Cracking the code of creative “capital:” Assessing student creativity in science, engineering and technology courses

Presenters:
Jen Katz-Buonincontro, Associate Professor, jkb@drexel.edu
Amanda Barany, Ph.D. Candidate, amb595@drexel.edu
Jessica Cellitti, Ph.D. Candidate, jmn334@drexel.edu
Tamara Galoyan, Ph.D. Candidate, tg532@drexel.edu
Rasheda Likely, Ph.D. Student, rsl67@drexel.edu
Magdalene Moy, Ph.D. Student, mkm99@drexel.edu
Elaine Perignat, Ph.D. Candidate, elaine@drexel.edu
Hamideh Talafian, Ph.D. Student, ht343@drexel.edu
Presentation format

1. Background
2. Definitions
3. 4 Project Examples
4. Group activity
Background: New PhD course Creativity & Innovation in STEM Education

- **4 projects**: culminating work of 7 students enrolled in this new PhD course in the School of Education at Drexel.

- **Essential learning question**, “What’s the best way to tailor STEM learning assessments based on the choice of the instructional strategy incorporating creative thinking or problem solving?

- “Critical and creative thinking”: one of eleven Drexel student learning priorities yet faculty members, researchers.

- **Creativity**: think of new, relevant or useful ideas that are high in quality; to produce, develop, invent, hypothesize (Bloom’s taxonomy) supported by people and climate (Isaksen, 1984)

- **Assessment features**: helps make creativity observable to self as teacher and to student in order to build durable learning; emphasizes creative process and products
ICE Model: Integrating Creativity into Education

(I) PLAN: Identify "creativity" in existing educational standards; Analyze curriculum for trouble spots, concepts that are hard to learn

(II) MAP: Map social-cognitive learning theories onto creative thinking cycle (peer learning strategies, cultural issues)

(III) DEVELOP: instructional prompts and assessments conducive to promoting creative thinking (formative and summative); select cognitive measure of creativity

(IV) PILOT: pedagogy in practice, make revisions and prepare for teaching again
Designing digital media tools for environmental advocacy

6. Creative Communicator

Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals. Students:

a. choose the appropriate platforms and tools for meeting the desired objectives of their creation or communication.

b. create original works or responsibly repurpose or remix digital resources into new creations.

c. communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models or simulations.

d. publish or present content that customizes the message and medium for their intended audiences.
### Designing digital media tools for environmental advocacy

<table>
<thead>
<tr>
<th>Class Activities</th>
<th>Assessment Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td></td>
</tr>
<tr>
<td>· Student inquiry research into environmental issue/problem of interest</td>
<td>· Students receive assessment rubrics</td>
</tr>
<tr>
<td>· Student inquiry research into potential solutions to the environmental problem</td>
<td>· Formative assessment: Rows I + D</td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
<td></td>
</tr>
<tr>
<td>· Student will be grouped (2-3 people) based on aligned environmental interests</td>
<td>· Formative assessment Row E</td>
</tr>
<tr>
<td>· Group researches local representative to understand their audience</td>
<td></td>
</tr>
<tr>
<td>· Group brainstorms potential methods of advocating for environmental change for their audience using digital media</td>
<td></td>
</tr>
<tr>
<td><strong>Day 3</strong></td>
<td></td>
</tr>
<tr>
<td>· Groups brainstorm pros and cons for their design ideas and decide how to</td>
<td>· Formative assessment Row A</td>
</tr>
<tr>
<td>address them</td>
<td></td>
</tr>
<tr>
<td>· Groups build “prototypes” for their top ideas</td>
<td></td>
</tr>
<tr>
<td>· Peer feedback through peer critique</td>
<td></td>
</tr>
<tr>
<td>· Groups choose their best design option</td>
<td></td>
</tr>
<tr>
<td><strong>Day 4</strong></td>
<td></td>
</tr>
<tr>
<td>· Design day – students develop their digital media projects</td>
<td>· Formative assessment Row L</td>
</tr>
<tr>
<td>· Gallery presentations of completed digital media projects</td>
<td></td>
</tr>
<tr>
<td><strong>Day 5</strong></td>
<td></td>
</tr>
<tr>
<td>· Students finalize messages to legislators, include documentation of digital media projects</td>
<td>· Summative assessment of final projects</td>
</tr>
</tbody>
</table>
**Formative Assessment:**

The IDEAL Problem Solver Heuristic

- Self-assessments
- Passed out to students during creative design phases
- Identifies students in need of support
- Identifies when students need support

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<table>
<thead>
<tr>
<th>(I've got this!)</th>
<th>3</th>
<th>2</th>
<th>(I need help!)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identifying</strong> the problem of interest as clearly as possible</td>
<td>I chose an environmental problem that I find interesting/important.</td>
<td>I chose an environmental problem that I find somewhat interesting/important.</td>
<td>I have a little interest in my topic; I think my topic is only important in some ways or contexts.</td>
</tr>
<tr>
<td></td>
<td>I can clearly explain what the issue is and why it is a problem.</td>
<td>I can explain most of the issue and why it is a problem, but there are elements I need to learn more about.</td>
<td>I do not think my environmental problem is interesting/important.</td>
</tr>
<tr>
<td><strong>Defining potential solutions/changes for which to advocate</strong></td>
<td>I have identified 4 or more changes or solutions I could advocate for (e.g., legislation changes, community programs, etc.)</td>
<td>I have identified 2-3 changes or solutions I could advocate for (e.g., legislation changes, community programs, etc.).</td>
<td>I have identified 1-2 changes or solutions I could advocate for.</td>
</tr>
<tr>
<td></td>
<td>I can explain in detail how each solution would solve the problem.</td>
<td>I can explain how each solution would solve the problem, but I have a few questions.</td>
<td>I can explain how some of these solutions might solve the problem, but there are many elements I do not understand.</td>
</tr>
<tr>
<td><strong>Exploring methods of communicating these advocacy messages</strong></td>
<td>I have identified 4 or more ways to communicate these advocacy messages to my legislator (e.g., video, log, digital art, etc.).</td>
<td>I have identified 2-3 ways to communicate these advocacy messages to my legislator.</td>
<td>I have identified 1-2 ways to communicate these advocacy messages to my legislator.</td>
</tr>
<tr>
<td></td>
<td>I can explain in detail how these methods would communicate my message.</td>
<td>I can explain how these methods would communicate my message, but I have a few questions.</td>
<td>I have not identified any ways to communicate these advocacy messages to my legislator.</td>
</tr>
<tr>
<td><strong>Acting on/Anticipating the pros and cons of each solution and selecting the best one</strong></td>
<td>I can clearly identify the strengths and weaknesses of each solution/ change.</td>
<td>I can identify the strengths/weaknesses of each solution, but I have a few questions.</td>
<td>I can identify some strengths/weaknesses for my solutions, but there are many elements I do not understand.</td>
</tr>
<tr>
<td></td>
<td>Based on my analysis of these pros and cons, I have chosen the best option.</td>
<td>Based on my analysis I narrowed my selection down to 1-2 best options, and need to further consider the pros and cons.</td>
<td>I have considered the pros and cons of each option, but need help narrowing it down.</td>
</tr>
<tr>
<td><strong>Look back at the process (evaluate)</strong></td>
<td>Looking back on my problem solving process, I feel I was able to complete all elements successfully.</td>
<td>Looking back on my problem solving process, I feel I was able to complete most elements successfully.</td>
<td>I have not been able to identify strengths/weaknesses for my solutions.</td>
</tr>
<tr>
<td></td>
<td>Looking back on my problem solving process, I feel I could improve on 1-2 elements of the problem solving process.</td>
<td>I feel I could improve on 1-2 elements of the problem solving process.</td>
<td>I need help brainstorming pros and cons and choosing the best option.</td>
</tr>
</tbody>
</table>

(Adapted from Bransford & Stein, 1984)
Summative Assessment of Creative Communication

- Summative assessment of students’ final projects
- Demonstration of clarity, creativity and creative voice, and intentional alignment with purpose and audience
- **Voice**: the tone of a student’s work as it conveys the her values, perspective and skill

(Brookhart & Nitko, 2013)

<table>
<thead>
<tr>
<th>Creative Communication</th>
<th>Expressing ideas in a creative and convincing way for audience and purpose</th>
</tr>
</thead>
</table>
| 6                      | The work demonstrates an appropriate voice for the topic, purpose, and audience, and shows a deep sense of involvement with the topic. The message is clear, interesting, and sincere. The piece has:  
  • An effective level of closeness to the audience or distance from it (e.g., a video-log should have a strong personal voice, while a video documentary may require a more objective voice; both should be lively or interesting).  
  • An exceptionally strong sense of purpose and audience; it should be apparent that the message and mode of communication were intentionally tailored to an individual representative.  
  • A sense that the topic has come to life; when appropriate, shows use of originality, liveliness, honesty, conviction, excitement, humor, suspense, and/or use of non-digital resources. |
| 5                      | The work demonstrates an appropriate voice for the topic, purpose and audience and shows involvement with the topic. The message is interesting and seems sincere. The piece has:  
  • An appropriate level of closeness to the audience or distance from (e.g., a video-log should have a strong personal voice, while a video documentary may require a more objective voice; both could be lively or interesting).  
  • A strong sense of purpose and audience; some elements of the work show the message and mode of communication were tailored to a representative.  
  • A sense that the topic has come to life; when appropriate, the piece shows originality, liveliness, honesty, conviction, excitement, humor, suspense and/or use of non-digital resources. |
| 4                      | A voice is present, and there is a sense of involvement with the topic. In places, the message is interesting and seems sincere. The piece has:  
  • A questionable or inconsistent level of closeness or distance from the audience given the mode of communication.  
  • A sense of purpose and audience, but may not be consistently or appropriately tailored to the needs of a representative.  
  • Originality, liveliness, humor and/or use of non-digital resources, when appropriate; however, at times voice may be too casual or formal. |

| 3                      | The creator doesn’t seem particularly involved with the topic or may seem either too personal or too impersonal. The piece has:  
  • A voice that doesn’t seem to match the topic, purpose, and audience.  
  • A limited sense that the work was created for a particular audience.  
  • A sense in places of the creator behind the work; however, this may appear inconsistently or inappropriately.  
  • Limited originality, liveliness, humor and/or use of non-digital resources, when appropriate; at times voice may be too casual or formal. |
| 2                      | The work provides little sense of involvement or evidence of a suitable voice. The piece has:  
  • Little or no sense that the creator cares about the topic; the message is mechanical, unclear, or inconsistent.  
  • Little or no awareness of matching the topic, purpose, and audience.  
  • Little or no sense of the creator behind the work; there are only a few places where the viewer and creator might feel a connection.  
  • A voice that is likely to be overly formal or overly personal. |
| 1                      | The work lacks a sense of involvement and a suitable voice. The piece has:  
  • No sense that the creator cares about the topic; the message is mechanical, unclear, or inconsistent.  
  • No sense that the piece was created for an audience.  
  • No hint of the creator behind the work; there are few if any places where the viewer feels connected to the creator. The piece doesn’t get the viewer involved. |
Game-Based Learning in an Evolutionary Biology Classroom

## Evolution Game

<table>
<thead>
<tr>
<th>Skill</th>
<th>Points (1-5)</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating Type</td>
<td>Carnivore - 5</td>
<td>Whereas an omnivore may receive 3 points and a herbivore only 1 point.</td>
</tr>
<tr>
<td>Size</td>
<td>Large - 5</td>
<td>Whereas an insect may be 1 point and a mouse 2 points.</td>
</tr>
<tr>
<td>Strength</td>
<td>Strong - 5</td>
<td>Whereas an insect may be 1 point and a mouse 2 points.</td>
</tr>
<tr>
<td>Defense</td>
<td>Medium - 3</td>
<td>Whereas an insect and a mouse may be 1 point.</td>
</tr>
<tr>
<td>Competition</td>
<td>Medium - 2</td>
<td>Depends on prey-predator relationship.</td>
</tr>
<tr>
<td>Adaptability</td>
<td>Narrow - 1</td>
<td>Being cold-blooded makes reptiles less adaptable. Whereas a mouse may be 4 points.</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>Small - 1</td>
<td>Whereas an insect may be 5 and a mouse 4.</td>
</tr>
<tr>
<td>Community</td>
<td>Small - 1</td>
<td>Most large (carnivorous) dinosaurs were solo predators, non-communal.</td>
</tr>
</tbody>
</table>

### Six principles of GBL:

1) The intervention must inspire **critical thinking**.
2) The intervention provides “just enough” **challenge** for players.
3) The intervention provides opportunities for players to discover/construct their own knowledge/understandings.
4) The intervention provides a fictional-world.
5) The intervention is “**social**”.
6) The intervention must be winnable (so as to provide goals, as well as some sense of competition).

(Cicchino, 2015)
Game-Based Learning in an Evolutionary Biology Classroom

Lesson Sequence

Figure 1. Lesson Sequence and Assessment Plan
Adapted Dynamic Consensual Assessment Technique (CAT)

<table>
<thead>
<tr>
<th>Rate (low 0-3 (high)</th>
<th>Product 1 Individual “Beast”</th>
<th>Product 2 Group “Improved Beast”</th>
<th>Product 3 Individual “Designed Beast”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Originality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rationale for features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapted features</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Originality = how different is this “beast” than from real-life animals
- Quality = how well do you think this “beast” is suited for its environment overall
  - Rationale for features = how well are the features explained
  - Adapted features = do you think this “beast” has all the important features for its environment (e.g. does it have several helpful features for survival)
Game-Based Learning in an Evolutionary Biology Classroom

Application

- Consensual Assessment Technique (CAT) is adaptable
  - Assess Person, Press (environment), Process, and/or Product
  - Discipline content can be added into the CAT
  - Can be used for a single timepoint or for a process
  - Students can be used as judges (peer feedback)
Divergent Thinking in Ecology

- **Fluency** which is the number of responses to a given stimuli in an exercise.
- **Originality** is the uniqueness of the answers to stimuli.
- **Flexibility** is the categories of responses to a stimuli.
- **Elaboration** is the extension of ideas within a specific category.

(Kaufman, Plucker, and Baer, 2008).
Divergent Thinking in Ecology

- “Conceptual gateways” or “portals” which leads to troublesome ways of thinking (Meyer & Land, 2003)- Threshold concept
- Knowledge that is ‘alien’, or counter-intuitive or even intellectually absurd at face value (Perkins, 1999)- Troublesome knowledge
## Divergent Thinking in Ecology

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Instructional prompts example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instances</strong></td>
<td>The participant is asked to generate possible instances of a class concept. Students will be asked to identify other instances where grass (plant) is used as food in another food chain.</td>
</tr>
<tr>
<td><strong>Uses</strong></td>
<td>The participant is asked to generate possible uses for a given objects. Students will be asked what other uses there are for grass (plant) outside of the food chain.</td>
</tr>
<tr>
<td><strong>Similarities</strong></td>
<td>The participant has to generate possible similarities between two objects. Students will be asked to identify the similarities grass (plant) has with other food in the food chain.</td>
</tr>
</tbody>
</table>
The Creative Problem Solving Process in Engineering

◉ Definitions of *creativity* differ by discipline

◉ Engineers tend to define creativity as a process, as opposed to a person or product (Cropley, 2001; Zhou, 2012).
  ○ Problem-Solving processes
  ○ Iterative design processes
  ○ Implementation of solutions

◉ Creativity “can be defined as a continuous process of thinking innovatively, or of finding and solving problems and implementing solutions” (Basadur & Gelade, 2003, p.23)
The Creative Problem Solving Process in Engineering

GENERATING ideas:
- Problem-Finding
- Exploring Solutions
- Divergent Thinking

CONCEPTUALIZING ideas:
- Consider alternate perspectives
- Develop abstract models

IMPLEMENTING ideas:
- Creating/ making
- Putting into action

OPTIMIZING ideas:
- Change abstract ideas to practical and implementable
- Develop action plan

Quadrant I: GENERATING
Creating options in the form of new possibilities—new problems that might be solved and new opportunities that might be capitalized on

Quadrant II: CONCEPTUALIZING
Creating options in the form of alternate ways to understand and define a problem or opportunity and good ideas that help

Quadrant III: OPTIMIZING
Creating options in the form of ways to get an idea to work in practice and uncovering all the factors that go into a successful plan for implementation

Quadrant IV: IMPLEMENTING
Creating options in the form of actions that get results and gain acceptance for implementing a change or a new idea

(Basadur & Gelade, 2003)
The Creative Problem Solving Process in Engineering

### Rubric For Student Assessment

- **Encourage Risk-Taking**
- **Encourage Resilience in Failure**
- **Flexible Rubric** (Instructors or Peers can assess at various points)
- **Individual or Group**
- **Formative and Summative Assessment**

<table>
<thead>
<tr>
<th>Stages</th>
<th>Description</th>
<th>Score 3</th>
<th>Score 2</th>
<th>Score 1</th>
<th>Score 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: Generating</td>
<td>This phase includes acquiring knowledge through sensing, seeking, and identifying possible problems. Students will explore ideas, gather information, and apply it.</td>
<td>Students generate a wide number of ideas (Fluency) and wide range of ideas (Flexibility).</td>
<td>Students generate a number of ideas and a range of ideas.</td>
<td>Students generate few ideas with a limited range.</td>
<td>Students generate a limited number of ideas without a range.</td>
</tr>
<tr>
<td>Stage 2: Conceptualizing</td>
<td>This phase requires abstract thinking in order to analyze and theorize about the information learned through the generating phase. Students begin developing models in order to understand and explain things.</td>
<td>Students take generated ideas and develop them further into fully conceptualized ideas. This would include models, drawings, and details that demonstrate foundational knowledge.</td>
<td>Students take generated ideas and develop them into partially conceptualized ideas. This would include some form of modeling or drawings that show some understanding of foundational knowledge.</td>
<td>Students take generated ideas and add more details without linking conceptualizations to foundational knowledge.</td>
<td>Students take generated ideas or add more details without linking conceptualizations to foundational knowledge.</td>
</tr>
<tr>
<td>Stage 3: Optimizing</td>
<td>This phase focuses on converting abstract ideas into practical solutions through analysis of the problem and evaluation of ideas.</td>
<td>Students critically evaluate ideas from Stage 2. Students then optimize their creative idea by generating specific steps towards implementation and identifying necessary resources.</td>
<td>Students evaluate ideas from Stage 2. Students then optimize their creative idea by generating broad steps towards implementation and identifying some necessary resources.</td>
<td>Students begin to evaluate ideas from Stage 2. Students then optimize their creative idea by generating broad steps towards implementation and identifying some necessary resources.</td>
<td>Students generate steps towards implementation and identify resources.</td>
</tr>
<tr>
<td>Stage 4: Implementing</td>
<td>This phase focuses on implementation of the solution or selected idea in response to the identified question or problem. This phase also includes evaluation of the outcome and making adjustments if necessary.</td>
<td>Students implement the optimized solution by completing the model, completing a self-assessment, and identifying potentially new problems.</td>
<td>Students implement the solution by completing two of the following: the model, completing a self-assessment, and identifying potentially new problems.</td>
<td>Students implement the solution by completing one of the following: the model, completing a self-assessment, and identifying potentially new problems.</td>
<td>Students do not implement solution successfully.</td>
</tr>
<tr>
<td>Activity Steps</td>
<td>Guiding Questions</td>
<td>Information</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>1. Identify course or informal learning opportunity (e.g. co-op) for integrating creativity</td>
<td>Which of my courses emphasizes coming up with new, quality and relevant ideas, products or processes?</td>
<td>Course Name:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Articulate how creativity is related to learning in this course</td>
<td>Why is creativity important for students in this course? Are there learning outcomes associated with creativity?</td>
<td>Relevance:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Determine if you focus more on students' creative process or creative product?</td>
<td>What is the creative product? (Or) When/ How do students engage in the creative process?</td>
<td>Process or Product:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Formative assessment of creativity</td>
<td>At what points/benchmarks in the course should students be required to demonstrate their creativity?</td>
<td>Benchmarks:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Summative assessment of creativity</td>
<td>Which final projects/learning outcomes are ripe for creativity?</td>
<td>Project/Outcomes:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Reflection</td>
<td>What are some challenges to assessing creativity in your course?</td>
<td>Challenges:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Selection of Recommended References


Selection of Recommended References (cont’d)


