

Start-Up and Sustaining 20 Years of STEM Outreach Research and Programming: The Food, Mathematics, and Science Teaching Enhancement Resource (FoodMASTER) Initiative

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ABSTRACT: Science and mathematics literacy are fundamental to the basic understanding of food and health and/or the pursuit of science-based careers. In 1999, the FoodMASTER Initiative (FMI) was created to provide an opportunity for youth to experience authentic, real-world health science activities in K-12 learning environments. FMI administrative locations have included Ohio University 1999-2005, East Carolina University 2006-2018 and Northern Illinois University 2018-current. The key programmatic elements for the FMI include: 1) curricular hands-on activities developed with teacher input, 2) free online access, 3) rigorous evaluation of program materials, and 4) robust partnerships with organizations that promote mathematics and science education. The purpose of this manuscript will be to 1) provide a rationale for the FMI programming, 2) share the curriculum and the process for developing curriculum and summarize the quantitative and qualitative findings of the 19 peer-reviewed articles, 3) discuss funding that was secured, 4) discuss strategies that lead to program sustainability, 5) discuss the mission and vision, and 6) summarize programmatic component sustainability.

INTRODUCTION

The Committee on STEM Education of the National Science and Technology Council (NSTC) clearly articulates a need for Americans to have access to lifelong science, mathematics, technology, and engineering (STEM) learning opportunities. Unfortunately, learners often become frustrated with science knowledge acquisition because information is taught without context, making it difficult to grasp the importance of the concept (Pajares, 1992). Guiding the development of STEM learning activities with Next Generation Science Standards (NGSS) and selecting subject matter content on learner's preexisting knowledge (Saunders, 1992) in combination with strategic pathways representing cross-cutting approaches (NSTC, 2018) can serve to empower all learners towards effective, productive citizenship.

While subject matter selection, meeting content standards, and creating relevance are important factors, teaching methods and approach should also be carefully considered if educators are to impact a learner's attitude and confidence towards science learning (Pajares et al., 2014). To date, traditional lecture-style and read-write learning style approaches continue to be the default teaching style for many educators. It is easy, efficient, and works for many learners; however, it often fails to appeal to a wide variety of learning styles, inspire curiosity, and create a love of learning. Educators must be willing and prepared to provide more engaging experiences for students that involve inquiry, hands-on learning, group discussion, questioning, demonstrations, problems, drawing, projects, and other teaching methods if they are

going to achieve quality outcomes (Kelly, 2000).

In 1999, a partnership was created between a rural elementary school teacher and a practicing rural dietitian and university faculty in Southeast Ohio to use food as a tool to teach food, science, and mathematics. Knowing that science and mathematics literacy are fundamental to individuals' basic understanding of food and health and/or the pursuit of science-based careers, the two professionals created a STEM program called the FoodMASTER Initiative. The purpose of the FoodMASTER Initiative (FMI) was to create a science education program rooted in constructivist learning theory (Phillips et al., 2004). Food was selected as the teaching tool because 1) students have preexisting experiences with foods, 2) it is conducive to hands-on activities, and 3) concepts can be linked to course content in biology, chemistry, environmental sciences, mathematics, nutrition, and health. Additional consideration for the use of food included: 1) food is already relevant for the learner, 2) food is an easily accessible material, 3) positive science and mathematics learning experiences can be inspired with various foods, and 4) food experiences can span across the P-20 learning environment in both formal and informal learning environments.

Given that the foundation of food and nutrition is rooted in mathematics and science subject matter, along with the potential to engage and inspire an individual's desire for life-long science learning, the FMI team was compelled to examine food and nutrition education through various teaching and learning methods (Stage et al., 2015). The multidisciplinary team of science, nutrition, and health educators began to discuss how to create a program for mathematics and science teachers that would allow for more time in the classroom devoted to issues related to food and nutrition while maintaining the required learning objectives of the Mathematics Standards Common Core State Initiative and Next Generation Science Standards (NGSS). Instead of using a traditional health education approach, the team focused on foundational mathematics and scientific knowledge to apply basic good nutritional science principles in the classroom. The advantages of this approach would be to 1) expand the number of teachers in the school system discussing food and health sciences, 2) support the acquisition of foundation knowledge that would further enhance knowledge in science

and mathematics, and 3) increase the number of content hours in nutrition science without taking time away from the core subject matter that is required, taught, and assessed with standardized testing.

PROGRAM MISSION AND VISION

The core mission of the FMI was established to address a long-standing lack of realistic sciences education opportunities for youth. The program vision is to provide teachers with authentic learning activities for classroom implementation to improve access, knowledge, and attitudes of youth towards science education (Diaz et al., 2018; Duffrin et al., 2010; Hovland et al., 2013; Roseno et al., 2014; Stage et al., 2017).

FUNDING SECURED

FoodMASTER began as a self-funded project partnering Ohio University with rural elementary students to learn mathematics and science using food. The project was called Kitchen Wizards and quickly demonstrated robust learning outcomes for both elementary and university students (Duffrin et al., 2005; McLeod et al., 2012). The project also captured the attention of Ohio University 1804 funds committee which provided additional funding to expand the proof-of-concept to six classrooms in Southeast Ohio.

In 2003, the Kitchen Wizard concept was modified and renamed the FoodMASTER Initiative. In 2005, team FMI received a National Institutes of Health (NIH) Science Education Partnership Award (SEPA). In 2008, the FMI received project funding from the United States Department of Agriculture. NIH SEPA remains the primary funder of the FMI.

KEY PROGRAMMATIC ELEMENTS

The FMI encourages teacher adoption of the FMI approach by alleviating what teachers and administrators might perceive as barriers to implementation. The developers created the curricular materials to 1) address science learning standards, 2) provide proficiency type questions, 3) use affordable food, supplies, and equipment, and 4) ensure

Table 1. *Funding Sources.*

Years	FoodMASTER Projects	Funding Source
1999-2003	Concept development	
2003-2004	Elementary Grades	Ohio University 1804 funds
2005-2008	Grade 3-5 Phase I	NIH Science Education Partnership Award R25RR020447
2008-2010	Grade 3-5 Phase II	NIH Science Education Partnership Award R25RR020447-04
2008-2010	FM Higher Education	USDA Higher Education Challenge Award NCE- 2008-38411-19041
2011-2016	Grade 6-8	NIH Science Education Partnership Award R25RR032144-01
2017-2022	Informal Science Learning	NIH Science Education Partnership Award R25GM129216

Table 2. *FoodMASTER Workbook General Topic Content.*

Topic	Grade 3-5 Science	Grade 3-5 Math	Grade 6-8 Science	Grade 6-8 Math	Higher Ed
Weights & Measures	Chapter 1	Chapter 1	Chapter 1		Chapter 2
Food Safety	Chapter 2	Chapter 2	Chapter 2		Chapter 1
Vegetables	Chapter 3	Chapter 3	Chapter 3		Chapter 3
Fruit	Chapter 4	Chapter 4	Chapter 4		Chapter 4
Milk and Cheese	Chapter 5	Chapter 5	Chapter 5		Chapter 7
Meat, Fish, Poultry	Chapter 6	Chapter 6	Chapter 6		Chapter 9
Eggs	Chapter 7	Chapter 7	Chapter 6		Chapter 8
Fats and Oil	Chapter 8	Chapter 8	Chapter 9		Chapter 10
Grains	Chapter 9	Chapter 9	Chapter 7		Chapter 5
Meal Management	Chapter 10	Chapter 10			
Energy Balance			Chapter 10	Activities 1-4	
Food Composition				Activities 5-8	
Super Tasters				Appendix	
Sugar			Chapter 8		Chapter 6
Quick Breads					Chapter 11
Yeast Breads					Chapter 12

that all materials are teacher tested and revised with relevant feedback. The curriculum includes the features of reinforcing healthy food selection, encouraging reading comprehension, and providing take-home activities for children and families to implement in the home learning environment.

Curriculum Development. FoodMASTER grades 3-5 was the first curricular manual developed, with twenty-four activities within 10 topic areas (see Table 2). Workbook activities introduce subject matter and promote reading comprehension through clever “Doodle bugs.” “Doodle bugs” encourages reading comprehension of the pertinent content for each chapter by asking students to underline or circle key concepts. Next, students and teachers must read and implement a hands-on activity. These activities generally use food as a hands-on tool to convey a scientific and/or mathematics concept.

Workbook developers created activities that require basic household cooking equipment, can be conducted in a regular classroom environment, and use food ingredients that are easily accessible. Other considerations are to provide as many edible end products as possible, especially using healthy food choices. While science and mathematics are the primary learning objectives, food and/or nutrition concepts are also integrated into each activity.

The workbook encourages students to demonstrate learning through laboratory reports and discussion; however, proficiency questions are available at the end of each chapter. These questions can assist the learner in checking basic knowledge and provide an opportunity for responding to standardized questioning. The workbooks provide addition-

al lessons to give students the opportunity to demonstrate thinking and learning skills in a “Try this at home” learning environment. The FoodMASTER grades 3-5 mathematics supplement, FoodMASTER grades 6-8 Science, FoodMASTER grades 6-8 Mathematics, and FoodMASTER Higher Education follow similar strategies, adjusted for grade level.

While FoodMASTER resource materials apply some variation in learning objectives and approaches, the process generally includes the following: 1) initial development of the curricular material based on educators’ needs and input, 2) pilot testing and implementation with formative evaluations 3) advisory panel review and revisions, 4) final implementation, and 5) data analysis after final revisions.

Workbooks for each learning level are guided by food subject matter and integration of science and mathematics concepts. All workbook activities are guided by and aligned with the Next Generation Science Standards (NGSS) and Common Core Mathematics Standards. NGSS and Common Core activity alignments can be found in the corresponding educator resources. Educators can choose to use the entire workbook or select individual activities based on their students’ learning needs and interest. Educator manuals, website videos, and teacher professional development activities assist educators in identifying the meaningful science and mathematics concepts within each chapter.

FoodMASTER workbook materials are evaluated by educators throughout the process of development. Curriculum developers utilize appropriate grade level teachers as consultants during the first stages of development. Workbook materials are then tested in a classroom or multiple classrooms and implementation teachers provide extensive feed-



Figure 1. FoodMASTER Workbooks. Graphic Art by Cara Cairns Design

back to revise materials in working towards a final product.

Curriculum Design. Workbook graphic design takes place prior to final implementation. The FoodMASTER activity material are produced by a professional graphic designer. This artistic enhancement improves visual appeal of the written information and applies high quality pictures and graphics. Educators who participate in final implementation receive printed hard copies and provide additional feedback post implementation. After the final implementation feedback is assessed, minor revisions are made to the final product. Finalized materials are then posted online, maintained free of charge, and made publicly available at www.foodmaster.org.

Curriculum and Material Access. FMI team members decided that all curricular materials would be available to educators free of charge. At the completion of each 5-year project, efforts have been made to ensure that curriculum and other research products are shared publicly. This effort effectively removes the barrier of cost for educators wanting to access materials.

Any potential user can go to the FMI website - www.foodmaster.org and download materials for free. Currently, the website contains grades 3-5, 6-8, and higher education resource manuals (see Figure 1). The FMI also partnered with another free website at the USDA National Agricultural in the Classroom, to offer components of both the FMI grades 3-5 and 6-8 materials.

The FMI team also prints and distributes free resource materials to educators through project participation and professional development opportunities. FMI book printing cost ranges from \$12 to \$50, depending on the size of the manual or workbook.

Evaluation of Materials and Programs. Recognizing the importance of data to support the development and utilization of FMI workbook materials, educational research and evaluation is a component of all projects. The grades 3-5 and

6-8 science workbook projects have applied the most funding thus far to provide extensive research and evaluation. Both projects were implemented and evaluated in multiple classrooms with participating educators in Ohio and North Carolina classrooms.

FMI institutional locations have determined where classrooms would be located for implementation and evaluation. Schools in desired geographic locations were approached directly with information about projects; teacher participation has been voluntary. School administration support was obtained before contacting teachers; this support was essential for subsequent voluntary teacher participation. In cases where well-matched comparison classrooms were utilized, teacher participation was also voluntary.

All research projects were approved by university Institutional Review Boards and participant consents were obtained. When students were involved, parental consent was also obtained. Students in implementation classrooms were not required to participate in research to be part of program implementation. In the cases of well-matched comparison classrooms, teachers in those classrooms received all the same program support materials as the implementation teachers after data collection period.

Grades 3-5 Food on the Farm, Grades 6-8 Food and You, and FoodMASTER Higher Education, have not undergone as extensive evaluation as have the Grades 3-5 and 6-8 science workbook activities. However, data from the grades 3-5 and 6-8 science workbook research informed much of the

Table 3. Project Descriptions.

Years	Projects	Geographic Location	Intervention Classrooms
2003-2004	Elementary Grades	Southeast Ohio	1
2005-2008	Grade 3-5 Phase I	Southeast Ohio	10
2008-2010	Grade 3-5 Phase II	Ohio and North Carolina	18
2011-2016	Grade 6-8	Eastern North Carolina	9

Table 4. *Pilot Study Research Descriptions.*

Author(s)/Year	Title	Description	Methods	Population	N	Journal
Phillips, S.K. et al., (2004)	Be a Food Scientist	Implementation and evaluation of a 14-week program called Kitchen Wizards	Implementation and Observation	4th grade student in South East (SE) Ohio	40	Science and Children
Duffrin, M. et al., (2005)	Developing Food Products and Enthusiastic Learners	Field trip experience for college and elementary school students designed around a food product development assignment	Implementation and Observation	College and elementary grade students in SE Ohio	56	Journal of Family and Consumer Sciences
Rivera, D. et al., (2009)	Improving Elementary School Students' Learning Outcomes Using Food-based Mentorship Programs	Food-based mentorship program involving college and elementary school students	Implementation, surveys, open-end comments, and observation	College and elementary grade students in SE Ohio	36	Journal of Teaching in Travel & Tourism

development of these materials. Efforts to implement and evaluate these products are on-going.

In general, FMI research projects collect both formative and summative data to evaluate outcomes and program effectiveness. Evaluation methods include process evaluation of educator efficacy (Roseno et al., 2017; Stage et al., 2016), student knowledge (Hodges et al., 2017; Hovland et al., 2013; Roseno et al., 2014; Stage et al., 2015) student attitudes, and dietary intake assessment. Data collection techniques include observations, pre and post knowledge assessment and surveys, and educator interviews. Table 4 summarizes data collected during pilot studies and table 5 and 6 summarize the grades 3-5 and 6-8 science workbook research. Evidence supporting the use of FMI approach and materials is drawn from these studies.

Pilot Studies. Pilot studies (Table 4) demonstrated successful student engagement and learning. The elementary students displayed enthusiasm for the curricular content and were engaged when utilizing food as a tool to learn science. Involving college students in the program enhanced their learning as well, especially through a mentorship process. Pilot study results warranted further exploration of the use of food as tools to engage elementary grade students in learning science. Subsequent to the first pilot studies, Kitchen Wizards was renamed FoodMASTER and further changes were made to the program content.

Grades 3-5 Studies. Of the eight studies completed with grades 3-5 (Table 5), two focused on attitudes, one focused on implementation of a mathematics lesson, four focused on knowledge gains, and one focused on nutrition teaching efficacy. Six of the eight studies utilized a pre and posting testing data set from a year-long implementation of the finalized grades 3-5 workbook. Educators utilizing the entire grades 3-5 workbook expose students to an average of 18 hours of food-based education over the academic year.

In general, students in all grades 3-5 activities were ob-

served as engaged participants. Overall, student participants' attitudes towards science increased at the completion of activities. The knowledge domains of nutrition, science, and mathematics (tested with researcher developed exams) indicated a collective increase in scores for all domains and a significant difference in scores between the intervention and well-matched comparison groups. Educator participants displayed gains in self-efficacy toward teaching nutrition that were significantly greater than changes observed in the educator well-matched comparison group.

Grades 3-5 project dissemination generated interest in expanding project concepts at higher grade levels. FoodMASTER expanded its resources to include middle grades 6-8 with the creation of a new science workbook. This workbook followed a similar subject matter, development, and research approach as the grades 3-5 workbook.

Grades 6-8 Studies. Of the two completed studies with grades 6-8 (Table 6), one focused on nutrition knowledge exam development and one focused on process evaluation. The studies evaluated educators and students in sixteen classrooms in Eastern North Carolina over the course of a year-long implementation of the grades 6-8 workbook lessons.

The nutrition knowledge exam included appropriate levels of item difficulty. Further analysis of student participant nutrition knowledge and attitudes remains in progress. For process evaluation, educators felt the program was a valuable experience for middle school students and were willing to repeat over half the chapters. Educators reported that the motivating factors for repeating activities included student enjoyment, standard alignment, ease of instructions, professional development training experience, and the provision of additional resources.

Overall, the pilot test, grades 3-5, and grades 6-8 projects have produced quality products and data to support the continued use and expansion of the FoodMASTER initiative. Additional data and details can be found in the 19 peer-re-

Table 5. *Grade 3-5 Research Descriptions.*

Author(s)/Year	Title	Description	Methods	Population	N	Journal
Duffrin, M. et al. (2010)	Using Food as a Tool to Teach Science to 3rd Grade Students in Appalachian Ohio	Attitudes towards science survey pre and post implementation of 45 hands on food lessons	Survey pre and post-test	Fourth graders in Southeast Ohio	280	Journal of Food Science Education
McLeod, S. et al. (2012)	Measuring Me: Using Nutrition Education Curriculum Activities to Teach Elementary Mathematics	Implementation of mathematics activity in fourth grade classrooms	Implementation and Observation	Fourth graders in North Carolina	298	Journal of Nutrition Education and Behavior
Hovland, J. et al. (2012)	Food-Based Science Curriculum Increases 4th Graders Multidisciplinary Science Knowledge	Fourth graders science knowledge gains	Science knowledge pre and post-test	Fourth graders in Ohio and North Carolina	580	Journal of Food Science Education
Roseno, A. et al. (2013)	Applying Mathematical Concepts with Hands-on, Food-Based Science Curriculum	Fourth graders mathematics knowledge gains	Mathematics knowledge pre and post-test	Fourth graders in Ohio and North Carolina	482	School Science & Mathematics
Stage, V. et al. (2015)	Food-based Science Curriculum Yields Gains in Nutrition Knowledge	Fourth graders nutrition knowledge gains	Nutrition knowledge pre and post-test	Fourth graders in Ohio and North Carolina	473	Journal of School Health
Stage, V. et al. (2016)	Implementation of a Food-based Science Curriculum Improves 4th Grade Educator's Self-efficacy for Teaching Nutrition	Fourth grade educator's self-efficacy for teaching nutrition	Self-efficacy pre and post-test	Fourth grade educators	34	American Journal of Health Education
Stage, V. et al. (2017)	Exploring Associations among Nutrition Science, and Mathematics Domains of Knowledge for an Integrative Food-based Curriculum: A Multiple Regression Analysis	Multiple regression exploring associations among nutrition, science, and mathematics knowledge	Secondary data analysis of grade 3-5 nutrition, science, and mathematics knowledge testing data	Fourth graders in Ohio and North Carolina	438	Journal of School Health
Diaz, S. et al. (2018)	The Importance of Improving Youths' Attitudes Toward Science (ATS): Validation of a Short Form Assessment of Attitudes in Science Constructs for Fourth Grade (AASC-4)	Validation of attitude towards science survey utilizing grade 3-5 survey data	Secondary analysis of grade 3-5 attitudes towards science survey data	Fourth graders in Ohio and North Carolina	1117	Journal of STEM Outreach

viewed publications that are listed in the reference section of this manuscript. The reference section includes publications on preschool (Geist et al., 2011; Roseno et al., 2015) and higher education (Duffrin, 2003, Rivera et al., 2009; Willard and Duffrin, 2003) projects that were outside the focused scope of the grades 3-5 and 6-8 projects.

Outreach and Partnerships. Robust partnerships are a key component of FMI research and development projects. Teacher partnerships had been the primary focus for FMI in earlier projects, and community educator partnerships have been the focus of later projects. Both formal science learning environment partnerships with K-12 teachers and informal science learning environments with community educators are the key to programming success.

Table 6. Grade 6-8 Research Descriptions.

Author(s)/Year	Title	Description	Methods	Population	N	Journal
Hodges, C. et al. (2017)	Middle school nutrition knowledge tool development in North Carolina.	Knowledge assessment of the FoodMASTER middle grades 6-8 workbook in 10 classrooms in Eastern North Carolina.	Nutrition knowledge pre and post-test	Seventh grade students in Eastern North Carolina	250	Nutrition and Food Science
Roseno, A. et al. (2017)	Process Evaluation of an Integrative, Food-based Science Curriculum in 8th Grade North Carolina Science Classrooms.	Process evaluation of implementation of the FoodMASTER middle grades 6-8 workbook in 10 classrooms in Eastern North Carolina.	Implementation, observation, feedback, exit survey, and exit interviews	Seventh grade teachers in Eastern North Carolina	8	Health Behavior and Policy Review

Formal Science Learning Environments. Initially, partnerships with K-12 teachers and schools were the foundation for the FMI. A strong partnership with teachers was necessary to enhance the quality of the materials and to move program expansion forward. It was the proof of concept data and endorsement of previous FMI teacher(s) that provided FMI researchers the ability to establish new teacher partnerships. When approaching new teacher partnerships, it was important to create interest and establish trust.

The process of establishing partnerships required several one-on-one teacher meetings. To begin teacher partnerships, first teacher contacts aim to establish interest in the FMI and to provide information about participation in current projects. For teachers expressing interest, FMI researcher(s) visit the teacher at their school and spend two hours with the teacher explaining project participation in further detail.

Once a teacher partnership is established, FMI researchers work with the teacher to gain school administrative approvals and set up project participation expectations. Over the course of a project, teachers receive multiple site visits from the project coordinator to support implementation and partnership building. At the conclusion of the grades 3-5 and 6-8 projects, the FMI had partnered with a total of 31 Ohio and 46 North Carolina classroom teachers.

Informal Science Learning Environments. As a component of the grades 6-8 project, the FMI proposed the development of a summer science experience for middle grade youth. This summer science experience forged a new partnership opportunity. Networking within the science education community introduced the FMI team to community organizations expressing interest in utilizing FMI workbook activities for science education programming.

As a result of the summer science camp experience, a robust partnership formed with a local North Carolina - organization called the Love A Sea Turtle Foundation (LAST). LAST promotes environmental advocacy through youth community service and science education. A large component of LAST programming involves food and nutrition, as well as protecting food systems. LAST supports youth lead-

ership development and provides services to underrepresented youth.

The FMI and LAST partnership have served to reach thousands of youth in Eastern North Carolina with access to FMI programming, leadership opportunities, and an experience in informal science education. Initial summer day camp programming in partnership with the Love A Sea Turtle Foundation in Eastern North Carolina included 258 Boys and Girls Club members. LAST has continued to assist the FMI by reaching youth through additional partnership with organizations that provide opportunities for underserved youth such as the Boys and Girls Clubs, Police Athletic League, and the SPOT.

Professional Development. As another component of outreach and partnerships, the FMI provides teacher and other professional development opportunities. The FMI team members have provided teacher professional development workshops to 270 elementary and middle school teachers through partnerships with the National Science Teachers Association regional meetings, Annual Environmental Health Sciences Summer Institute for K-12 Texas Educators, North Carolina Association for Biomedical Research, and the Northern Illinois University P-20 Center. The FMI team has also partnered with the School Nutrition Services Dietetics Practice Group of the Academy of Nutrition and Dietetics, introducing the FMI concept in a workshop to 58 registered dietitians attending the 2011 Food and Nutrition Conference Expo.

SUSTAINABILITY

The FMI team works diligently to address its biggest challenge, sustainability. One component is current project partnerships with six universities and one nonprofit 501(c)(3) organization. The goal is developing and delivering FMI concepts in science education programming. While still a work in progress, the university partnerships aim to support mentorship-based project partnerships. These mentorships can continue to expand and establish successful programs in other communities.

At the 20-year anniversary of the initiative, the team created a significant amount of curricular materials and data to support the use of FMI materials. The FMI team has found that partnering and mentorship with formal and informal science education organizations appears to be the keys to expansion and sustainability success. Current efforts are underway to permanently integrate and establish the FMI within the structure of the Northern Illinois University P-20 Center. The FMI team believes new opportunities are rooted in educator professional development, along with continued strategic mentor-based program expansion.

ASSOCIATED CONTENT

More detailed acknowledgements and free materials can be found at www.foodmaster.org.

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ABBREVIATIONS

FMI: FoodMASTER Initiative; HEC: Higher Education Challenge; LAST: *Love A Sea Turtle Foundation*; NGSS: Next Generation Science Standards; NIGMS: National Institute of General Medical Sciences; NIH: National Institutes of Health; ; P-20: Preschool through Higher Education; SEPA: Science Education Partnership Award; STEM: Science, Mathematics, Technology, and Engineering; USDA: United States Department of Agriculture

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