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Sustainable Polymers: New 4-H STEM Curricula

Steven Worker
smworker@ucanr.edu

Jennifer McCambridge
University of Minnesota, hende219@umn.edu

Anne Stevenson
University of Minnesota, steve020@umn.edu

Jane Fields
jfields@umn.edu

Alexa Maille
ask37@cornell.edu

See next page for additional authors

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Cover Page Footnote

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Authors

Steven Worker, Jennifer McCambridge, Anne Stevenson, Jane Fields, Alexa Maille, C L. Meehan, Amie Mondl, Charles Malone, and Martin H. Smith

Sustainable Polymers: New 4-H STEM Curricula

Steven Worker[1], Jennifer McCambridge[2], Anne Stevenson[2], Jane Fields[2], Alexa Maille[3], Cheryl Meehan[4], Amie Mondl[2], Charles Malone[3], and Martin H. Smith[4]

AUTHOR: [1]University of California Extension. [2]University of Minnesota. [3]Cornell University. [4]University of California, Davis.

Abstract. There are many environmental issues surrounding the global production and use of plastics. Three science curricula (Grades K–2, 3–5, and 6–8) were developed to introduce youth to the past, present, and future of plastics. Designed using research-based methods and grounded in effective science pedagogy, the curricula provide young people opportunities to explore viable alternatives to plastics and develop knowledge and skills necessary to help mitigate environmental impacts associated with the production, use and disposal of plastics. Evaluation results demonstrated that youth improved their understanding of polymers and intention to help reduce impacts of plastics on the environment.

INTRODUCTION

Globally, the production and use of plastics grew rapidly after World War II. Today, over 381 million metric tons of plastic are produced annually, which represents a nearly 200-fold increase over the past 70 years (Ritchie, 2018; United States Environmental Protection Agency [EPA], 2020). Despite efforts to "reduce, reuse, and recycle" plastic products, there are large volumes of plastic produced and discarded yearly. Significantly, only approximately 8% of plastic waste is recycled, while an estimated 75% is disposed of in landfills (EPA, 2020). Additionally, roughly 10% of plastic refuse—including extremely harmful microplastics—ends up in the world's oceans (Thompson, 2006; Worm et al., 2017). These facts have led to the assertion that there is a "(micro)plastic crisis" (Shen, M. et al., 2020). Furthermore, the entire life cycle of a petroleum-based plastic product, from extraction of raw materials to manufacturing and post-consumer use, contributes to climate change and has other detrimental environmental impacts (Hamilton et al., 2019). Because of these negative effects, it is important to help young people explore viable alternatives to petroleum-based plastics such as sustainable polymers, bioplastics made from renewable resources. Bioplastics are designed to retain many advantages of petroleum-based plastics while helping to mitigate the environmental impact (Hillmyer, 2017).

CURRICULUM DEVELOPMENT

When learning about environmental issues, it is imperative that education efforts are in, about, and for the environment (Lucas, 1972). To that end, we developed, tested, and published three experientially based curricula (Kolb, 1984) focused on advancing youths' understanding of the production, use, and disposal of petroleum-based plastics and engagement in efforts to reduce their use and explore alternatives. This effort, led by the NSF Center for Sustainable Polymers, involved Extension professionals from California, Minnesota, and New York in a curriculum development process advanced by Smith et al. (2017). This effort supported National 4-H STEM goals (National 4-H Council, 2019) and addressed 4-H programmatic needs in environmental education (Worker et al., 2017).

The overarching goals of the three curricula (aimed at kindergarten-second grade, third through fifth grade, and sixth through eighth grade, respectively; see Figure 1) were to introduce youth to the prevalence and impacts of plastics in everyday life. Guided inquiry activities (Marek & Cavallo, 1997) designed for facilitation by professionals or volunteers in nonformal education settings (e.g., 4-H clubs, afterschool programs, camps; in-person and hybrid learning environments) focus on exploration of the environmental impacts of oil-based plastics, as well as emerging work on sustainable bioplastics. Participating youth engage in activities that examine the advantages and disadvantages of traditional plastics as well as the ways that scientists and engineers are working to develop bioplastics.

In addition to the inclusion of STEM content, the curricula promote scientific and engineering practices (National Research Council, 2013; Worker, 2013). Furthermore, the curricula for grades third through fifth and sixth through eighth include opportunities for authentic applications whereby youth engage in school- and community-based action projects related to plastics and sustainability. The curricula are available at shop4-H.org and 4hpolymers.org.

EVALUATION

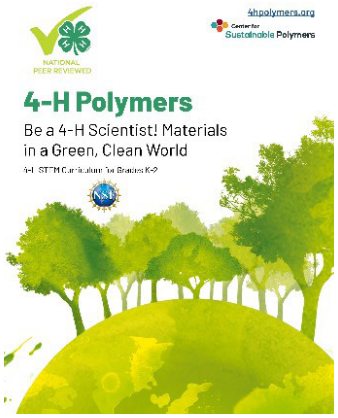
Three types of evaluation were utilized. The development team conducted preliminary evaluation to ensure learning objective alignment, content organization, and activity sequencing. Pilot testing occurred by implementing activities with youth and gathering formative data on usability and developmental appropriateness (Fields et al., 2016). Subsequently, activity modifications were made based on formative data.

Evaluators at the Center for Applied Research and Educational Improvement at the University of Minnesota and members of the development team conducted outcome evaluation in order to assess changes in participants' knowledge of and interest in curricula learning objectives. The curriculum for kindergarten through first grade participants was implemented at 23 sites with 161 youth in 2016 and 2017; the curriculum for third through fifth grade participants was implemented at five sites with 75 youth in 2019. Age-appropriate self-report survey instruments were used to collect outcome data (Halloran & Fields, 2019; Stevenson et al., 2017). Due to the COVID-19 pandemic, outcome testing of the curriculum for sixth through eighth grade participants was not possible. Alternatively, 17 field educators reviewed the curriculum to provide assessments of the activities relative to content, learning objectives, pedagogy, and community engagement.

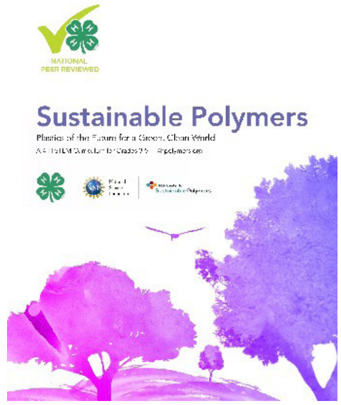
For the kindergarten-second grade curriculum, youth participants reported learning that many things are made of plastic (86%) and some materials can be recycled and some cannot (89%); youth also suggested ideas for how to care for the environment (87%) and expressed their intent to help family or friends recycle more (91%) (Smith et al., 2017). For the third through fifth grade curriculum, youth reported improvements in their level of understanding of key concepts across five content modules; module six focuses on service learning and was not included in the evaluation. These results were represented by the change in mean scores on the post-module retrospective surveys (Halloran & Fields., 2019). For example, at the item level, 64% of youth responded *A lot* to the item, "My understanding of what polymers are" as opposed to 11% of participants before taking part in the curriculum. Additionally, 70% of participants responded *A lot* to the item "My understanding of how I can reduce the impact that plastics have on the environment is" after completing the curriculum, whereas only 30% had done so in the pre-implementation evaluation. For the sixth through eighth grade curriculum, field educators agreed that activities would advance learning, be consequential and inspiring, and provide connections to authentic issues. These educators commented that guided inquiry promotes discourse among learners and that active learning projects help youth become involved in exploring "big questions" they face in their daily lives.

CONCLUSION

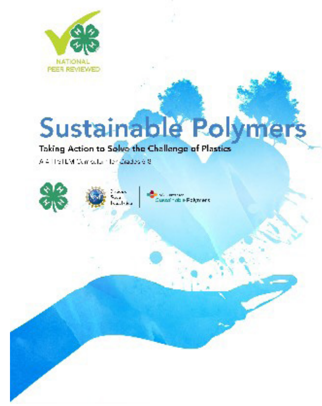
To help support young people in understanding and addressing issues associated with the production, use, and disposal of plastics, we developed and tested STEM curricula that engage participants in this authentic environmental issue, are about youth becoming involved civically to address the issue, and advocate for sustainable environmental solutions. Research shows that integrating science learning with materials and experiences with which youth are familiar can lead to more meaningful and engaged learning, and youth are more likely to be motivated to help improve their communities (Vander Ark et al., 2020). Lastly, the curricula advance youth scientific literacy by addressing relevant content, advancing practices of science, improving interest in and attitudes toward science, and engaging youth in community-based action projects (Smith et al., 2015).



4-H Polymers: Be a 4-H Scientist! Materials in a Green, Clean World
(6 modules for grades K–2)



Sustainable Polymers: Plastics of the Future for a Green, Clean World
(6 modules for grades 3–5)



Sustainable Polymers: Taking Action to Solve the Challenge of Plastics
(3 modules for grades 6–8)

Figure 1. Sustainable Polymers curricula.

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