3D Science Learning in Agriculture through Sustainability.

Craig Kohn, Michigan State University
Taylor Bogardus, Schoharie High School

KBS LTER
Kellogg Biological Station
Long-term Ecological Research

MICHIGAN STATE UNIVERSITY

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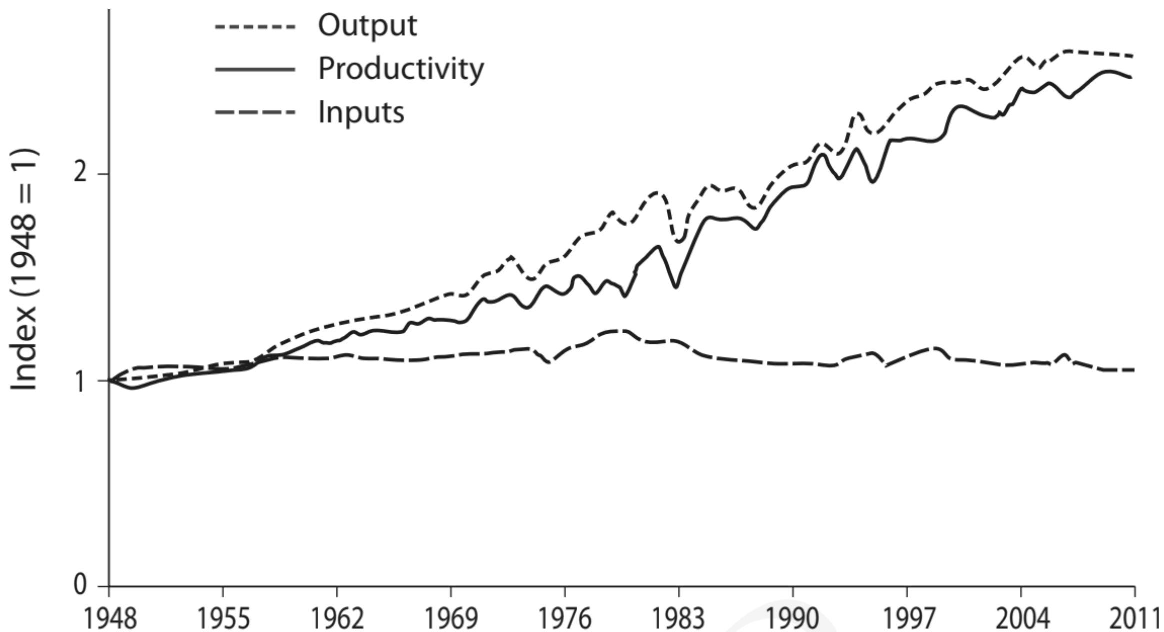
Future of Agriculture

- **From the surface, US ag looks incredibly successful.**
  - Since the 1940s, outputs have more than doubled while inputs have remained constant.



The Future of Agriculture

- **However, there are also clear concerns:**
  - We need to produce 70% more food by 2050 using 250 million fewer acres of farmland.
  - Conventional ag production in the US is not suitable for changing climate conditions (esp. the increased risk of flooding and drought).
  - Agriculture is also the primary source of water contamination in the US.
  - Only 2-10% of US farmland is cultivated using fully-sustainable soil management practices.
  - This is causing a rate of soil erosion 10x greater than what is sustainable.

- **Rural agricultural populations also face significant disparities in health, education, and economics.**
  - E.g. over 50% of gross farm income in the US went to the largest 5% of farming operations.
  - Farm bankruptcy rates increased 20% in 2019.

The Purpose of Ag Ed?

- **Why does agricultural education exist? Are we primarily trying to…**
  - A. Continue to create the agriculture industry as it currently exists over and over?
  - B. Enable our students to recognize that agriculture urgently needs changing?
  - C. Prepare our students make these changes as future agriculturalists?

In This Presentation…

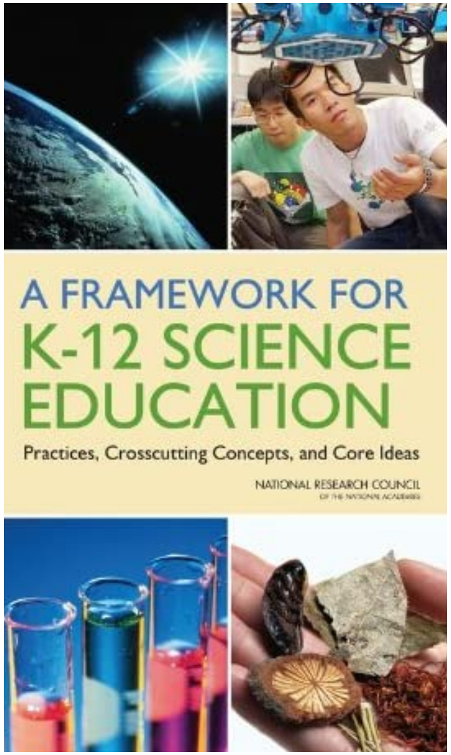
- **Overall Objective:** How can we design agricultural education to enable more informed & sustainable decision-making?

- **Presentation Outline:**
  1. Summary of research in science education.
  2. Overview of our research-based agriscience curriculum.
  3. Applications in your own classrooms.

Framework for K12 Science Education
&
The Next Generation Science Standards

Framework for K-12 Science Education

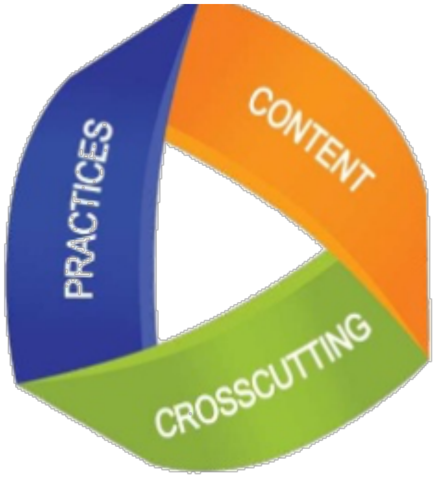
- **In the late 2000s, a wide body of research indicated that there were problems with traditional K12 science in the US.**
  - K12 science was not sufficiently preparing students for careers or for informed decision-making.
  - This posed significant risks to the United States.
- **The National Research Council published the *Framework for K12 Science Ed* in 2012.**
  - A consensus of decades of rigorous investigation in K–12 science & engineering
  - Summarizes how students learn science in a manner that results in informed decision-making (Schwarz, et al., 2016).
  - The science standards of 44 states are based on the *Framework*.

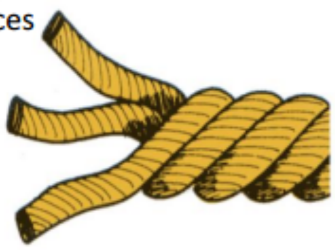


Next Generation Science Standards (NGSS)

- **In 2013, a state-led initiative used the findings of the *Framework* to create a set of internationally-benchmarked science education standards.**
  - These became known as the *Next Generation Science Standards (NGSS)*.

- **The Framework and NGSS both argue that effective science education must be three dimensional, or composed of three interconnected components.**
- **These components include:**
  1. Disciplinary Core Ideas (*what scientists know*).
  2. Science & Engineering Practices (*what scientists do*).
  3. Crosscutting Concepts (*how scientists think*).





What Scientists Do
Science and Engineering Practices

1. Asking Questions (for science) and Defining Problems (for engineering)
2. Developing and Using Models
3. Planning and Carrying Out Investigations
4. Analyzing and Interpreting Data
5. Using Mathematics and Computational Thinking
6. Constructing Explanations (for sci) and Designing Solutions (for eng)
7. Engaging in Argument from Evidence
8. Obtaining, Evaluating, and Communicating Information

What Scientists Know
Disciplinary Core Ideas

PHYSICAL SCIENCES
PS1: Matter and Its Interactions
PS2: Motion and Stability: Forces and Interactions
PS3: Energy
PS4: Waves and Their Applications in Technologies for Information Transfer

LIFE SCIENCES
LS1: From Molecules to Organisms: Structures and Processes
LS2: Ecosystems: Interactions, Energy, and Dynamics
LS3: Heredity: Inheritance and Variation of Traits
LS4: Biological Evolution: Unity and Diversity

EARTH AND SPACE SCIENCES
ESS1: Earth's Place in the Universe
ESS2: Earth's Systems
ESS3: Earth and Human Activity

ENGINEERING, TECHNOLOGY, AND APPLICATIONS OF SCIENCE
ETS1: Engineering Design
ETS2: Links Among Engineering, Technology, Science, and Society

How Scientists Think
Crosscutting Concepts

1. Patterns
2. Cause and Effect: Mechanisms and Explanation
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter: Flows, Cycles, and Conservation
6. Structure and Function
7. Stability and Change

What is 3D science instruction?

- **3D science instruction emphasizes ‘figuring out’, not ‘learning about’.**
  - In other words, sense-making and reasoning are prioritized over memorizing rote content.
  - Students must use both knowledge and practice to explain phenomena and design solutions.

- **For example, in a traditional biology unit, students might *learn about* photosynthesis.**
  - However, in 3D science, students would *figure out* how plants make their own food.

3D Science vs. Traditional Science

3D Science

1. **Anchored by driving questions about phenomena.**
2. **Minimal emphasis on learning facts and/or procedures.**
3. **Max emphasis on reasoning & sense-making skills.**
4. **Sci/Eng Practices are used throughout a unit (vs. a one-time stand-alone lab).**
5. **Content, practices, and reasoning are seamlessly assessed together.**
6. **Learning is relevant to lives of all students.**

Traditional Science

1. Emphasizes learning maximal amounts of content.
2. Max emphasis on memorization of facts.
3. Minimal intentional inclusion of reasoning & sense-making.
4. If Sci/Eng Practices are included, they're separate from learning content.
5. Assessment primarily focuses on memorization of content.
6. Learning is irrelevant to some or even most students' lives.

Examples of 3D Assessment

- **Assessing 3D science learning looks very different from traditional multiple choice tests. Examples include:**

- **Generating Evidence**: "*What are three things you should measure in soil to determine its suitability for crop production? Explain your reasoning for your choices.*"

- **Applying Evidence to Claims**: "*The following graph shows how dissolved oxygen is affected by water temperature. Explain how runoff from a hot parking lot may affect the ecological health of a nearby stream.*"

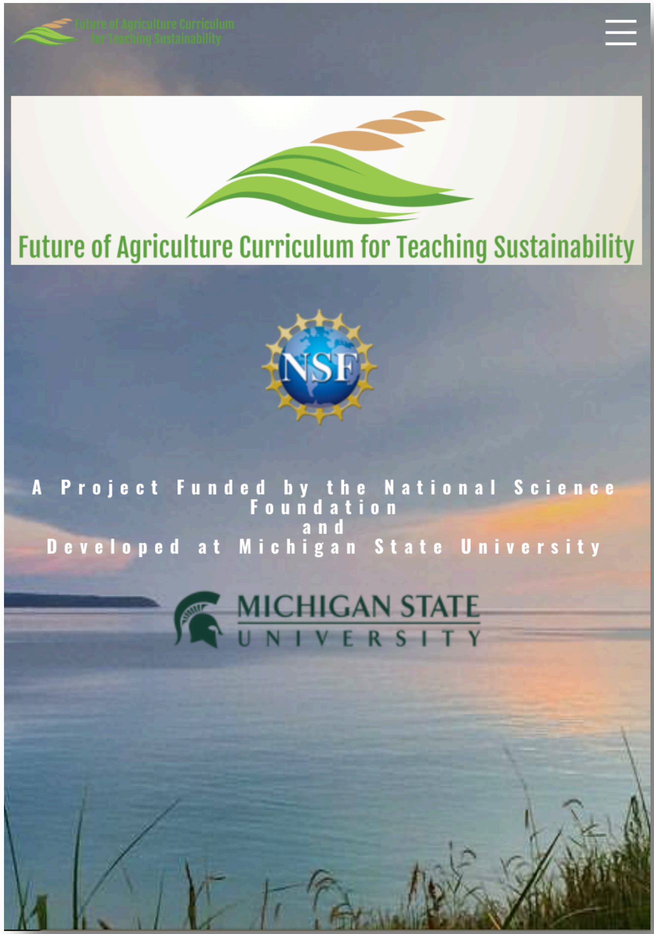
- **Reasoning About Validity of Claims of Others**: "*Evaluate the accuracy of the following statements about how CO2 levels relate to precipitation patterns. Explain your stances with evidence and reasoning.*"

Future of Agriculture Curriculum for Teaching Sustainability (FACTS)

Future of Agriculture Curriculum for Teaching Sustainability

Intro to *F.A.C.T.S.*

- **FACTS is a 2-semester high school agriscience curriculum.**
  - Includes both Natural Resources & Horticulture courses.
  - Aligned to both NGSS & AFNR
  - SAEs are explicitly incorporated into the curriculum.
  - It is freely available online (factsnsf.org).



FACTS History

- **This is part of a 5^+ year MSU research project funded by the National Science Foundation.**
  - The key goal is to maximize the adoption of more informed and more sustainable practices among future agriculturalists.
  - This includes education & social science research.
- **We use Design-Based Research.**
  - This means that we partner with teachers to test and refine the curriculum in actual classrooms.
  - We also work directly with agriculturalists and agricultural scientists in the field.
- **This work is ongoing.**
  - The curriculum is far from finished, and is continuously being revised and improved as new findings emerge.

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FACTS 5-Day Structure

- **Most FACTS units follow a consistent structure:**
  - Day 1 – Case Study Data & Model Development
  - Day 2 – Scaffolded Core Instruction & Model Revision
  - Day 3 – Collaborative Investigation & Model Testing
  - Day 4 – Review & Assessment
  - Day 5 – Career & Community Connections
- **Unit sections end with authentic assessments in real-world contexts over multiple days.**

Future of Agriculture Curriculum for Teaching Sustainability

Week 8 Habitat Loss

Oct 22-26

Monday: Data Dive & Model Development (*Weekly Packet -* *Word* / *PDF*)

Tuesday: Notes (PPT / PDF) & Class Discussion

Wednesday: Lab Activity (*see packet*)

Thursday: Assessment

Friday: Career Connections - Cover Letters (*SCE Packet -* Word/PDF)

Week 9 Invasive Species

Oct 29-Nov2

Monday: Data Dive & Model Development (*Weekly Packet -* *Word* / *PDF*)

Tuesday: Notes (PPT / PDF) & Class Discussion

Wednesday: Lab Activity (*see packet*)

Thursday: Assessment

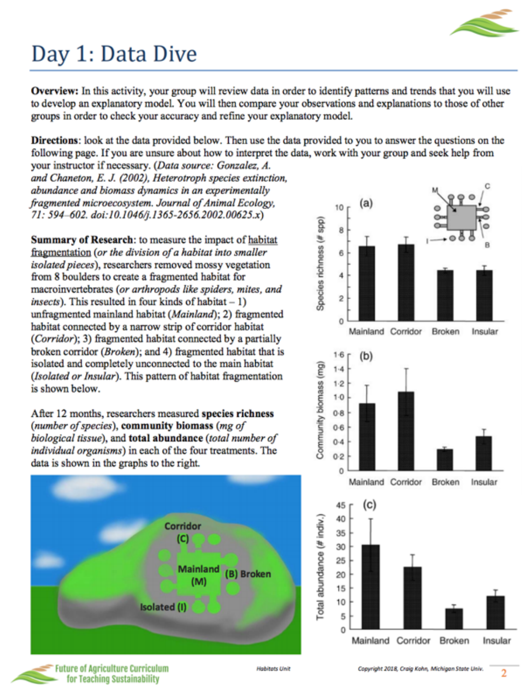
Friday: Career Connections - Peer Reviews of Resumes & C

(*SCE Packet -* Word/PDF)

Example Unit: Habitat Loss

- **Section 2, Unit 2: Habitat Loss**
  - Occurs after the *Atoms to Ecosystems* section.
  - Occurs after the Extinctions Intro unit.

- **Unit Structure**
  - Day 1: Data Dive - Gonzalez and Chaneton (2002)
  - Day 2: Island Biogeography Model
  - Day 3: Habitat Risk Assessment
  - Day 4: Assessment
  - Day 5: Career Connections



Day 1: Data Dive

Overview: In this activity, your group will review data in order to identify patterns and trends that you will use to develop an explanatory model. You will then compare your observations and explanations to those of other groups in order to check your accuracy and refine your explanatory model.

Directions: look at the data provided below. Then use the data provided to you to answer the questions on the following page. If you are unsure about how to interpret the data, work with your group and seek help from your instructor if necessary. (*Data source: Gonzalez, A. and Chaneton, E. J. (2002), Heterotroph species extinction, abundance and biomass dynamics in an experimentally fragmented microecosystem. Journal of Animal Ecology, 71: 594–602. doi:10.1046/j.1365-2656.2002.00625.x*)

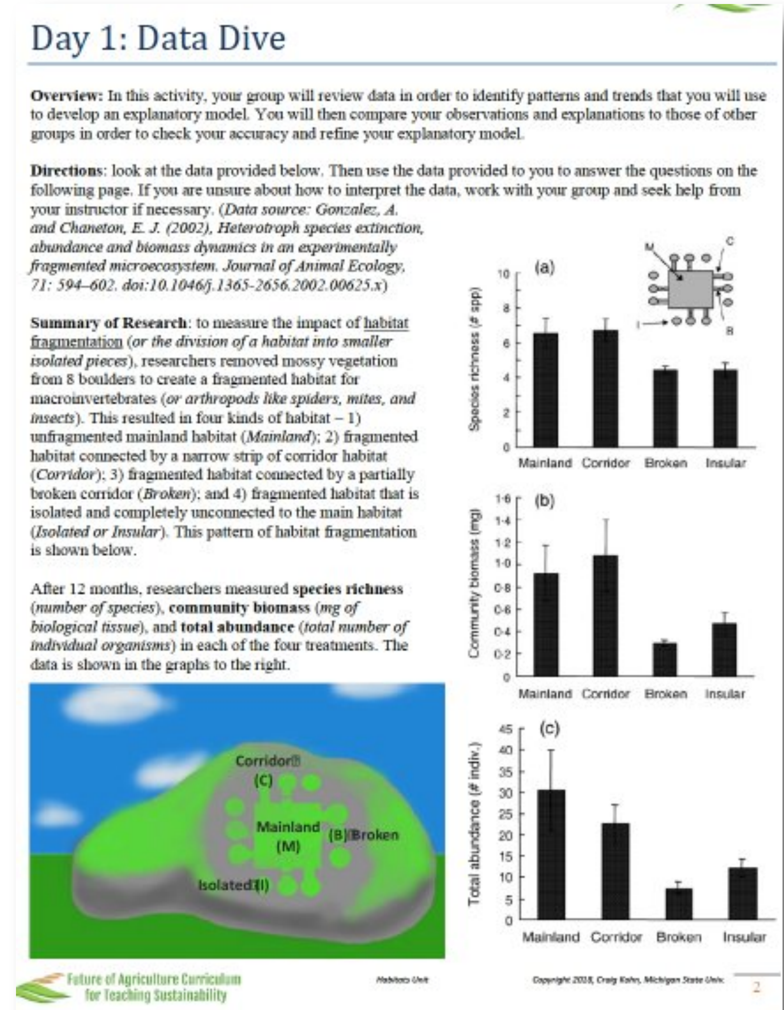
Summary of Research: to measure the impact of habitat fragmentation (*or the division of a habitat into smaller isolated pieces*), researchers removed mossy vegetation from 8 boulders to create a fragmented habitat for macroinvertebrates (*or arthropods like spiders, mites, and insects*). This resulted in four kinds of habitat – 1) unfragmented mainland habitat (*Mainland*); 2) fragmented habitat connected by a narrow strip of corridor habitat (*Corridor*); 3) fragmented habitat connected by a partially broken corridor (*Broken*); and 4) fragmented habitat that is isolated and completely unconnected to the main habitat (*Isolated or Insular*). This pattern of habitat fragmentation is shown below.

After 12 months, researchers measured **species richness** (*number of species*), **community biomass** (*mg of biological tissue*), and **total abundance** (*total number of individual organisms*) in each of the four treatments. The data is shown in the graphs to the right.

Future of Agriculture Curriculum for Teaching Sustainability   Habitats Unit   Copyright 2018, Craig Kohn, Michigan State Univ.   2

FACTS Models & Argumentation

- Each week utilizes case studies featuring authentic data from real-world considerations.
- Students are coached in using data to develop explanatory models in small groups.
- These models are then connected to localized AFNR scenarios.



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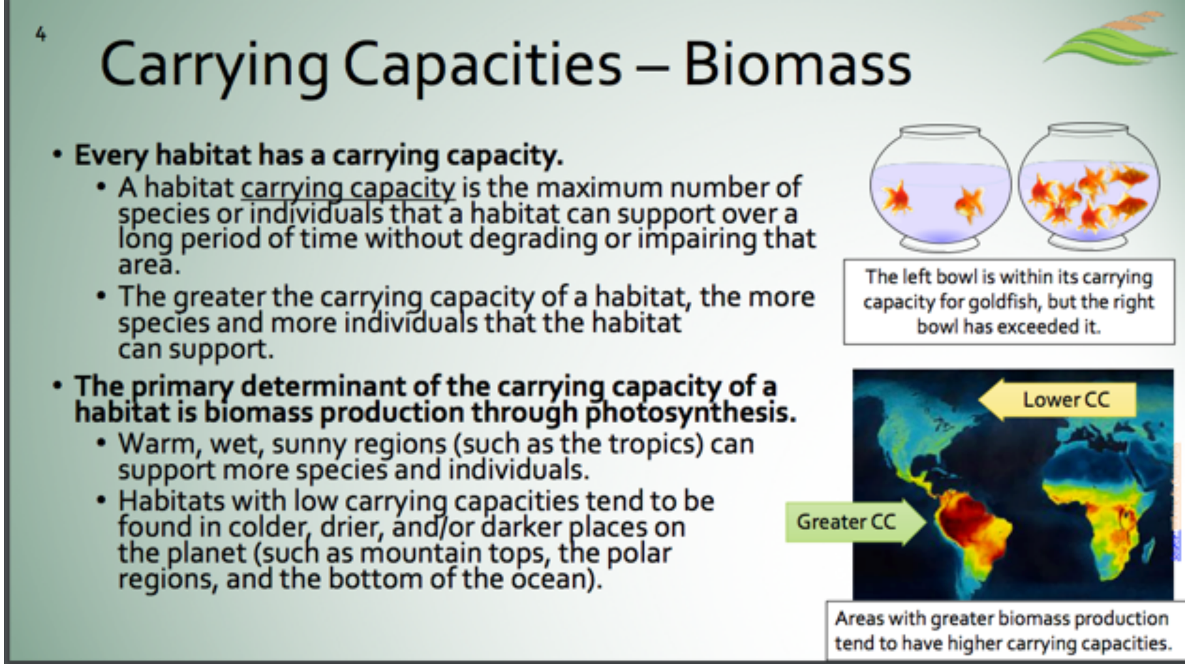
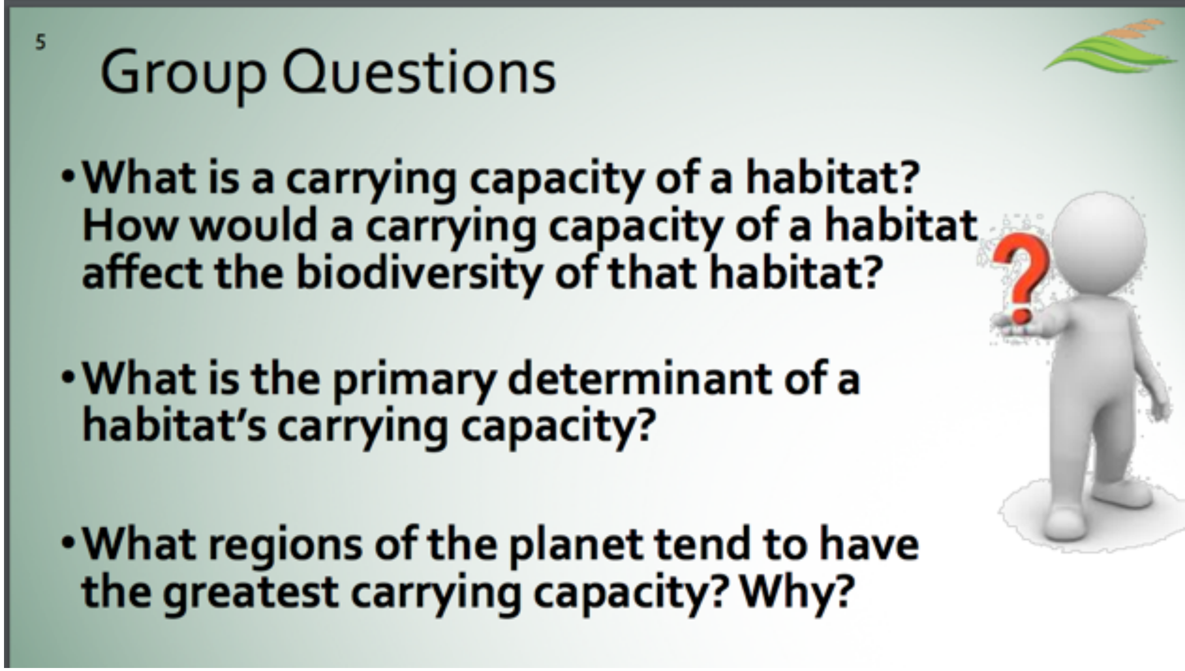
Future of Agriculture Curriculum for Teaching Sustainability

- FACTS supports students as they engage in reasoning and sense-making.
- The curriculum provides students with a “*sense-making toolkit*” that help them to develop clear connections across ideas, practices, and concepts.

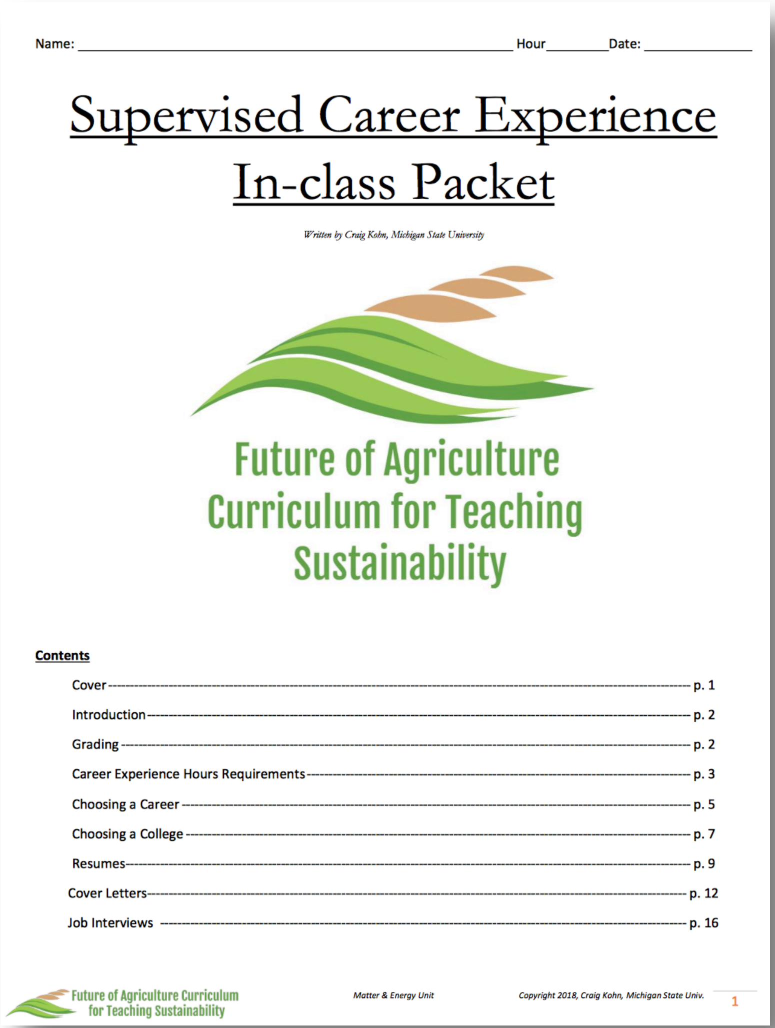




FACTS & SAEs

- **FACTS uses SAEs as a graded component of the instruction.**
  - Science learning must be place-based and authentic to be impactful.
- **FACTS utilizes the Supervised Career Experience packet* to guide students in their SAEs:**
  - Each student shadows community professionals for 15+ hours and develops a college & career portfolio.
  - These experiences also support classroom discussion and student reasoning about course topics.

**Piloted as part of the National Council for Ag. Education's SAE for All campaign*



Name: ______ Hour______Date: ______

Supervised Career Experience

In-class Packet

Written by Craig Kohn, Michigan State University

Future of Agriculture Curriculum for Teaching Sustainability

Contents

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Matter & Energy Unit

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Providing 3D Science in Your Classrooms

3 things you can do now

- **Assess your own curriculum.**
  - Is your curriculum and instruction more about "*learning about*" or "*figuring out*"?
  - Consider auditing your curriculum with the NGSS Lesson Screener.
- **Start identifying courses that are easiest to transition to 3D science learning.**
  - Some are easier than others.
- **Try changing one lesson.**
  - It is often best to adopt NGSS slowly – this is hard!
  - This allows you to adjust to an entirely new way to teach over time.

3 things you can do over time

- **Replace traditional curriculum with NGSS-aligned materials.**
  - Be careful – many curricula claim to be NGSS aligned but are not.
- **Form groups to share effective resources.**
  - Email listservs, district inititatives, NAAE Communities of Practice, etc. are all great options.
  - Consider partnering with your science dept.
- **Seek out additional training.**
  - NGSS is still relatively new; lots of opportunities are available, especially from NSTA.
  - Consider partnering with university faculty – often additional funds are available for this.

Questions to ask yourself.

1. **Is this lesson more "figuring out" or "learning about"?**
2. **Which does this emphasize more: reasoning & sense-making, or memorization and repetition?**
3. **Am I assessing both knowledge and practice, or just knowledge?**
4. **Are my students more prepared to create improved conditions, or to continuously recreate the conditions that currently exist?**

Please visit our website: www.factsnsf.org

Questions? Email me – kohncrai@msu.edu

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Works Cited

- Bransford, J. D., & Schwartz, D. L. (1999). Rethinking Transfer: A Simple Proposal with Multiple Implications. *Review of Research in Education*, *24*, 61. https://doi.org/10.2307/1167267
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18*(1), 32–42. https://doi.org/10.3102/0013189X018001032
- Engle, R. A., & Conant, F. R. (2002). Guiding Principles for Fostering Productive Disciplinary Engagement: Explaining an Emergent Argument in a Community of Learners Classroom. *Cognition and Instruction*, *20*(4), 399–483. JSTOR.
- Gee, J. P. (2004, December 13). *Language in the Science Classroom: Academic Social Languages as the Heart of School-Based Literacy*. Establishing Scientific Classroom Discourse Communities. https://doi.org/10.4324/9781410611734-7
- Kim, P., Suh, E., & Song, D. (2015). Development of a design-based learning curriculum through design-based research for a technology-enabled science classroom. *Educational Technology Research and Development*, *63*(4), 575–602. https://doi.org/10.1007/s11423-015-9376-7
- National Research Council (U.S.) (Ed.). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press.
- NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.* National Academies Press.

Research Basis

- **In addition to the *Framework*, FACTS curriculum was designed using findings from highly-cited research publications.**
- **Some of these include:**
  - Lave & Wenger (1991): Communities of Practice
  - Bransford & Schwarz (1999): Preparation for Future Learning.
  - Engle & Conant (2002): Productive Disciplinary Engagement
  - Brown, Collins and Duguid (1989): Cognitive Apprenticeships
  - Gee (2005): Science Social Languages