and science. Each of the courses includes assignments that require students to consider other content areas involved in STEM.

<table>
<thead>
<tr>
<th>Array (date)</th>
<th>Topic - Activity</th>
<th>Grades for Math class</th>
<th>Grades for Science class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting to know the course 8/14 - 8/18</td>
<td>Introductory Activities</td>
<td>1. Video introduction posted/shared via YouTube</td>
<td></td>
</tr>
<tr>
<td>Learning Array 1 7 days 8/19 - 8/25</td>
<td>Resources for sharing Begin the conversation</td>
<td>1. Synthesis of articles 2. Brainstorming of possible interviewees and community events or meetings 3. Essay on current perceptions of STEM</td>
<td>1. Hangout meeting over articles</td>
</tr>
<tr>
<td>Learning Array 2 14 days 8/26 - 9/8</td>
<td>Standards Resources for sharing</td>
<td>1. standards exploration and connections 2. Apply standards to teaching that current event with a brainstorming session with group</td>
<td>1. Group discussion</td>
</tr>
<tr>
<td>Learning Array 3 7 days 9/9 - 9/15</td>
<td>Inquiry, Science, Engineering Design as approaches to problem-solving Explore and review app</td>
<td>1. Engineering Design Process</td>
<td>1. Identify community need and an app that can help students (science) 2. 1 page lesson overview with standards that includes the app (science)</td>
</tr>
<tr>
<td>Learning Array 4 7 days 9/16 - 9/22</td>
<td>Using tools to teach science Natural disasters and EDP</td>
<td>1. Develop a lesson, to be included on webpage, using EDP that involves the “issue you identified” (CO1, 3, 4, 5, 6, 8-11)</td>
<td>1. Identify disaster from list and then compiling the process for how technology/engineering/science could be used for either the development of what caused the event or in how to solve.</td>
</tr>
<tr>
<td>Learning Array 5 14 days 9/23 - 10/6</td>
<td>A focus on the local for STEM education</td>
<td>1. Video of teaching 2. Interview with STEM Professional 3. Review and reflect upon teaching video</td>
<td>1. Begin reading The Immortal Life of Henrietta Lacks (Part 1) 2. Contextual info</td>
</tr>
</tbody>
</table>

Figure 1. Fall 2019 Schedule: Grades are divided per content course, but work for each course occurred over the same time period and addressed common topics.
Integrated Assignments

Each professor felt it was important to provide assignments that included content from ALL STEM areas when possible, and opportunities were created to encourage students to make those cross-curricular connections as well. Throughout each course, we use the same terminology and have cross-over activities: the science course focuses on context (either place or community) while in math, the student looks at approaches to instruction (problem or project based); STEM standards are addressed in one class but used in both; both require an e-Learning module addressing multiple components of STEM; unit plans and individual lessons produced for both courses require the same format and require integrated content. The only assignment that seems unrelated in the beginning involves the assigned reading for science; students are required to read *The Immortal Life of Henrietta Lacks* and develop STEM related lesson ideas based on the resource. Both professors agreed on the inherent value in incorporating this publication into the curriculum, as it so eloquently allows connections to be made visible between medicine and science, technology and humanity, as well as the advances we have made through technology, medicine, engineering and human rights. The link between human rights and STEM is ever-present and allows for thoughts to shift as we encourage deeper analysis and reflection on how these issues currently impact our own communities. Given this overlap, we encourage students who are in both courses to make connections between not only the individual content areas, but also across other STEM disciplines in connection with social issues.

We often introduce an idea in one class, continue with related content in the other, and then bounce back to expand it with additional lessons or activities in the original class. The best example
of this begins in the science section where students are required to select a current event from a professor-identified list of natural or man-made disasters. These topics are chosen based upon both the societal and STEM-based contributions they may have for potential student learning. The “current event” project involves a list of topics/incidents that have happened in the last decade and are connected to STEM. Within the science course, students conduct research on how STEM exists within the “event” while amassing science content-specific knowledge that allows them to put together a narrated presentation aligning with local and national standards for their grade level. The next math learning array requires them to use the engineering design process (EDP) to solve problems. The instructor for the math course encourages students to use the current event topic as a springboard for developing their EDP lesson plan. While they are working on the EDP, they are asked to develop a webpage in science that asks them to put together the content understanding with newly acquired knowledge from math, technology and engineering and look at the topic from a social perspective. Students sign up for the topic of their choice and conduct research on what, why, how, where, and when, along with what that event meant for society and the community in which it occurred. The current event is assigned as a science course activity, but leads into the engineering design process learning array that takes place in math. The very next science array then requires the student to take the information gained from researching the current event and turn it into a webpage that includes components connecting STEM to society.

In selecting topics for the current event, both professors work together to discuss things that would align well for instruction in each course while encapsulating a social justice concern. We attempt to include topics that are comprehensive and will have some connection to all aspects of STEM but specifically impact a local community; sample topics for the current event have included: Hard Rock Hotel Collapse in New Orleans, LA; Georgia droughts of 2016; Flint River, MI water crisis; cave flooding and scout rescue in the Philippines; various hurricanes and wildfires in the recent decade; the COVID-19 impact on the economy; logging in the Brazilian rainforest; Michigan dam collapse of 2020. As new events occur globally and locally, we continue to update the list. We encourage discussion about which topic is a best fit, and we often include issues that come up in the local news that might be relevant to the students and represent STEM as a social issue. The assignment descriptions for the natural disaster webpage as well as the EDP are provided in the appendix.

An example of the connections made between the current event topic selection and webpage developed in the science course and the engineering design process lesson plan developed in the math course can be illustrated by work focused on Hurricane Michael, which made landfall in the Florida Panhandle as a category 5 hurricane on October 10, 2018. First introduced by a student via a narrated presentation in the science course during an assignment about natural and current events, our student explained potential classroom connections to STEM concepts and the impact of Hurricane Michael to students in the local community. Elaboration was provided on wind damage to homes and buildings in Florida, Georgia, and Alabama, and the potential to develop lesson plans that incorporate hurricane proof building design. In Table 3, an excerpt of the engineering design process lesson plan that was subsequently developed for the math course in which students design houses to withstand wind loads, is presented.
An Excerpt from an Engineering Design Process Lesson Plan in the Math Course

**Engagement**

The teacher will begin the learning activity by reading a story about the three little pigs. Students will be given time to think and discuss why the houses made of straw and sticks fell apart. This discussion will help to transition the students onto the topic of force, and how different forces, like wind, are able to act upon structures, such as the pigs’ houses. The teacher will also show the students real-life examples of how forces can affect building structures (images of destruction following Hurricane Michael). The teacher will then present the design challenge to the students and pass out the design briefs. Students will need to work with their team to design, create, build, and test a new house for the pigs to live in that will be able to stay standing against the wolf’s huffing and puffing.

**Explore**

Each group will be given a cardboard box lid, five index cards, and a strip of masking tape. The students will be told that they are not to spend five minutes to work with members of their group to begin observing and brainstorming ideas about how to use these materials to construct their house. The students will be required to record their observations and initial ideas on the Initial Observation/Brainstorming page of their design briefs. Using the observations that were made during this initial exploration phase, groups will create and build their own designs for the pigs’ houses.

**Explain**

The groups will share their individual designs. During this time, the students will need to fully explain their idea and justify why they made the design choices they did. Before starting this part of the activity, the teacher will remind the students about what it means to give constructive criticism and will explain to the students how they can use the observations they have made as evidence to support why they are for or against certain aspects of the designs. While the students are sharing, the teacher will be walking around the room, stopping to probe and question the groups as necessary. After groups finish sharing, the groups will bring their models over to the wind test area, which will simulate the Big Bad Wolf’s huffing and puffing, or real-life connection to high powered wind storms. The wind test will be conducted by having the students place their model three feet away from the fan. The fan will then be turned on at full power. If the model can withstand the full power of the fan at the three-foot mark, the teacher will move the model closer to the fan in six-inch intervals. Each group will make observations about what is happening to their model during the test and will record how close the model was able to get to the fan before being blown over. These observations will be recorded on the Wind Test Observations page in the design brief.

**Extend**

Once all of the groups have been given the opportunity to test the houses they designed, the teacher will gather the students in a whole group setting. The teacher will then ask the students to share and discuss what they noticed and learned from completing this activity. The teacher will use the class discussion about what happened to the housing models to allow the students to be able to see the connection between this project and the destruction that occurred in the Florida panhandle in the wake of Hurricane Michael. The teacher will explain that after a storm, communities have to assess the damage and use that information to help them rebuild. Groups will have time to redesign their models. Students will be challenged to think about how they used materials the first time and how they could
utilize these materials in a better way. The students will sketch and record their new group design on the Redesign page of their design brief. When groups have completed construction of the new design, they will test it using the same procedures as before. During this round of testing, students will make and record observations about how this new design performed during the wind test. The students will record these observations on the Wind Test Observations Take-Two page of the design brief.

**Evaluation**

Once all of the groups have finished testing their new designs, the students will gather as a whole group to share what they learned from this experience. The teacher will use this discussion as a way to informally assess the students’ understanding of the concepts presented during this activity. The students will independently complete the Student Reflection page in the design brief. Once finished, the students will turn in their completed design brief which will be used to formally assess students on their understanding of addition and subtraction, how forces can impact structures, and the Engineering Design Process. As part of this reflection, the students will also complete a self-assessment rubric evaluating how they were able to work through the steps of the Engineering Design Process.

Later in the semester during the science course, our student developed a natural event webpage based on Hurricane Michael and shared her webpage with her classmates via discussion board. The purpose of this assignment was to educate her fellow classmates about the event, to provide additional resources about it, to explain how each aspect of STEM has real-world connections to it, and to suggest lesson planning ideas that incorporate the event. As seen in Figure 3, connections to the engineering design process lesson plan assignment completed for the math course are evident.
Integrated Projects in the Classroom

One of the main goals, as stated previously, was to help teachers begin the process of implementing integrated STEM content rather than teaching STEM as siloed subjects. In addition to these projects occurring in each class over the course of the semester, students were required to develop unit plans that integrated STEM content through community-based approaches and a problem/project based format. These unit plans often identified a local issue and worked to help solve problems in the classroom, but they also expanded many of the lesson ideas that may have been created for basic classroom assignments. Table 4 below indicates how a pre-K teacher planned to address issues of green space in her community with her students. As evidenced in her lesson outline, various aspects of STEM were included along with additional content needed for classroom instruction. One interesting component is the formative and performative nature of the included assessments, and another is the specific objectives that demonstrate the teacher’s plan for students to be able to apply knowledge about abstract concepts to concrete solutions. This same type of outline is included in the appendix to represent a fifth-grade teacher who used her natural disaster project to frame the second week of her unit while addressing multiple, integrated STEM components, including video game design that incorporated historical events related to natural disasters.
Table 4  
*Connections between Objectives, Assessment and STEM Content for Pre-K*

<table>
<thead>
<tr>
<th>Lesson 6</th>
<th>Lesson 7</th>
<th>Lesson 8</th>
<th>Lesson 9</th>
<th>Lesson 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include objective, essential questions (must have 2+ content daily)</td>
<td>Students will describe roles and responsibilities of a variety of occupations. Students will demonstrate understanding of more complex vocabulary through everyday conversations. Students will match sets of objects with the same number.</td>
<td>Students will make real-world connections between stories and real-life experiences. They will identify the importance of participating in activities related to health.</td>
<td>Students will understand how people effect their environment. Students will explore the use of technology and understand its role in their environment.</td>
<td>Students will create simple representations of their school environment. Students will match sets of objects with the same number. Students will recognize and name common two-dimensional shapes; they will combine these shapes to form new ones.</td>
</tr>
</tbody>
</table>

What aspects of STEM are addressed?  
- Math, Technology & Science  
- Engineering & Technology  
- Science, Technology & Engineering  
- Math, Technology & Engineering  
- Math, Technology & Engineering

Anticipated outcomes - assessment type  
- Video recording of the exploration and extended activity.  
- The class chart of ideas for the playground.  
- The classroom video that the students make.  
- Notes from students’ participation. Matrix on the students’ use and understanding of two-dimensional shapes.  
- Video of the students during the lesson.

**Conclusion**

Since the start of our STEM Endorsement, we have had 35 students who are teachers in grades k-12, most of whom teach in elementary school settings, complete the endorsement. We have learned from them and from one another what makes our co-taught courses more successful. While we have no way of knowing for certain how these objectives are enacted within schools after our teachers have graduated the program, it is our hope that they continue implementing the practices they developed in our courses to grow a more community-based, socially aware STEM curriculum within their own classrooms and schools. It has been our experience that creating student to student connections and student to professor connections have been the keys to encouraging student engagement in content that most of them have not encountered in the integrated format we have developed. Having smaller classes has also allowed us to spend more time emphasizing the social
aspects of STEM and helping students see the local connections that exist where they live. The continued work in the capstone course allows us to “see” the rewards of student understanding and how they begin to further engage with the community. The process has been rewarding and we feel that the changes have made us, as well as the program, better. We are constantly redefining what better means, in regard to the endorsement and what is happening in the world and will likely do that as long as we are responsible for these series of courses. Because our vision of co-teaching relies on collaborative planning based on student feedback and our own analysis of past semesters of our integrated courses, this effort is a work in progress that will continue through future iterations of our co-taught courses.

References


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APPENDIX A

PARTIAL READING LIST FOR CO-TAUGHT STEM COURSES (readings that address equity or social justice have an asterisk):


APPENDIX B

ASSIGNMENT SAMPLE FROM SCIENCE FOR ECOJUSTICE (Learning Array 3: Natural event or Man-Made disaster Website):

Construct a web page for your current event from Learning Array 2. Background research has already been collected, and you have an informational video that can be included for reference. Some of the following may have been included in your narrated presentation, however, you should delve more deeply into the social and environmental aspects of your current event. Think more broadly to include additional content areas, as this lesson will serve as the basis for the unit plan you create for this course. Please use the following questions and prompts to guide your research and web page development.

Consider using the current event that you choose to develop the Engineering Design Process Lesson Plan for the companion course, Math for Social Justice.

1. Identification of “event”. Who, what, when, and where? Please include a brief narrative as to why it is relevant to your community or a community.
2. What are the societal implications of this issue? Consider culture, economy, etc.
3. How could technology have been used to prevent or lessen the impact of this issue?
4. What technological advances are discussed in relation to this current event? (what happened after or as a result of?)
5. How is science represented? Why is this an accurate depiction of science and/or technology?
6. Choose one aspect of technology that is in some way related to the event and explain: How was the technology developed? What was its original purpose – why was it developed?
7. What are the benefits for society as a result of this new technology or the service it provides?
8. How has society been negatively impacted as a result of this technology or the service it provides?
9. What concepts could be used to educate the public regarding this technology? How would you help the common person understand the applications of this technology?
10. How has engineering helped to better protect us from or warn us about these types of events?
11. What mathematical principles can be connected to this event and how would you make it meaningful for your students?
APPENDIX C

ASSIGNMENT SAMPLE FROM MATH FOR SOCIAL JUSTICE (Learning Array 4: Engineering Design Process Lesson Plan):

For this assignment, you will create a lesson plan that **starts with a mathematics standard and incorporates at least two standards from two other STEM content areas.** The lesson plan template is located on the last page in the Unit Plan document.

This lesson plan should incorporate an Engineering Design Process, although it is up to you to decide which version of the EDP (5-step, 7-step, etc.) makes the most sense for your students. Keep in mind you have a goal beyond incorporating the EDP to also address topics you believe your students will care about for reasons of personal or community interest. A connection should be made to positively impact lives - their own or their family members’ lives, or their community, or society as a whole.

In Science for Ecojustice during Learning Array 3, you are developing a web page that addresses a natural event or man-made disaster. Consider extending that project by connecting the engineering design process that you choose as the focus of your lesson plan to the natural event or man-made disaster you investigated in your web page.

Remember that you will prepare a 5-lesson Unit Plan that will serve as the Key Assessment for this course. This EDP lesson plan can be one of your lesson plans to include in the Unit Plan. You may even find this initial lesson plan covers only part of the EDP cycle for the activity you choose and you may ultimately be able to develop two or three lesson plans for the Unit Plan from the full EDP cycle based on the activity you choose.
APPENDIX D

ADDITIONAL EXAMPLE FOR 5TH GRADE UNIT PLAN FOR INTEGRATED CONTENT

<table>
<thead>
<tr>
<th>Include objective, essential questions (must have 2+ content daily)</th>
<th>Lesson 6</th>
<th>Lesson 7</th>
<th>Lesson 8</th>
<th>Lesson 9</th>
<th>Lesson 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will show how to use the exponential form of a number to increase value.</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Students will express the relationship between the growth of bacteria is based on certain conditions.</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Students will observe and record the different phases of cell division through modeling and drawings.</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Students will use the powers of ten and exponents to understand the division of cells along with the elapsed time of a real-world situation of the growth of HeLa Cells?</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

What aspects of STEM are addressed?

|----------------|---------------------------------------|-----------------------------------|----------------------------------------|----------------------------------------|

□ Students will develop an understanding of how GIS can increase their spatial awareness of natural disaster events locally and nationally.
□ Students will research information using a variety of technological tools.
□ Students will research and create a timeline that chronically maps out natural disaster events within Georgia and/or the South.
□ Students will examine data to determine the current cost of natural disasters.
□ Students will compare what natural disaster costs more and which is less based on facts.
□ Students will report their finding and similarities of two natural disasters.
□ Students will examine the history of video gaming, gaming consoles, and technological development by exploring the pixelated history of gaming.
□ Students will design pixelated images based on historical video game characters.
□ Students will construct a video game.
□ The student will distinguish that mathematical algorithms enable us to code computer programs, including a basic video game.
□ Students will reorganize their coding based on trial and error based on its performance.
□ Students will modify their game based on the gaming algorithm with mathematical concepts and performance.