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Michael K. Daugherty
University of Arkansas

Heather D. Kindall
University of Arkansas

Vinson Carter
University of Arkansas

Lindsey M. Swagerty
University of Arkansas

Cathy Wissehr
University of Arkansas

See next page for additional authors

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Integrating Informational Text and STEM: An Innovative and Necessary Curricular Approach

Authors

Michael K. Daugherty, Heather D. Kindall, Vinson Carter, Lindsey M. Swagerty, Cathy Wissehr, and Sarah Robertson

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Michael K. Daugherty, Heather D. Kindall, Vinson Carter, Lindsey M. Swagerty,
and Cathy Wissehr
University of Arkansas

Sarah Robertson
Puster Elementary School

ABSTRACT

Recent standards-based reforms call for the use of a variety of informational texts at the elementary level. Informational texts are essential for implementing integrated problem-based science, technology, engineering, and mathematics (STEM) learning in elementary classrooms. Additionally, integrated STEM projects support the use of informational texts as students conduct research, design solutions, and communicate their results, thereby providing real-world applications of informational text. Elementary teachers need encouragement and support in order to increase the use of informational texts that assist in implementing effective STEM lessons. The authors provide strategies for melding informational texts with problem- and project-based learning in STEM.

Keywords: Informational text; Integration; STEM

The educational system in the United States is undergoing significant changes with the wide-scale implementation of new standards-based reforms, the push for deeper levels of critical thinking, and the incorporation of higher frequencies of informational text use (Calkins, Ehrenworth, & Lehman, 2012; National Governors Association Center for Best Practices [NGA] & Council of Chief State School Officers [CCSSO], 2010a). Coupled with this shift in education is a contradiction in the U.S. employment ratings; even with national unemployment rates at historically high levels, large numbers of jobs are going unfilled. Most of these jobs have one thing in common: They require employees with an educational background in science, technology, engineering, and mathematics, otherwise known as STEM (Engler, 2012). When addressing Congress in 2012 on the Encouraging Innovation and Effective Teaching Act (H.R. 3990), U.S. Representative Bucshon of Indiana noted that

“The [national] STEM workforce is exploding [or expanding rapidly] and is expected to continue to grow well into the future. From 2000 to 2012, STEM jobs grew nearly 8%, from 2010 to 2018 that increase is expected to jump to nearly 17%.” (Brown, 2012, para. 1)

Echoing these findings, “a study by Georgetown University Center on Education and the Workforce shows that by 2018, 8 million jobs in the U.S. economy will require a college degree in STEM”

(Murphy, 2011, para. 3). Rep. Bucshon summarized his comments to Congress by asserting that ““STEM education is vital to the careers of the future and what better way to encourage student participation than by putting before them teachers who have a passion [for] and experience within STEM fields”” (Brown, 2012, para. 1).

Brenner (2009) noted that there is a rising effort in the United States to engage additional numbers of young students in STEM fields and in STEM-related career paths. One way to improve instruction and engage students in the interdisciplinary aspects of science, technology, engineering, and mathematics is through an integrated approach to STEM education. Instead of teaching each of the STEM disciplines as parallel subjects, they are intertwined and presented in a holistic or interdependent approach using problem-solving strategies (Lantz, 2009). Sanders (2009) suggests that the elementary classroom provides an excellent launching point for this STEM integration. Elementary teachers who use STEM lessons that introduce creativity and innovation can help students with career exploration and development (McLaughlin, 2009). Although it is becoming more common to hear the term STEM spoken in elementary schools, there is still much ground to cover before it can be said that STEM is truly a part of the elementary school curriculum. The development and expansion of greater skills in STEM is increasingly important for student achievement at all levels of education, and given the most recent changes in education in the United States, it is becoming more popular and hence more acceptable for schools to integrate the STEM disciplines.

The newest round of standards-based reforms, the most prevalent of which is the Common Core State Standards (CCSS), requires teachers to integrate literacy into all aspects of the curriculum. The International Reading Association’s (2010) *Standards for Reading Professionals* require teachers to model reading and writing as lifelong skills used for authentic purposes in daily life. Further, Danielson (2007), whose work is used in many states as a teacher evaluation instrument, states that teachers should plan activities and assignments in their classrooms designed to promote deep, meaningful learning. These learning activities have three characteristics in common: They (a) emphasize thinking and problem-based learning, (b) permit choice and initiative, and (c) encourage depth rather than breadth. All of these are characteristics of informational text reading and writing as well as STEM education.

The STEM Dilemma

Despite the lucrative potential of STEM and the seemingly boundless opportunities in these fields, many young people remain reluctant to enter career fields that require a background in STEM. Murphy (2011) postulated that

Children at birth are natural scientists, engineers, and problem-solvers. They consider the world around them and try to make sense of it the best way they know how: touching, tasting, building, dismantling, creating, discovering, and exploring. For kids, this isn’t education. It’s fun! (para. 5)

However, “by the time students reach fourth grade, a third of boys and girls have lost interest in science. By eighth grade, almost 50 percent have lost interest or deemed it irrelevant to their education or future plans” (Murphy, 2011, para. 6). This means that millions of students are turning their backs on science and on STEM when we need them most. Gomez, Oakes, and Leone (2006) noted that even those students who do not turn their backs on STEM often enter postsecondary

programs without a clear understanding of the field, its practice, or its impact on society. Given this startling information, we assert that K–12 teachers should be responsible for helping students understand this significance. This understanding can be done through both integrated STEM and informational text.

Standards and Elementary STEM

Science and mathematics are not new to elementary classrooms. However, the introduction of technology and engineering at the elementary level has been a relatively recent phenomenon in schools, as is the increased use of informational texts in the early grades. One reason for these shifts at the elementary level is the development of the idea that in order to make the biggest impact on students, you must reach them at an early age (DeJarnette, 2012; Murphy & Mancini-Samuelson, 2012). Various sets of standards, including the CCSS (NGA & CCSSO, 2010a, 2010b), the National Research Council’s *Framework for K–12 Science Education* (2012), and *Technology for All Americans* (International Technology Education Association, 1996), are calling for increased coverage of engineering and technology in elementary education. Inclusion of engineering and technology at the elementary level provides children with the opportunity to be fully engaged and think critically about the problems that society is facing, especially through use of the engineering design process—which is central to the study of technology and engineering. Informational text could be a natural vehicle through which this content is explored and a student’s interest is developed and fed.

Although STEM is not directly mentioned in the CCSS, it should receive considerable attention based on the skills and competencies called for in these standards. Calkins, Ehrenworth, and Lehman (2012) note that the CCSS represent the most sweeping reform in K–12 education that this country has ever seen and suggest that they will play an influential role in American schools. The *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects* (CCSS ELA) emphasize much higher levels of reading comprehension than previous standards, placing equal weight on reading and writing and stressing the importance of critical thinking and problem-based learning (NGA & CCSSO, 2010a). The CCSS ELA point out that cognitive and intellectual growth occurs through time, across years, and across disciplines, which will require the integration of literacy into all content areas including, but not limited to, science and technical subjects (NGA & CCSSO, 2010a). The CCSS ELA call for an increased emphasis on reading, interpreting, and understanding various types of informational texts as pivotal skills connected to STEM teaching and learning.

“STEM literacy involves the integration of [each of the] STEM disciplines and four interrelated and complementary components” of STEM literacy (Bybee, 2010, p. 31). The *National Science Education Standards* (NSES; National Research Council, 1996) laid the groundwork for combining science with mathematics and technology; however, the goals proposed by the NSES have often fallen short in practice. The *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) will put integration into practice by directly linking science content to technology and engineering practices as well as to the objectives in the *Common Core State Standards for Mathematics* (CCSSM; CCSSO & NGA, 2010b).

Mayes and Koballa (2012) align the CCSSM with the *Framework for K–12 Science Education’s* Science and Engineering Practices (SEPs). The eight mathematical practices within the CCSSM directly align with the SEPs of the framework. Further analysis reveals that several of these SEPs

also align with the standards in the CCSS ELA, specifically Practice 4 (“analyzing and interpreting data”), Practice 7 (“engaging in argument from evidence”), and Practice 8 (“obtaining, evaluating, and communicating information”). This alignment is particularly strong given the assumption that the majority of the texts used when teaching STEM at the elementary level would be informational in nature.

Informational Text and STEM Learning

Duke (2003) “define[s] *informational text* as text written with the primary purpose of conveying information about the natural and social world . . . and having particular text features to accomplish this purpose” (p. 14). According to Keene (2008), there has been a growing awareness that informational literacy is the key factor in successful participation in our global society—a society in which “success in schooling, the workplace, and society depends on our ability to comprehend this information” (Duke, 2004, p. 40). Furthermore, we live in an information-based world in which most of what we read daily is informational text (National Assessment Governing Board, U.S. Department of Education, 2008). “The amount of information that we confront on a daily basis is more than most people had to contend with in an entire lifetime only a little more than 100 years ago” (Benson, 2002, p. 1). Students need to understand where and how to find information in order to survive (Duke, 2004, 2010).

In the *Reading Framework for the 2009 National Assessment of Educational Progress* (NAEP; National Assessment Governing Board, U.S. Department of Education, 2008), the Grade 4 assessment was divided equally between passages of literary and informational text, and “in K–5, the [CCSS ELA] Standards follow NAEP’s lead in balancing the reading of literature with the reading of informational texts” (NGA & CCSSO, 2010a, p. 5). Calkins et al. (2012) refer to the CCSS as “an absolutely crucial wake-up call” (p. 9). A critical look at the CCSS reveals that these standards are designed to provide all students with a thinking curriculum beginning in the earliest grade, kindergarten. Taking all this into consideration, there should be little debate about whether we should include informational text in early schooling. The real question is: How should this inclusion be accomplished?

Given calls for the increased use of informational texts and the rapidly expanding interest in engaging younger students in integrated STEM education content, it seems clear that these two initiatives can be complementary. Integrated STEM education requires students to be engaged in real-world investigations that originate with their own questions and research (Mayes & Koballa, 2012). These investigations must be grounded in evidence that is recognized by the educational community. This evidence can best emerge from reading, conducting research, and creating informational texts. Informational texts will complement the integration of STEM by exposing young students to informational text structures and features such as tables, graphs, charts, and symbols that must be taught explicitly (Maloch, 2008). When students discover the connection between conducting research, gathering information directly related to a STEM problem, and ultimately solving that problem, they will be developing skills that will benefit them throughout their lives.

Informational texts have the ability to present the concepts of STEM in a new way for elementary students. It is important for teachers, librarians, and parents to choose informational texts relevant to subject areas that can spur deeper thought and curiosity about STEM content areas (Hill, 2013). Informational texts have the ability to engage and inspire the young reader

by showing the possibilities of STEM. Van Loo (2012) was able to draw upon informational texts to connect STEM not only within literature but also within the real world. He carefully selected different informational texts that satisfied the CCSS ELA requirements but also drew upon STEM. After reading the informational text, he would engage students in discussions about the science, technology, engineering, and mathematics and challenge them to think about how things could have been different if certain engineering and technology had been developed within the setting of the plot. This method of presentation creates a segue to introduce students to design challenges and critical thinking, all the while creating a purposeful learning experience with both the informational text and the STEM subject areas. Clearly, informational texts have the capacity to advance intellectual understanding and the application of that newfound knowledge in solving engaging STEM problems. Table 1 displays select notable informational texts that may be used to set the stage for STEM learning. The recommended works all address innovation, and many have been recognized through various awards, such as the Robert F. Sibert Informational Book, Caldecott, and Newbery medals.

Table 1
Recommended STEM-Related Informational Texts

Author	Title
Jennifer Berne	<i>On a Beam of Light: A Story of Albert Einstein</i>
Franklyn M. Branley	<i>Floating in Space</i>
Robert Byrd	<i>Electric Ben: The Amazing Life and Times of Benjamin Franklin</i>
Vicki Cobb	<i>Harry Houdini</i>
Elisha Cooper	<i>Farm</i>
Lois Ehlert	<i>Color Zoo</i>
Olivia Evans	<i>Discoveries and Inventions (Encyclopedia with Flaps)</i>
Bruce Goldstone	<i>Great Estimations</i>
Steve Jenkins & Robin Page	<i>How Many Ways Can You Catch a Fly?</i>
Steve Jenkins & Robin Page	<i>What Do You Do With a Tail Like This?</i>
Barbara Kerley	<i>A Cool Drink of Water</i>
David Macaulay	<i>Cathedral: The Story of Its Construction</i>
David Macaulay & Neil Ardley	<i>The New Way Things Work</i>
JoAnn Early Macken	<i>Flip, Float, Fly: Seeds on the Move</i>
Patrick O'Brien	<i>You Are the First Kid on Mars</i>
Alice & Martin Provensen	<i>The Glorious Flight: Across the Channel With Louis Bleriot</i>
Joyce Sidman	<i>Swirl by Swirl: Spirals in Nature</i>
Kathleen Thorne-Thomsen	<i>Frank Lloyd Wright for Kids</i>
Vera B. Williams	<i>Three Days On a River In a Red Canoe</i>

Using Problem-Based Learning as a Delivery Vehicle

Many elementary teachers express discomfort in the STEM disciplines and question their ability to teach STEM (Hibpsman, 2007). Lantz (2009) noted that elementary level teachers often

lack adequate content knowledge in science and mathematics as well as experience in effectively integrating these subjects into a lesson or unit. Although “there have been attempts to define the results (function) of STEM education,” there has been little agreement about how this should be accomplished (Lantz, 2009, p. 3). Students engaged in STEM should become “problem-solvers,” “innovators,” “logical thinkers,” and “technologically literate” (Morrison, 2006, p. 2–3). Currently, there are neither national STEM standards nor certification requirements to teach STEM. One thing that almost all researchers seem to agree upon is that a problem-based learning (PBL) environment may be the best method for delivering STEM in the elementary classroom.

PBL has been successfully implemented and widely used in a number of disciplines including health care, architecture, engineering, economics, technology education, social studies, and science (Krajcik & Blumenfeld, 2006; Massa, Dischino, Donnelly, Hanes, & DeLaura, 2011). A study by Marx et al. (2004) confirmed that PBL has been successful at increasing students’ tests scores compared to traditional instruction. The researchers found that PBL creates an atmosphere in which students feel compelled to conduct research, ask questions, and explore beyond the stated requirements of a given lesson.

Deep knowledge of each of the STEM disciplines is not required to fully engage elementary students in informational text and integrated STEM content. Rather, an understanding and application of the pedagogy of integrated STEM education is required. Integrated STEM education is best delivered through creative problem-based integrated lessons and activities in which the elementary students assume the role of problem solvers, researchers, inventors, and designers to solve problems that draw from many disciplines. These problems are typically unstructured theme-based design problems that cause the elementary students to solve engaging problems directly related to content standards. The pedagogies and heuristics unique to the fields of STEM education draw from the scientific model of inquiry and the engineering design loop (or process) to provide elementary students with a framework for addressing the research and learning needed to solve a given problem.

The *engineering design loop* (heuristic) is used as a learning tool for elementary students as they progress through a STEM problem that is referenced back to informational text (see Figure 1). Generally, the engineering design loop requires that the elementary student complete a number of steps, including clarifying the problem, conducting research on how others have solved similar problems, brainstorming potential solutions, selecting a potential solution, constructing a model or prototype, testing the chosen solution (model or prototype), evaluating the solution (model or prototype), and presenting the solution. The role of the teacher is to design robust STEM problems that extend upon informational text, deliver important standards-based content, and engage the elementary students. The teacher also provides students with the impetus for considering informational texts, gathering research, and engineering a potential solution to the STEM design problem. These strategies can be drawn directly from the CCSS ELA (i.e., “write informative/explanatory texts to examine a topic and convey ideas and information clearly”; NGA & CCSSO, 2010a, p. 20) and the International Technology Education Association’s (2007) *Standards for Technological Literacy* (STL; i.e., “develop abilities to apply the design process”; p. 115).

For example, one STEM challenge calls for the elementary students to apply the engineering design process to solve a problem called the “Balancing Act” (see Figure 2). In this lesson, the students work in teams to create a mobile that displays the relationship between science (the natural world) and technology (the human-made world) through the artistic expression of the



Figure 1. The design loop project. Preservice teachers personalized their own design loop by including pictures and elements that would aid younger students within the elementary classroom.

mobile. The students conduct background research on mobiles (the only art form to originate in the United States), gather information about the nature of science and the human-made world from informational texts such as *Alexander Calder and His Magical Mobiles* by Jean Lipman and Margeret Aspinwall (1981) or *Mobiles: Building and Experimenting with Balancing Toys* by Bernie Zubrowski and Roy Doty (1993), and then locate artifacts that can be arranged in a state of equilibrium to represent the relationship between nature and technology. This experience shows students how the individuals that they just read about in the informational text went about solving the problems that they faced. The engineering design loop has the potential to be used as a resource for students to solve a variety of problems inside and outside of the classroom. The experience of solving the activity will provide multiple ways for our students to learn and retain information as well as provide an interest for continued learning.

Kwan (2000) notes that despite the benefits to student learning, many teachers are reluctant to initiate PBL and STEM in their classrooms, citing concerns about classroom management, releasing control over learning activities, and inability to answer students' questions. By combining informational texts, integrated STEM, and the PBL methodology to establish the background organization, motivation, and structure for creating meaningful learning (Lauritzen & Jaeger, 1997), many existing teacher concerns should be eliminated. The use of STEM content, PBL teaching methods, the use of heuristics, a connection to children's literature or other informational texts, and linking to appropriate state and national standards will allow teachers to present disciplines with which they have limited backgrounds in an engaging and nonthreatening manner.

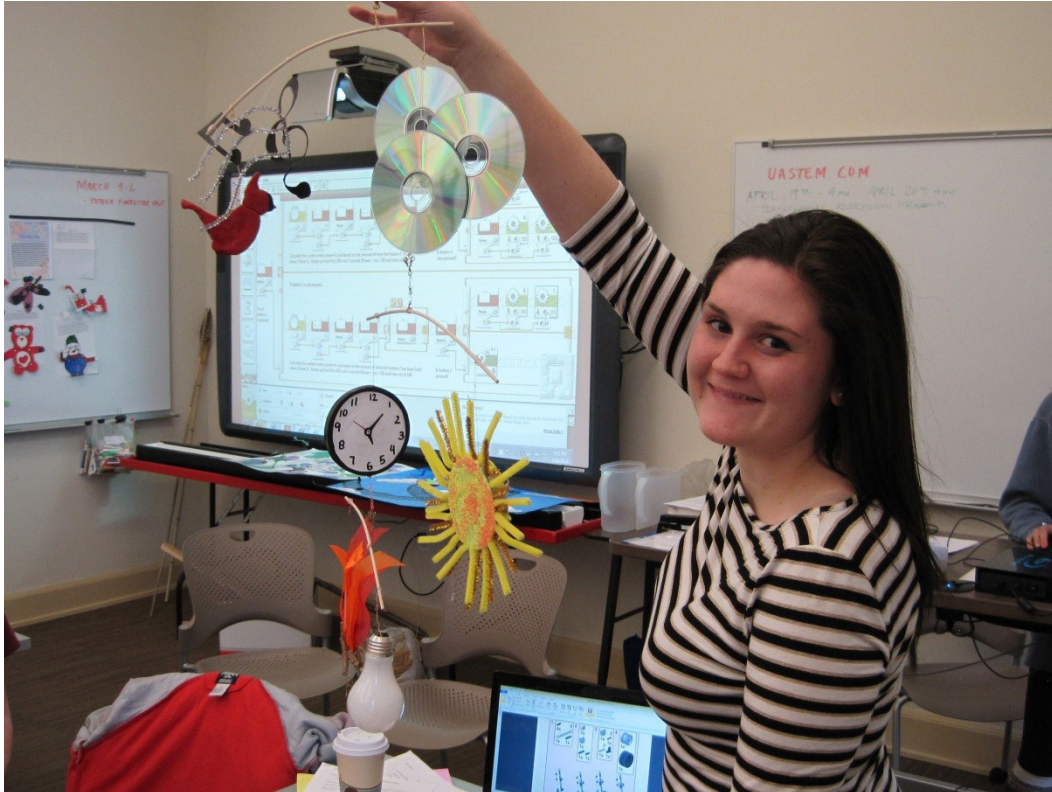


Figure 2. Balancing act. Preservice teachers create a mobile that displays the relationship between science (the natural world) and technology (the human-made world).

Application of a STEM-Based Informational Text Lesson

Most in the STEM community would agree that it is critical that young students have an early understanding of the differences between natural and human-made environments. Similarly, it is important for young students to understand that most engineers and technologists spend a great deal of time trying to create inventions, products, and systems that improve on the natural world. For example, Swiss inventor George de Mestral invented Velcro after examining the hooks on cockleburs attached to his dog upon returning from a nature hike. A basic STEM-based informational text lesson might examine the relationship between natural fibers and patterns made by spiders and the human-made products that might ensue.

Using an informational text such as *Are You a Spider?* by Tudor Humphries and Judy Allen (2003) or *Spiders* by Nic Bishop (2007)—depending upon the age of the students—as a springboard for learning could facilitate a rich STEM experience. The lesson might begin by reading the chosen text focusing on spiders and discussing the life and contributions of spiders. This could be followed by viewing videos of spiders making webs online (see <http://www.youtube.com/watch?v=r5aKhnWniWU&feature=related>). The students could also be asked to stand in a circle and toss a ball of yarn back and forth across the circle to form a human web. Finally, the students could be grouped into teams and asked to design a web using thread that would hold the greatest number of pennies. This STEM activity addresses standards related to geometry and measurement (CCSSM); scientific inquiry and technological design (NGSS); and engineering design, invention and innovation, and the design process (STL).

To complete this activity, a wooden or Styrofoam frame, pushpins, coins, and fine sewing thread will be needed. First, the teams are introduced to the concepts of strength, geometric shapes and their attributes (e.g., triangles, squares, circles), measurement, spacing, weights, the design loop (how engineers make decisions), and product assessment and testing. After the teams have completed research in which they examine natural spider webs using available informational texts, they will complete brainstorming sessions to determine the best way to improve the natural design to hold the greatest number of coins. (The math content of this STEM activity could be further augmented by asking the teams to build a web that would hold the greatest amount of money using coins of different denominations.) After decisions about the design have been made, teams will use the pushpins around the perimeter of the frame and then weave a human-made web by wrapping the thread around the pushpins. After the human web has been completed, the teams will assess the quality of their design, much like engineers would, placing coins on the web to the point of failure and then revisiting the design several times in an attempt to improve upon their design (refer to Figure 3). It is also important for the teams to describe the rationale for their team design. At this point, the teacher would determine whether the students included comments about the concepts introduced at the beginning of the activity, such as geometric shapes, measurement, and spacing.

Student performance in this STEM activity could be assessed by determining the degree to which the teams utilized the engineering design loop; determining whether the students applied knowledge of geometry, measurement, shapes, and spacing; and evaluating the improvements made to the final product based on the team testing with coins. Finally, teams could be assessed on their ability to describe the process used to create their human web during the team presentation.



Figure 3. Human-made web. After examining natural spider webs, preservice teachers determine the best way to improve the natural design.

This STEM-based informational text lesson will provide young students with a measure of understanding about the intricate relationship between the natural environment and the human-made world as well as a glimpse into the roles that engineers, scientists, technologists, and mathematicians play in the development of inventions and products that we all take for granted. The lesson will also provide young students with a great introduction to PBL using informational text as a springboard for learning, the engineering design process, and the role of the all four STEM disciplines in providing solutions to human problems.

Summary and Call to Action

STEM is increasingly important to our society, and efforts need to be undertaken to engage students in the study and application of these disciplines at an early age. Although STEM programs seem to abound at the secondary school level, few integrated STEM education programs exist at elementary schools across the nation, and relatively few practicing elementary teachers seem to be prepared to deliver comprehensive STEM programs. Meanwhile, alarming numbers of students seem to be opting out of STEM programs of study at the secondary and postsecondary levels, many making the decision to avoid STEM courses and programs of study as early as fourth or fifth grade.

To change the status quo, we must prepare a new generation of teachers who have the desire and skills to engage elementary students in the STEM disciplines early and keep them engaged throughout elementary, secondary, and postsecondary education. This will require attention to standards in all four disciplines, the ability to utilize current curriculum standards to access and communicate information, an enthusiasm for finding and exploiting the connections between disciplines, an inclination to utilize differing teaching methods, a commitment to teacher professional development, and a willingness to develop and teach content that may be inching toward uncharted territory.

By providing elementary students with engaging, positive, and successful experiences with the STEM disciplines, we can create an environment in which children yearn for more information, search for solutions to human problems, regularly cross disciplinary boundaries, willingly conduct research seeking answers, and continue learning well beyond the classroom. Delivering integrated STEM education in the elementary classroom is another step toward creating a more involved and more intellectually curious society as well as an insurance policy for the future of our nation. This process begins by preparing elementary teachers who are capable, comfortable, and enthusiastic about implementing integrated STEM education in the elementary classroom.

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Authors

Michael K. Daugherty, University of Arkansas, Professor of Technology and Engineering Education and Head of the Department of Curriculum and Instruction; mkd03@uark.edu

Heather D. Kindall, University of Arkansas, Assistant Professor of Childhood Education and Program Coordinator of the Childhood and Elementary Education Program; hkindall@uark.edu

Vinson Carter, University of Arkansas, Assistant Professor of STEM Education; vcarter@uark.edu

Lindsey M. Swagerty, University of Arkansas, Director of the Education Renewal Zone; lmswager@uark.edu

Cathy Wissehr, University of Arkansas, Clinical Associate Professor of Science Education; cwissehr@uark.edu

Sarah Robertson, Lovejoy Independent School District, Puster Elementary School Teacher; sarah_robertson@lovejoyisd.net