Leveraging Design Thinking Practices in Integrated STEM Environments with Implications for Assessment Opportunities

• Paul A. Asunda, Ph.D.
  • Assistant Professor

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AGENDA

• Background
• Integrated STEM defined
• Design Thinking Defined in Context of presentation
• Standards/learning outcomes and STEM Learning
• Designing purposeful assessment
• Pedagogical continuum to support student learning goals
• Closure
Integrated STEM defined

• In this presentation, i-STEM has been defined as:

• an approach to teaching and learning in a manner such that the curriculum and content of the four individual STEM disciplines seamlessly merge into real-world experiences contextually consistent with authentic problems and applications in STEM careers

• Such integration may refer to making meaningful connections between core disciplinary practices of each STEM domain being integrated, with the goal of using this integrated knowledge to solve real-world problems (Mobley, 2015; STEM Taskforce Report, 2014)
Design Thinking defined

- Design Thinking is a methodology used by designers to solve complex problems, and find desirable solutions for clients.
- A design mindset is not problem-focused, it’s solution focused and action oriented towards creating resolutions.
- Design Thinking draws upon logic, imagination, intuition, and systemic reasoning, to explore possibilities of what could be—and to create desired outcomes that meet user needs.
- See Framework for Design thinking

https://www.creativityatwork.com/design-thinking-strategy-for-innovation/
Role of STEM Related Programs

• Most employers want workers who are able to reason and solve problems using some math, science, or technology knowledge.

• Many postsecondary programs aim to increase the diversity of the STEM workforce or prepare students to be innovative.

• Most STEM programs reported having some outcome measures in place,
  • but GAO found that some programs did not measure an outcome directly related to their stated objectives.
STEM Related Skills

• Science skills to break down a complex scientific system into smaller parts, recognize cause and effect relationships, and defend opinions using facts

• Mathematic skills for calculations and measurements

• Attention to detail to follow a standard blueprint, record data accurately, or write instructions

• Technical skills to troubleshoot the source of a problem, repair a machine or debug an operating system, and computer capabilities to stay current on appropriate software and equipment.

• In summation these skills are: Analytical skills to research a topic, develop and design a project plan and timeline that leads to viable solutions, identify a probable solution, prototype the said solution, test and draw conclusions from research results.

• How does Design thinking inform /integrate into STEM related programs?
Context of Presentation

• Assessment serves as a communicative device between the world of education and that of the wider workforce

• A 2014 report from the Government Accountability Office (GAO) that examined **STEM Education and it’s the Relationship between Education and the Workforce and impact of STEM initiatives at the post secondary level revealed**

• Most programs objective is to prepare students for STEM careers
• To assess such skills calls for assessment strategies that may range from the most informal of exchanges to the extremely formal,
  • Can span everything from school reports to high-stakes public examinations, and from individual job interviews to national monitoring,
  • the common factor being the use of assessment data of one kind or another as a publicly acceptable code for quality.

• Assessment has to move from ‘assessment of learning’ to ‘assessment for learning’, whereby assessment procedures and practices are developed to support learning and underpin rather than undermine student confidence, achievement and progress (Black & Wiliam, 1998; Torrance & Pryor, 1998; Gipps, 1999; Shepard, 2000)

• In this presentation assessment will be defined as
• Ongoing process of establishing clear measurable outcomes of student learning while providing students sufficient opportunities to achieve those outcomes.

• This process offers systematic gathering of data, analysis as well as interpretation of resulting information to determine how well student learning matches our expectations as a consequence understand and improve instruction delivery to enhance student learning.
Reflection Questions

• What is the difference between assessment and grading?

• What is the difference between assessment and teaching to the test?

• What is the difference between assessment and evaluation?

• What is the difference between assessment and research?

• What is the difference between assessment and program review?

• What is the difference between assessing student learning and assessing institutional effectiveness?

• What is the difference between assessment and accountability
1. Think of an assignment in a course you have taught or taken.
   • Did the assignment help students learn important goals of the course
   • Might the completed assignment be evidence of student achievement of a
     program or college learning goal? Which goal?

2. Are the academic programs at your college required to undergo any
   periodic program review?
   • What are the guidelines for those reviews
   • Is evidence of student learning part of the review?
The Standards, Backward Design, Developing and Assessing Integrated STEM problems

• In today’s learning environments, outcomes that teachers anticipate from their students and instruction are tied to educational standards.

• Proponents of standard-based educational reforms claim that standards offer teachers a congruent process in designing their instructional practice.

• Many instructional design models suggest identifying intended learning outcomes that mirror objectives of a course and determining the types of learning activities that represent these objectives.

• One of these is models is backward design process, a three-stage process that teachers can use to develop integrated STEM course
• More specifically, to start this process, teachers begin by asking themselves:
  • What is worthy and requiring of understanding?

• To answer this question, one must consider local, state, and national standards.

• If the answer from this first question is not based on the standards, it is probably not worthy of teaching and learning (Reeve, 2002; Wiggins & McTighe, 2005).
STEM and THE CURRICULUM

• As STEM initiatives become the driving force of educational change through P-20, all instructors would say that they want their students to master higher-level thinking skills as reflected by the revised blooms taxonomy

• The T and E in STEM – Technology and Engineering Education as vehicle for INTEGRATION through Design thinking and problem solving
Instructional Practices that May Reflect Integrated STEM in the Curriculum

Consider the content of units in Sciences, Mathematics and Engineering/technology education. Due to the overlap of concepts identified these units may be considered for integration through PBL.

The content and assessment types identified in the area shared by all three units needs to be clearly specified.

• Eng/Tech eD
• Mathematics
• sciences
units from the Sciences and Engineering/technology Education have been integrated.

A unit from Mathematics is integrated with a unit from Engineering/technology Education

- Eng/Tech eD
- Math
- sciences
Design Thinking thru Engineering Design as a vehicle

• Blumrich (1970) stated that design was an activity that establishes and defines solutions to and pertinent structures for problems not solved before, or new solutions to problems which have previously been solved in a different way (Clark and Ernest, 2010)

• NRC (2012) posited that from a teaching and learning point of view, it is the iterative cycle of design that offers the greatest potential for applying science knowledge in the classroom and engaging in engineering practices
Role of Engineering Design in Engineering and Technology Education thru Integrated STEM

• The Standards for Technological Literacy (ITEA, 2000/2002) Standards 8, 9, 10, and 11 highlight design concepts to be introduced throughout the K-12 curriculum

• The design process described in Standard 8 for students in Grades 9-12 is very similar to the introductory engineering design process described in freshman engineering design textbooks, specifically the book by Eide, et al. (1997). Hailey, Ereksen, Becker and Thomas, (2005)
Classical Engineering Design process
(from introductory engineering text by Eide, et al.)

- Identify the need
- Define problem
- Search for information
- Identify constraints
- Specify evaluation criteria
- Generate alternative solutions

- Engineering Analysis
  - Optimization
  - Decision

- Design specifications
  (So it can be made)

Communications

"Grades 9-12 Design Process"
(from Standards for Technological Literacy)

- Defining a problem
- Brainstorming
- Researching and generating ideas
- Identifying criteria and specifying constraints
- Exploring possibilities

- Selecting an approach and developing a design making a model of prototype

- Testing and evaluating the design specifications
- Refining the design

Communicating process and results

- Creating or making it
Using Blooms Taxonomy to Develop an Integrated STEM lesson through Engineering Design, What Might This Look?

• Data can only be collected on observable behaviors

• ABET student outcomes do not define observable behaviors, therefore, learning objectives should be formulated for each outcome describing the desired observable student performance

• Such may imply that an engineering technology education teacher seeking to integrate STEM concepts into their curriculum may redesign traditional technology education problem based activities into a STEM integrated project that depicts a stated standard performance and desired outcome
Example: Air Blaster Car

• Focus of the design of this car revolves around four main areas
  • principles of aerodynamics involved with air blaster car construction,
  • design of vehicle
  • construction of vehicle
  • and racing of vehicle

• This can be illustrated by figure 2 where scientific concepts that explain the principles of aerodynamics, and the mathematic principles behind racing the car are integrated with engineering technology principles behind design and construction of the vehicle
Airblaster... con’t

• The next step will be to develop objectives, learning activities and materials, and evaluation criteria for each of the four areas

• This is the point at which the congruence principle becomes particularly important

• Maintaining the congruence among the objectives, learning activities, and evaluation criteria is critical to the effectiveness of the instruction

• Congruent instruction means that learning activities are designed to support the objectives and that the evaluation methods are designed to assess important learning outcomes represented by the objectives
<table>
<thead>
<tr>
<th>STL/NGSS Standards</th>
<th>Objectives</th>
<th>Levels in RBT</th>
<th>Knowledge dimension in RBT</th>
</tr>
</thead>
<tbody>
<tr>
<td>STL8-10-MS</td>
<td>Research pertinent information on underlying principles of aerodynamics with air blaster car construction</td>
<td>Remember, and Understand</td>
<td>Factual</td>
</tr>
<tr>
<td>NGSS-MS-PS3-1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STL9, 16-MS, MS-PS3-3., MS-PS3-4.</td>
<td>Recognize principles of Newton’s Third Law of Motion and how it relates to air blaster car competition</td>
<td>Understand and Apply</td>
<td>Conceptual</td>
</tr>
<tr>
<td>STL9, 16-MS, MS-PS3-2.</td>
<td>Explain how mass, friction, and design of air blast car relate to its movement</td>
<td>Understand and Apply</td>
<td>Procedural</td>
</tr>
<tr>
<td>STL9-11-MS, MS-PS3-4., MS-PS3-5.</td>
<td>Utilize the process of engineering design to design and develop a drawing design which shows understanding of air blaster concepts and construct a prototype car, present the model to peers</td>
<td>Apply, analyze, create and evaluate</td>
<td>Meta-cognitive</td>
</tr>
</tbody>
</table>
Developing Learning Activities for the Remember and Understand Level (Factual) Dimension

• conduct research into underlying principles of winning car designs,
  • finding information about the basics of aerodynamics as it relates to cars
  • the underlying principles into construction of these cars

• Ask students to demonstrate their knowledge and comprehension of factual knowledge by producing at least three different designs based on fact finding mission

• Teacher should give students opportunities where they can connect the factual to conceptual knowledge as they progress through the activity
Students’ Sketches Depicting Factual and Conceptual Levels of Bloom’s Taxonomy
Learning Activities for the Application and Analysis Levels (Procedural) Dimension

• Teacher design classroom experiences that give students an opportunity to explore and explain how force, mass, friction, and design parameters relate to an air blaster car
  • students may be asked questions like:
    • why is it important to be aware of how force and mass affect acceleration?
    • what other factors may play a role, and why? And how?

• Then students will be expected to eventually apply these principles to the design of a car
Students’ Prototypes Depicting Conceptual and Procedural Levels of Bloom’s taxonomy
Learning activities for the Apply, Analyze, Create and Evaluate Levels (Meta-cognitive) Dimension

• Students can be asked to create a prototype from their preconceived designs and feedback sessions with an overarching question;
  • how do engineering technologists apply what we have done in class in real life practice?

• This process helps students understand the relationship between mass and acceleration as they consider what materials to use for constructing the prototype vehicle

• The students will conduct their own research and analyze the information to select the best design for their own vehicle
Students’ depicting procedural and meta-cognitive levels of Bloom’s taxonomy
<table>
<thead>
<tr>
<th>STL/NGSS Standards</th>
<th>RBT Dimension</th>
<th>Activity corresponding to Original bloom cognitive processes</th>
<th>Suggested Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>STL8-10-MS</td>
<td>Factual</td>
<td>Students to submit portfolio of sketches that document initial research of challenge, criteria and constraints they experienced used to design air blaster car, Car Design Sketches.</td>
<td>Complete submitted portfolios with at least 2 sketches detailing, the challenge, criteria and constraints in the context of performance improvement</td>
</tr>
<tr>
<td>NGSS-MS-PS3-1.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
| STL9, 16-MS,       | Conceptual      | Speed and weight of car: students to record weight of their cars in grams, race car three times on a race track and calculate the speeds of their cars by utilizing the formula Speed = Distance / Time.  
Compare the data from their findings to those of their peers, and be able to explain how the weight (mass) of their car impacted the rate of the speed it travelled. | Application of the Formula speed = distance/time upon students recording of weight of the car and tie to race on a specified length track.  
Students provide an explanation of how the mass of their car impacted the speed compared to at least 2 peers.  
Application of the process of engineering design and STEM concepts to design and manufacture air blaster car |
| MS-PS3-3., MS-PS3-4.|                 |                                                                                                 |                                                                                        |
| STL9-11-MS         | Procedural      | Manufacture (cut, shape, sand, paint, and detail) car as per chosen design utilizing provided materials and tools. Weigh car and race car on track 3 times and record the speed | Justification of their selection of given design, and how these design modeled the design process and STEM concepts compared to the design of 2 peers. A description of how they can improve their design or their peers utilizing the engineering design process. |
| MS-PS3-2.          |                 |                                                                                                 |                                                                                        |
| STL9-11-MS         | Meta-Cognitive  | Project reflection, students to write about their overall experience with project. For example, how their compared to peers, and what would they change about their car to make it better, faster. More aerodynamic? Smaller wheels? Shorter race track? |                                                                                        |
A Continuum Of Practice

Some of the instructional strategies that one may use to teach integrated STEM that may support Design thinking practices:

- Lecture
- Demonstration
- Questioning
- Discussion
- Guided Practice
- Independent Practice
- Grouping
- Role Playing
- Simulation
- Reflective

Inquiry / Thinking
Conclusion

• As instructors incorporate a backward design process and leverage design thinking thru engineering design practices to teach STEM concepts, Bloom's taxonomy can be a helpful guide in achieving congruence in integrating cross cutting concepts and how a particular integrated STEM experience may capture and enhance concepts and experiences that can be applied to solve complex challenges that may lead to a particular outcome and how these outcome may be evaluated.
• Paul A. Asunda Ph.D
• Assistant Professor
• Department of Technology Leadership and Innovation
• pasunda@purdue.edu