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Can STEM Save the World?

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Theory To Practice

Can STEM Save the World?

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Abstract

The article's title asks, "Can Science, Technology, Engineering, and Mathematics (STEM) save the world?" The answer is not straightforward. The challenges to saving the world are too complex, and some extend beyond STEM disciplines to include other fields (e.g., economics, politics, and cultures). Opportunities for immediate progress become more apparent when considering the question, 'Should STEM contribute to an understanding of global challenges?' The answer is undoubtedly "yes." This theory-to-practice paper explores foundations for quality STEM education in problem-solving by considering a global issue.

Keywords

STEM, science education, global issues, problem-solving

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Exploring Connections Between a Contemporary Situation and STEM

In July 2023, while preparing this article, approximately 170 million Americans and citizens in many other countries experienced the hottest month in recorded history. Severe weather captured headlines across the U.S., highlighting the unprecedented intensity of the heat wave. For instance, "July has been so blistering hot, that scientists already calculate it's the warmest month on record" (Borenstein, 2023). In Phoenix, Arizona, residents endured over 30 consecutive days of record-setting high temperatures above 110°F, while those in the Midwest sweltered through a heat wave that filled emergency rooms and led to severe water shortages (Bushard, 2023). Meanwhile, Florida's ocean temperatures were labeled a "hot tub," reaching between 90°F and 100°F, putting marine ecosystems in unprecedented conditions (The Guardian, 2023). Reflecting the gravity of the situation, President Joe Biden declared, "We are in the midst of a climate crisis," stressing the urgent need for resolute policies to address this existential threat (Biden, 2023).

At some point, the reports, commentaries, and recommendations made connections to science, technology, engineering, and mathematics. Individuals provided explanations for phenomena such as heat domes and sustained extreme temperatures. They also suggested means of adapting such as staying indoors and using air conditioners. They asked about possible solutions, problems, and alerts with regional power grids. Reporters asked about the probability of severe weather in the future and the quantification of causes and consequences of various phenomena.

There were predictable questions about climate change. Is the extreme heat a result of global warming? How can global warming affect severe weather? STEM professionals answered questions such as these by clarifying the difference between weather and climate and explaining the negative consequences of increased atmospheric energy. These factors contribute to the probability of weather with more intensity, longer duration, and greater frequency.

While the extreme heat of July 2023 presented STEM connections to natural and human events, other examples such as wildfires, droughts, hurricanes, and emerging and reemerging diseases are plentiful. The connections noted in prior paragraphs clarified a need to establish a foundation for STEM. This exploration implies the need for a brief explanation of STEM disciplines.

Explanations of STEM Disciplines

Classroom teachers and others responsible for curriculum, instruction, assessment, and professional learning may need introductory ideas about STEM disciplines. Here are brief descriptions that will initiate a process that establishes and subsequently increases one's knowledge of STEM (adapted from Bybee, 2020).

Science is a means of explaining both the natural and human worlds. It starts with questions and advances through the collection of evidence, using that evidence to propose answers. Scientific explanations can extend beyond simple answers to include the development of models, identification of laws, and construction of theories—all grounded in empirical evidence.

Technology, on the other hand, is a way of adapting to the world. It stems from human wants and needs, encompassing innovations in areas such as information, communication, and transportation, along with related artifacts. These innovations must be designed within the boundaries of natural and human constraints.

Engineering represents both a body of knowledge and a process for solving problems. It is closely tied to technology and is often described as “design under constraint,” where the constraints can include natural laws, time, financial resources, and the quality of proposed solutions.

Mathematics involves the study of patterns and relationships among quantities, numbers, and space. These relationships may exist purely among abstractions, without any direct real-world connections, but mathematics can also address experiences, phenomena, and real-world applications. Its usefulness extends across a broad range of disciplines.

The exploration referred to the STEM disciplines in questions that referred to “explanations for phenomena,” “means of adapting,” “possible solutions,” and “probability of severe weather in the future.” Further connections are in the paragraph on climate change.

Exploring STEM Education and Climate Change

To truly deepen learning, STEM instruction should be punctuated with the connections between students, citizens, and global issues and combined in classroom experiences that highlight the transdisciplinary nature of the disciplines that comprise STEM (Science, Technology, Engineering, and Mathematics) (Bybee, 2020). While the STEM acronym is a common phrase, understanding the interconnectedness of the disciplines often eludes many educators. The combined effects of STEM disciplines lead to a deeper understanding of a global issue like severe weather highlighted in National Standards (National Research Council [NRC] 2012; NGSS Lead States, 2013).

All students should understand that human activities, particularly the release of greenhouse gases from burning fossil fuels, are major contributors to the current rise in the Earth's surface temperature (NGSS Lead States, 2013). In terms of technology, it is essential for students to grasp how diverse tools, such as enhanced radars and satellites, are used for practical purposes like collecting data, measuring temperature changes, and forecasting weather. These technologies have advanced significantly in recent decades (ISTE, 2000). From an engineering perspective, classrooms can explore common problems related to reducing our reliance on fossil fuels by developing alternative energy sources and addressing the influence of current infrastructures, such as the urban heat island effect, which exacerbates severe conditions (NGSS Lead States, 2013). Finally, mathematics plays a critical role in analyzing complex patterns and using data triangulation to create models that explain long-term trends and predict the impact of severe weather and climate changes in both the immediate and distant future (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010).

The four STEM disciplines emphasize critical thinking, problem-solving, and innovations needed so students can make informed decisions about complex and multifaceted global issues like severe weather. These examples are among the many that educators can choose from based on appropriate grade-span standards. If STEM is described in terms of how interconnections between disciplines lead to deeper understanding, then there are implications for making STEM instruction accessible to all learners.

Helping Students Make Sense of STEM

These four disciplines and key instructional elements can serve as fundamental drivers to enhance students' understanding of global issues. Schmoker's (2019) 'indispensable competencies' focus on the essential elements that improve STEM instruction.

Clear, Coherent STEM Units of Instruction

Instead of beginning with traditional lessons and favorite activities, using Understanding by Design (UbD) procedures helps educational leaders identify STEM unit learning outcomes in terms of what would count as acceptable evidence and how students would have experiences to allow them to make more accurate scientific claims. UbD emphasizes that units should focus on transfer goals that specify what students should do with their learning in the long run (Wiggins & McTighe, 2005). Using UbD, we can create more coherent instructional units for what to teach and prioritize planning on what matters most for students to know and be able to do.

Identifying the evidence-based claims desired of students in planning helps focus teaching on developing conceptual understanding and transfer of learning through purposeful investigation and aligns with the goals of the *Frameworks for K-12 Science Education* (McTighe & Silver, 2020; NRC, 2012). The power of starting with evidence-based claims is a way to seamlessly teach in Standards-minded ways because students can only arrive at an evidence-based claim using the unique combination of disciplinary core ideas, science and engineering practices, and crosscutting concepts (NGSS Lead States, 2013). In addition, focusing on evidence-based claims ensures students are developing the meaning of underlying concepts using practices and logical thinking—A significant goal if we want students to use STEM to analyze and explain global issues. Using the Standards can help focus the content on what is most essential for STEM understanding for different grade spans. All other planning considerations emerge when we begin with the end learning goals in mind.

Sound STEM Instruction

Belinger (1992) suggested that effective instructional design should focus on "big variables," research-based elements that create powerful classroom experiences and engage students in active meaning-making. High-leverage instructional practices help maximize valuable class time, making them essential for every STEM teacher to incorporate into learner-centered instructional design. One approach is to target regional or global phenomena related to citizens' lives, making learning more relevant to students. This can be achieved through global or regional concerns, problems, or projects (Krajcik & Czerniak, 2018), place-based scenarios (Gruenewald, 2003), or socioscientific issues (Zeidler & Kahn, 2014) that are appropriate for the students' grade level. Additionally, effective instruction begins by eliciting students' ideas, experiences, and reasoning. Teachers activate learning by identifying and leveraging these incoming ideas, capturing the brain's attention, and creating a need-to-know environment (McTighe & Willis, 2019). When students encounter limits in their current understanding during explorations, teacher explanations and elaborations help establish the next steps for learning (Bybee, 2013). It is also crucial to provide ongoing opportunities for students to reflect on their learning and how far they have come, a process known as “metacognition” (Bransford, Brown, & Cocking, 2000; Hattie, 2009). Interdisciplinary connections between STEM and other subjects should be explicit, as students' evidence-based claims can serve as assessment evidence. Informative and argumentative writing aligns with the Common Core State Standards (CCSS) in English Language Arts (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Many global issues intersect with social studies topics, making these connections crucial and highly relevant (National Council for the Social Studies, 2010).

Authentic STEM Literacy

The broad purposes of STEM education center on specific goals. National efforts to advance STEM education focus on three primary aims: achieving higher levels of STEM literacy for all citizens, developing a deep technical workforce that meets 21st-century needs, and cultivating an advanced research and development workforce that includes diverse individuals across professions.

STEM literacy involves conceptual understandings, procedural skills, and abilities that empower individuals to address personal, social, and global STEM-related issues. It encompasses foundational concepts and processes across STEM disciplines and aligns with relevant state standards. Education aimed at fostering STEM literacy supports several goals: acquiring scientific, technological, engineering, and mathematical knowledge to identify issues, acquire new knowledge, and apply this understanding to STEM-related challenges; understanding STEM disciplines as human endeavors involving inquiry, design, and analysis; recognizing the contributions of STEM disciplines to material, intellectual, and cultural developments; and engaging with STEM-related personal and social issues as concerned and effective citizens (Adapted from Bybee, 2020).

The concept of “authentic” in Schmoker’s 2018 recommendations emphasized the basics of reading, writing, and discussion, underlining their essential role in literacy. However, a broader meaning of authentic should include life situations directly related to STEM, such as public health, resources, environments, and hazards, as well as processes that encourage students to make sense of these situations. This expanded approach emphasizes a model of claim-evidence-reasoning in discussions, reports, and presentations (Brown et al., 2023).

Designing an Introductory STEM Unit

Educators can design effective STEM instruction using the competencies described above and their support from educational research. The 5E instructional model—Engage, Explore, Explain, Elaborate, and Evaluate—provides a valuable framework for sequencing STEM learning (Bybee, 2020). Research strongly supports the 5E model, emphasizing that this sequence fosters long-lasting student understanding, which must be actively earned by the learner (Bybee et al., 2006). Furthermore, a wealth of high-quality instructional materials illustrates classroom and curricular examples of the 5E model, all aligned with research in cognitive and neurosciences (Brown, 2021; 2019; 2018).

To effectively implement the 5E instructional model and integrate the identified competencies, it is essential to begin by engaging students with a global issue that aligns with grade-level standards. By targeting a global problem, teachers establish relevance and can elicit students' ideas and experiences related to the phenomenon, using their backgrounds as assets for future learning. Next, exploration should occur through the lens of the STEM disciplines, with students collecting data or analyzing existing information. The data gathered serves as evidence for claims about phenomena, explicitly connecting to the STEM disciplines through exploration. During the explanation phase, students should construct evidence-based claims integrating the STEM disciplines. Teachers then enhance understanding by introducing academic vocabulary identified in standards that cannot be easily accessed through hands-on or mind-on explorations.

The elaboration phase deepens students' engagement with the global issue, allowing them to explore more nuanced details and gain additional data-based experiences. When applicable, this phase includes further exploration to test the utility of newly acquired ideas in varied contexts. Finally, the evaluation phase offers students a chance to reflect on their developing understanding of how the STEM disciplines have reshaped their comprehension of the global issue. It also allows teachers to assess students' abilities, use evidence to support their STEM claims, and demonstrate learning.

Conclusions

In the introduction, we ask, "Should STEM contribute to an understanding of global challenges?" This paper underscores the essential role of STEM education in addressing these issues and the importance of thoughtfully designed instructional sequences to make complex global challenges accessible to all students. By integrating these essential elements, we empower students to see STEM as a democratizing force that equips them to understand the world's pressing challenges and actively participate in shaping solutions. In doing so, students gain the knowledge and skills to make informed, impactful decisions that affect their lives and our shared future.

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