Innovative Frameworks for Teaching and Learning

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Luanna Prevost, Ph.D.

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https://aaas-iuse.org

Please note: The discussion break-out groups following the presentations will NOT be recorded.
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AAAS IUSE Initiative

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Innovative Frameworks for Teaching and Learning

Melanie Cooper, Ph.D.
Luanna Prevost, Ph.D.
What is 3D Learning? (and why should we do it?)
More Acknowledgements

CER Group members and collaborators whose work is discussed here
Mike Klymkowsky
Amy Pollock
Lynmarie Posey
Olivia Crandell
Samantha Houchlei
Aishling Flaherty
Elizabeth Day
Ryan Bowen
Sewwandi Abeywardana
3DL provides us with a way to help students structure and use their knowledge.
The Theory

Measuring Change

The Evidence
“The framework is designed to help realize a vision for education in the sciences and engineering in which students, over multiple years of school, actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields.”
The Three Dimensions
Disciplinary Core Ideas

Fundamental ideas that underlie all topics in a discipline

Crosscutting Concepts

Tools or lenses for making sense of phenomena

Scientific Practices

Methods that scientists use to make sense of events or phenomena


Why Core Ideas?
Underlie a wide range of phenomena
Applicable and relevant across the curriculum
Predictive
Generative of new ideas and connections
Experts’ knowledge is organized into an underlying framework that reflects deep understanding of the discipline.
3DL4US Core Ideas
Constructing curricula around core ideas should allow students to link and contextualize knowledge.
How do we help learners to connect knowledge? (to make it useful?)
“Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge. Both elements—knowledge and practice—are essential.”
Scientific and Engineering Practices
How we put knowledge to use

1. Asking questions (and defining problems)
2. Developing and using models
3. Planning and carrying out investigations (and designing solutions)
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Developing explanations (and designing solutions)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

Ideas that are important to all science disciplines: epistemic resources or lenses to focus attention on particular aspects of a phenomenon

1. Patterns
2. Cause and effect
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter conservation, cycles and flows
6. Structure and function
7. Stability and change
Three-dimensional learning (3DL) explicitly integrates core ideas, crosscutting concepts, & scientific practices
Ideally, we want to build curricula around core ideas (not topics), that provide opportunities for students to use their knowledge – by engaging in scientific practices, supporting connections to be made across phenomena and across disciplines.
At MSU we used the Framework to provide a coherent approach to gateway course transformation

(and extending)

Creating a Coherent STEM Gateway at Michigan State University

3DL4US three-dimensional learning for undergraduate science

Engaging faculty to determine the core ideas, science practices and cross cutting concepts promote change

Our change model:

Engaging faculty to determine the core ideas, science practices and cross cutting concepts promote change

and changes in assessment practices

leads to changes in classroom practice
Engaging Faculty:

Since 2013 over 80 faculty have participated in a two-year fellowship program.


Measuring change

We collected data on persistence, grades, affective domain, faculty perceptions etc.

BUT...

◦ we know that grades do not necessarily equate with learning
◦ And what faculty say does not necessarily align with their practice
Measuring change

By looking at the course assessments.
- Using the Three-Dimensional Learning Assessment Protocol (3DLAP)

By investigating classroom practice
- Using the Three-Dimensional Learning Observation Protocol (3DLOP)
Evaluating the extent of a large-scale transformation in gateway science courses

We evaluate the impact of an institutional effort to transform undergraduate science courses using an approach based on course assessments. The approach is guided by *A Framework for K-12 Science Education* and focuses on scientific and engineering practices, crosscutting concepts, and core ideas, together called three-dimensional learning. To evaluate the extent of change, we applied the Three-dimensional Learning Assessment Protocol to 4 years of chemistry, physics, and biology course exams. Changes in exams differed by discipline and even by course, apparently depending on an interplay between departmental culture, course organization, and perceived course ownership, demonstrating the complex nature of transformation in higher education. We conclude that while transformation must be supported at all organizational levels, ultimately, change is controlled by factors at the course and departmental levels.
Characterizing Assessments with the 3D-LAP

We coded 4020 questions using the 3D-LAP over four years for introductory biology, chemistry and physics courses.
The 3D-LAP provides criteria for each dimension.
Two assessments: Elicit different evidence

Which compound is likely to be most soluble in water?

A. CH₃CH₂OH
B. CH₃OCH₃
C. CH₃CH₂CH₃

Constructing a model,

- Bonding and Interactions, Structure property relationships
- Using the model to support an explanation
- Cause and Effect

A. Draw the structures of three molecules: CH₃CH₂OH and show how they interact with each other.
B. Do the same for CH₃OCH₃.
C. Now draw a molecule of CH₃CH₂OH in solution and show how it interacts with the water molecules.
D. Do the same for CH₃OCH₃.
E. Which substance do you predict to be more soluble in water?
F. What factors are you considering in your selection?
G. Why do these factors affect the solubility?
3D-LAP Showed Increase in 3D Questions Over Four-Year Project


Characterizing Instruction with the 3D-LOP

We coded over 181 recordings of 65 course sections using the 3D-LAP over four years for introductory biology, chemistry and physics courses.
The 3D-LOP (learning observation protocol)

<table>
<thead>
<tr>
<th>Topics</th>
<th>Teaching Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td></td>
</tr>
<tr>
<td>CI</td>
<td></td>
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<tr>
<td>CC</td>
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</tbody>
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Timeline
The 3D-LOP (learning observation protocol)

An “active learning” class that is not 3D
3DL is not active learning, but...

We have found that 3DL is more likely to be associated with active learning, whereas the reverse is not necessarily true.

<table>
<thead>
<tr>
<th></th>
<th>Not Active</th>
<th>Active</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not 3D</td>
<td>229</td>
<td>95</td>
<td>324</td>
</tr>
<tr>
<td>Exp.: 205</td>
<td></td>
<td>Exp.: 119</td>
<td></td>
</tr>
<tr>
<td>$r_{11}$: 2.66</td>
<td></td>
<td>$r_{12}$: 4.90</td>
<td></td>
</tr>
<tr>
<td>3D</td>
<td>35</td>
<td>58</td>
<td>93</td>
</tr>
<tr>
<td>Exp.: 59</td>
<td></td>
<td>Exp.: 34</td>
<td></td>
</tr>
<tr>
<td>$r_{21}$: 9.78</td>
<td></td>
<td>$r_{22}$: 16.6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>264</td>
<td>153</td>
<td>417</td>
</tr>
</tbody>
</table>

chi-square, 33.9, p < 0.001, phi=0.285
The Evidence
This decrease in DFW rate practically translates to approximately 740 more students earning a grade of 2.0 or above in Year 3 compared to Year 0.

MSU gen chem students from transformed course score above the national average on the American Chemistry Society nationally normed conceptual exam, even though the exam covers more (and different material)
Selected Publications Comparing Transformed vs Traditional chemistry courses

Analyzing the structure of student’s organic chemistry knowledge

We asked students to draw a diagram of the important ideas in organic chemistry and coded them.

One semester transformed courses

- Transformed
  - Progression: 40%
  - Sensemaking: 30%
  - Topics: 30%

- Traditional
  - Progression: 30%
  - Sensemaking: 30%
  - Topics: 40%

Cramer's V = 0.175

p = 0.017

Three semesters transformed courses

- Transformed
  - Progression: 50%
  - Sensemaking: 40%
  - Topics: 10%

- Traditional
  - Progression: 40%
  - Sensemaking: 30%
  - Topics: 30%

Cramer's V = 0.3

p = 0.006
What happens to students who switch between traditional and transformed?
What happens to students who switch between traditional and transformed?

Manuscript in preparation
What do students think they are assessed on?

- **Use of knowledge**
  - OCLU (N = 248)
  - Traditional (N = 604)

- **Rote/Memorization**
  - OCLU (N = 248)
  - Traditional (N = 604)

- **Generalities**
  - OCLU (N = 248)
  - Traditional (N = 604)
Mechanistic reasoning (3DL) tasks are more equitable.
Summary

3DL is a guide/template for designing curriculum and assessment materials that support students’ development of connected and useful knowledge.

3DL typically incorporates “active learning” but goes beyond simple student engagement.

Transformation can be assessed by using the 3D-LAP and LOP.

Faculty can use the 3D-LAP and LOP to guide instructional and assessment design.

Students in 3D chemistry courses appear more likely to persist, less likely to believe memorization is the goal, and more likely to construct connected knowledge structures.

Students in 3D chemistry courses are more likely to engage in mechanistic reasoning and other scientific practices.

3DL assessment items are more equitable than those that rely solely on mathematical calculations.
Discussion Questions

How does this align with what you think STEM graduates should be able to do?

How might you incorporate this approach in your classroom?

How do we convince funding agencies and university administrations to support and sustain programs that have been shown to be effective and inclusive?
Transforming STEM education through multidimensional teaching and learning: From Ecology to Beyond

Presenter: Luanna Prevost
Associate Professor, University of South Florida
Chair, 4DEE Subcommittee, Ecological Society of America
Development of the 4DEE Framework

1986 – Paul Risser call-to-arms on Ecological Literacy

2007 – Poll Members of the Ecological Society of America (ESA)

2018 – ESA Adopted Framework

1980s – Concerns over Science Literacy

1980s-2000s Numerous publications and reports on ecoliteracy (Klemow, Berkowitz, SBI)

2015 – ESA 4DEE Task Force

2019 – ESA 4DEE Subcommittee

The importance of a fourth dimension to ecologists

What should people know, feel or be able to do to be ecologically literate?

- Science Process, Thinking Skills, 728
- Identification, Natural History, 178
- Attitudes, Feelings, 288
- Human Ecology Concepts, 2937
- Ecology Concepts (not humans), 3509

Number of Coded Elements in Major Categories (n total = 7656)

ESA 2007 Member survey N= 1032
What is the Four-Dimensional Ecology Education (4DEE) Framework?

I. Core Ecological Concepts
II. Ecological Practices
III. Human-Environment Interactions
IV. Cross-Cutting Themes

Integration Across Dimensions

**Core Ecological Concepts (CEC)**
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes
- Biomes
- Biosphere

**Ecological Practices (EP)**
- Natural History
- Fieldwork
- Quantitative reasoning and computational thinking
- Designing and critiquing investigations
- Communicating and applying ecology
- Working collaboratively

**Crosscutting Themes (CCT)**
- Structure & Function
- Pathways & Transformations of Matter and Energy
- Systems
- Spatial & Temporal Scale

**Human-Environment Interactions (HEI)**
- Human dependence on the environment
- Human accelerated environmental change
- How humans shape and manage resources/ecosystems/the environment
- Ethical dimensions
Leveraging the Human-Environment Dimension

• Unique approach to a life sciences education framework

• Meet the needs of the Gen Z and future generations

• Prepare the 21st century workforce
Implementing 4DEE

- Start with learning objectives
- Gradually incorporate new dimensions
- Make explicit connections among dimensions through integration
- Align objectives and assessment

Interpret data to determine ecological interactions between organisms and the impact of human activities on these interactions

Understand the ecological interactions between organisms

Predict/model the ecological interactions between organisms

Connecting dimensions for authentic learning contexts

- Field Experiences
- Undergraduate Research Experiences
- Community Engagement
- Issues of environmental justice and ethics
- Accelerated environmental change

Connecting dimensions for inclusive education

• Opportunities for student choice and connecting to communities

• Incorporation of practices to build self efficacy and sense of community

• Explicitly illustrate how ecology/biology applies to other disciplinary interests
4DEE across the curriculum

- Lesson
- Course
- Program
- Informal Learning

Social Sciences
How might 4DEE inform other disciplines?

- Microbiology?
- Physiology?
- Medicine?
- Chemistry?
- Physics?
- Engineering?
- Geosciences?
How might 4DEE apply to your course, program, discipline?

• Where/how might the human elements apply to your discipline?

• How might multidimensional frameworks be applied so that students can see how what they are learning matters in the real world?

• How do we assess with these new frameworks?

• How do we prepare faculty for the cross-disciplinary exchanges that frameworks call for?
Acknowledgements

Coauthors:
Ken Klemow, Wilkes University
Amanda Sorensen, Michigan State University
Alan Berkowitz, Cary Institute of Ecosystem Studies

ESA 4DEE Subcommittee

Teresa Mourad, ESA Director of Education and Diversity Programs
Jessica Johnston, Education Programs Manager
Facilitated Breakout Rooms

Dr. Melanie Cooper

• How does this approach align with what you think STEM graduates should be able to do?
• How might you incorporate this approach in your classroom?
• How do we convince funding agencies and university administrations to support and sustain programs that have been shown to be effective and inclusive?

Dr. Luanna Prevost

• Where/how might the human elements apply to your discipline?
• How might multidimensional frameworks be applied so that students can see how what they are learning matters in the real world?
• How do we assess these new frameworks?
• How do we prepare faculty for the cross-disciplinary exchanges that frameworks call for?
Discussion Breakout Room Recap
Thank you for attending!

Slides and recording will be available in the coming weeks.

We value your feedback, please take a few minutes to complete the survey.