2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39031

Board 183: Utilizing On-Site Sustainability Technology to Engage K-12 Students in Engineering Learning (Work in Progress)

Rachel Burch, University of Delaware

Rachel Burch is a 5th year PhD candidate at the University of Delaware in the Department of Civil and Environmental Engineering. Rachel is researching the sustainable treatment of food waste using aerobic bio-digesters with hopes of recovering resources, such as biogas, from the food waste. Rachel has a passion for sustainability and engineering education, both of which she is incorporating into her work in her time as a graduate student.

Dr. Amy Trauth, American Institutes for Research

Amy Trauth, Ph.D., is a Researcher at American Institutes for Research (AIR) and Affiliate Faculty in the Department of Mechanical Engineering at the University of Delaware. Her research focuses on equity and access in science and engineering education and K-12 STEM teacher education.

Dr. Michael Chajes, University of Delaware

Michael Chajes is a Professor of Civil and Environmental Engineering and Dean of the Honors College at the University of Delaware. His teaching and research focuses on (1) bridge testing, evaluation, and rehabilitation, (2) sustainability applications, and (3) and engineering education. During his 33 years at UD, Dr. Chajes has also served as Dean of the College of Engineering.

Dr. Daniel Cha, University of Delaware

Dr. Daniel K. Cha is a Professor in the Department of Civil and Environmental Engineering at University of Delaware. He has over 30 years of academic and industrial research experience in the area of environmental biological processes. Most of his research has focused on microbial degradation of environmental contaminants in natural and engineered systems, and sustainable solutions to wastewater treatment. Dr. Cha received his Ph.D. degree in Civil Engineering from the University of California at Berkeley. Prior to joining University of Delaware, Dr. Cha also worked as a consulting engineer for an environmental consulting firm and an assistant engineer at a wastewater treatment plant.

Utilizing On-Site Sustainability Technology to Engage K-12 Students in Engineering Learning (Work in Progress)

Abstract
Research to develop sustainable technologies in response to the changing climate, combined with educating K-12 students about those technologies, is vital in creating a sustainable future. This study was designed to create a partnership between researchers and K-12 schools to increase student knowledge about sustainability and to generate interest in engineering and STEM careers by utilizing environmental bioengineering technology as a tool to teach sustainability principles. In this study, an aerobic biodigester for the sustainable disposal of food wastes was installed in a K-12 school, and researchers assisted teachers in generating hands-on, engineering-focused lesson plans based on the digester technology. A pre-/post-assessment was conducted for a biology lesson. Results indicate students improved in their knowledge of sustainability issues related to food waste and aerobic respiration. Students also self-reported learning more about sustainability, engineering, and biology concepts through the lesson. Perhaps most importantly, students were excited about the hands-on learning experience provided by the digester and expressed increased interest in engineering and STEM-related careers.

I. Introduction

Climate change is a pressing societal issue and researchers are working to find viable solutions. As they do, it is imperative that the results be translated into learning opportunities for the future generations of environmental leaders: K-12 students [1], [2]. Partnerships between researchers and K-12 teachers have proven highly beneficial in increasing student learning [1], [2].

The *Framework for K-12 Science Education* [3] and the Next Generation Science Standards (NGSS) [4] place emphasis on the integration of engineering principles and practices into K-12 science education. Unlike previous science education standards, engineering was included in the NGSS for two reasons: to reflect the importance of understanding the human-built world and to recognize the value of better integrating the teaching and learning of STEM fields. Research indicates that exposure to and engagement in engineering during K-12 education provides students with knowledge of the breadth of real-world problems solved by engineers [5], [6]. Early exposure to engineering problem-solving is a useful tool for recruiting diverse youth into engineering fields [7], [8]. Pursuit of engineering means that youth develop both engineering knowledge *and* affinity with the profession. In K-12 education, this includes increasing students' knowledge of engineering and engineering fields, and also supporting engineering identity development and affiliations with engineering as a community of practice [7], [8], [5], [9], [10], through authentic opportunities to learn.

Issues of sustainability, environmental engineering and energy provide relevant examples of real-world problems that are tangible to K-12 students and can be explored in the classroom to create authentic learning opportunities [11]. Exposure to environmental engineering technologies engages students in engineering problem solving while helping them understand the importance and relevance of the sustainability issues the technologies are addressing. Previous studies have shown increased student interest and performance in STEM classrooms as a result of project-based learning that addresses real-world issues in sustainability and utilizes sustainable technologies in the classroom [11], [12].

II. Research Questions

This study created a partnership among researchers, K-12 educators and students by using an environmental bioengineering technology in the classroom to increase student knowledge and engagement with sustainability, engineering and related core science concepts. This study aimed to enhance students' knowledge of engineering technologies related to sustainability, and interest in engineering overall, through curricula that integrated bioengineering principles. The research team sought to answer the following questions:

- To what extent does engagement in biodigester-related science lessons influence students' knowledge of bioengineering and sustainability issues related to food waste?
- How do students report their experiences with the lessons and their interest in engineering and STEM-related careers?

III. Technical Background

Because global food systems account for about one third of all greenhouse gas emissions, they are a major area of interest for climate scientists and engineers [13]. Within food systems, food waste disposal is one of the most significant challenges in waste management, and food waste is directly related to the National Academy of Engineering's Grand Challenges [14]. According to the Environmental Protection Agency [15], 35% of food goes uneaten or unsold in the United States, and more food waste is sent to the landfill than any other single material in our everyday trash. In the US alone, 63.1 million tons of food waste were generated in 2018, and 68% of this food waste went directly to landfills or incineration plants.

The aerobic biodigester used for this study (Figure 1) was designed and manufactured by BioHiTech America [16] to address the issue of sustainable food waste disposal. The digester is approximately the size of a washing machine and can easily be installed in the kitchens of restaurants, grocery stores, and cafeterias. The biodigester utilizes aerobic degradation in which microorganisms break down organics in the food waste into carbon dioxide, water, ammonia, and soluble inert materials [17]. Moving mechanical arms in the digester further break down the food waste. Temperature is maintained via warm water showered on top of the food waste. The result is a liquified slurry that is redirected from the landfills with potential to be repurposed for energy, fertilizers and other methods of resource recovery.

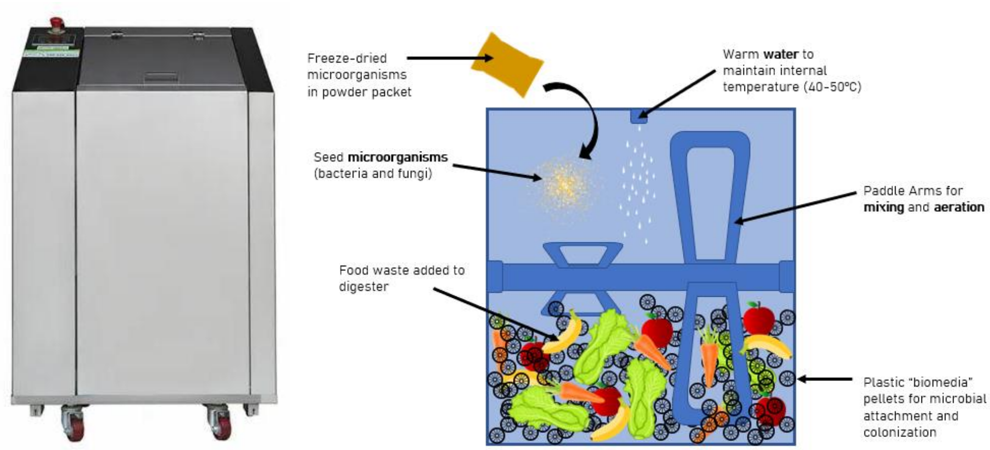


Fig. 1. Aerobic digester (left) [16] and aerobic digestion process (right).

IV. Methods

A. Study Context. This study took place at the Tower Hill School, a private high school located in Wilmington, Delaware. The majority of students travel from surrounding suburban areas to attend the school. The student population is 64% White, 18% Asian, 6% Black, 1% Hispanic, 11% Multiracial. About 38% receive some financial assistance to offset costs of attendance.

B. Teacher-Developed Sustainability Curricula. After the aerobic biodigester was installed at Tower Hill School, the research team conducted a workshop with twelve science teachers during which they learned about the aerobic biodigester and related sustainability issues (Appendix I). Three teachers developed hands-on, engineering-focused lesson plans that included the digester technology: microbiology (biology); pH, acids and bases (chemistry); and water resources (environmental science). The biology lesson was the first lesson conducted, and the evaluation and results of this lesson are reflected in this paper. Table 1 shows the biology lesson objectives, instructional activities, and assessment items used to analyze changes to student knowledge before and after the lesson (additional details can be found in Appendix II).

TABLE 1. Instructional activities for each learning objective and associated NGSS standards.

	Learning Objective	Instructional Activities	Pre-/Post-Assessment Items[1]	NGSS PEs[2]
1	Identify and describe sustainability issues related to food waste broadly and at their school	PowerPoint presentation on: ● Food waste production per capita by state, regional waste handling ● Connection of food waste to sustainability pillars and environmental impacts	Q1-Q3: prompts related to amount of food waste generated annually in the U.S, proportion that ends up in landfills, and environmental impacts of food waste in landfills	HS-ESS3-4, HS-ETS1-3
2	Explain how decomposition in the Biodigester is affected by factors related to technology design	Visit to school cafeteria to learn about: ● How the biodigester works – system components and their functions ● Connection of biodigester to engineering and microbiology	Q4-Q7: prompts related to how the biodigester works, which types of organisms are used in the biodigester, and the chemical process used (aerobic respiration)	HS-ESS3-4, HS-LS1-7
3	Use knowledge of aerobic respiration to plan and conduct an investigation related to temperature and reaction rate.	Investigate aerobic respiration: ● Plate microbes ● Culture at different temperatures ● Estimate and classify culture growth ● Draw conclusions about effect of temperature on biodigester function	Q8-Q11: prompts related to factors that affect biodigester functioning – pH, temperature, and the availability of reactants	HS-LS1-7, HS-PS1-6

[1] full pre-/post-assessment can be found in Appendix II. [2] full description of NGSS performance expectations can be found in the endnotes.

C. Data Sources and Analysis. We utilized concurrent triangulation mixed methodology using pre-/post-sampling methods and qualitative analysis [18]. An eleven-question pre-/post-assessment was administered immediately before the lesson began and immediately after the lesson concluded. Students (n=17) were aggregated to discern what difference, if any, emerged in overall knowledge and skills after the lesson. Descriptive statistics were applied to the data set to determine trends. Additionally, a survey (Appendix III) was administered to the students (n=14) at the completion of the lesson which asked a combination of open-ended and true-false questions to determine whether the students perceived the lesson helped them to learn about sustainability, STEM, and engineering. Survey responses were analyzed using thematic analysis.

V. Results

A. Pre-/Post-Assessment. On the pre-assessment, students answered more than half of the items correctly [μ = 6.1, σ = 1.8, η = 6.0, range = 7.0] indicating students had some background knowledge related to the science content and skills in the bioengineering lesson. On the post-assessment, student scores improved [μ = 7.6, σ = 1.9, η = 8.0, range = 6.0], indicating growth in students' content knowledge and skills from pre- to post-assessment.

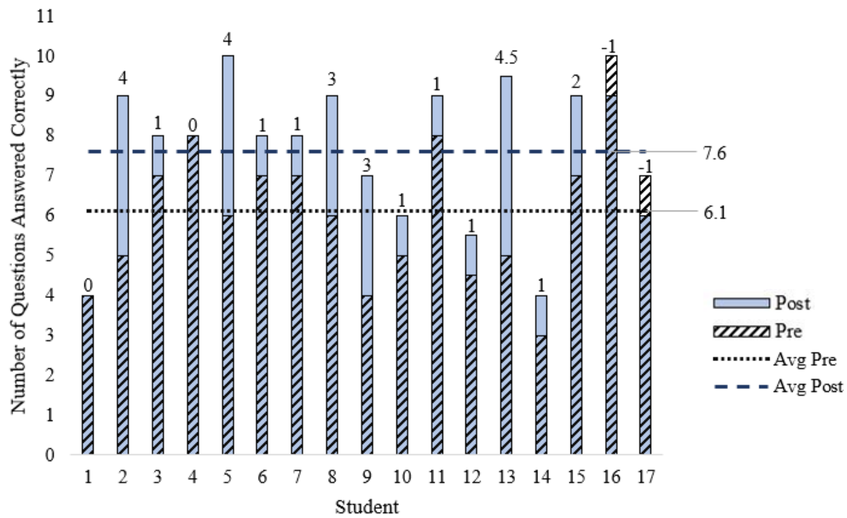


Fig. 2. Change in student scores from pre-assessment to post-assessment per student. Change in scores is quantified (numbers above columns).

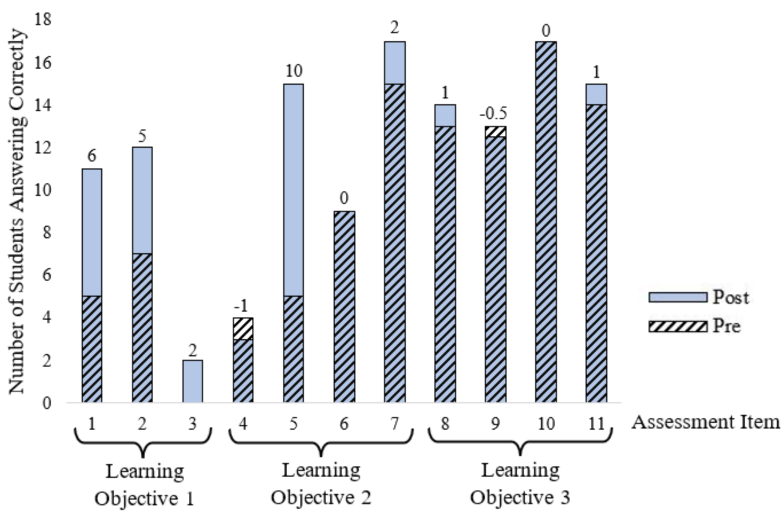


Fig. 3. Change in student scores from pre- to post-assessment for the eleven assessment items. Change in scores is quantified (numbers above columns).

Figure 2 shows the change in each individual student's performance from pre- to post-assessment (reported by the numbers above each column). Mean scores for the pre- and post- assessments are also reported. In addition to considering overall student improvement on the assessment, we analyzed students' performance on each of the eleven assessment items (Figure 3). Numbers printed above each column quantify the change in scores from the pre- to post-assessment. On the pre-assessment, students had low initial scores on items related to Objective 1 (Q1-Q3), mixed high and low scores on items related to Objective 2 (Q4-Q7), and overall high scores on items related to Objective 3 (Q8-Q11). These pre-assessment scores indicate that students had very little knowledge of food waste as a sustainability issue prior to the bioengineering lesson, but they did have skills related to data analysis and knowledge of factors that affect the rate of aerobic respiration in a system. As indicated by the post-assessment, students' knowledge and skills improved. In relation to Objective 1, students increased their understanding of sustainability issues related to food waste by more than a third (35%). The pre- to post- assessment change (ca. 60%) was in students' ability to identify aerobic respiration as the biological process used by microorganisms to decompose food waste. Overall, student performance from pre- to post-assessment indicates that they increased their knowledge of sustainability issues, food waste, and aerobic respiration.

B. Student Survey. Analysis of survey responses related to student interest in STEM careers indicated that half of the students (50%) are interested in STEM careers; 57% of these students said their interest was positively impacted by their participation in the lesson. Of the 50% of students that were not interested in STEM careers, 43% still perceived the bioengineering lesson increased their knowledge of STEM careers. All students who took the survey perceived they learned more about STEM more generally as a result of the bioengineering lesson. More than half (57%) of students perceived increased knowledge of sustainability, and more specifically, sustainability as it related to food waste. More than half (57%) perceived greater awareness of the connections among sustainability, engineering problem solving and biodigester technology. Student responses strongly indicated that they enjoyed learning about the biodigester and how it works (64%) and how the effluent produced in the biodigester could be sustainability repurposed (29%).

VI. Conclusions and Impacts

This study aligns to key characteristics of education for sustainable development [19] while also enhancing students' knowledge of the ways in which engineering can be used to solve environmental problems [6]. The collaboration between researchers and teachers provided youth with opportunities to engage in core science concepts in the service of learning about a real-world problem. Students engaged in consequential sustainability learning [20] [21] by investigating how biodigester technology works to mitigate the problem of food waste at a local scale in the context of biology. Learning opportunities like these serve to enhance students' science and engineering literacy while also supporting their awareness of issues related to the environment – sustainable use of natural resources, environmental impacts, and human actions that exacerbate global climate change. This study indicates potentially effective means for increasing students' knowledge of sustainability issues while also supporting or improving their interest in engineering and STEM.

VII. Study Limitations and Next Steps

The generalizability of the results of this study is limited by study context and participants. The study took place at one private high school with one teacher and seventeen students to date, all of which were advanced learners. Thus, the ability to infer potential impacts on high school science teachers and students is limited. The other two lessons developed during the teacher professional development workshop will be conducted to increase the sample size of this study. Additionally, performing these lessons in schools with greater representative student diversity would also enhance our ability to generalize impact.

VIII. References

[1] S. L. Robinson and J. A. Mangold, "Implementing engineering and sustainability curriculum in K-12 education," in *Volume 5: Education and Globalization*, San Diego, California, USA: American Society of Mechanical Engineers, Nov. 2013, p. V005T05A033. doi: 10.1115/IMECE2013-66693.

[2] S. Knowlton, J. Fogleman, F. Reichsman, and G. De Oliveira, "Higher education faculty collaboration with K-12 teachers as a professional development experience for faculty," *J. Coll. Sci. Teach.*, vol. 044, no. 04, 2015, doi: 10.2505/4/jcst15_044_04_46.

[3] *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, D.C.: National Academies Press, 2012, p. 13165. doi: 10.17226/13165.

[4] NGSS Lead States, *Next Generation Science Standard: For States, By States*. Washington, D.C.: National Academies Press, 2013.

[5] T. J. Moore, K. M. Tank, A. W. Glancy, and J. A. Kersten, "NGSS and the landscape of engineering in K-12 state science standards," *J. Res. Sci. Teach.*, vol. 52, no. 3, pp. 296–318, Mar. 2015, doi: 10.1002/tea.21199.

[6] T. J. Moore, A. W. Glancy, K. M. Tank, J. A. Kersten, K. A. Smith, and M. S. Stohlmann, "A framework for quality K-12 engineering education: Research and development," *J. Pre-Coll. Eng. Educ. Res. J-PEER*, vol. 4, no. 1, May 2014, doi: 10.7771/2157-9288.1069.

[7] C. Jackson *et al.*, "Equity-oriented conceptual framework for K-12 STEM literacy," *Int. J. STEM Educ.*, vol. 8, no. 1, p. 38, Jun. 2021, doi: 10.1186/s40594-021-00294-z.

[8] M. Yilmaz, J. Ren, S. Custer, and J. Coleman, "Hands-on summer camp to attract K–12 students to engineering fields," *IEEE Trans. Educ.*, vol. 53, no. 1, pp. 144–151, Feb. 2010, doi: 10.1109/TE.2009.2026366.

[9] National Center for Science and Engineering Statistics (NCSES), *Diversity and STEM: Women, Minorities, and Persons with Disabilities 2023. Special Report NSF 23-315*. Alexandria, VA: National Science Foundation, 2023. [Online]. Available: https://ncses.nsf.gov/wmpd

[10] A. Clark and R. Kajfez, "Engineering identity in pre-college students: A literature review," in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida: ASEE Conferences, Jun. 2019, p. 32727. doi: 10.18260/1-2--32727.

[11] J. DeWaters and S. Powers, "Improving science literacy through project-based K-12 outreach efforts that use energy and environmental themes," in *2006 Annual Conference & Exposition Proceedings*, Chicago, Illinois: ASEE Conferences, Jun. 2006, p. 11.738.1-11.738.17. doi: 10.18260/1-2--158.

[12] A. Collier, D. Knight, K. Hafich, M. Hannigan, M. Polmear, and B. Graves, "On the development and implementation of a project-based learning curriculum for air quality in K-12 schools," in *IEEE Frontiers in Education Conference*, El Paso, TX: IEEE, 2015, pp. 1–7. doi: 0.1109/FIE.2015.7344246.

[13] P. Pauw *et al.*, "Transforming the finance system to enable the achievement of the Paris Agreement," in *The Closing Window: Climate crisis calls for rapid transformation of societies: Emissions Gap Report 2022*, 2022, p. 65.

[14] National Academy of Engineers, *NAE Grand Challenges for Engineering*. Washington, D.C.: National Academies Press, 2017.

[15] EPA, "2018 Wasted food report: Estimates of generation and management of wasted food in the United States in 2018," *EPA-530-R-20-004*, 2020, [Online]. Available:

https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf
[16] Recoup Environmental, “Aerobic digesters: Solutions for food waste.” 2023. [Online]. Available: https://recoupenv.com/digesters/
[17] Water Environment Federation, “Anaerobic digestion fundamentals.” Water Environment Federation. [Online]. Available: https://www.wef.org/globalassets/assets-wef/direct-download-library/public/03---resources/wsec-2017-fs-002-mrrdc-anaerobic-digestion-fundamentals-fact-sheet.pdf
[18] Creswell, J. W., *Research design: Qualitative, quantitative, and mixed methods approaches.* Los Angeles: Sage Publications, 2013.
[19] C. Chew Hung, *Climate change education: Knowing, doing and being.* London: Routledge, 2014.
[20] E. Tan, A. Calabrese Barton, and C. R. Nazar, “Youth enacting social-spatial justice in middle school STEM: Advancing justice work in hyperlocal and interscalar ways,” *Cogn. Instr.*, vol. 41, no. 1, pp. 94–124, Jan. 2023, doi: 10.1080/07370008.2022.2081692.
[21] A. Wals and J. Dillon, “Conventional and emerging learning theories: Implications and choice for educational researchers with planetary consciousness,” in *International Handbook of Research on Environmental Education.*, New York: Routledge, 2013, pp. 253–261.

IX. Endnotes

NGSS Performance Expectations being used directly or developed during the bioengineering lesson.

HS-ESS3-4. Evaluate or refine a technological solution that reduces the impacts of human activities on natural systems.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products as equilibrium.

Appendix I: Teacher Professional Development

A. Lunch-and-Learn. After the aerobic biodigester was installed at the Tower Hill School in the spring of 2022, the researchers gathered with a group of twelve science teachers from various grade levels (including lower, middle, and upper schools) to conduct a lunch-and-learn workshop about the digester. During this workshop, the researchers gave a presentation on the digester, its function, and the installation process for the digester at the school. Teachers were given the opportunity to engage with the presentation and ask questions. Following the presentation, teachers were given time to think about and share ideas regarding how they could educate their students about the digesters in their various classes. At the end of the lunch-and-learn workshop, the researchers asked for three volunteer teachers to participate in a week-long professional learning workshop to flesh out and create lesson plans based on their ideas.

B. Professional Learning Workshop. Three high school science teachers (biological sciences, chemical sciences and environmental sciences) volunteered to participate in the professional learning workshop. The goals of this workshop were to help teachers learn more about the biodigester technology and related issues in sustainability, and to assist them in creating hands-on, engineering-focused lesson plans involving the digester technology. The workshop took place over the course of three days in Summer 2022 through synchronous online sessions for about 2.5 hours each day. The table below shows the activities during each synchronous workshop session and tasks completed by teachers asynchronously after each session. Teachers refined and finalized their lesson plans within three weeks after the workshop. The teachers were paid a stipend for time spent developing these lesson plans and their cooperation in administering the lessons and reporting the results to the research team.

Day	Synchronous Workshop Activities	Asynchronous Tasks
1	• Presentation on digester technology and sustainability issue of food waste disposal • Reviewed resources for teachers (slides, diagrams, technical information on the digester) • Brainstorming session for teacher lesson planning	Develop an outline of lesson related to course content that incorporates digester technology
2	• Teachers shared lesson outlines • Feedback and idea-sharing among researchers and teachers • Final questions and clarifications	Revise lesson outline, begin development of draft lesson plan
3	• Teachers presented draft lesson plans • Feedback and idea-sharing among researchers and teachers	Revise and finalize lesson plan

C. Teacher Feedback. At the conclusion of the professional learning workshop, teachers reported a greater understanding of sustainable engineering technology and its application at their school. Prior to this professional learning opportunity, they were aware of the installation of the digester, but they did not know enough about it to use it as an instructional tool. Teachers appreciated the opportunity to ask questions of the research team and for the feedback provided on their lesson plans. They shared enthusiasm for using the biodigester to craft a relevant, authentic lesson for students. They gave suggestions of ways that the workshop could be expanded to other science teachers at the school during professional development days, and they have proposed presenting at various environmental summits held annually by the school and in the state.

Appendix II: Pre-/Post-Assessment for Biology Lesson

1. On average, how many tons of food waste are produced each year in the United States?
   A. 6 million
   B. 16 million
   C. 60 million
   D. 600 million

2. On average, what proportion of food waste produced per year in the U.S. ends up in a landfill?
   A. 7%
   B. 17%
   C. 47%
   D. 75%

3. Which environmental problems are created directly as a result of food waste in landfills? Choose all that apply.
   A. Sea level rise
   B. Greenhouse gas emissions
   C. Biodiversity loss
   D. Leaching of pollutants into watershed
   E. Large scale deforestation
   F. Soil erosion

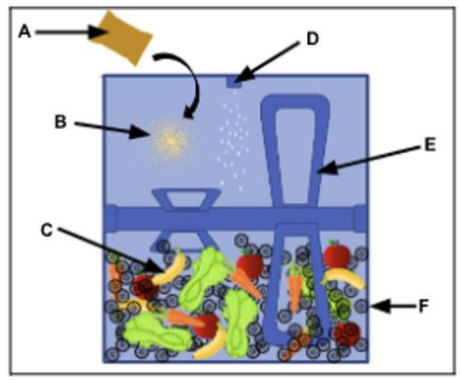
Questions	PE	SEP	DCI	CCC
1-3	HS-ESS3-4, *HS-ETS1-3*	INFO	ESS3.C, *ETS1.B*	C/E

4. Which organism(s) are primarily responsible for decomposing organic matter like food waste? Choose all that apply.
   A. Algae
   B. Animals
   C. Bacteria
   D. Fungi
   E. Plants

5. Which biological process is primarily used by decomposers to break down food waste?
   A. Aerobic Respiration
   B. Ethanol Combustion
   C. Glycolic Fermentation
   D. Photosynthesis

6. Which of the following chemical equations represents the overall chemical process used by decomposers to break down food waste?
   A. $6\ CO_2 + 6\ H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$
   B. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{energy}$
   C. $C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O + \text{energy}$
   D. $C_6H_{12}O_6 \rightarrow 2\ CO_2 + C_2H_5OH + \text{energy}$

Questions	PE	SEP	DCI	CCC
4-6	HS-LS1-7	MOD (6 only)	LS1.C	E/N (6 only)



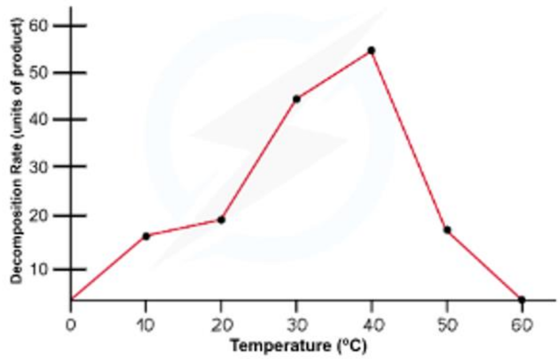
A biodigester is illustrated on the right; it can be used in commercial kitchens to reduce the amount of food waste thrown in the trash.

- **Letter D** shows a jet that sprays 40-50°C (100-120°F) water into the system.
- **Letter E** shows a paddle arm that turns continuously as food waste is broken down.

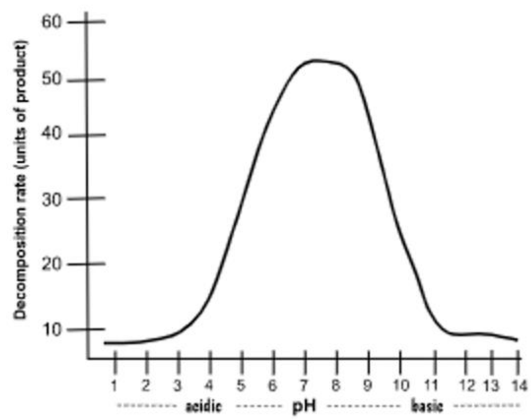
7. Predict what would happen if the paddle arm (letter E) got jammed and could not turn.
   A. Food waste would not be broken down effectively by decomposers; oxygen would not be evenly distributed in the system.
   B. The biodigester would continue to function normally; the paddle arm just packs food in more tightly.
   C. Food waste would be broken down rapidly by decomposers; they would run out of food and die.
   D. The biodigester would take less energy to run; this would make it more efficient and environmentally friendly.

8. Predict what would happen if the water sprayed into the biodigester by the jet (Letter D) was room temperature (21°C, 70°F).
   A. Food waste would continue to be broken down as normal in the biodigester system.
   B. Food waste would be broken down more quickly in the biodigester system.
   C. Food waste would be broken down more slowly in the biodigester system.
   D. Food waste would be broken down at double the rate in the biodigester system.

9. The graph on the right shows the relationship between temperature and decomposition. Choose two data points from the graph and explain how they support your answer to question #8.
Sample response:
At 40°C, the decomposition rate is nearly 60 units of product.
At 20°C, the decomposition rate is about 20 units of product.



10. The graph on the right shows the relationship between pH and decomposition rate. Which of the following conclusions can be drawn from the patterns in the graph?
A. The decomposition rate in the biodigester increases as pH increases.
B. The optimal pH for decomposition in the biodigester is very acidic or very basic.
C. The decomposition rate in the biodigester is not affected by pH.
D. The optimal pH for decomposition in the biodigester is neutral.



11. A group of students decides to set up a lemonade stand as a fundraiser at the school's football game. They make 30 gallons of lemonade and throw all of the used lemons into the biodigester. Predict what will happen to the decomposition rate in the biodigester and justify your prediction using patterns in the graph.

Prediction:
Decomposition rate would slow significantly.

Justification:
The graph indicates that decomposition rate is low (below 10 units of product) at pH less than 3 (very acidic).

Questions	PE	SEP	DCI	CCC
7-11	HS-PS1-6, *HS-ETS1-3*	DATA (7, 8, 10) ARG (9, 11)	PS1.B, *ETS1.B*	PAT

Appendix III: Student Survey Questions

1. What is one thing you learned from the lesson?

2. What did you most enjoy from the lesson?

3. What can be improved in this lesson next time?

4. Are you interested in an engineering or STEM career in the future?

   ____YES ____NO

5. Did this lesson positively influence your interest in engineering or STEM careers?

   ____YES ____NO

6. Do you feel that you understand more about engineering and STEM based on the lesson?

   ____YES ____NO