Real-World Engineering Problem-Solving in the High School Curriculum

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Research Experiences for Teachers: Connecting with Community Colleges

- Research
- Connect
- Recruit
2013-Project Components

• Develop **pedagogical modules** based on Understanding by Design (UbD) and Universal Design for Learning (UDL) for our college

• Research Project
  – Develop Lesson plans for an online mathematics course
    • Intended for Veterans
    • Emphasis on energy applications using the design process
  – Identify the students’ deficiencies in the pre/post tests as they relate to the lesson plans and map to the lesson plans
Sources & Data

• **Course:** BIOE 100 Mathematics for Engineering Applications

• **Textbook:** Introductory Mathematics for Engineering Applications by K. S. Rattan and N. W. Klingbeil

• **Data and Resources:**
  – Instructor’s notes
  – Wright State University
Engineering Mathematics Topics

Engineering Applications in:

- Linear and Quadratic Equations
- Trigonometry and Sinusoids
- 2-D Vectors
- Complex Numbers
- Systems of Linear Equations
- Derivatives & Integrals
- Differential Equations
Goals for Offering the Course at HS

• To provide the opportunity for students who had shown an interest in engineering from a diversified body.

• To engage in a rigorous college prep math course, with engineering applications, to help ensure academic success in college.
Demographics

- **Population**
  - 3 HS from Washington DC and Maryland to target under-represented and diversified students

- **Student Mathematics Background**
  - AP Calculus (Majority)
  - Pre-Calculus (Some)
  - Honors Algebra II (Rare)
HS Instructional Activities

• 16 week sessions
• 4 hours per week
  – 3 hours lecture
  – 1 hour laboratory

• MATLAB routine incorporated for engineering applications
All 10 senior students in Fall 2012 Class pursued post high school education:

- 2 Montgomery College
- 5 UMD-College Park
- 3 at other 4 year institutions
Summer 2013

• Redesign the course based on UbD and UDL strategies
• Develop lesson plans for an online engineering mathematics course
  – Intended for Veterans
  – Emphasis on energy
Approach: *Traditional Learning*?
Or: Learning by Design?

CREATE

ASK

LEARN

IMPROVE

PLAN
Understanding by Design (UbD) Strategy

- **Stage 1: Desired Results Identify the Main Goals**
  - Desired Understandings
  - Essential Understandings
- **Stage 2: Assessment**
  - Evidence Performance Tasks
- **Stage 3: Learning Activities**
Universal Design for Learning (UDL)

Are there multiple ways these stages might be represented?

• Representation
  – Visualization, manipulation, activities, review...

• Action and Expression
  – Activities, multiple assessments, assistive technologies

• Engagement
  – Collaboration & community, self reflection
Sample UbD Plan: Established Goals

Topic: Vectors in Engineering

Goal: Relate and use the concept of vectors to model engineering problems such as: kinematic motion, forces, electric fields and momentums.
Stage I-A: Desired Understandings

Students will:

• Use vectors to represent quantities as they relate to their directions and their position in a 2-D Cartesian Plane

• Relate trigonometric functions to vectors in the plane

• Graph the polar presentation of vectors

• Perform Operations on vectors
Stage I-B: Essential Understandings

• Trigonometric functions and basic identities
• Kinematic motion
• Laws of sines and cosines
• Polar coordinates
• Angular (rotational) displacement
Stage II-A: Performance Tasks

• Apply Pythagorean theorem both graphically and algebraically
• Explain and show operations on vectors geometrically
• Introduce the position vectors geometrically and using trigonometry
• Use vectors in engineering problems such as Static Equilibrium and Force problems
Stage II-B: Assessment Plan for the Essential and Desired Knowledge

• Pretest the student’s knowledge of pre-requisite skills (Essentials)
• Class discussions, activities and worksheets, group and individual assignments
• Use a computing device for visualizations, modeling and computation
• Stress the skills that students demonstrated deficiencies from the pretest through the lesson
• Post-test on Desired Knowledge
Stage III: Learning Plan

- Worksheets
  - graphical, numerical, and algebraic approaches
- Incorporate Universal Design for Learning (UDL) throughout lesson and assessments
- Technology
- Open online resources
  - Khan Academy
Reaction to the Course

• Course
  – An effective way of teaching applied mathematics to the students majoring in engineering

• Textbook
  – A good reference book
  – Needs accompanying study/teaching guides and supplemental materials
Pre-Post Tests Comparison

Interpretation

• There was improvement but...
  – Improvement was not always statistically significant
  – Applications: Yes
  – Skills: No but this was not a skills course

• Is there a need to refine the assessment tool(s)?
Recommendations for Improvement

• Use show work format (give partial credit)
• Pretest:
  – Skills reflecting the essential understandings
• Post test:
  – Include skills from the pretest where students showed deficiencies
  – Application problems reflecting the main learning objectives (Desired Understandings)
Accomplishments

• Contributed to the developing effort on a new online engineering mathematics course intended for Veterans
• Learned many engineering applications to incorporate in my classes
• Enhanced my skills in using UbD and UDL in teaching
Acknowledgement

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• Ms. Toby Ratcliffe (BioE100 teacher)
• Dean Deborah Wrobel (Harford CC)
HANDOUTS
### Understanding By Design — Backwards Design Process
(Developed by Grant Wiggins and Jay McTighe, 2002)
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#### Stage 1 – Desired Results

**Content Standard(s):**
- [Comes from professional standards in your field]

**Understanding (s)/goals**
Students will understand that:
- [this is a goal, not an objective.
  List the big ideas or concepts that you want them to come away with, not facts that they must know]

**Essential Question(s):**
- [What leading questions can you ask of students to get them to understand the Big Ideas?]
- [Address the heart of the discipline, are framed to provoke and sustain students interest; unit questions usually have no one obvious “right” answer]

**Student objectives (outcomes):**
Students will be able to:
- [These are observable, measurable outcomes that students should be able to demonstrate and that you can assess. Your assessment evidence in Stage 2 must show how you will assess these.]
- [Your learning activities in Stage 3 must be designed and directly linked to having students be able to achieve the understandings, answer the essential questions, and demonstrate the desired outcomes]

#### Stage 2 – Assessment Evidence

**Performance Task(s):**
- [Authentic, performance based tasks that have students apply what they have learned and demonstrate their understanding.]
- [designed at least at the application level or higher on Bloom’s Taxonomy.]
- [Rubrics can be used to guide students in self-assessment of their performance]

**Other Evidence:**
- [includes pre-assessment, formative assessment, and summative assessment evidence]
- [Can be individual or group based]
- [Can include informal methods (such as thumbs up, thumbs down, and formal assessments, such as quiz, answers to questions on a worksheet, written reflection, essay]

#### Stage 3 – Learning Plan

**Learning Activities:**
- [This is the core of your lesson plan and includes a listing describing briefly (usually in bullet or numbered form so easy to follow) what:
  - the students will do during the class to prepare them for the outcomes you expect of them.]
  - the teacher will do to guide the learning]
Universal Design for Learning Strategy

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Three Primary Brain Networks

- Recognition Network
  - supported by Multiple Means of Representation
- Strategic Network
  - supported by Multiple Means of Expression
- Affective Network
  - supported by Multiple Means of Engagement

Universal Design for Learning Guidelines

I. Provide Multiple Means of Representation
1. Provide options for perception
2. Provide options for language, mathematical representation, and symbols
3. Provide options for comprehension
4. Provide options for resources
5. Provide options for engagement

II. Provide Multiple Means of Action and Expression
6. Provide options for physical action
7. Provide options for communication
8. Provide options for executive functions

III. Provide Multiple Means of Engagement
9. Provide options for sustained effort and persistence
10. Provide options for self-regulation

Ressourceful, knowledgeable learners
Strategic, goal-directed learners
Purposeful, motivated learners

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