Inspiring Future Mass Properties Engineers: NASA’s *Orion* Ascent Abort-2 and the Office of STEM Engagement

SAWE Paper 3713

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Introduction

Goal

To strengthen your understanding of how NASA’s Office of STEM Engagement (OSTEM) works to enhance STEM literacy in students, inspiring them to explore and pursue technical careers

Objectives

• Describe research about educator professional development, student engagement and workforce connections
• Demonstrate evidence-based (best) practices for inspiring students about mass properties engineering

Image Credit: NASA Commercial Crew Program 2018 Children’s Artwork Calendar
Vision: We immerse the public in NASA’s work, enhance STEM literacy, and inspire the next generation to explore.

Mission: We engage the nation in NASA’s mission

Create unique opportunities for students and the public to contribute to NASA’s work in exploration and discovery.

Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA’s people, content and facilities.

Strengthen public understanding by enabling powerful connections to NASA’s mission and work.

Graphic Credit: NASA Office of STEM Engagement
Reimagining Learning

Video Credit: TEDx Program, TEDx Ideas worth spreading
Technology is constantly changing K-12 and postsecondary education, including professional development:

- Z-degrees and open educational resources (OERs) [1]
- Digital badges [2,3]
- Flipped classrooms [4,5]
- Virtual reality (VR) field trips [6,7]
Engaging Students Requires a Flipped Approach

- Novel ways to teach and learn
- Meets students where they are
- Requires application of classroom concepts
- Highly engaging and inclusive of 21st century “soft” skills
- Exposure to real-world workforce connections
- Effective integration of technology

Image Credits: NASA Flickr
Digital Badges provide ongoing, individualized instruction that fits budget, geographic and time constraints. [11,12,13]
NASA’s badging system allows individuals to select from an ever-growing pool of exciting learning opportunities, to demonstrate mastery of various STEM topics, and to earn a badge for their personal accomplishments.

Graphic Credit: NASA STEM EPDC/Texas State University
U.S. Students’ STEM Competency

2015 Trends in International Mathematics & Science Study (TIMSS) – 4th- & 8th-graders [8]
2015 Program for International Student Assessment (PISA) – 10th-graders [9]
  • 25th out of 70 countries → science literacy
  • 38th out of 70 countries → mathematics literacy

2015 National Science Board Science & Engineering (S&E) Indicators – undergraduates [10]
  • 1,915,608 baccalaureate degrees awarded → 649,922 in S&E (33.9%)
  • 832,862 Master’s & doctorate degrees awarded → 220,083 in S&E (26.4%)
  • U.S. students complete S&E degrees (32.5%) at lower rates (Japan [57.2%], Singapore [41.8%], etc.)

Gaps in U.S. STEM achievement persist over time and become even larger in high school.
The Engineer of 2020 should be creative, possess an interdisciplinary outlook, and appreciate global contexts.
Engineering program chairs indicated the following curricular emphases [15]:

- **Design Skills** ($\bar{x} = 3.8$) includes creativity and innovation, defining design problems, and generating and evaluating potential solutions

- **Professional Skills** ($\bar{x} = 3.8$) includes teamwork, oral and written communication, and project management

- **Interdisciplinarity** ($\bar{x} = 3.2$) includes integrating and applying knowledge from various engineering disciplines (much less on non-engineering fields)

- **Professional Values** ($\bar{x} = 2.9$) includes societal impacts on engineering, ethical issues, influence of personal values on ethical decision making, and lifelong learning

“...interdisciplinarity and professional values receive less emphasis in the [engineering] curriculum....”
Alumni contrast their coursework emphases with career realities [15]:

**Graphic Credit:** 2020 Vision: Progress in Preparing the Engineer of the Future

1 = Little/No emphasis, 2 = Slight, 3 = Moderate, 4 = Strong, and 5 = Very strong emphasis

Skills emphasized in *Engineer of 2020* are important to graduates in their current positions, but are given less emphasis in their degree programs.
Methods

Theme: NASA’s Ascent Abort-2 (AA-2) flight test
Purpose: Document interdisciplinary, customer-service business model development of two education products

Methodology: Mixed methods research design [16]

• Quantitative (flipped classroom):
  • 19 secondary school teachers
  • Survey with Likert-type scale answers
  • Descriptive statistics (i.e., means with standard deviations)

• Qualitative (digital badge):
  • Narrative case study research
  • Visual observations & document analysis
  • Timeline of salient points with quotes; verified by member checks

Mixed methods research blends quantitative and qualitative data collection procedures, offering an interdisciplinary, integrated perspective that neither approach can offer on its own.
Secondary grade math teachers recognized value in the flipped classroom technique and anticipated using it in their teaching of modeling and simulation. [17]

Table 1. Survey Results for Orion AA-2 Flipped Classroom Unit

<table>
<thead>
<tr>
<th></th>
<th>1-Strongly agree</th>
<th>2-Agree</th>
<th>3-Neither agree nor disagree</th>
<th>4-Disagree</th>
<th>5-Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I enjoyed this session</td>
<td>12</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. This session provided information that will be useful to me</td>
<td>13</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. The material was presented clearly to me</td>
<td>14</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. I foresee applying things I learned in this session to my classroom teaching</td>
<td>10</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>5. These activities will engage my students</td>
<td>9</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>6. This activity improved my understanding of MODSIM</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

| Question #2: n = 19; $\bar{x} = 1.32 \pm 0.48$ | Question #4: n = 18; $\bar{x} = 1.72 \pm 1.02$ | Question #5: n = 19; $\bar{x} = 1.68 \pm 0.75$ | Question #6: n = 19; $\bar{x} = 2.32 \pm 1.29$ |

<table>
<thead>
<tr>
<th>Too Basic</th>
<th>About Right</th>
<th>Too Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. For my experience level, the session was:</td>
<td>1</td>
<td>18</td>
</tr>
</tbody>
</table>

8. To what extent did the session help you: (1=lowest; 10=highest)

a. Understand the definitions of modeling & simulation?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

b. Learn about the applications of MODSIM?

| 0 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 0  | 5  |
“With the badge’s primary focus on mass properties, Langley’s EPDC Specialist sought to also incorporate instructional activities for educators...in alternative formats that could be easily grasped by their younger students.”
(Weiss & Smith, 2019, p. 19)

Inclusion of history and social studies in the badge emphasize Engineer 2020 skills (interdisciplinarity).
Qualitative Results: Digital Badge

Alternate qualitative and quantitative formats broaden the digital badge’s potential audience.
Qualitative Results: Digital Badge

“Option #3 and the elephant/turtle/earth picture? Seriously, where did this come from, can I use the graphic? I learned something new and makes me want to know more! Great spin on mass properties too... I may challenge some senior SAWE leaders to answer the CG [center of gravity] question on that one!”

(Weiss & Smith, 2019, p. 20)

Culturally relevant teaching (CRT) activities integrate cultural contexts, art and STEM content (another Engineer 2020 skill).

‘The World Turtle’ (Credit: Chibineo; Creative Commons (CC))

Space Shuttle Endeavour at the Kennedy Space Center (Credit: NASA)
Activity: Modeling a Launch Abort System

Can you balance the Orion AA-2 Launch Abort Vehicle (LAV) mass properties?

**STEP 1**
Collect your flight hardware pieces to make your AA-2 Launch Abort Vehicle (LAV):
- (Quantity) Item
  - (1) pipe cleaner = AA-2 Crew Module (CM) Boilerplate
  - (1) popsicle stick = Launch Abort System (LAS)
  - (4) paper clips = ballast blocks

**STEP 2**
Integrate the CM to the LAS:
Place the stick towards the center of the pipe cleaner and wrap around the stick.

**STEP 3**
Complete your LAV assembly:
Twist the ends of the pipe cleaner and shape to form your Crew Module (CM) to complete the LAV.

**STEP 4**
Conduct a mass properties test of your LAV:
Try to balance your LAV payload on your finger or a post. Talk with a friend about what you observe:
- Can you balance your LAV?
  - Place post or finger here to try to balance!

**STEP 5**
Assemble 2 ballast blocks and test the LAV again:
Add your 4 ballast blocks (paper clips) somewhere on your LAV (the pipe cleaner and stick assembly) and try again to balance your LAV payload on a finger or a post. Talk with a friend about what you observe:
- Place post or finger here to try to balance!

**STEP 6**
Move ballast blocks to adjust the alignment of the LAV:
Is the LAV balancing straight up-and-down? If not, move the ballast blocks to a different location to get the LAV pointed straight up-and-down. Try different ballast configurations to observe what moving the ballast does to the LAV:
- This balancing will help control where the rocket will go when it launches!

**SOLUTION EXPLANATION**
Mass properties are mass, center of gravity (or location of mass), and inertia. The Center of Gravity (CG) of the LAV with just the CM and LAS is harder to balance because the CG is up higher. When you add the ballast blocks, the mass and location of mass of the system changes, moving the CG to a point that is easier to balance!

**IMPORTANCE OF MASS PROPERTIES**
In this example, when the ballast blocks are added in the right location, the LAV rocket will be balanced, stable, controllable, and fly in the location you want it to go when it launches!

Graphic Credit: NASA Flight Test Management Office, Public Affairs Office and Office of STEM Engagement

Credit: Society of Allied Weight Engineers (SAWE)

Credit: NASA Langley Flickr

Credit: Society of Allied Weight Engineers (SAWE)
Purpose: Examine utilization of an interdisciplinary engineering micro-credential by educators

Methodology: Mixed methods research design [16]

• Quantitative (online survey):
  o Likert-type scale & free-response questions
  o Descriptive & analytical statistics (multivariate regression or ANOVA)
  o Participants self-select into second phase

• Qualitative (interview or focus group):
  • Open-ended question protocol; ~30 minutes
  • Emergent themes – incorporation of interdisciplinary content
  • Invitation to submit artifacts documenting usage of interdisciplinary content

Research study may provide insight into meaningful strategies for instilling an interdisciplinary mindset in the next generation of mass properties engineers.
# Next Generation STEM

<table>
<thead>
<tr>
<th>Commercial Crew Program</th>
<th>Moon To Mars</th>
<th>Small Steps to Giant Leaps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A Focus on Human Spaceflight to Space Station with our Commercial Partners</strong></td>
<td><strong>A Focus on Transportation Systems for Moon to Mars Missions</strong></td>
<td><strong>A focus on the Future of NASA Aeronautics Innovation</strong></td>
</tr>
<tr>
<td>• New and refreshed interdisciplinary K-12 STEM content</td>
<td>• App development challenge – visualizes launch data from Orion AA2 test flight</td>
<td>• Educational videos focusing on the X-59 and basic sound principals</td>
</tr>
<tr>
<td>• Education Professional Development (PD) Webinars and digital badges</td>
<td>• Virtual connections with NASA Subject Matter Experts</td>
<td>• Principals of sound activities and video demonstrations</td>
</tr>
<tr>
<td>• Virtual and experiential educator PD opportunities</td>
<td>• Computer science mentorship</td>
<td>• Education Professional Development Webinars and digital badges</td>
</tr>
<tr>
<td>• Virtual field trips to NASA and partner facilities</td>
<td>• STEM engagement content module include K-12 activities</td>
<td>• Citizen’s science challenge – Mapping ambient noise</td>
</tr>
<tr>
<td>• Cutting edge, New Virtual Reality Experiences</td>
<td>• Education Professional Development Webinars and digital badges</td>
<td></td>
</tr>
</tbody>
</table>

**Graphic Credit:** NASA Office of STEM Engagement

Society of Allied Weight Engineers, Inc. - Document contains no export controlled technical data
Cultivating Lifelong Learners

• Grades K-12
• Educators

Graphics and Images Credit: NASA Commercial Crew Program
Teaching Through Immersive Experiences

Video Credit: NASA Education STEM on Station
Virtual Reality

Spherical Videos

Society of Allied Weight Engineers, Inc. - Document contains no export controlled technical data
End-of-Presentation Thought Question

EPD TEACHER RESOURCE TRAINING Please answer the following poll: As a student, which of the following instructional tools did you use? (Respond to all that apply)

- TI 81-84 Plus Calculator
- Slide Rule
- Fortran Punch Cards
- Overhead Projector
- Desmos
- Chalkboard
- MATLAB
References


