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Short Course on Sustainable Polymers for High School Students

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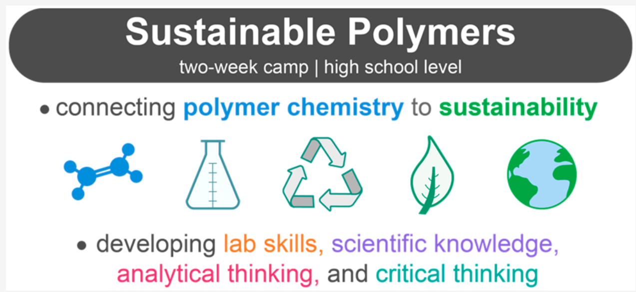
ABSTRACT: A two-week summer camp for high school students focused on sustainable polymers was developed and implemented. Students took part in experiments and interactive lessons that demonstrate polymer chemistry fundamentals alongside associated sustainability challenges and opportunities. For example, polymer concepts related to chemical properties (reactivity, structural architecture, molecular weight) and physical properties (density, tensile strength, thermal properties) were discussed, as well as how these properties affect materials' recyclability and degradability. Teaching these important concepts to students is especially timely given the global plastic waste dilemma. Responses to postcourse surveys suggest that students were intellectually engaged while gaining practical laboratory and research skills, broadening their understanding of polymer chemistry and sustainability, and becoming prepared for post high school studies.



KEYWORDS: *High School/Introductory Chemistry, Polymer Chemistry, Hands-On Learning/Manipulatives, Inquiry-Based/Discovery Learning, Laboratory Equipment/Apparatus, Materials Science, Physical Properties*

INTRODUCTION

Chemistry and chemical principles will play a pivotal role as we transition to a more sustainable society (e.g., in utilizing renewable materials).[1,2] Integrating sustainability concepts into chemistry curricula, as noted by Fisher, "offers a context for learning chemistry that is rich in possibilities that connect with our students—their interests, their priorities, and the challenges they will face as they enter society as adults."[3,4] Enabling students to understand the intersections of chemistry and sustainability will help build an educated and innovative workforce and prepare students to make informed decisions in the future.[5−10]

Incorporating sustainability concepts into curricula is particularly relevant to the polymer field given the burgeoning plastic waste crisis. Both the dwindling supply of raw materials and the environmental damage of plastic waste have been highlighted in widely circulated reports, including the Ellen MacArthur Foundation report on "The New Plastics Economy"[11] and several others.[12−14] Because polymeric materials are so ubiquitous, it is easy to connect scientific lessons on this topic to the daily experiences of students, as demonstrated by a large number of polymer-specific outreach and learning modules developed for high school students,[15−18] including several that are framed around sustainability.[19−23] For example, Burmeister and Eilks used a socio-critical and problem-oriented approach to develop lesson plans on the chemistry of plastics for secondary school students.[24] Both the students and teachers described the lesson plans as motivating, interesting, and challenging and reported that these lesson plans promoted higher-order cognitive skills in communication and evaluation.

All of these factors motivated us to focus our high school summer camp on the theme of "Sustainable Polymers." We had been teaching a polymers-focused summer camp annually as part of the Michigan Math and Science Scholars (MMSS) program since 2015;[25] but, on the basis of both student feedback and our own interests, we shifted the focus entirely to sustainable materials in 2017. We incrementally revised the course materials for 2018 and 2019 and collected student data in 2019. This course takes the students through mimicking and critiquing conventional recycling processes for petroleum-derived plastics to examining the characteristics of bio-derived and synthetic sustainable polymers.

We designed the course to be both accessible and interesting to students with a range of educational backgrounds, from those with no chemistry experience to those who have already taken advanced high-school-level classes. Fundamental chemistry concepts were presented alongside real-world applications of polymers to promote meaningful learning.[26,27] The laboratory portion includes extended "research-like" experiments, which

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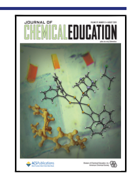


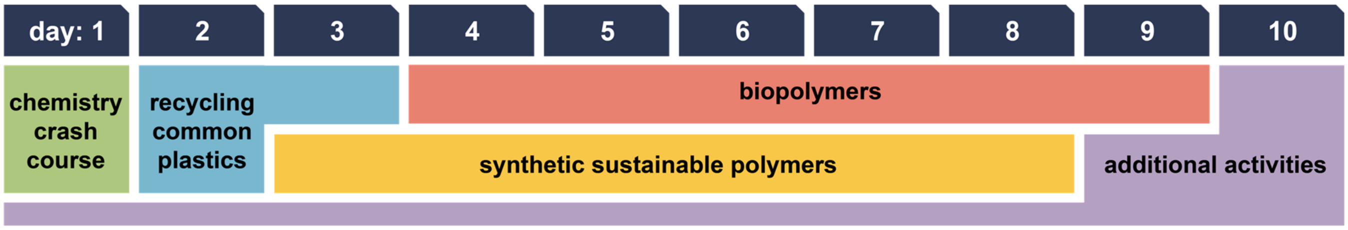


Figure 1. Organization of course. Each block width spans the days that included that segment.

require students to work in groups to generate hypotheses, design and run experiments, analyze results, and evaluate their hypotheses. In many cases, students design and execute second- (and sometimes third-) generation experiments based on their findings. The curriculum is complemented with a creative science communication project, field trips that showcase different applications of polymer science, and infographics to illustrate polymer uses.[28]

■ COURSE DESIGN

Course Objectives

The overarching course goal is to provide an engaging educational experience. Specific course objectives are as follows:

1. Students will leverage their existing knowledge to master new concepts.
2. Students will be able to explain how aspects of polymer chemistry are related to real-world sustainability issues.
3. Students will be able to define new terms related to polymer chemistry and sustainability.
4. Students will perform laboratory techniques and analyze data.
5. Students will practice laboratory research skills, including developing hypotheses and designing experiments to evaluate them.
6. Students will compare their high school experiences to college experiences.

Setting and Participants

The Michigan Math and Science Scholars program is a summer enrichment program held annually at the University of Michigan, which aims to increase knowledge and foster an interest in math and science among high school students.[25] The program is divided into three two-week sessions and includes over 30 courses across various math and science disciplines. In 2019, 471 students from 23 countries and 32 US states attended the program, ranging in grade from rising sophomores to rising seniors. These students formally applied to the program and were selected by MMSS staff on the basis of their school transcript, personal statement, letter of recommendation from a teacher, and availability of their course preference. The "Sustainable Polymers" course was capped at 16 students to ensure a safe lab environment. The course was cointructed by a professor, a postdoctoral associate, a graduate student, and an undergraduate teaching assistant. IRB approval was obtained, and all students and their legal guardians consented to use of the students' content, including survey responses and photos.

Course Structure

The course meets Monday through Friday from 9:00 AM−4:30 PM, with a lunch break from 12:00 PM−1:30 PM.[29] Course content is organized into five segments (Figure 1), which will be described in detail below. Four of these segments (Chemistry Crash Course, Recycling Common Plastics, Synthetic Sustainable Polymers, and Biopolymers) include a series of experiments and lectures related to each topic. The experiments in each segment are adapted from published procedures and sequenced to build lab skills, as well as examine challenges and opportunities in the sustainable polymers field. The last segment (Additional Activities) is composed of miscellaneous activities related to the course objectives and the program mission (details of each are described below).

■ SAFETY AND HAZARDS

The experiments described herein present specific hazards that must be managed. These hazards include exposure to high-temperature surfaces and materials (150 °C oven in Processing Plastics and hot plates in multiple experiments), corrosives and toxic reagents (1 M HCl and tin(II) ethylhexanoate in Synthesizing Triblock Copolymers, NaOH in Depolymerizing Compostable Items), and potential allergens (starches and food additives in Biopolymers). To minimize student exposure to these hazards, the instructors perform most hazardous tasks by handling all objects going in/out of the oven, as well as dispensing the HCl and tin reagents. Otherwise, the instructors inform and closely monitor the students. Volatile liquids are handled in a fume hood, and proper PPE (lab coats, goggles, gloves, long pants, socks, and closed-toed shoes) is worn at all times. Detailed safety information for each procedure is also included in the Supporting Information (SI).

■ CHEMISTRY CRASH COURSE

Interactive Lessons (Morning)

Because the students come from diverse educational backgrounds (e.g., some have not taken a chemistry course whereas others have taken advanced chemistry courses), the first day focuses on ensuring that all students have the same basic knowledge. This "crash course" is intended to be both simple and engaging. The "think−pair−share"[30] teaching strategy is used to establish an "Interactive Lesson" format. The morning is spent going through lessons on organic chemistry (SI, Lesson Plan 1) and polymer basics (SI, Lesson Plan 2). The purpose of these lessons is to familiarize all students with the core chemical concepts (e.g., molecular weight) used throughout the camp. Each lesson begins by defining key topics, then delving into the chemistry concepts embedded in each, and finally connecting this new information to real-life examples (listed in Figure 2). Identifying where sustainable polymers are encountered in our daily lives sets the theme of the course. Then, the students' previous knowledge of plastic recycling is expanded by examining related data, including EPA statistics collected on plastics recycling in the US[31] and findings in the 2017 study on the production, use, and fate of all plastics.[14] In 2019, a graph depicting the changing amount of global plastic exports was also

Discussion topics

What is/are:

- science
- chemistry
- organic chemistry
- sustainability
- sustainable polymers

Chemistry concepts

- periodic trends
- electron counting
- Lewis structures
- chemical bonds
- nomenclature
- drawing molecular structures
- polymer structures
- structure–property relationships

Connections to real-life

- compounds found in chocolate (organic chemistry)
- recycling data of commodity polymers (polymer sustainability)

Figure 2. Overview of Chemistry Crash Course content.

discussed because many students brought up the effects of China's ban on plastic waste collection.[32]

Lab Skills Boot Camp (Afternoon)

The purpose of the "boot camp" is to introduce students to the research laboratory and offer a fun, low-stakes experience with the equipment they will later use (SI, manual, p 10). The boot camp is adapted from an undergraduate organic chemistry course at U-M.[33] After a safety walk-through led by an instructor, the students embark on a self-guided lab tour in which they locate and take "selfies" with a list of common laboratory items. This activity serves to familiarize the students with routine lab items and give them time to get comfortable in the lab space. The remainder of the boot camp focuses on learning and practicing common chemistry lab calculations (e.g., unit conversions and stoichiometry) and using lab equipment (e.g., micropipettes, balances, and glassware). The students apply these technical skills to making oobleck, the popular chemistry/physics demo of a non-Newtonian fluid.[34]

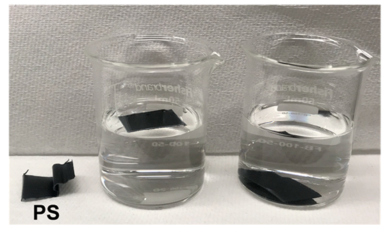
RECYCLING COMMON PLASTICS

Sorting Plastics

The next set of experiments demonstrates how polymeric properties affect the way plastics are recycled (SI, manual, p 24). After reviewing some of the properties and applications of commodity polymers, students recreate two of the key recycling steps—sorting and melt-processing. In the sorting experiment, students are challenged to design a system to separate a mixture of unknown plastic pieces on the basis of density. This experiment is adapted from an open educational resource by Schumm,[35] and similar activities have been reported.[36] The students are familiar with the concept of density (from the earlier crash course) and are provided with a procedure for calculating the density of an ethanol/water mixture and density charts for aqueous salt solutions. Most students will prepare several different density solutions and use a "sink or float" test to identify each plastic piece (Figure 3). Some students will streamline the process by gradually increasing the density of a single solution (by adding water to ethanol) to observe which plastic pieces would float first.

In 2019, all students accurately identified the poly(ethylene terephthalate) (PETE) and polystyrene (PS) pieces due to their distinctive densities. As anticipated, there was less agreement in distinguishing high-density poly(ethylene) (HDPE), low-density poly(ethylene) (LDPE), and poly(propylene) (PP) items because these plastics have similar densities (0.90−0.97 g/mL). These results were framed within a discussion on the challenges encountered in plastic separation. Additional articles on this topic were provided to complement the discussion (SI, Supplementary Content).

Sort plastic using density. Plan and execute a series of "sink or float" tests to separate and identify unknown plastics.



26 wt% NaCl (ρ = 1.2) 28 vol% EtOH (ρ = 0.94)

density (g/mL)	
LDPE:	0.91–0.94
PP:	0.91–0.94
HDPE:	0.94–0.97
PS:	1.05–1.07
PETE:	1.38–1.39

Figure 3. Overview of the Sorting Plastics experiment. The photo shows a representative "sink or float" test performed on a piece of polystyrene (PS).

Processing Plastics

In this experiment, the students reshape plastic pieces into new items using melt-processing (SI, manual, p 42). This activity is adapted from an open educational resource by Stewart.[37] An explanation of thermoplastics and thermosets is used to connect a polymer's chemical structure to its physical properties and recyclability. Specifically, the fact that most thermosets are unable to be recycled by melt-processing because cross-links prevent the polymers from melting is emphasized. After this discussion, students recreate the "heat and remold" step of plastic recycling. They melt HDPE scraps from milk cartons and food container lids into new shapes using silicone molds (Figure 4). This activity works on other polymer types as well, such as PETE.[38]

Many students observe changes to the material quality after processing, including discoloration or nonuniformity of the repurposed plastics (Figure S1). These observations demonstrate an important reality of recycling via melt-processing; the material quality is often downgraded and there can be

Recreate the melt-and-remold recycling step. Melt HDPE plastic scraps into new shapes.

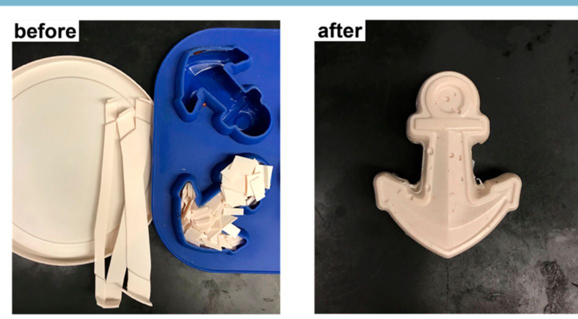


Figure 4. Overview of the Processing Plastics experiment. The photos show an example of reshaping food container lids (before) into a new object (after) using a silicone mold.

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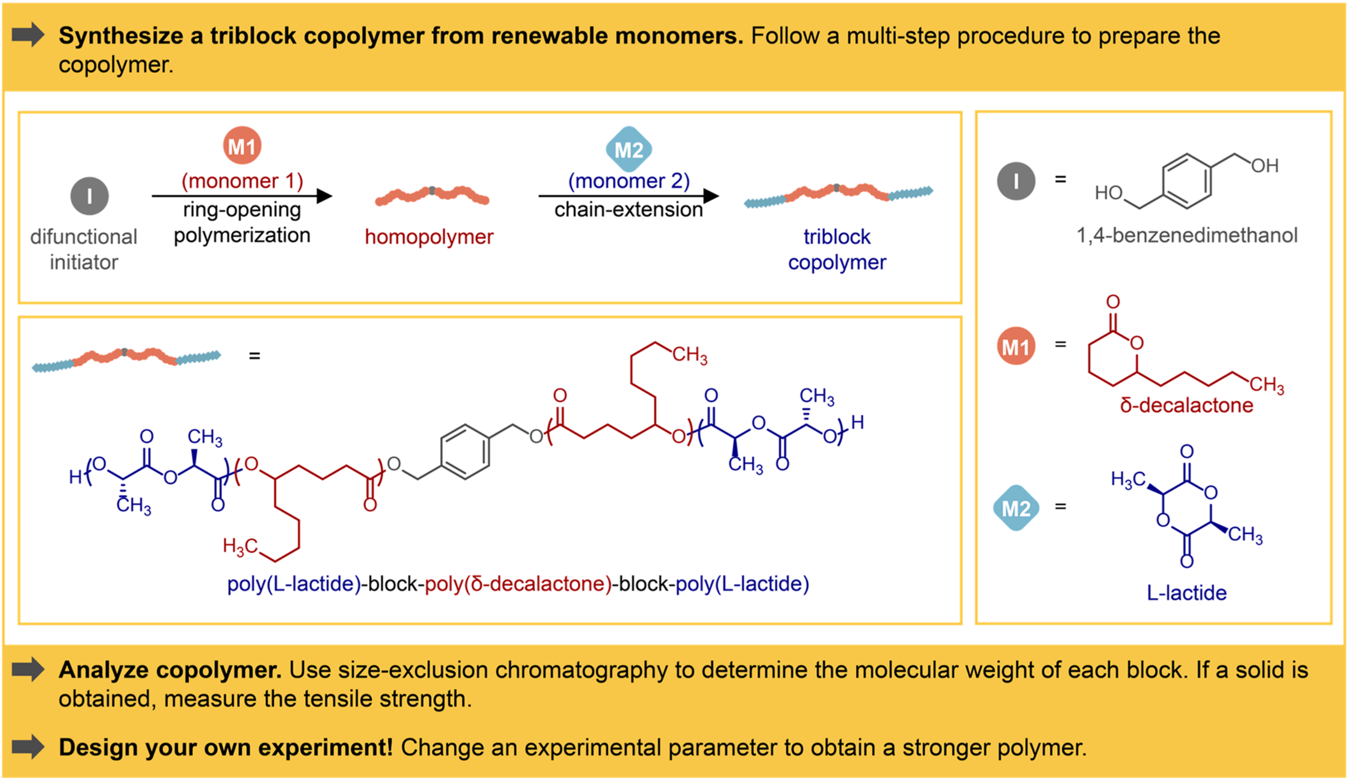

Figure 5. Overview of the Synthesizing Triblock Copolymers experiment. A generic reaction scheme and structures of starting materials and products are shown.

undesirable effects from colorants and additives.[39] An optional "bonus experiment" is offered for interested students to further investigate these effects (SI, manual, p 46), where they design a process that simulates repeated melt-processing and monitor how this process affects the quality of the resulting plastic. Again, additional articles on melt-processing were provided for the students (SI, Supplementary Content).

Student Impressions

After finishing the recycling experiments, we asked the students in a brief writing prompt to describe something new they learned from these experiments that they would share with friends or family (SI, Table S3). The responses included both new technical knowledge (thermoplastics, thermosets, and density; objective #3) and information on recycling and plastic pollution (objective #2). Students were also asked if their view of recycling changed as a result of this experiment: 11 students replied "yes" and 4 replied "no" (1 response was illegible). In most cases, the students whose view of recycling changed explained that recycling is not as simple as they initially thought, recognizing that polymer science plays a role in plastics sustainability (objectives #1 and #2). Some representative student responses include:

> "Recycling has always seemed as this perfect thing that was very efficient. Now I realize that not much of the plastic we throw [away] is recyclable." (objectives #1 and #2)

> "It's not something that can be dealt with by only policies ([as] I previously thought). Instead there is still many challenges in [the] scientific area." (objectives #1 and #2)

■ SYNTHETIC SUSTAINABLE POLYMERS

Synthesizing Triblock Copolymers

These experiments focus on poly(lactic acid) (PLA), a prominent sustainable polymer in the marketplace.[40] In the first experiment, students synthesize triblock copolymers following a procedure developed by Wissinger and co-workers (SI, manual, p 49).[41] This experiment incorporates common laboratory techniques, including stoichiometric calculations, pH measurement, precipitation, and vacuum filtration. Additionally, students are introduced to polymer science concepts including copolymers (SI, Interactive Lesson 3), size-exclusion chromatography (SI, Interactive Lesson 4), and mechanical properties testing. Students work in pairs to synthesize copolymers containing poly(lactic acid) ("hard" block) and poly(δ-decalactone) ("soft" block) (Figure 5); both blocks are synthesized from renewable monomers and are degradable. The strength of the copolymer depends on the length of each block, and to test this, different monomer ratios are assigned to each pair of students. The synthesis and isolation of the copolymer takes place over multiple days to ensure adequate reaction and drying time. During the interim, the students learn about tensile strength testing as part of the Biopolymer Plastics experiment (see below), which they also apply to measure the strength of films made from their triblock copolymer.

After completing the experiment once, the class results (molecular weight, tensile strength) are compiled on a shared spreadsheet (Table S1) and these data are analyzed together. Each group uses this information to formulate a hypothesis and then design and execute a second experiment to test it. In 2019, the students aimed to obtain a stronger material in round 2 and predicted they could do so by changing a variable such as monomer feed ratio, reaction time, or reaction temperature.

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Many students were eager to attempt this reaction again, especially if they obtained a weak or viscous material in round 1. In most cases, the students increased the relative amount of L-lactide monomer and succeeded in obtaining a stronger material, but some students found that increasing the amount of L-lactide too much led to a brittle material that cracked easily. Designing their own hypothesis-driven experiment exposed students a more authentic research experience, enabling them to use critical thinking skills.

Depolymerizing Compostable Items

Next, students depolymerize commercially available "green" plastic cups made from PLA (Figure 6). This experiment connects with students' prior knowledge and experiences, as many of them have encountered similar "eco-friendly" plastics in their lives. After reviewing the mechanism for ester hydrolysis, students carry out the reaction on PLA under basic conditions (SI, manual, p 64). Students perform liquid−liquid extraction to isolate and purify the hydrolyzed product (i.e., L-lactic acid). After drying the product, they characterize it using infrared spectroscopy (SI, Interactive Lesson 5). In 2019, all groups successfully obtained the hydrolyzed product and noticed the obvious change in material properties, transitioning from a flexible solid to a thick, viscous liquid. Some groups observed green particulates in their crude reaction mixture and concluded that, although the cup is degradable, the green label printed on it is not does not break down under these conditions.

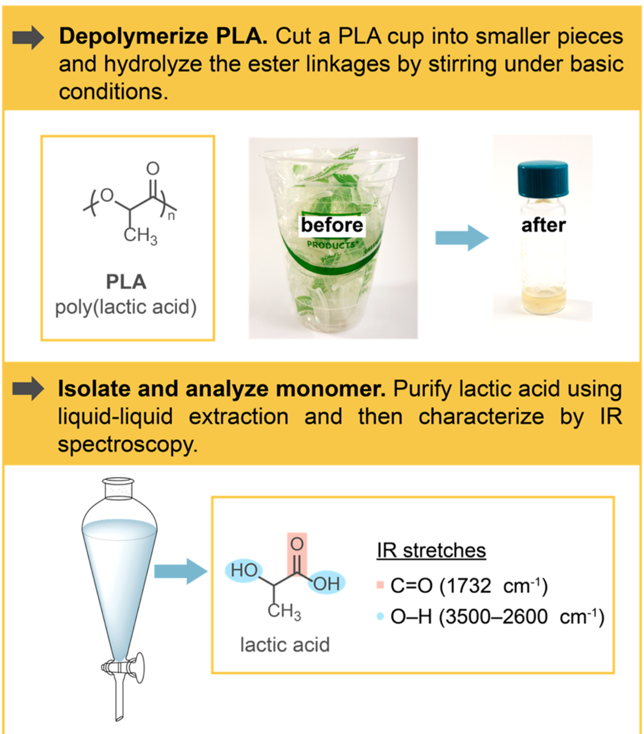

Figure 6. Overview of the Depolymerizing Compostable Items experiment. The top box shows photos of the PLA plastic cup starting material and lactic acid obtained after hydrolysis. The bottom box shows key IR data of lactic acid, obtained from the SDBS database.[42]

Student Impressions

As above, we asked the students what they learned from these experiments that they would share with others. The responses included theory on the synthetic chemistry related to polymerization and depolymerization (objective #3), the relationship between polymer structure and properties (objective #3), the recyclability of polymers related to structure (objective #2), and technical skills gained in lab (SI, Table S5; objective #4). The responses demonstrated that this segment successfully met some of the course goals:

> "From this experiment, I learned that the process to degrade PLA is pretty slow, unless we could use water to break the ester bond of the polymer backbone. This method is called hydrolysis. The process can also be accelerated by acid or base. We basically break PLA bonds into monomers, which is the lactic acid, with extra OH bonds." (objectives #2 and #3)
>
> "I learned how to depolymerize compostable plastics such as PLA. This is something I would share with my family because we use plastic cups made of PLA frequently." (objectives #1 and #3)
>
> "From the triblock polymer synthesis, all of the chemicals have a tiny amount required to do the experiment. I used to ignore the differences (such as 1 mL) in measurements, but after [this experiment] I've learned that small differences could influence the results." (objectives #4 and #5)

■ BIOPOLYMERS

Formulating Biopolymer Films

Biopolymers, or polymers obtained from nature, are the focus of the next segment (SI, Interactive Lesson 6). When asked to name specific biopolymers at the start, most students would come up with DNA, RNA, or proteins, but a few mentioned saccharide-based polymers (e.g., cellulose). In this experiment, adapted from Stevens[43] and Wissinger,[44] students design their own formulations for bioplastic films using starches and additives (SI, manual, p 74). Pairs of students select their starches and additives from a list, with a specified mass ratio but without guidance on what might result from each reagent choice. After solvent-casting films in the oven, the tensile strength of the films is measured using a simple setup (Figure 7). Students compare the strength of biopolymer films with and without their chosen additive. An array of bioplastics with varying tensile strengths, appearances, and flexibility/brittleness are obtained because each group selects a unique combination of starch and additive.

After collecting and analyzing the class data from the initial round of films (SI, Table S2), the students devise a new formulation they think will produce a stronger film and evaluate this hypothesis experimentally. Since this protocol is rather streamlined, there is sufficient time in the course to do several iterations. In 2019, many students switched either their initial starch or additive choice in favor of one that performed better in another formulation. Others changed the additive quantity, and in some cases, students observed that adding too much additive had adverse effects on film strength. Similar to the triblock copolymer synthesis experiment, this practice develops independent thinking skills and exposes students to a research-like experience. Overall, we found that the students enjoyed the opportunity to repeat experiments with modifications and observe their results.

Degrading Biopolymers

The students then degrade starch using a procedure adapted from Miskevich[45] (SI, manual, p 96), in which an amylase

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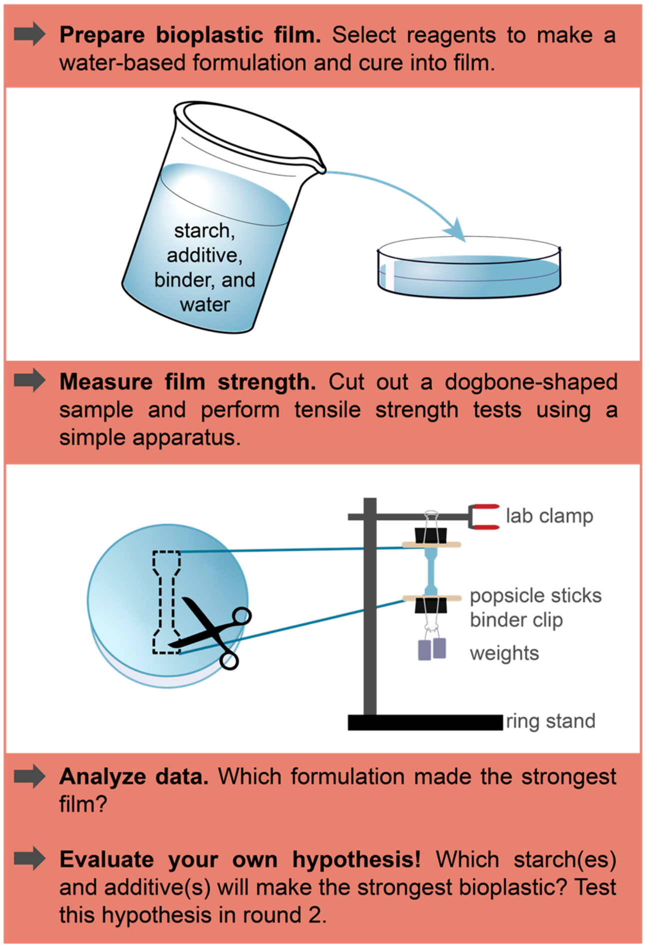

Figure 7. Overview of the Formulating Biopolymer Films experiment. The graphics depict the key steps performed in this experiment.

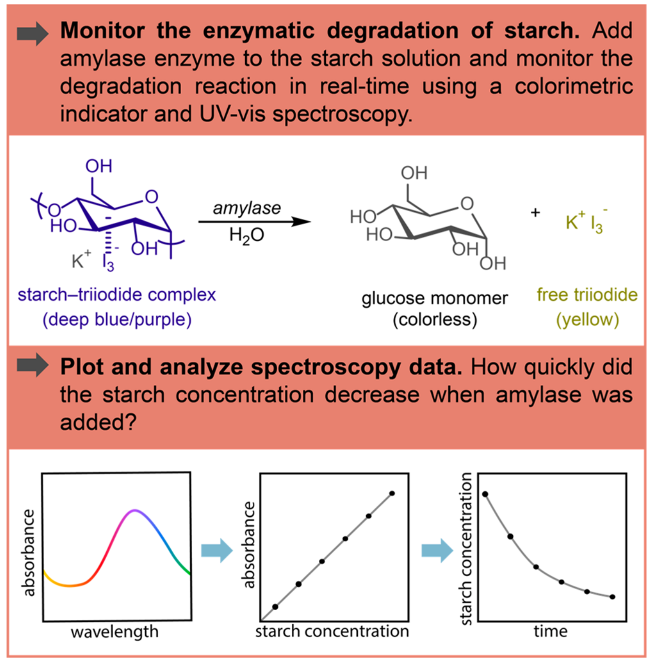

Figure 8. Overview of the Degrading Biopolymers experiment. The top box shows the degradation reaction performed, and the bottom box contains generic examples of the key plots used in data analysis.

enzyme catalyzes starch hydrolysis (Figure 8). Fresh starch solutions are degraded in lieu of the bioplastic films they made earlier because the variable starch concentration in each film complicates the analysis. Using UV−vis spectroscopy, students analyze the starch concentration using the colorimetric triiodide indicator (SI, Interactive lesson 7). They first generate a calibration curve and then perform the enzymatic hydrolysis experiment, monitoring absorbance and converting this data to starch concentration over time. Practicing these data processing skills is a useful exercise since it is generalizable to other math and science disciplines. All groups observed a net decrease in starch concentration, but the smoothness of their curves varied significantly on the basis of the wavelength selected for monitoring, with monitoring at 550 nm providing the smoothest data.

Student Impressions

After completing both biopolymers experiments, we again asked the students to share something new they learned from the experiments that they would share with friends or family (SI, Table S6). Many students wrote about various biopolymer information and physical properties (tensile strength) of materials (objective #3). Others included technical/experimental skills (objective #4), and three students specifically listed spectroscopy. The responses collectively demonstrated that this segment successfully met several course objectives:

> "Bioplastics are not so hard to make, some of them can be made from common materials [that] can be found in [the] kitchen." (objective #1)
>
> "I thought the biopolymer would be weaker in terms of tensile strength, but actually, our biopolymers had stronger tensile strength [than the triblock copolymer]. Next, depending on the additives, the tensile strength of the same starch used will be different." (objectives #3 and #4)
>
> "From the biopolymer tensile [strength] testing, I learned that biopolymers usually are weak and can't hold much, so their applications are limited." (objectives #1 and #4)
>
> "I learned that a lot goes into a formulation and it takes a lot of trial and error to get something right." (objectives #4 and #5)
>
> "(1) Try and make the experiments as accurate as you can and be careful, (2) read the instructions carefully and follow step by step, and (3) be patient with the experiment." (objective #4)

■ ADDITIONAL ACTIVITIES

Being a laboratory intensive course, there is often downtime while students wait for experiments to conclude. These moments are ideal for incorporating activities that enhance the curriculum while also providing flexibility in the camp schedule.

Stop-Motion Animation Project

Students use a significant portion of this time working in small groups (2−3 people) to create a stop-motion animation video describing an everyday product made with polymers (SI, manual, p 6). They choose the products and polymers that they want to highlight and are provided with a list of guiding questions related to the history, properties, and recyclability (objectives #1 and #2). Students create a storyline, craft props to depict it, and create a final video on their devices (e.g., smartphone, tablet) using a stop-motion app.[46] In addition to

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offering a creative avenue, this assignment develops research and communication skills. The final projects are watched together on the last day of camp, and some have been posted on YouTube.[47]

Undergraduate Panel

We conduct an afternoon panel session (~1 h) where undergraduate panelists share their experiences in applying to college, selecting a college, selecting a major, changing majors, doing research, and balancing extra-curricular activities with academics. This panel provides an open space for students to ask questions related to college and university life and compare it to their high school experiences (objective #6).

Laboratory Tours

Short tours of research laboratories (~10 min each) are arranged to highlight university research settings and expose students to alternative research areas and topics, including synthetic chemistry, surface chemistry, physical spectroscopy, and computational chemistry (objective #6).

Field Trips

We arranged several field trips to interact with polymers in the surrounding community. A tour of the University of Michigan football stadium, the "Big House", exposes students to collegiate athletics and, with infographics, highlights the use of polymers in synthetic turf and fibers used in athletic clothing (objective #3).[48] We also tour ThingSmiths,[49] a local 3D printing company, to observe a major application of thermoplastics, including PLA (objective #2). We go to a local ice cream shop (complemented by an infographic) and invite international graduate students and postdocs so that the international students have an opportunity to discuss studying abroad in an informal setting (objective #6).

Tie-Dying Biopolymers

At the end of the course, cotton shirts are tie-dyed, which provides a keepsake for the students and demonstrates chemical concepts (covalent reactions between dye molecules and cellulose fibers; objective #3). We plan to develop a more detailed lesson module on this topic for future iterations, similar to Bopegedra.[50]

■ STUDENT IMPRESSIONS

Course Material

At the completion of the course, the MMSS program organizers provide a survey to gather student feedback on the quality of the material and whether the course met the MMSS program's objective to foster interest in math and science. The survey asked the students to rate how strongly they agreed with a list of statements, and their responses are summarized in Figure 9. Every student agreed the course material was interesting, and a majority (13/16) agreed that they would like to further their study in the material covered. These responses support the idea that students' interests are engaged by linking core polymer chemistry concepts to real-world sustainability issues (objective #2).

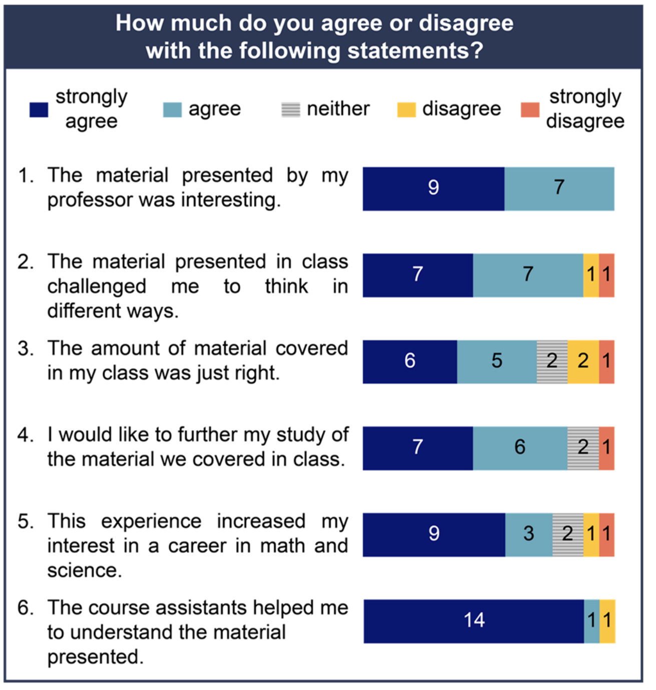

Figure 9. Student responses to the survey given at the conclusion of the course.

Perspective on Sustainable Polymers

To interrogate how the students' understanding of sustainability and sustainable polymers evolved over the camp, we distributed the same short writing prompt on the first and last day and then categorized the responses. For example, the students were asked to define *sustainability* (SI, Tables S7 and S9). On the first day, most responses concentrated on the durability or "environmental friendliness" of an object/process, and these general viewpoints were maintained on the final day. However, their responses were longer, more detailed, and more complex at the end of the course than at the beginning. Course concepts (recyclability, renewability, and degradability of materials) were mentioned only 4 times on the first day and increased to 12 on the last (objectives #2 and #3). The increased references to sustainable material considerations indicate that the course expanded these students' perspective on sustainability.

Examples of student responses for the definition of sustainable:

> "A thing that could be used constantly." (Day 1) "A material or substance that is durable, environmentally friendly, and cost-effective." (Day 10)
> "A style of living that is environmentally friendly and can last a long time." (Day 1) "Using replaceable resources, creating products that could be degraded back to the raw material." (Day 10)

The students were also asked what *role* they have in the area of sustainability and sustainable polymers (SI, Tables S8 and S10). The number of students who saw themselves as potential researchers or scientists increased from 5 to 9 students, suggesting that participating in the course increased their interest or confidence in this career path. Other roles included an educator or promoter, a student, or an informed consumer.

Examples of student responses:

> "[none]" (Day 1) "I am a potential researcher." (Day 10)
> "Recycle, use less plastic" (Day 1) "Because of this program, I would like to do research on this subject." (Day 10)

■ SUMMARY

This two-week course for high school students combined chemistry and sustainability through a series of experiments and lessons on sustainable polymers. Student feedback suggests that the course objectives were met. Primarily, students were

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intellectually engaged by connecting new scientific information to their prior interests in sustainability (objective #1). The increased consideration of material properties in student responses to the prompt "what is sustainability?" between pre- and postcourse survey suggests the course content influenced their perspective on this socio-scientific topic (objective #2). The reiteration of technical concepts from the curriculum (i.e., chemical and physical properties of polymers, experimental techniques) by students in free response surveys after completing each course segment suggests that new scientific knowledge about polymer chemistry was successfully learned (objective #3) and laboratory skills were gained (objective #4). Conducting research-like experiments and carrying out an independent communication project enabled authentic research experiences (objective #5), while participating in class discussions and additional activities offered perspective into collegiate experiences (objective #6). The detailed curriculum presented here is well suited for use in other on-campus high school enrichment or outreach programs.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.0c00507.

Laboratory manual with course syllabus, tentative schedule, lesson plans with materials and supplies list, and UV−vis operating instructions and troubleshooting (PDF, DOCX)

Daily schedule, lesson plans with graphics, materials and supplies lists, and links to supplementary content, figure of refurbished plastic piece after melt-processing, and tables of student survey responses (PDF, DOCX)

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Notes

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