IDENTIFYING & OVERCOMING OBSTACLES IN INTEGRATED STEM EDUCATION THROUGH RESEARCH AND PRACTICE

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CURRENT CHALLENGES IN INTEGRATED STEM EDUCATION

1. Multiple Definitions

Researchers, educators, and school systems have different conceptualizations of STEM. There is a need to establish consensus on characteristics of STEM.
DEFINING STEM EDUCATION

“the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning”

(Kelley & Knowles, 2016, p. 3)
Rationale for the Inclusion of Engineering

1. Engineering provides a *real-world context* for learning mathematics and science;
2. Engineering design tasks provide a context for developing *problem-solving skills*; and
3. Engineering design tasks are complex, and as such, promote the development of *21st century skills*. 
DEFINING STEM EDUCATION

"the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning”

(Kelley & Knowles, 2016, p. 3)
MOVING FROM DEFINITIONS TO IMPLEMENTATION

Need integrated STEM frameworks to guide curriculum development and implementation

Frameworks for integrated STEM are necessary to support researchers and educators to develop curriculum and engaging learning opportunities for students.
INTEGRATED STEM FRAMEWORK

- Real-World Problem
- Engineering Design Challenge
- Context Integration
- Content Integration
- STEM Practices
- 21st Century Skills
- STEM Careers
Real-World Problem
Engineering Design Challenge
Context Integration
Content Integration
STEM Practices
21st Century Skills
STEM Careers

Only 12% of engineers are women
87% of the STEM workforce is white

4.01 million
Elementary
Middle
High
278,000
College
1.3 million
167,000

Only 12% of engineers are women
87% of the STEM workforce is white
The task should require learning and/or application of STEM content
• Evidence-based reasoning
• The real-world problem should be complex with multiple possible solutions
• Students should have agency in making design decisions
Sample Curriculum Unit: Laser Security

DEFINE THE PROBLEM
WHO needs WHAT because WHY?

- Who is the client?
- What does the client needs?
- What are the criteria and constraints?

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**Dear Engineers,**

My company, Galactic Games, has a problem. We design and build arcade games and one of longest and best games is the claw game, Diggin' for Fools' Gold. For some reason, people are losing interest in the game and aren't playing it as much. I've attached a news article about claw games, which explains a little about why. We need to figure out how to get people interested in our game again. Can you help us?

Sincerely,

Orion Nova
President, Galactic Games
LEARN ABOUT THE PROBLEM

- What kind of background knowledge is needed?
- What materials will be needed?
- What has already been done to solve the problem?
Sample Curriculum Unit: Laser Security

PLAN A SOLUTION

- What are possible design solutions?
- How do these designs meet the criteria and constraints?
Sample Curriculum Unit: Laser Security

TRY A SOLUTION
• Use constraints, criteria, and trade-offs from plan to build a prototype, model, or product

TEST A SOLUTION
• Collect and analyze data to determine the usability of a design solution
Sample Curriculum Unit: Laser Security

**DECIDE ON A SOLUTION**

- Are users able to use the design to help with the problem?
- Does the design meet with the criteria and constraints
Although guiding frameworks are helpful, individuals still conceptualize STEM education in different ways. There is a need to establish a common vision among stakeholders who work together.

Little is known about integrated STEM beyond the context of science classrooms. There is a need to expand into other classroom contexts.

K-12 teachers are still in need of professional development to support shifts towards integrated STEM. Curriculum materials need to be developed.
Until recently, no observation protocols were available to help educators and researchers understand what integrated STEM “looks like” in practice.
THE STEM OBSERVATION PROTOCOL (STEM-OP)  
A first attempt to develop a tool to measure and improve STEM education

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<tr>
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- 10 observable items
- Brief item descriptions
- 4-point Likert scale (0-3) with detailed descriptions of each level
- A set of user guidelines, which will be shared as part of an online training platform
### Contextualizing Student Learning

*Learning is contextualized within an appropriate (e.g., age, gender, race, etc.) real-world problem or design challenge that connects to the content of the lesson. Connections between students’ learning and the context are explicit so that students understand the importance of their learning.*

<table>
<thead>
<tr>
<th>0.</th>
<th>The teacher does not contextualize the lesson within a real-world problem or design challenge.</th>
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<tbody>
<tr>
<td>1.</td>
<td>The teacher contextualizes the lesson by alluding to a real-world problem or design challenge, but does not connect to what the students are learning.</td>
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<td>The teacher contextualizes the lesson by briefly connecting a real-world problem or design challenge with what the students are learning.</td>
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<td>The teacher contextualizes the lesson by emphasizing the connections between the real-world problem or design challenge and what students are learning and helps them make explicit connections between the content and the context.</td>
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DESCRIPTION OF DATA SET

- Used STEM-OP to score 2030 video-recorded observations collected from a prior project
- Teachers participated in intensive professional development
  - Integrated STEM was framed using a design-based framework (Moore et al., 2014a; Moore et al., 2014b)
- Teachers developed integrated STEM curriculum
- Implemented curriculum in classrooms

Science Content
- 999 Physical Science
- 434 Earth Science
- 597 Life Science

Grade Level
- 885 Elementary (K-5)
- 1071 Middle School (6-8)
- 74 High School (9-12)
WHAT WE’VE LEARNED ABOUT THE CURRENT STATE OF INTEGRATED STEM

Low overall means of all items with biggest concerns around Items 1, 9, and 10. These items are also underrepresented in observations (> 60% are scored as 0). Items 3 and 8 (engineering heavy) show similar, but less extreme patterns.

Research Question: To what extent is integrated STEM education being implemented in K-12 science classrooms?

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**Research Question:** What differences, if any, exist between scores across different science domains?

Items 1, 2*, 3, 4, 5, 6, 8, and 9 are more present in physical science observations compared to earth* and life science. These items (except Item 8) are more present in earth science compared to life science.

Items 1, 2, 3, 4, 5, 6, and 9 scored at higher levels in physical science observations compared to life science. Some additional differences exist between physical and earth science (5, 6, and 9) and between earth and life science (2 and 6).

**Of Note:** Items 4, 7, and 10 do not vary by science domain

**Lingering Question:** How do we improve STEM integration within life science in particular?
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**Research Question**: What differences, if any, exist between scores across grade levels?

- Items 2, 3, 6*, 7, 8, and 10 are more present in elementary observations compared to middle and high school* observations. No differences in Items 1, 4, 5, and 9.
- Items 2, 7, and 10 drop in presence as grade band increases.
- Item 2 mean scores drop as grade-level increases.
- Items 2, 3, 4, 6, 7, and 10 scored at higher levels in elementary observations compared to middle school. Some additional differences exist between elementary and high school (2 and 10) and between middle and high school (2). No differences in Items 1, 5, 8, and 9.

**Lingering Questions**: Are elementary teachers more intentional and explicit in their guidance related to context, student collaboration, and STEM career interest? Why does context in particular decrease in presence and “rigor” as grade level increases?
WHAT WE’VE LEARNED ABOUT THE CURRENT STATE OF INTEGRATED STEM

Research Questions: How do integrated STEM lessons that include mathematics perform on an integrated STEM observational protocol compared to lessons without mathematics? What levels of mathematical cognitive demand are represented in physical, earth, and life science integrated STEM units?

Mathematics is only present in 31% of observed lessons in our data set. When it is present, the overall scores are statistically significantly higher for Items 3 – 9. Item 2 showed no differences, and Item 1 was higher in non-maths observations.

A deeper analysis revealed that when mathematics is present, it is primarily addressing lower cognitive levels.

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LINGERING QUESTIONS

What does all of this mean for the following...

- Practice and Classroom Implementation
- Impact on Students
- Curriculum Development
- Teacher Education and Professional Learning
- Assessment
- Research
OTHER RESOURCES


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