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Improving Students' Learning Behaviors Through Hands-On Algae Based Project*

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Algae were used as a special topic area for a first-year engineering project that was collaboratively taught through instructional pairing. The selection of "algae" was intentional as it is ubiquitous and it has been used by many civilizations for nutrition, healing, and in aquaculture. The current challenging research on algae ranges from biofuels, innovative materials, electricity to much more. As such, algae can be used for teaching a variety of core engineering concepts such as materials, energy, fluid mechanics, thermodynamics, water and wastewater treatment, nutrition, and green engineering. The "algae" theme can also be easily extended to integrate concepts from humanities such as global engineering challenges, ethics, gender/racial biases, and public policy. The overarching goal of the algae project was to introduce students to project based learning using a live organism and to expose students to engineering fundamentals and core concepts from the humanities. The project was taught over the course of four weeks of a semester with a group of 69 first year engineering students. Hands on activities along with a team project were an integral part of the course. Students were assigned to teams and then given the role of investigating the potential for algae to be used to grow the economy of a country of their choice. Over the course of the project, students conducted hands-on experiments focused on cell culture, harvesting, gas transfer, and other algae applications. The team project allowed them to learn about governance, politics, policy, economy, and social issues about their country. Students' adaptive learning practices and perceived confidence of learning were assessed through surveys and focus groups. Students demonstrated increases in their learning goal orientation, task value and perceived confidence in learning with some statistically significant changes as observed in their self-efficacy and self-regulated learning. Focus group results further supported how this project was able to provide a venue for students to make connections with their selected career path and build perseverance when facing difficult problems. Although the sample size is small, the results show positive trends for the use of an algae based collaboratively taught project to improve student's adaptive learning and perceived confidence in learning.

Keywords: project-based learning; humanities; global challenges; algae

1. Introduction

It is common knowledge that educators in science and engineering are always invested in innovative ways to excite and retain students to keep them globally competitive [1]. Science and engineering are essential partners for America's future. The United States still lags behind the world in technological innovation because of its poor performance in teaching math and science [2]. A recent report indicates that the USA ranks 35 out of 64 countries in the *Program for International Student Assessment* (PISA), which every three years measures reading ability, math and science literacy and other key skills among 15-year-olds [2]. Math scores reported by the National Assessment of Educational Progress show that the average fourth- and eighth-grade math scores declined two and three points, respectively, between 2013 and 2015 [3]. Many students who do undertake science and engineering studies in college are unprepared and drop out in frustration, while other potentially capable students never consider these subjects in the first place. In 2008, the National Academy of Engineering (NAE) introduced the 14 Grand Challenges for Engineering in the 21st century to boost enthusiasm for engineering careers [4]. These challenges identified the need for technological innovations for global progress with focus on education, affordable energy and infrastructure, clean water, climate change,

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enhanced learning, and cybersecurity. Critics of the NAE Grand Challenges have indicated that the identified challenges fall short of progressive humanities and qualitative social sciences [5]. It has been identified that the greatest challenge among engineers is *"cultivating deeper and more critical thinking"* beyond product innovation. *"The critics state that it is time that engineers think holistically and critically about their role in making the world a better place and assist their non engineering fellow citizens using thought processes that go beyond superficial STEM (Science Technology Engineering Mathematics) promotions. It is time that engineering and the humanities came together to produce the 'Global Engineer'."* Others have shown concern that the Grand Challenges are too narrow in focus and whether the list would be different for different diverse groups. Despite the criticism, there is general consensus that the Grand Challenge movement is generating excitement in engineering education across the country and many schools are participating in the Grand Challenge Scholars Program (GCSP) to attract and interest their students [4].

The case for project-based learning throughout the engineering curriculum is compelling. In comparison to traditionally-taught students, students who participate in project-based learning are more motivated, demonstrate better communication and teamwork skills, and have a better understanding of issues of professional practice and how to apply their learning to realistic problems [6–14]. At the undergraduate level, the process of "guided discovery", in which students are presented with a problem to solve and supported in their discovery and interpretation is recommended to optimize learning within a collaborative, project-based setting [8].

Within an engineering context, Prince and Felder [15] present strong evidence that inductive teaching methods are more effective than traditional deductive teaching methods. Their review of inductive methods includes case studies, discovery learning, and project-based learning. The Grand Challenges theme was chosen to create relevance and increase motivation to learn. Exploring the many uses of algae provides opportunities for meaning making that has individual and cultural context, allowing learners to establish connections between classroom content, their profession, and the rest of their lives.

1.1 Context and objectives

Our "Algae Grows the Future" initiative is an innovative effort to promote a well-balanced approach to introduce engineering student to Global Grand Challenges with a strong focus on combining critical reflection with activities that relate to the humanities, especially literary readings, sociology, environmental justice and public policy. In an ASEE (American Society for Engineering Education) Prism article [5] it was pointed out that *"the current generation of students, the so-called millennials, has a deep altruistic streak. They're concerned about the environment, poverty, and inequality, and they generally want to help humankind. However, they don't always see engineering as a means to achieve those goals."* The project is specifically designed to develop a cadre of engineering students that embrace not only the scientific skills for innovative inquiry but also have a deep knowledge base for reflective thinking regarding the impact of their contributions to the world.

Algae are a common microorganism known to all [16, 17]. Algae have been estimated to include anywhere from 30,000 to more than 1 million species [16]. This photosynthetic microorganism is present globally in abundance and uses CO_2 as a source of carbon. While algae is recognized as a photosynthetic organism that is ubiquitous, it is rare that that a connection is made to the prospect of this microbe playing a significant role of impacting the future of this world and society.

For many countries such as Japan, New Zealand, India, and Brazil, algae plays a major role in their economy, diet and energy. These countries have invested in the use of algae to successfully grow their economy [18]. A major advantage in growing and using algae is that it does not impact land and crops. The high production efficiencies of algae biofuels also make it attractive for providing energy security. Algae derived biofuels can provide job growth at various skill-levels [18]. Innovative algae-based industries, both public and private, can provide opportunities for economic growth in both nonmetropolitan and regional areas.

The multifaceted use of algae is presented in Fig. 1 below. The figure clearly demonstrates why scientists and engineers are invested in algae research and algae derived products.

The three main objectives of our "*Algae Grows the Future*" project were (1) to develop educational methods that explore uses of algae to address global engineering challenges (2) to increase self-confidence and self-esteem of students and (3) to retain students in STEM degree programs.

1.2 Instructional design

The curriculum materials developed in this project use collaborative inquiry-based approaches with instructional scaffolding to maximize student learning. Each module is introduced with a case study that provides context to motivate students to work on the given design challenge. Teams of students are engaged in guided discovery through meaningful activities and interactions that occur in different learning environments. Their observations during

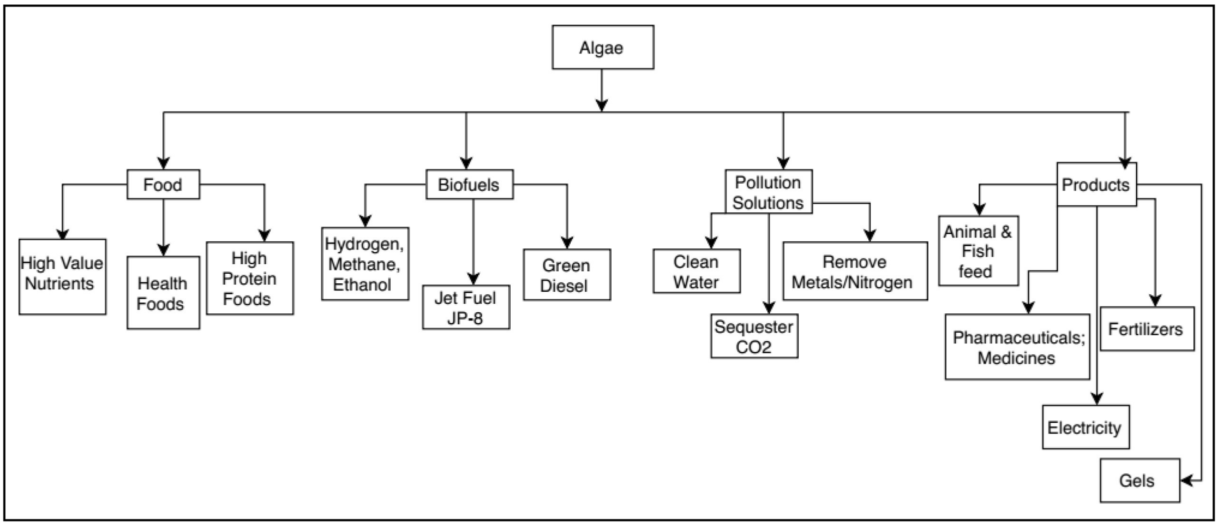

Fig. 1. Multifaceted Uses of Algae.

the guided discovery allow them to find underlying engineering principles which inform their design of an algae-based product or process. The instructional design used in this project is grounded in a cognitive situative constructivist learning framework. Constructivist learning theory emphasizes the role of the learner in the internal creation and storing of mental models that build on prior experience and interpretation of the current situation [19, 20]. In the situative paradigm, both learning and identity formation occur through changing participation opportunities in a community of practice [19]. Knowing also necessarily involves making meaning of the learning activities in a personal and cultural context. The learning modules therefore incorporate elements of instructional design that are integral to this cognitive-situative framework [21–23].

1.3 Collaborative teaching practices

This project addresses the need to cultivate engineers' critical understanding of the global, economic, societal and environmental impacts of engineering solutions. Algae provides the basis for a collection of inquiry based educational activities that combine science, engineering, social sciences and the humanities. This fosters an understanding of the broader context of engineering work. A series of cost-effective, multidisciplinary, adaptable and transferrable hands-on experiments were developed to introduce engineering and science principles through algae's versatility as a renewable fuel source, a tool for greenhouse gas mitigation, a component in the treatment of wastewater, and many more applications in the chemical industries such as health products, nutraceuticals, food and medicine. The project is unique as it can be taught by any engineering faculty and is not discipline specific. Moreover, this was a joint effort between engineering and faculty from the humanities and social sciences. Every engineering activity was connected thoughtfully to core concepts from the humanities and social sciences via select readings, movie assignments and short documentaries. These assignments exposed them to social and cultural issues. For example, teams watched movies such as Erin Brockovich, A Civil Action, Bhopal Express, The Whale Rider, Hidden Figures, The Wind Rises and A Rabbit Proof Fence. The teams are also exposed to gender biases in STEM fields by learning about Rosalind Franklin, Henrietta Lacks and Stephanie Kwolek [24–27]. An innovative feature of the project was to word every engineering problem in a global language along with components of ethical dilemma. For example, a simple unit conversion problem was worded as shown in Fig. 2.

2. Methods

2.1 Study design

Four sections of a first-year engineering design course participated in the algae-based project in the last 4 weeks of the semester. Each of these course sections followed the same set of algae-based activities, and the instructional team met at least once per week to review plans and resources for the upcoming week. During these instructional review meetings, faculty would share with one another which aspects of the project were working well in addition to any areas where students may have been struggling. This form of open dialogue between the instructors enabled them to learn from one another and enhance their ability to provide meaningful experiences to their students.

Spirulina (a blue-green alga) is a remarkable source of nutrients, containing the highest natural source of complete proteins, omega fatty acids, iron, and antioxidants. The health applications of a superfood like spirulina can translate across countless circumstances, from saving lives in the Central African Republic to providing everyday nutrients to anyone around the world. The St. Joseph Health Centre in Bangui, a Central African Republic, grow their own algae as a supplement for malnourished children who have suffered the ravages of war since 2013. The following information is available:

The protein content of Spirulina is 6 grams of protein/gram of Spirulina.
Daily Protein Needs: 1.5 g protein for every 2lbs of body weight for children aged 2-8 years.
Average weight of impoverished 2-8 year olds in Bangui ~ 17 lbs
# of malnourished children in Bangui/year ~ 10,000

1. *How many tons of Spirulina will be needed annually to provide adequate protein to the children of Bangui?*
2. *What are your thoughts on countries that waste tons of food but will not donate to needy nations?*
3. *Do you believe that restaurants, cafeterias in the USA should waste edible food instead of donating it to food shelters because of liability concerns?*

Fig. 2. Sample Problem on Unit Conversion.

As part of the algae-based project, students were told that they were hired by an organization interested in expanding their algae technologies to new countries. To prepare for this expansion, the students were asked to create a detailed design presentation that discussed how their assigned country could benefit from algae production by examining factors including history, climate, demographics, government and economic factors, social issues, and energy sources that would be relevant to their country. In the weeks prior to this presentation, the students were scaffolded through a series of hands-on lab activities and classroom-based discussions that assisted with students learning about algae growth as well as harvesting, gas transfer, and algae applications. More information on these project-based materials can be found in Section 2.2.

The four faculty members that participated in this project were also grouped into pairs based upon their assigned course sections. Students had the benefit of learning from each member of the faculty pair during this project, as the faculty pairs worked together to identify the relevant strengths to the proposed project activities and undertook leading these exercises for both class sections. For instance, two of the faculty members (one in each faculty pair) have graduate level degrees in chemical engineering with an emphasis on biotechnology. This made these faculty members particularly suitable for leading the hands-on lab activities since they were well versed in the theories behind cell growth kinetics and gas transfer. The other two faculty members whose graduate degrees were in other engineering disciplines could provide their insight on connecting the work done in the lab activities to the project through classroom-based discussions. This collaborative teaching approach in the course provided a more enriching learning experience for the students overall.

To understand how participation in this collaboratively taught algae-based project impacted students adaptive learning and perceived confidence in their learning, students in each course section were given the opportunity to complete a pre- and post-survey and to participate in a focus group. In total, 54 students completed the pre- and post-survey instrument and 9 students participated in the focus group out of the total of 69 students across all 4 sections. Proper human subjects research approval was obtained prior to the conduct of this study.

2.2 Algae problem based learning materials

The algae-based project was designed to allow for broad use and collaboration amongst multiple faculty participants. Early on in the project development, a website [28] was constructed that contained all of the project-based materials and allowed for a common source of information for faculty that were interested in adopting this project for their class. This website is also available for students/ K-12 (Kindergarten—12th grade) educators with resources such as laboratory handouts, lectures, sample exams, videos and relevant links. One important aspect of this project was dissemination for elementary and middle school children via a game titled Algae City [29–30]. The game was developed through the Unity Game Engine. The game's storyline revolves around the idea of the player introducing algae into a modern metropolitan area as a solution for its heavy pollution and depletion of natural resources. There are four main modules—water purification, production and growth, transportation, and cosmetics. Included in the modules are five mini-games, including materials and surfboards, pharmaceutical gels, batteries, food and nutrition, and animal feed. Faculty members that were interested in the algae project were invited to a workshop given by the lead instructor where an overview of the project was given, student feedback from prior implementations was shared, and discussion of how faculty could assist one another and collaborate during the upcoming implementation was discussed. Faculty also worked on each hands-on activity following the laboratory handouts to prepare for their classes.

The following sections describe in more detail the specific project-based activities that were incorporated in this collaborative implementation of the algae-based project.

2.2.1 Algae growth kinetics

Students worked with *Chlorella vulgaris*, a common freshwater alga. Each team was provided with a small volume of alga that was used for batch growth studies. This activity forced students to learn the growth needs of algae, the proper use of a spectrophotometer to measure growth, setting up the experiment, and taking daily data on experimental conditions. Data analysis included the use of simple integration techniques for determining the algae growth rate. Plotting of data and a laboratory report were also required. Student teams could study the impact on growth rates by changing experimental conditions such as light intensity, temperature and pH. Because algae are live microbes containing DNA, a discussion on Rosalind Franklin's contribution to the discovery of DNA and the unethical use of her work by Watson-Crick leading to their Nobel Prize was discussed [31]. The ethical controversies surrounding the case of Henrietta Lacks and her HELA cells were also introduced to the class [32].

2.2.2 Algae harvesting

The major challenge for the algae industry is the separation of algae from water. Students worked on various types of methods for algae separation, ranging from simple to sophisticated. These methods include simple drying via evaporation, filtration and centrifugation. These experiments again require students to collect data and analyze it in order to report on the grams of dry algae grown per ml of water. Students also recognized that algae require a lot of water for growth; this can be an obvious reason that many countries avoid establishing algae-based economy. Students watched Water Wars as part of the humanities component and understood that the distribution of water resources are a global political issue [33].

2.2.3 Gas transfer

Algae use carbon dioxide for energy and growth. As such, students were exposed to a visual batch experiment demonstrating how gases from air are dissolved in water. This experiment again required students to collect and plot their data using integral calculus. Since carbon dioxide is a green-house gas, there was discussion about climate change and the need for future generations to protect the planet. Students watched An Inconvenient Truth as part of this exercise [34].

2.2.4 Algae applications

Students were introduced to a variety of different algae applications through a jigsaw-based activity. Students from each country group were assigned to become an expert in one area of algae applications after which they would return to their original country group to teach one another. For example, in a class of 16 students each country group consisted of 4 students. Once divided for the jigsaw activity, the class had distributed into 4 new groups consisting of one student from each of the original country groups. The algae application areas included biofuel, food, materials, and cosmetics. Students in the application area groups were guided by provided web-based resources and articles that enabled them to learn quickly about a new topic. Together they constructed a "top ten" list that they would each use to help teach the other students in their country group about this form of algae application. As an added incentive for the students to engage in this classroom activity, students were told that after they had taught their country group about the algae application area, the class would participate in a Kahoot exercise that would test each student's knowledge of all the algae applications. Kahoot is a game-based platform to enhance student learning [35]. The country teams with the highest score at the end of the exercise would receive a prize. Students were told that no materials could be on their desks and that their laptops would have to be closed during the Kahoot activity which encouraged them to put effort in both the learning and teaching portion of this classroom exercise.

Students in select sections also participated in making algae biofuel, algae batteries, algae gels and cosmetics such as lip gloss using algae oil. On the day of team final presentations, the class was treated to an algae themed party that included commercial algae chips and algae juice.

3. Assessment

The impact of the learning activities was assessed via pre- and post surveys and feedback from focus groups.

3.1 Adaptive learning and perceived confidence for learning assessment

In this project we were also interested in answering the research question: does students' adaptive learning engagement and perceived confidence for learning change as a result of their participation in collaboratively taught algae-based project activities? To investigate this question, we had students complete surveys on their adaptive learning and perceived confidence at the start and end of the algae-based project. Additional insight on the responses to these questions were obtained by the student focus groups that were conducted at the end of the project.

Items from two validated survey instruments were used in combination in the pre- and post-survey design. Students' adaptive learning engagement was measured using the previously validated instrument on students' adaptive learning engagement in science [36] as it was felt that this first-year engineering course was in close alignment with the science disciplines. To measure students' perceived confidence for learning we employed the perceived competence scale [37]. Our sample size was too small in order to perform a factor analysis on the results obtained but we did perform an internal consistency reliability analysis to ensure that the items in each construct were reliable in the first-year engineering context. Our analysis found that the minimum Cronbach's alpha across all five constructs of interest was 0.918, with values ranging from 0.918 to 0.963, indicating an acceptable value of internal consistency reliability [38].

To analyze the pre- and post-survey data we used both a paired t-test and the Wilcoxon Rank Sign non-parametric equivalent test, due to slight skewness observed in the distribution of responses to some of the survey questions [39]. In general, the results from both statistical analyses were in close alignment with one another.

3.2 Student focus groups

The nine students who participated in the focus groups represented all six of the engineering disciplines at Rowan University. There were two students from Biomedical Engineering, two students from Mechanical Engineering, and one student each from Civil and Environmental Engineering, Chemical Engineering, and Engineering Entrepreneurship. Focus groups were facilitated by an independent researcher who was not involved in the instruction of the course to provide students with a forum in which they could openly discuss their experiences and perceptions of the course and the project without concerns regarding the perceptions of the instructor. The focus group questions were semi-structured and included the following six questions in order:

1. How do you approach learning in Freshman Engineering Clinic II?
2. Do you think the topics you learned as part of the algae project will be useful in your engineering professional development?
3. In the context of the algae project, do you feel that you were able to learn even if you encountered difficulties?
4. How interesting is the algae project to you?
5. What does engineering in a broader context mean to you?
6. In this course we have included examples that have social relevance such as how can engineering benefit different populations. Do you see this as being relevant to engineering?

Before beginning, the focus group participants were welcomed and given an overview of the topic and purpose of the study. They were assured that it would be completely acceptable for them to express different opinions, perceptions and experiences from their peers. They were also assured of confidentiality and that that the results would be reported anonymously. During the discussion, the focus group participants were given the opportunity to express their answers to each question, including agreeing or disagreeing with their peers. Before proceeding to the next question, the facilitator confirmed all students were satisfied that they had contributed everything they wanted to share regarding the question being discussed. This was particularly relevant when the discussion developed with participant input that built upon prior responses. Field notes were recorded by the facilitator.

4. Results and discussion

4.1 Impact on adaptive learning and perceived confidence

The analysis of the pre- and post-survey data was conducted across five different constructs: learning goal orientation, task value, self-efficacy, self-regulation, and learning within the context of the course in question. We found that there was very little change in the learning goal orientation with no statistically significant differences over the course of the project and small effect sizes. The questions focused around learning goal orientation assessed student goals and how important they felt it was to learn and understand the engineering content that was being taught. It is not surprising that changes in these measures didn't occur over the course of this short project as they really focused on student's overall perception of engineering and its importance in their career. Although we would hope that students would see increased value in their engineering education through participation in this project, it is very unlikely that they would change their goals over the short duration of this particular project. Learning orientation has been shown to be a relatively stable construct within engineering students based on a recent study by Stolk et al. [40]. In their study, they measured learning orientation attitudes within engineering students over a period of two years and observed no significant changes over a two-year period of time which lends support as to why no observed change was found during the short duration of our study.

There was a general trend towards increases in task value, although no items showed statistically significant differences and all the effect sizes were small. The task value questions focused upon whether students felt the material they were learning was relevant to them and of practical value. It was encouraging to see the positive trend observed as it showcased that even though this particular project didn't relate to all of the students majors with its focus on cell culture, the students were still gaining value through their participation. Eccles and Wigfield [41] have highlighted in their work that task value can be a predictor for plans and enrollment decisions in science and mathematics-based courses. The positive increase observed could support that this project was able to reinforce for students that they made the appropriate selection of major. This observation was further supported by the results obtained from the focus group that are discussed in Section 4.2.

As shown in Table 1 students' self-efficacy scores showed a general trend towards increases with a statistically significant increase in "I can figure out how to do difficult work" (p = 0.011 for both tests; Cohen's d = 0.364). This may be attributed to the nature of the analysis they had to perform on the algae experiments. For many students this was their first hands-on calculations of mathematical parameters such as growth rate and gas transfer coefficient throughout this semester, as the other projects they participated on were more abstract and didn't require mathematical calculations.

The area where the most notable differences based on project participation were observed was related to student self-regulation. Table 2 summarizes the results obtained.

Students self-regulation of learning showed noticeable increases with statistically significant differences observed in "I continue working even if there are better things to do" (p = 0.025 t-test and p = 0.029 Wilcoxon Rank Sum test; Cohen's d = 0.312); "I concentrate so that I will not miss important points" (p = 0.008 t-test and p = 0.009 Wilcoxon Rank Sum test; Cohen's d = 0.404); "I do not give up even when the work is difficult" (p = 0.009 both tests; Cohen's d = 0.360); and "I keep working until I finish what I am supposed to do" (p = 0.004 both tests; Cohen's d = 0.412). These results were promising as they demonstrated that the students were invested in this particular project. It is possible that because the project was introduced in a manner that suggested the students were work-

Table 1. Average Student Responses for Self-Efficacy

Statement	Pre-Average	Post-Average	p-value (Paired Samples t-Test)	p-value (Wilcoxon Ranked Sign Test)	Cohen's d (effect size)	Glass' Delta (effect size)
I can master the skills that are taught.	4.13	4.30	0.118	0.129	0.217	0.191
I can figure out how to do difficult work.	4.20	4.44	0.011	0.011	0.364	0.315
Even if the engineering work is hard, I can learn it.	4.31	4.35	0.687	0.819	0.059	0.052
I can complete difficult work if I try.	4.41	4.50	0.341	0.394	0.142	0.122
I will receive good grades.	4.09	4.20	0.277	0.317	0.138	0.129
I can learn the work we do.	4.33	4.46	0.146	0.157	0.203	0.173
I can understand the content taught.	4.39	4.46	0.419	0.491	0.106	0.092
I am good at this subject.	4.09	4.28	0.067	0.072	0.238	0.222

Table 2. Average Student Responses for Self-Regulation

Statement	Pre-Average	Post-Average	p-value (Paired Samples t-Test)	p-value (Wilcoxon Ranked Sign Test)	Cohen's d (effect size)	Glass' Delta (effect size)
Even when tasks are uninteresting, I keep working.	4.04	4.24	0.078	0.086	0.258	0.236
I work hard even if I do not like what I am doing.	4.06	4.24	0.086	0.090	0.224	0.200
I continue working even if there are better things to do.	3.80	4.06	0.025	0.029	0.312	0.283
I concentrate so that I will not miss important points.	4.02	4.31	0.008	0.009	0.404	0.357
I finish my work and assignments on time.	4.43	4.44	0.859	0.984	0.014	0.013
I do not give up even when the work is difficult.	4.24	4.50	0.009	0.009	0.360	0.300
I concentrate in class.	4.08	4.26	0.129	0.142	0.202	0.200
I keep working until I finish what I am supposed to do.	4.11	4.41	0.004	0.004	0.412	0.368

ing towards the overall goal of demonstrating why their particular country would be most effective for the growth of algae and that all elements of the project re-directed students to think about this central goal, it helped them to be more engaged with the work that they had to complete. It is also possible that the students felt that some of the content was more difficult than what they had seen previously, and this made them feel at the end of the project that they were able to persevere despite difficulties.

Finally, students showed increases in their perceived confidence for learning across all four items with a statistically significant increase in "I am capable of learning the material in this course ($p=0.007$ t-test and $p=0.004$ Wilcoxon Rank Sum test; Cohen's $d = 0.402$). It may be that students felt confident that they were able to analyze the data from the experiments and could draw conclusions that were relevant. This would have been aided by the choices made by the instructional team to allow the faculty members with prior experience in chemical engineering to lead the hands-on components of the project. Students may have also enjoyed this project and felt that the assignments were scaffolded to their level.

4.2 Focus group results

The focus group data that was obtained provides some additional insight into these results. For instance, students shared that they benefited from working in a "real-world" environment that required them to figure out what resources they needed in order to solve a problem. One student explained that while they probably would not use the specific topical content in their career as an electrical engineer, they considered the development of problem-solving ability to be invaluable in the course. Students appreciated the need to return to the lab daily to take samples of the growing algae and considered it to be closer to a "real world" experience than other class and lab work; they commented specifically on the responsibility of taking the sample during a certain period of time and coordinating with team members to accomplish the task.

Students expressed confidence in their ability to learn in the course. One student talked about the classroom environment, noting that the combination of short notes and active participation in class was rewarding and it helped them pay attention and succeed in the class. This result would have been directly correlated to the choices made by the instructional team to leverage the strengths of each instructor when selecting which individual would focus on which aspect of this collaborative based project. Several students commented that there were clear expectations associated with each assignment, and they were comfortable knowing that they were meeting those expectations (and sometimes going above and beyond). One student also commented that the research-oriented project was more familiar than the previous project, which was design based. Other students commented that the previous (design-based) project was their first exposure to a more open-ended and poorly-defined problem.

When asked if they were able to learn even when they encountered difficulties, there was general agreement among students. Students discussed the importance of learning to persevere, to keep working when they experienced setbacks with their project. They referred to challenges associated with their lab experiments, for example, sample evaporation or ambient temperature change, and discussed how they dealt with these setbacks to ensure that the project goals were met. When discussing laboratory challenges, one student explained that their group was committed to doing quality work. "We learned how important it is to "do it right, don't take the easy way out".

When asked how interesting the algae project was to them, students' responses were very positive. In particular, three aspects of the project excited several students: the hands-on experiments, the wide range of applications of algae, and the global context of the applications. One student commented that their interest in the subject "motivated me to go further and do more than the bare minimum"; another mentioned that interest "boosts the quality of discussions and reports", and a third student said that their interest encouraged them "to seek deeper knowledge that could be applied to solving different problems".

4.3 Limitations of study

These results are very promising and denote that a collaboratively taught algae-based project can have a positive impact on students' self-efficacy and self-regulation within a first-year course. The generalizability of these results is still somewhat limited however due to the small sample size that was used as part of this study, 54 students completed the survey instrument and only 9 students participated in the focus group. The study was also only conducted at a single institution that routinely integrates collaborative based teaching into its coursework which may have contributed to the successful results obtained with this project. In the future, it would be beneficial to replicate this study across multiple institutions to verify that the collaborative nature of this project works well in multiple instructional environments.

5. Conclusions

The "Algae Grows the Future" project provides an innovative approach for integrating engineering and the humanities/social sciences. The use of a simple microbe to teach engineering fundamentals is innovative and stimulates students' critical thinking. This study used the compelling subject area of algae growth as a means for creating a collaborative teaching-learning experience for students in a first-year engineering course. Instructors leveraged a common website with detailed project materials and then separated into teaching pairs to leverage their own specific background strengths when determining how to most effectively present the project to the students. Instructional teams also met on a weekly basis to discuss the implementation of the project and determine where changes needed to be made to improve the student experience. Through leveraging this collaborative teaching approach, it was possible to provide students with an engaging project that led to increases in their self-efficacy and self-regulation as it related to learning course material. Focus group results highlighted the benefits of the hands-on component of the project and the opportunity to conduct detailed experiments followed by mathematical calculations as a forum for improving their persistence when learning new content. These preliminary results indicate that when structured effectively a collaborative team-based teaching approach can lead to beneficial improvements in students' adaptive learning behaviors and perceived confidence in learning engineering content.

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