HIGH SCHOOL APPROPRIATE ENGINEERING CONTENT KNOWLEDGE IN THE INFUSION OF ENGINEERING DESIGN INTO K-12 CURRICULUM: STATICS

NCETE Core 4 Research Paper

NCETE Core 4 - Engineering Design in STEM Education, Spring 2009

College of Education, University of Georgia

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Student: **Edward Locke** (edwardnlocke@yahoo.com)

Appendix 1:

Proposed Model for Infusing Engineering Design into K-12 Curriculum

Everyday Products: Best Engineering Design Concept Exposure

→

A **Streamlined**, **Systematic** & **Cohesive**

K-12 Through University Engineering Education

Strictly Matching Students'

Stages of Cognitive Development

Four-Stage Curriculum Model
For Incorporating
Engineering Design
Into K-12 Engineering & Technology Education Program

Presenter:

Edward Locke

Sponsor:

John Mativo

General Guidance For The Proposed Model

Constructive Philosophy (Dr. Roger Hill, 2006)

- **General education role:**
  "Technology education should retain a general education role, providing hands-on learning activities for all students and encompassing approaches to design and problem-solving that extends beyond engineering to embrace aesthetics and artistic creativity."

- **Change in technology teacher education necessary:**
  "Implementing an engineering design emphasis in technology education would also require changes in technology teacher education courses."

→

The Proposed Model

Implements **engineering design** as a part of **general education** curriculum.

Defines needed **changes** to implement engineering design in K-12 **technology teacher education courses.**

Critical Advice (Dr. Robert Wicklein & Dr. Jay Rojewski, 1999)

- **Lack of mental process training:**
  "In order to solve technological problems one must develop appropriate intellectual methods and processes. […]. the mental processes and techniques used in solving technological problems could remain rather consistent over time."

- **Inconsistent delivery:**
  "Often, curriculum developers in technology education start out to create state-of-the-art instructional activities, only to find that their curriculum materials are out of date soon after they are published."

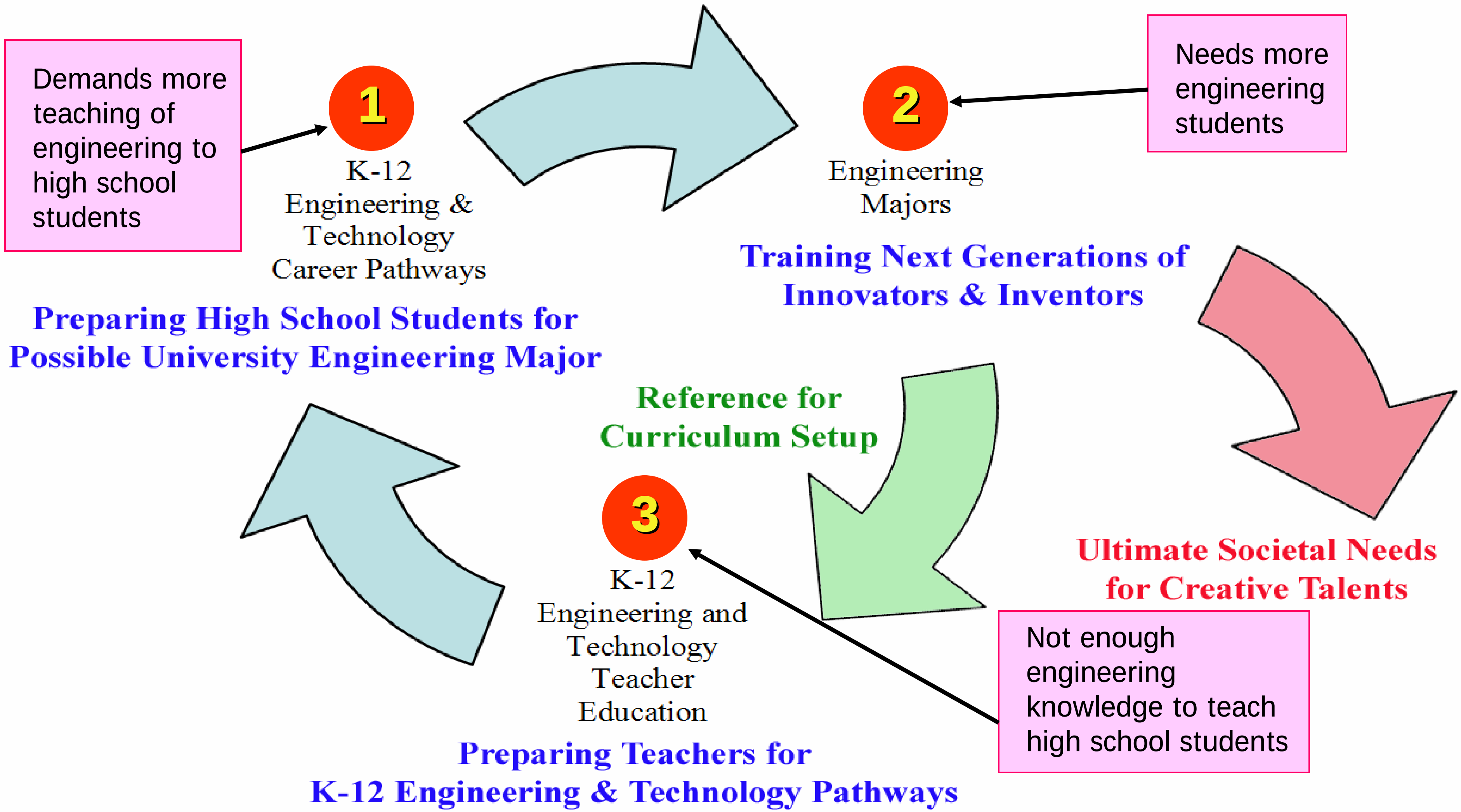
→

Focuses on an incremental engineering design **mental process** for a regular K-12 engineering & technology curriculum.

Offers a **stable framework** for future K-12 Engineering & Technology curriculum, while incorporating **state-of-the-art instructional activities.**

Rationale for The Proposed Model

Current Discrepancies Among Three Institutional Expectations on Engineering & Technology Education



The Proposed Model

For Future
B.S. in Engineering & Technology Teacher Education Program

A Renovated Curriculum

Louisville, Kentucky
ITEA
2009

Three Components for Infusing Engineering Design into K-12 Technology Teacher Education Programs

Inclusion of Engineering Design
Into B.S. K-12 Engineering and Technology Teacher Education Program

Basic Engineering Analysis
(K-12 appropriate Statics & Dynamics, Mechanism, Material Science, Strength of Materials, etc.)

Engineering Design "Capstone"
(Design process: engineering design proposal, analysis, prediction and simulation, notebook and portfolio, etc.)

Engineering Design Pedagogy
(For teaching engineering analytic skills and design process, and developing curriculum

A

B

C

The Proposed Bachelor's of Science Program in K-12 Engineering and Technology Teacher Education

General Core →

Math & Science →

GENERAL CORE COURSES

Area A - Essential Skills - 9 Hours

English – 6 Hours

ENGL 1101 - English Composition I	3 hrs
ENGL 1102 - English Composition II	3 hrs

Math – 3 Hours

Math 1113 - Precalculus	3 hrs

Area B – Institutional Options – 4-5 Hours

No change from existing program.	4-5 hrs

Area C – Humanities/Fine Arts – 6 Hours

No change from existing program.	6 hrs

Area D – Science, Mathematics and Technology – 23 Hours

Math – 11 Hours

Math 2250 - Calculus I for Science and Engineering (Differentiation)	4 hrs
Math 2260 - Calculus II for Science and Engineering (integration)	4 hrs
Math 3000 - Introduction to Linear Algebra	3 hrs

Physics – 8 Hours

Physics 1111-1111L - Introductory Physics (Mechanics, Waves, Thermodynamics)	4 hrs
Physics 1112-1112L - Introductory Physics (Electricity and Magnetism, Optics, Modern Physics)	4 hrs

Chemistry – 4 Hours

Chemistry 1211-1211L - Freshman Chemistry I and Lab	4 hrs

The Proposed Bachelor's of Science Program in K-12 Engineering and Technology Teacher Education

General Core

Area E – Social Sciences - 12 Hours	
No change from existing program.	12 hrs
Area F Course Related to Major – 10 Hours	
EDUC 2120 - Exploring Socio-Cultural Perspectives on Diversity	4 hrs
EPSY 2130 - Exploring Learning and Teaching	3 hrs
EDIT 2000 - Computing for Teachers	3 hrs
Basic Physical Education	1 hr
Total General Core Hours	**65-66 hrs**

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The Proposed Bachelor's of Science Program in K-12 Engineering and Technology Teacher Education

Add new course/content: Engineering Digital Simulation Technology →

Engineering Foundation →

Engineering Pedagogy →

MAJOR COURSES

College of Education Requirements

K-12 Engineering and Technology Education Area of Emphasis Requirements – 54 Hours

Foundation Engineering and Technology Requirements – 36 Hours

Engineering and Technology – 30 Hours

ETES 5010&5100 - Appropriate Engineering & Tech in Society	4 hrs
ETES 5020A - Technical Design Graphics: 2D Drafting	3 hrs
ETES 5060 - Energy Systems	3 hrs
ETES 5070 - Research and Experimentation in Tech Studies	3 hrs
ETES 5090A - Principles of Technology I: Statics and Dynamics	4 hrs
ETES 5090B - Principles of Technology II: Strength of Materials and Material Selection	4 hrs
ETES 5040 - Construction Systems	3 hrs
ENGR 2110 - Engineering Decision Making	3 hrs
ETES 5140/7140 - Laboratory Planning, Management, and Safety	3 hrs

Engineering and Technology Curriculum Development – 6 Hours

ETES 5020 - Communication Systems	3 hrs
ETES 2320 - Creative Activities for Engineering Tech Teachers	3 hrs

The Proposed Bachelor's of Science Program in K-12 Engineering and Technology Teacher Education

Engineering Major →

Engineering Design →

Engineering Analysis and Technology Options: - 12 Hours

Additional options could be developed according to needs. Each student is required to choose one Option of 3 courses from the following:

Mechanical Design Option - 12 Hours

ETES 5020B - Technical Design Graphics: 3D Solid Modeling and Design	3 hrs
ETES 5090C - Principles of Technology III: Fluid Mechanics & Aerodynamics	3 hrs
ETES 5090D - Principles of Technology IV: Heat Transfer & Thermodynamics	3 hrs
ETES 5090E - Mechanism Design & Selection	3 hrs

Manufacturing System Option - 9 Hours

ETES 5030/7030 - Manufacturing Systems	3 hrs
ETES 5090F - Robotics and Automatic Systems	3 hrs
ETES 5090G - Production Enterprises	3 hrs

Electrical and Electronics Option - 9 Hours

ETES 5090H - Foundations of Electronics	3 hrs
ETES 5090I - Advanced AC and DC Circuits	3 hrs
ETES 5090J - Digital Electronics	3 hrs

Capstone Engineering Design Courses – 6 Hours

ETES 5110A/7110A - Engineering Design I	3 hrs
ETES 5110B/7110B - Engineering Design II	3 hrs

K-12 Engineering and Technology Education Area of Emphasis Subtotal — 57 hrs

The Proposed Bachelor's of Science Program in K-12 Engineering and Technology Teacher Education

Engineering Pedagogy →

The K-12 Engineering and Technology Teacher Education Requirements – 15 Hours

EOCS 2450 – Practicum in K-12 Engineering and Technology	I	1 hr
EOCS 3450 – Practicum in K-12 Engineering and Technology	II	2 hrs
ENGR 1920 - Introduction to Engineering		2 hrs
EOCS 4350 - Curriculum Planning in K-12 Engineering and Technology Studies		3 hrs
EOCS 2450 – Instructional Strategies in K-12 Engineering and Technology Studies		3 hrs
EOCS 5550 Students w/ Special Needs in Progr. of Occupational Studies		3 hrs

Total Teacher Education Hours **14 hrs**

TOTAL SEMESTER HOURS REQUIRED FOR GRADUATION
130-132 HOURS

Note:
Under the proposed program, the total number of science, engineering analysis and design courses is 22; and the total semester hours is 74 (57% of the total semester hours required for graduation):

Area D – Science, Mathematics and Technology	**6 Course**	**23 Hours**
K-12 Engineering and Technology Education Area of Emphasis Requirements	**16 Courses**	**51 Hours**

Proposed B.S. Degree in K-12 Engineering & Technology Teacher Education

Curriculum Flow Charts

General Notes:

1st, 2nd and 4th years share same courses across all Options (or "Majors"); 3rd year varies in 3-4 courses due to different Options of Engineering Pathways or "Majors."

Mechanical Design Option (129-135 Hrs)

1st Year

Spring
- ENGL 1101 - English Composition I (3)
- Math 3000 - Introduction to Linear Algebra (3) ①
- Math S** - Beginning Calculus (4) ②
- Physics 1111-1111L - Introductory Physics (Mechanics, Waves, Thermodynamics) (4)

Summer
- SPCM 1100 - Introduction to Public Speaking (3)
- POLS 1101 - American Government (3)
- HIST 2112 - American History Since 1865 (3)
- Basic Physical Education (1)

Fall
- ENGL 1102 - English Composition II (3)
- Chemistry 1211-1211L - Freshman Chemistry I and Lab (4)
- Physics 1112-1112L - Introductory Physics (Electricity & Magnetism, Optics, Modern Physics) (4)
- ENGR 1920 - Introduction to Engineering (2)

2nd Year

Spring
- ENGR 2110 - Engineering Decision Making (3)
- ARGD 3010 - Design Drawing Techniques (Perspective Drawing) (3) ③
- ETES 5090A - Principles of Technology I: Statics and Dynamics (4)
- ETES 5020A - Technical Design Graphics: 2D Drafting (3)

Summer
- PSYC 1101 - Elementary Psychology (3)
- ECON 2106 - Principles of Microeconomics (3)
- EDUC 2120 - Exploring Socio-Cultural Perspectives on Diversity (4)

Fall
- EDIT 2000 - Computing for Teachers (3)
- ETES 5070 - Research and Experimentation in Tech. Studies (3)
- ETES 5090B - Principles of Tech. II: Material Strength/Selection (4)
- Area B - Institutional Options (4-5)

3rd Year

Spring
- ETES 5020B - Tech Design Graphics: 3D Solid Modeling/Design (3) ④
- ETES 5090C - Principles of Technology III: Fluid Mechanics & Aerodynamics (4)
- ETES 5060 - Energy Systems (3)
- ETES 5020 - Communication Systems (3)

Summer
- ETES 5010&5100 - Appropriate Engr. & Technology in Society (4)
- ETES 2320 - Creative Activities for Engr. & Tech Teachers (3)
- EPSY 2130 - Exploring Learning and Teaching (3)

Fall
- ETES 5090D - Principles of Technology IV: Heat Transfer & Thermodynamics (4)
- ETES 5090E - Mechanism Design & Selection (3)
- ETES 5090H - Electronics Circuitry & Component Selection (3)
- ETES 5030/7030 - Manufacturing Systems (3)

4th Year

Spring
- ETES 5110A/7110A - Engineering Design I (3)
- EOCS 5550 Students w/ Special Needs in Progr. of Occupational Studies (3)
- EOCS 2450 – Practicum in K-12 Engineering and Technology I (1)
- ETES 5040 - Construction Systems (3)

Summer
- EOCS 2450 – Instructional Strategies in K-12 Engineering and Technology Studies (3)
- EOCS 4350 - Curriculum Planning in K-12 Engineering and Technology Studies (3)

Fall
- ETES 5110B/7110B - Engineering Design II (3)
- EOCS 3450 – Practicum in K-12 Engineering and Technology II (2)
- ETES 5140/7140 - Laboratory Planning, Management, and Safety (3)

Notes

1. Needed for practical engineering design
2. Needed for practical engineering design. Special course (integrals & differentials)
3. Needed for engineering design sketches
4. Including MasterCAM interface

Legend

- General Core
- Math & Science
- Engineering Foundation
- Pedagogy
- Technology
- Engineering Specialty
- Optional
- Engineering Design Capstone
- Teaching Practicum

Manufacturing Option (127-133 Hrs)

1st Year

Spring
- ENGL 1101 - English Composition I (3)
- Math 3000 - Introduction to Linear Algebra (3) **1**
- Math S** - Beginning Calculus (4) **2**
- Physics 1111-1111L - Introductory Physics (Mechanics, Waves, Thermodynamics) (4)

Summer
- SPCM 1100 - Introduction to Public Speaking (3)
- POLS 1101 - American Government (3)
- HIST 2112 - American History Since 1865 (3)
- Basic Physical Education (1)

Fall
- ENGL 1102 - English Composition II (3)
- Chemistry 1211-1211L - Freshman Chemistry I and Lab (4)
- Physics 1112-1112L - Introductory Physics (Electricity & Magnetism, Optics, Modern Physics) (4)
- ENGR 1920 - Introduction to Engineering (2)

2nd Year

Spring
- ENGR 2110 - Engineering Decision Making (3)
- ARGD 3010 - Design Drawing Techniques (Perspective Drawing) (3) **3**
- ETES 5090A - Principles of Technology I: Statics and Dynamics (4)
- ETES 5020A - Technical Design Graphics: 2D Drafting (3)

Summer
- PSYC 1101 - Elementary Psychology (3)
- ECON 2106 - Principles of Microeconomics (3)
- EDUC 2120 - Exploring Socio-Cultural Perspectives on Diversity (4)

Fall
- EDIT 2000 - Computing for Teachers (3)
- ETES 5070 - Research and Experimentation in Tech. Studies (3)
- ETES 5090B - Principles of Tech. II: Material Strength/Selection (4)
- Area B - Institutional Options (4-5)

3rd Year

Spring
- ETES 5020B - Tech Design Graphics: 3D Solid Modeling/Design (3) **4**
- ETES 5090F - Robotics and Automatic Systems (3)
- ETES 5060 - Energy Systems (3)
- ETES 5020 - Communication Systems (3)

Summer
- ETES 5010&5100 - Appropriate Engr. & Technology in Society (4)
- ETES 2320 - Creative Activities for Engr. & Tech Teachers (3)
- EPSY 2130 - Exploring Learning and Teaching (3)

Fall
- ETES 5090G - Production Enterprises (3)
- ETES 5090E - Mechanism Design & Selection (3)
- ETES 5030/7030 - Manufacturing Systems (3)
- ETES 5090H - Electronics Circuitry & Component Selection (3)

4th Year

Spring
- ETES 5110A/7110A - Engineering Design I (3)
- EOCS 5550 Students w/ Special Needs in Progr. of Occupational Studies (3)
- EOCS 2450 – Practicum in K-12 Engineering and Technology I (1)
- ETES 5040 - Construction Systems (3)

Summer
- EOCS 2450 – Instructional Strategies in K-12 Engineering and Technology Studies (3)
- EOCS 4350 - Curriculum Planning in K-12 Engineering and Technology Studies (3)

Fall
- ETES 5110B/7110B - Engineering Design II (3)
- EOCS 3450 – Practicum in K-12 Engineering and Technology II (2)
- ETES 5140/7140 - Laboratory Planning, Management, and Safety (3)

Notes

1. Needed for practical engineering design
2. Needed for practical engineering design. Special course (integrals & differentials)
3. Needed for engineering design sketches
4. Including MasterCAM interface

Legend

- General Core
- Math & Science
- Engineering Foundation
- Pedagogy
- Technology
- Engineering Specialty
- Optional
- Engineering Design Capstone
- Teaching Practicum

Electrical & Electronics Option (127-133 Hrs)

1st Year

Semester	Courses			
Spring	ENGL 1101 - English Composition I (3)	Math 3000 - Introduction to Linear Algebra (3) ①	Math S** - Beginning Calculus (4) ②	Physics 1111-1111L - Introductory Physics (Mechanics, Waves, Thermodynamics) (4)
Summer	SPCM 1100 - Introduction to Public Speaking (3)	POLS 1101 - American Government (3)	HIST 2112 - American History Since 1865 (3)	Basic Physical Education (1)
Fall	ENGL 1102 - English Composition II (3)	Chemistry 1211-1211L - Freshman Chemistry I and Lab (4)	Physics 1112-1112L - Introductory Physics (Electricity & Magnetism, Optics, Modern Physics) (4)	ENGR 1920 - Introduction to Engineering (2)

2nd Year

Semester	Courses			
Spring	ENGR 2110 - Engineering Decision Making (3)	ARGD 3010 - Design Drawing Techniques (Perspective Drawing) (3) ③	ETES 5090A - Principles of Technology I: Statics and Dynamics (4)	ETES 5020A - Technical Design Graphics: 2D Drafting (3)
Summer	PSYC 1101 - Elementary Psychology (3)	ECON 2106 - Principles of Microeconomics (3)	EDUC 2120 - Exploring Socio-Cultural Perspectives on Diversity (4)	
Fall	EDIT 2000 - Computing for Teachers (3)	ETES 5070 - Research and Experimentation in Tech. Studies (3)	ETES 5090B - Principles of Tech. II: Material Strength/Selection (4)	Area B - Institutional Options (4-5)

3rd Year

Semester	Courses			
Spring	ETES 5020B - Tech Design Graphics: 3D Solid Modeling/Design (3) ④	ETES 5090H - Electronics Circuitry & Component Selection (3)	ETES 5060 - Energy Systems (3)	ETES 5020 - Communication Systems (3)
Summer	ETES 5010&5100 - Appropriate Engr. & Technology in Society (4)	ETES 2320 - Creative Activities for Engr. & Tech Teachers (3)	EPSY 2130 - Exploring Learning and Teaching (3)	
Fall	ETES 5090F - Robotics and Automatic Systems (3)	ETES 5090E - Mechanism Design & Selection (3)	ETES 5090I - Advanced AC and DC Circuits (3)	ETES 5090J - Digital Electronics (3)

4th Year

Semester	Courses			
Spring	ETES 5110A/7110A - Engineering Design I (3)	EOCS 5550 Students w/ Special Needs in Progr. of Occupational Studies (3)	EOCS 2450 – Practicum in K-12 Engineering and Technology I (1)	ETES 5040 - Construction Systems (3)
Summer	EOCS 2450 – Instructional Strategies in K-12 Engineering and Technology Studies (3)	EOCS 4350 - Curriculum Planning in K-12 Engineering and Technology Studies (3)		
Fall	ETES 5110B/7110B - Engineering Design II (3)	EOCS 3450 – Practicum in K-12 Engineering and Technology II (2)	ETES 5140/7140 - Laboratory Planning, Management, and Safety (3)	

Notes

1. Needed for practical engineering design
2. Needed for practical engineering design. Special course (integrals & differentials)
3. Needed for engineering design sketches
4. Including Electronics Workbench or P-Spice

Legend

- General Core
- Math & Science
- Engineering Foundation
- Pedagogy
- Technology
- Engineering Specialty
- Optional
- Engineering Design Capstone
- Teaching Practicum

The Proposed Model

For Future K-12 Engineering & Technology Curriculum

An Innovative & Streamlined Engineering Education

Louisville, Kentucky
ITEA
2009

Basic Components

Infusion of Engineering Design into K-12 Curriculum

Regular K-12 Engineering & Technology Curriculum:

"Incremental" Design Model

Reference for The Proposed Model

Overall Structure of The Proposed Model

Streamlined Engineering Education K-12 thru University & Beyond

- ✓ **Massachusetts** Department of Education guidelines;
- ✓ **Engineering K-Ph.D** program (Duke Univ. Pratt Sch. of Engineering);
- ✓ **Dr. Lewis:** “Codification” of HS engineering curriculum;
- ✓ **Dr. Thompson**: “A series of focused courses and instructional activities that lead a student through the engineering design process”

Infusing Engineering Design into Math, Physics & Chemistry

- ✓ **Dr. Wicklein:** “Hypothetical high school curriculum plan;” using design to link engineering and science.
- ✓ **Dr. Mativo:** Animatronics (interdisciplinary, integrative STEM); analysis & design

K-12 Engineering Design

Analytic

- ✓ **Georgia Dept. of Education** Engineering Pathways.

Design

- ✓ **Various scholar:** Definition for design process.

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K-12 Engineering Road Map

Engineering & Technology Main Courses Sequence

Grades K-5 (Kindergarten – Elementary School)

Knowledge Content

Integrated STEM Courses (3; one/two years):

- Mathematics.
- Technology

1. Intro to Science;
2. Intro to Engineering;
3. Intro to Technology)

Design Process

- Conceptual & creative.

Grades 6-8 (Middle School)

Knowledge Content

STEM-integrated Science & Technology Courses (6 Courses, one/semester):

- Engineering Technology

1. Drafting;

6. Electrical Circuitry & Component Selection).

Design Process

- Engineering & Technology Experiment.

- Physical lab experiments.
- Digital simulation.

Grades 9-12 (High School)

Knowledge Content

STEM-integrated Engineering Courses (one/semester):

- Foundation (3 Courses.

1. Statics & Dynamics,
2. Material Strength & Selection,
3. Heat Transfer & Thermodynamics, or Fluid Mechanics & Aerodynamics).

- Pathways (3 Major Courses; one/semester).
- Design "Capstone" (2 Courses)

Design Process

- "Analytic Reduction" for Well-structured & analytic (9-11) for Main Courses
- Ill-structures and "Systems Thinking" (12) for "Capstone."

Both delivery of Knowledge Content & training on Design Process progress linearly and incrementally.

1st Stage

Same for all Math, Science, Engineering, and Technology Pathways.

Integrated STEM Enrichment → Integrated Design

K-12 Engineering Road Map

Engineering & Technology Main Courses Sequence

Grades K-5 (Kindergarten – Elementary School)

Knowledge Content

Integrated STEM Courses (3; one/two years):

- Mathematics.
- Technology

1. Intro to Science;
2. Intro to Engineer
3. Intro to Technolo

Design Process

- Conceptual.

Grades 6-8 (Middle School)

Knowledge Content

STEM-integrated Science & Technology Courses (6 Courses, one/semester):

- Engineering Technology

1. Drafting;
2. 3D Modeling
3. Power & Energy;
4. Construction Systems;
5. Manufacturing Systems.
6. Electrical Circuitry & Component Selection).

Design Process

- Engineering & Technology Experiment.

Predictive Analysis:

- Formula-based calculations;
- Physical lab experiments.
- Digital simulation.

Grades 9-12 (High School)

Knowledge Content

STEM-integrated Engineering Courses (one/semester):

- Foundation (3 Courses.

1.Statics & Dynamics,
2.Material Strength &

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Courses; one/semester).

- Design "Capstone" (2 Courses)

Design Process

- "Analytic Reduction" for Well-structured & analytic (9-11) for Main Courses
- Ill-structures and "Systems Thinking" (12) for "Capstone."

Both delivery of Knowledge Content & training on Design Process progress linearly and incrementally.

2nd Stage

Variable according to different Math, Science, Engineering, and Technology Pathways, based on local needs.

Integrated STEM Enrichment → Integrated Design

K-12 Engineering Road Map

Engineering & Technology Main Courses Sequence

Grades K-5 (Kindergarten – Elementary School)

Knowledge Content

Integrated STEM Courses (3; one/two years):
- Mathematics.
- Technology
1. Intro to Science;
2. Intro to Engineering;
3. Intro to Technology)

Design Process

- Conceptual.

→

Grades 6-8 (Middle School)

Knowledge Content

STEM-integrated Science & Technology Courses (6 Courses, one/semester):
- Engineering Technology
1. Drafting;
2. 3D Modeling
3. Power & Energy;
4. Construction Systems;
5. Manufacturing Systems
6. Electrical Circuitry & Component Selection).

Design Process

- Engineering & Technology Experiment.

Predictive Analysis:
- Formula-based calculations;
- Physical lab experiments.
- Digital simulation.

→

Grades 9-12 (High School)

Knowledge Content

STEM-integrated Engineering Courses (one/semester):
- Foundation (3 Courses.
1. **Statics & Dynamics**,
2. **Material Strength & Selection,**
3. **Heat Transfer & Thermodynamics**, or **Fluid Mechanics & Aerodynamics**).
- Pathways (3 Major Courses; one/semester).

Design Process

- **"Analytic Reduction"** for Well-structured & analytic (9-11) for Main Courses
- Ill-structures and "Systems T... 12)

3rd Stage

Both delivery of Knowledge Content & training on Design Process progress linearly and incrementally.

Variable according to different Math, Science, Engineering, and Technology Pathways, based on local needs.

Integrated STEM Enrichment → Integrated Design

K-12 Engineering Road Map

Engineering & Technology Main Courses Sequence

Grades K-5 (Kindergarten – Elementary School)

Knowledge Content

Integrated STEM Courses (3; one/two years):
- Mathematics.
- Technology
1. Intro to Science;
2. Intro to Engineering;
3. Intro to Technology)

Design Process
- Conceptual.

→

Grades 6-8 (Middle School)

Knowledge Content

STEM-integrated Science & Technology Courses (6 Courses, one/semester):
- Engineering Technology
1. Drafting;
2. 3D Modeling
3. Power & Energy;
4. Construction Systems;
5. Manufacturing Systems
6. Electrical Circuitry & Component Selection).

Design Process
- Engineering & Technology Experiment.

→

Predictive Analysis:
- Formula-based calculations;
- Physical lab experiments.
- Digital simulation.

Grades 9-12 (High School)

Knowledge Content

STEM-integrated Engineering Courses (one/semester):
- Foundation (3 Courses.
1. Statics & Dynamics,
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- "Analytic Reduction" for Well-structured & analytic (9-11) for Main Courses
- Ill-structures and "Systems ... (12) ..."

3rd Stage

Both delivery of Knowledge Content & training on Design Process progress linearly and incrementally.

Variable according to different Math, Science, Engineering, and Technology Pathways, based on local needs.

Integrated STEM Enrichment → Integrated Design

K-12 Engineering Road Map

Engineering & Technology Main Courses Sequence

Grades K-5 (Kindergarten – Elementary School)

Knowledge Content

Integrated STEM Courses (3; one/two years):
- Mathematics.
- Technology

1. Intro to Science;
2. Intro to Engineering;
3. Intro to Technology)

Design Process

- Conceptual.

Grades 6-8 (Middle School)

Knowledge Content

STEM-integrated Science & Technology Courses (6 Courses, one/semester):
- Engineering Technology

1. Drafting;
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3. Power & Energy;
4. Construction Systems;
5. Manufacturing Systems
6. Electrical Circuitry & Component Selection).

Design Process

- Engineering & Technology Experiment.

Predictive Analysis:
- Formula-based calculations;
- Physical lab experiments.
- Digital simulation.

Grades 9-12 (High School)

Knowledge Content

STEM-integrated Engineering Courses (one/semester):
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3. Heat Transfer & Thermo... or Fluid M... Aerody...

- Pathwa... Courses; one/semester).
- Design "Capstone" (2 Courses)

Design Process

- "Analytic Reduction" for Well-structured & analytic (9-11) for Main Courses
- Ill-structures and "**Systems Thinking**" (12) for "Capstone."

4th Stage

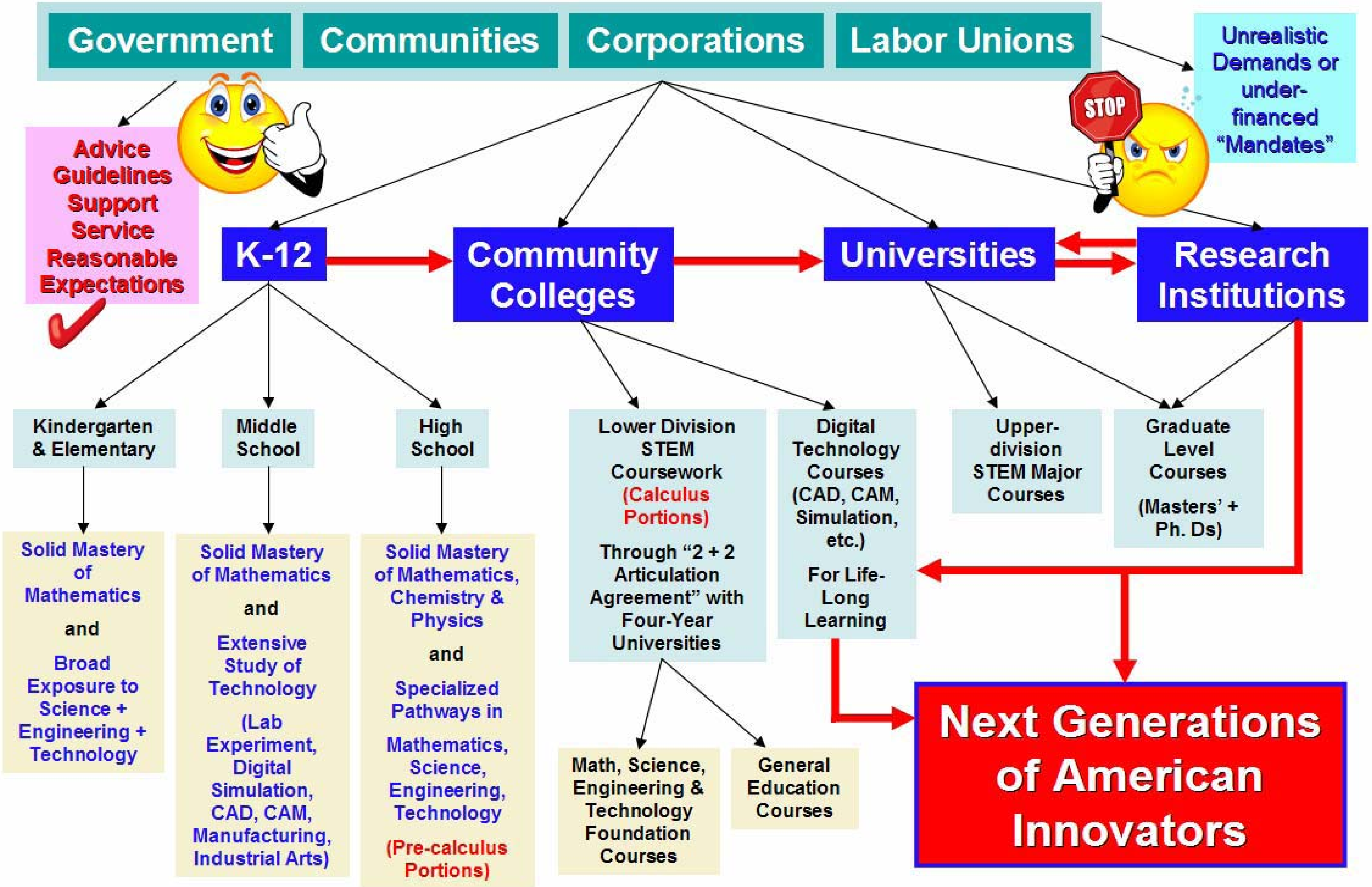
Variable according to different Math, Science, Engineering, and Technology Pathways, based on local needs.

The design "capstone" courses give students opportunities to apply engineering analytic skills and design process in solving real-world engineering problems.

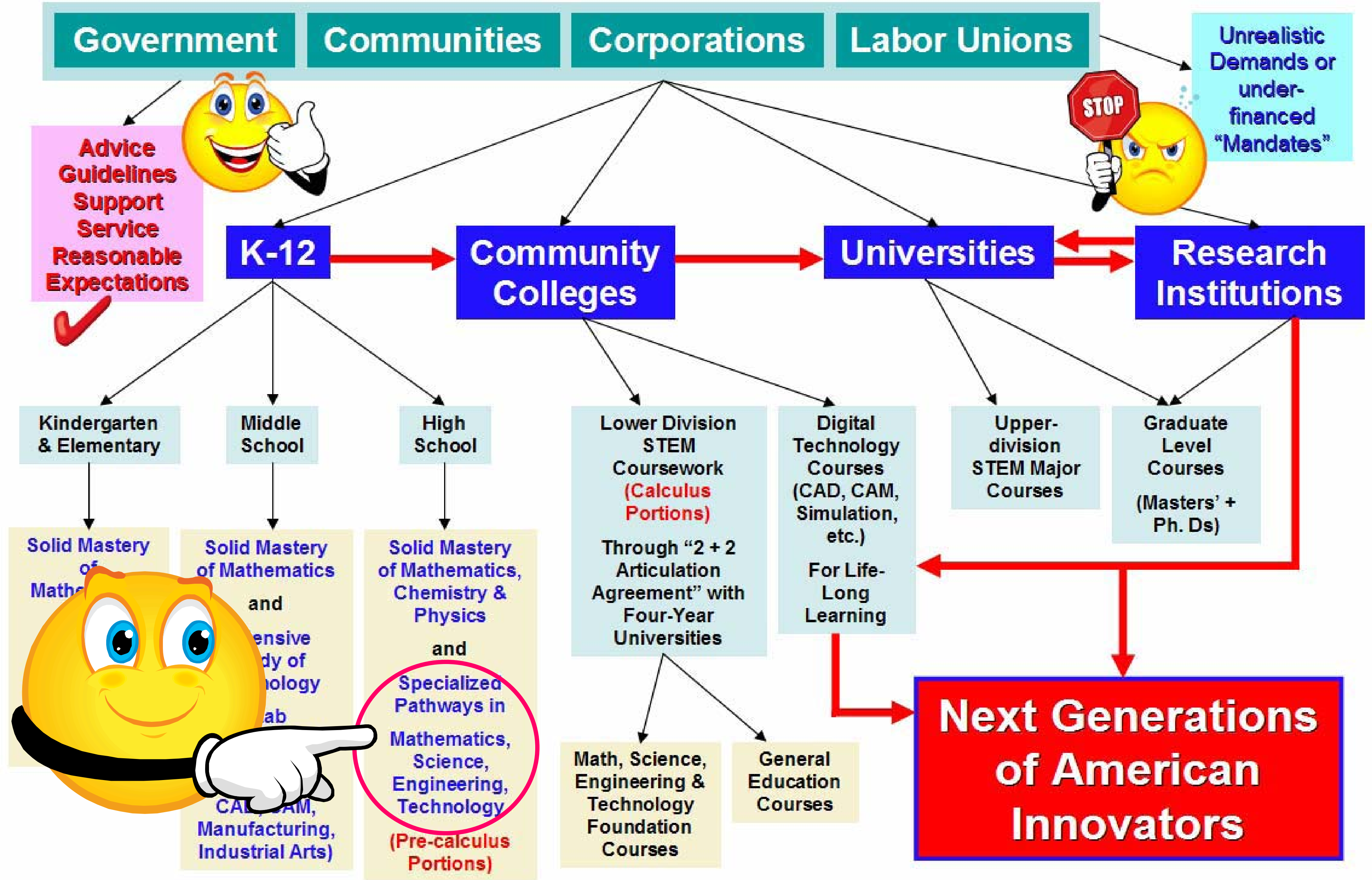
Beyond K-12 Engineering & Technology …

How About Mathematics and Science?

Streamlined STEM Education Process



Streamlined STEM Education Process



Basic Components

Infusion of Engineering Design into K-12 Curriculum

Extracurricular Enrichment

(After-School & Summer Camp Design Projects: "Recursive Design Model" Open-ended & Ill-Structured)

K-12 Engineering Road Map

Engineering & Technology Main Courses Sequence

Grades K-5 (Kindergarten – Elementary School)		Grades 6-8 (Middle School)		Grades 9-12 (High School)	
Knowledge Content	Design Process	Knowledge Content	Design Process	Knowledge Content	Design Process
Integrated STEM Courses (3; one/two years): • Mathematics. • Technology 1. Intro to Science; 2. Intro to Engineering; 3. Intro to	• Conceptual.	STEM-integrated Science & Technology Courses (6 Courses, one/semester): • Engineering Technology 1. Drafting; 2. 3D Modeling; 3. Power & Energy; 4. Construction Systems; 5. Manufacturing Systems. 6. Electrical Circuitry & Component Selection).	• Engineering &	STEM-integrated … Fluid Mechanics & Aerodynamics). • Pathways (3 Major	• "Analytic … for "Capstone."

Knowledge Content is organized in engineering design projects, to be conducted as extra-curricular or summer camp activities:

- Challenging projects for high achievers;
- Second opportunity for low achievers to review previously learned subjects.

Recursive but systematic delivery. "System Thinking" model of holistic engineering design process.

Dr. Mativo: **Animatronics** (interdisciplinary, integrative STEM project, with Mini Lessons teaching engineering design science and art).

Other existing programs: **Project Lead The Way**, etc.

Across Stages

Integrated STEM Enrichment → Integrated Design

K-12 Engineering Road Map

Engineering & Technology Main Courses Sequence

Grades K-5 (Kindergarten – Elementary School)

Knowledge Content

Integrated STEM Courses (3; one/two years):

- Mathematics.
- Technology

1. **Intro to Science;**
2. **Intro to Engineering;**
3. **Intro to Technology)**

Design Process

- **Conceptual.**

"Linearly Incremental"

Grades 6-8 (Middle School)

Knowledge Content

STEM-integrated Science & Technology Courses (6 Courses, one/semester):

- Engineering Technology

1. **Drafting**;
2. **3D Modeling**
3. **Power & Energy**;
4. **Construction Systems;**
5. **Manufacturing Systems.**
6. **Electrical Circuitry & Component Selection**).

Design Process

- **Engineering & Technology Experiment.**

Predictive Analysis:

- Formula-based calculations;
- Physical lab experiments.
- Digital simulation.

Grades 9-12 (High School)

Knowledge Content

STEM-integrated Engineering Courses (one/semester):

- Foundation (3 Courses.

1. **Statics & Dynamics**,
2. **Material Strength & Selection,**
3. **Heat Transfer & Thermodynamics**, or **Fluid Mechanics & Aerodynamics**).

- Pathways (3 Major Courses; one/semester).
- Design "Capstone" (2 Courses)

Design Process

- **"Analytic Reduction"** for Well-structured & analytic (9-11) for Main Courses
- Ill-structures and **"Systems Thinking"** (12) for "Capstone."

"Recursively Systemic"

Dr. Mativo: **Animatronics** (interdisciplinary, integrative STEM); analysis & design

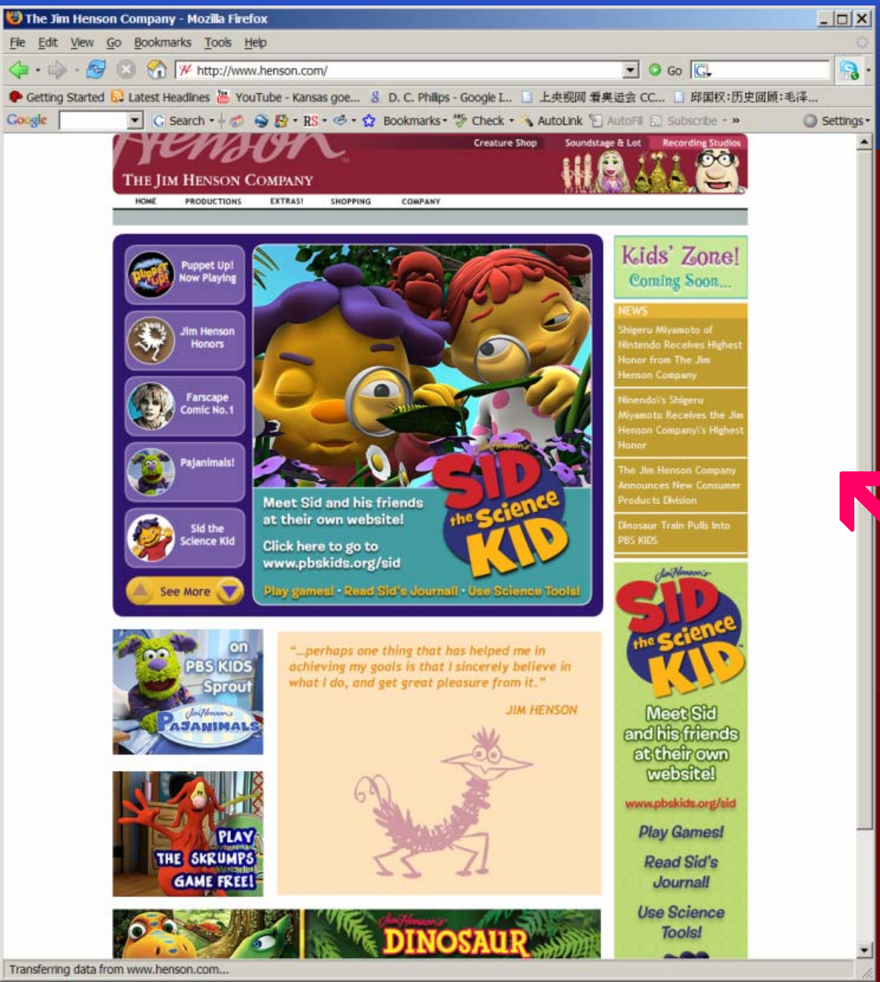
Other existing programs: **Project Lead The Way**, etc.

Integrated STEM Enrichment → Integrated Design

Animatronics

An Interdisciplinary & Integrative STEM Project for Teaching Engineering Analysis & Design

(For Grades 7 – 12)



Designed by
Dr. John Mativo et al
Ohio Northern University
(2005)

Industry Support

Source:
http://www.henson.com/

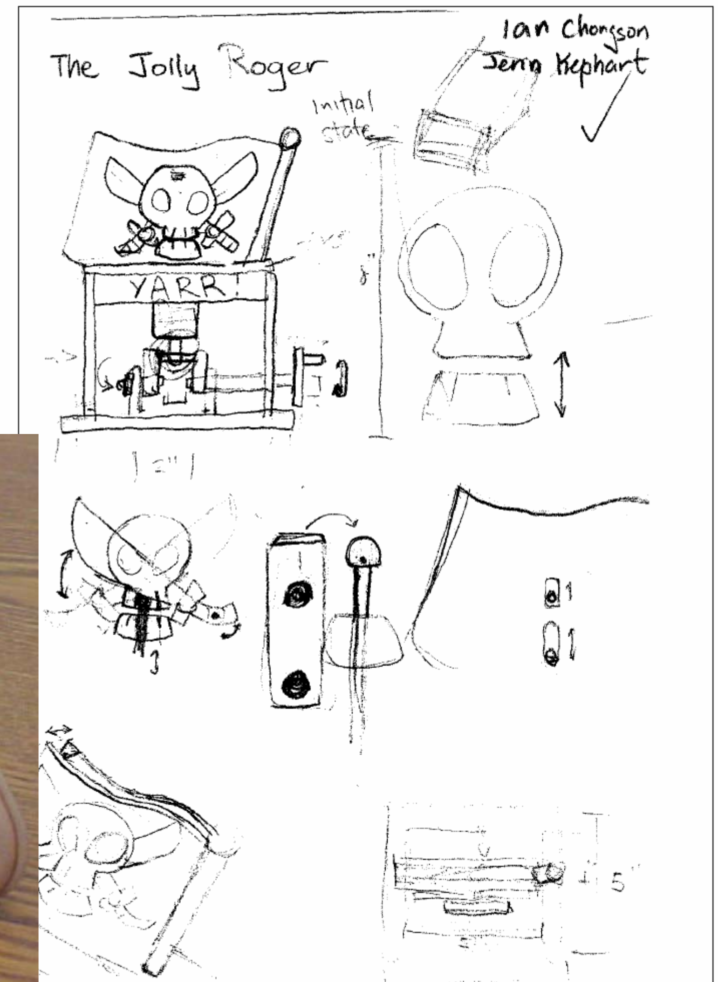
Louisville, Kentucky
ITEA
2009

College Interdisciplinary Design Project for Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department

(Designed and Implemented by Dr. John Mativo et al, 2005)

Animatronics for college students: Open-ended and creative **honors course**.

- Animated mechatronic blob,
- Penguin,
- Robotic trash can, and a
- Human/monster hybrid.



Modeling with polymer based clays

College Interdisciplinary Design Project for Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department

(Designed and Implemented by Dr. John Mativo et al, 2005)

Animatronics for college students: Combines analytic and design skills from several different but interconnected fields.

- **Mechanical engineering** (material selection, manufacturing process, mechanism design and assembly).
- **Electronics** (actuators, sensors, controls).
- **Microcontrollers structure** and **programming,**
- **Emerging technologies** (muscle wires, air muscles, micro- and nanocontrollers).
- **Two- and three-dimensional art** (costuming from fabrics to rubber Latex, and modeling.
- **Industrial product design.**

Mechanism design

Reverse engineering: dissecting a mechatronic ladybug

Middle to High School (Grades 7-12)
Interdisciplinary Design Project for Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department

(Designed and Implemented by Dr. John Mativo et al, 2005)

Animatronics for high school students: A grades 7-12 project (weekend program complemented by a summer capstone experience).

- **STEM enrichment**: For gifted and talented secondary school students (sponsored by Ohio Department of Education. A three-day summer camp of four local middle school students from the gifted and talented program.
- **Cross-disciplinary faculty collaboration:** With an art professor to strengthen the art component of the program (art and tech education modeling materials such as oil based clays, polymer and earth based clays, urethane and other polymers used).

Animatronics in daily life: My collection of animatronics toys. The cat's eyes have sensors that can respond to waving hands.

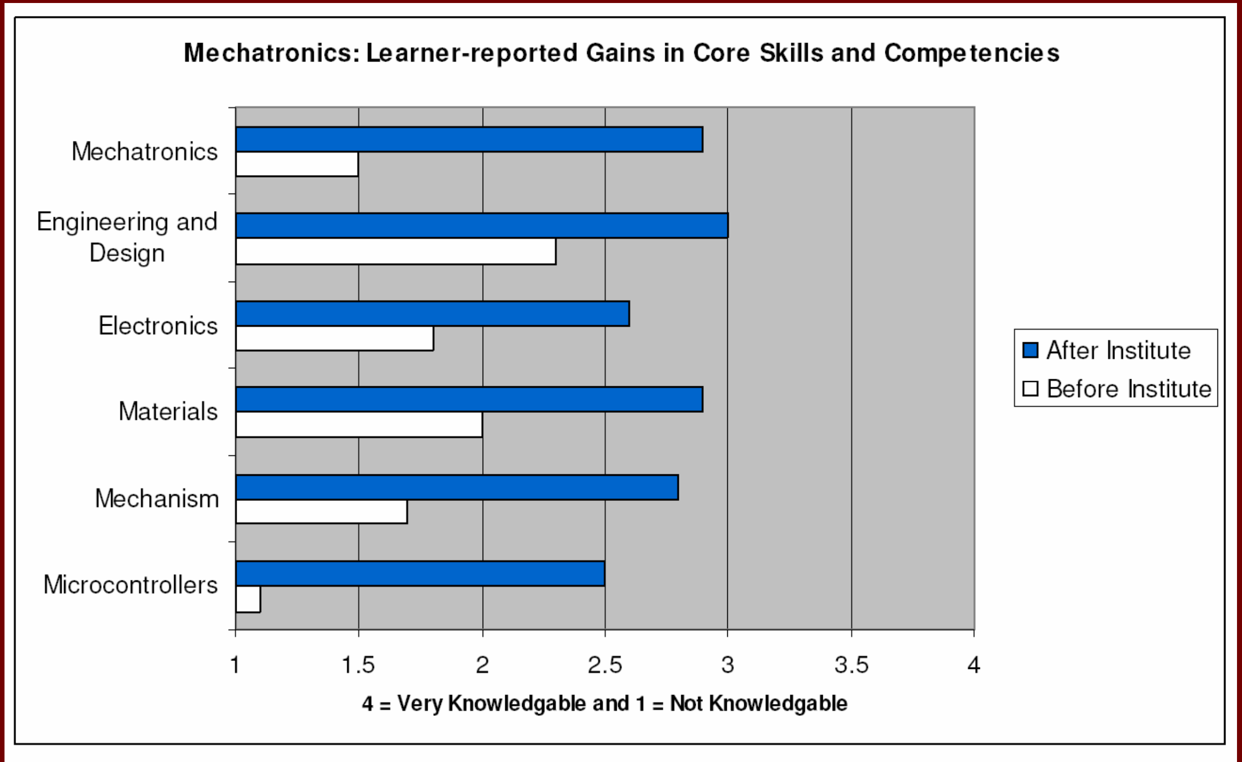
Middle to High School (Grades 7-12)

Interdisciplinary Design Project for Mechatronics and Robotics Program at Ohio Northern University Technological Studies Department

(Designed and Implemented by Dr. John Mativo et al, 2005)

Animatronics for high school students:

- **Improving STEM in secondary schools:** Dr. Mativo et al's pedagogic experiment indicated that learning engineering design help high school students to increase interests in STEM and enhance academic success.



High students improve STEM learning through inclusion of engineering design.

Outcome Beyond K-12 Engineering

Possible Outcomes

Suggestions for high academic achievements:
- All "A" or "B" in Engineering & Technology Main courses; plus
- All "A" or "B" in Integrated STEM Enrichments

College Science & Engineering Majors

Science:
- Math teachers,
- Physicists; and
- Chemists;

Engineering:
- Mechanical Engineers;
- Manufacturing/Industrial Engineers;
- Electrical & Electronics Engineers;
- Civil Engineers;
- Computer Programmers;
- Genetic Engineers;
- Agricultural Engineers, etc..

Suggestions for above average academic achievements:
- Mostly "B" in Engineering & Technology Main course; plus
- Mostly "B" in Integrated STEM Enrichments

College Technology Majors

Science:
- Lab technician;

Engineering:
- Drafters;
- Surveyors;
- Architects;
- Robot Operators;
- Electrical Technicians,
- Industrial Product Designers (or Engineers), etc.

Design Experience For All

Suggestions for average academic achievements:
- Mostly "B-" in Engineering & Technology Main course; plus
- Mostly "B-" in Integrated STEM Enrichments

Other College Majors

Profession:
- Managers;
- Statisticians;
- Economists; etc..

Workforce

Employment:
- Office Clerks, etc.

Note:
- **ABSOLUTELY NOT a scheme for "academic tracking;" but an Academic Affirmative Action for All Low-achieving K-12 Students;**
- **Equal access to engineering and technology literacy for all K-12 U.S. students;**
- **Freedom of choice of future careers;**
- **The Proposed Model would offer even "B-" students better preparation for college engineering major than what the current programs could possibly offer.**

Feasibility of the Proposed Model

Matching children's cognitive maturity with creative pedagogy

- **At ages 3 and 5:** Children as young as 3 years of age can engage in oral and visual planning as part of the process of making things from materials; their planning involved the use of lists and designs of what they intended to make. Most of the children were able to make the conceptual leap from oral planning to 2-D designing, predominantly with front views (Fleer, 2000, p. 47-58).

- **At ages 5 - 7 and beyond:** "Students as young as 5 to 7 years old" can engage in simple invention activities such as creating a new type of sandwich, using design journals to record creative thoughts (Druin & Fast, 2002, pp. 192-194) (Druin & Fast, 2002, p. 194). The level of developmental maturity occurred around 5 to 6 years of age; a creative peak at 10 to 11 years old; and "after age 12, a gradual but steady rise in creativity occurred through the rest of adolescence until a second peak was reached around 16 years of age (Claxton, Pannells, & Rhoads, 2005, p. 328).

- **Facility sharing:** Sharing laboratory facilities between high schools, two-year community colleges and four-year universities could make engineering and technology education more cost-effective. This has been don in many places. →Los Angeles Trade Technical College with California State University. Regional Occupational Center in California allows students from different high schools to share same facilities for technology-related courses.

Professional Development for the Proposed Model

Incremental phasing-in of the professional development process under the Proposed Model with ABSOLUTELY no new burden on current generation of K-12 STEM teachers

- **Current generation of K-12 mathematics and science teachers:** They could continue teaching K-12 mathematics and science (physics, chemistry, biology, zoology, environmental science, anatomy/physiology, etc.) using the available subject knowledge they have acquired, **teaching K-5 students knowledge about engineering and technology** with (1) **minimal amount of training on creative and conceptual design ("science fiction" style imagination);** and (2) **provision of instructional materials that require no background in hard-core engineering and technology**. Actually, under the Proposed Model, these teachers would NO LONGER be imposed new requirements on short-term training in engineering and technology (which generally speaking is not cost-effective), but instead, would be able to concentrate on teaching the subjects they have been and would be adequately trained for.

- **Current generation of K-12 technology teachers:** They would be **teaching Grades 6-8 (middle school) students, instead of Grades 9-12 students, technology courses they have been trained for** (including industrial arts such as wood and metal working, CAD, manufacturing process, etc.). They might undergo further training on lab experiment and digital simulation, as well as experiment-based design, as an in-depth extension of their former educational attainment; but they would NO LONGER be imposed new requirements on short-term training in engineering analysis and design (which generally speaking is not cost-effective).

- **Future generation of K-12 Engineering & Technology teachers:** They would be **FULLY and ADEQUATELY trained to tech Grades 9-12 engineering curriculum** (plus Grades K-8 engineering and technology, after the current generation of technology teachers retire). They would continue training on engineering and technology to upgrade their skills.

Liberate Our K-12 Teachers from Too Much Extra Burdens! Let them Teach Only What They Are Comfortable With!

Curriculum Development for the Proposed Model

Incremental improvement of the existing instructional materials under the Proposed Model, using as references the Recommended List of High School Appropriate Engineering Topics (to be made available at the end of my research), Dr. John Mativo's multidisciplinary Animatronics engineering analysis and design project, with ABSOLUTELY little or no new cost for developing K-12 engineering and technology curriculum.

- **Currently available FREE Internet science, engineering and technology teaching and learning materials, and FEE-based PBL (project-based-learning) high school engineering and technology curriculum:** Many existing programs, such as Project Lead The Way, High School That Works, Engineering by Design, Duke University Pratt School of Engineering K-Ph.D program, have contributed to bringing engineering and technology subjects to K-12 students; under the Proposed Model, they would not only continue to operate but actually expand by more systematically, cohesively, seamlessly and stream-linearly infusing engineering analytic knowledge content and design process.

1. **In the regular K-12 Engineering and Technology curriculum ("Engineering and Technology Main Course Sequence"):** They could continue to be used for teaching K-5 science and technology subjects with little change, while incorporating engineering analytic principles, concepts and formulas, from the Recommended List of High School Appropriate Engineering Topics, for eventual use in Grades 9-12 engineering and technology curriculum.
2. **In the Extracurricular Enrichment ("Integrated STEM Enrichment → Integrated Design") programs:** They could continue to be used the way they are, or undergoing some changes by incorporating more engineering analytic knowledge content.

Respect for the Great Achievements of K-12 Educators
Continuity + Change

Curriculum Development for the Proposed Model (Continued)

- **Future FREE Internet Grades 9-12 Engineering Textbooks:** An international volunteer organization consisting of graduate engineering students and their professors in the English-speaking countries (United States, Ireland, Great Britain and other Commonwealth of Nations states) could be organized to collectively write FREE English-language version of Grades 9-12 Engineering Lessons, using as reference the following:

1. The Recommended List of High School Appropriate Engineering Topics (to be made available at the end of my research;
2. The Animatronics multidisciplinary engineering analytic and design project model developed by Dr. John Mativo at Ohio Northern University and tried at Ohio high schools;
3. The textbook format in my FREE textbook on Engineering Descriptive Geometry and Sheet-Metal Design with Autodesk Inventor, as well as other formats to be developed.

It Takes A Village to Raise A Child.

(Quotation from Secretary of State Hillary Rodham Clinton)

It Takes A Global Commonwealth to Improve Engineering Education.

(A new but self-evident idea)

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2009

Major Differences:

Proposed Model vs. Existing Programs

Program Classification and Societal Needs

Program Scope

Program Status

Program Outcome

Program Flow

Program Curricular Structure

Major Differences between the Proposed Model and the Existing Programs

Major Difference	The Existing Programs	The Proposed Model
Program Classification and Societal Needs	• Tend to be more focused on technology as an appendage of engineering.	• Would switch the balance to the hard-core engineering design side.
Program Scope	• Tend to treat K-12 engineering and technology subjects in a "Black Box."	• Would take a more systematic and cohesive approach with codification of K-12 engineering and technology knowledge content; "Transparent Box"

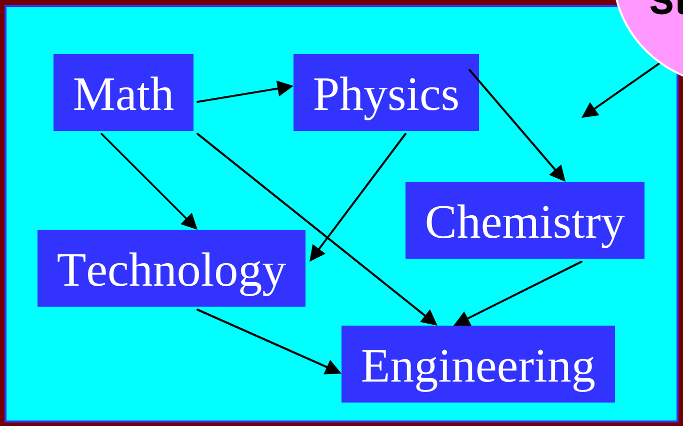
The Existing Programs: "Black Box"

Works? ✓
Why? ✗
How? ✗

Knowledge transfer? ✗

The Proposed Model: "Transparent Box"

Better for K-12 Students !



(Comment from Dr. David Gattie, UGA, Friday, March 20, 2009)

Works? ✓
Why? ✓
How? ✓

Knowledge Transfer? ✓

Major Differences between the Proposed Model and the Existing Programs (Continued)

Major Difference	The Existing Programs	The Proposed Model
Program Status	More “after-school science enrichment” or “curriculum enhancement,” or at most “pre-engineering” programs.	Engineering and technology education as an integral part of the K-12 curriculum.
Program Outcome	Aimed more at improving STEM scores for high school students.	Reasonably expecting graduates from K-12 engineering and technology programs to be well-prepared for (1) College engineering programs; or (2) Entering engineering technology-associated workforce (CAD drafter, etc.) with some additional training.
Program Flow	Not differentiating engineering design approach into incremental stages that match K-12 students’ ages.	Differentiating design process into four different stages, each matching a stage in K-12 education.
Program Curricular Structure	Not clearly delineating the engineering and technology courses that K-12 students could take at each stage of their academic journey.	Clearly delineating K-12 engineering and technology courses at each stage K-12 journey.

For Better Grades

No Clearly Defined Stages

For Better Careers

Clearly Defined Stages

Comparison Chart

Utah State University Program: Engineering & Technology Education (T&E in STEM) Degree in Engineering and Technology Education (To Start Fall 2009)				My Proposed Program: Bachelor of Science in K-12 Engineering & Technology Teacher Education			
Note	Course #.	Course Name	Hrs	Note	Course #.	Course Name	Hrs
Composite Major (64 credits)							
Engineering Education (9 credits)							
PLTW	ETE 1200[5]	Computer-Aided Drafting & Design	3	FETR	ETES 5020A	Technical Design Graphics: 2D Drafting	3
PLTW	ETE 2020[5]	Computer Integrated Mfg Sys	3	MS*	ETES 5090F	Robotics and Automatic Systems	3
PLTW	ETE 2660[5]	Principles of Engineering	3	FETR	ENGR 2110	Engineering Decision Making	3
	NO COURSE			E&T	ETES 5070	Research and Experimentation in Tech. Studies	3
	NO COURSE			CED	ETES 5110A/7110A	Engineering Design I	3
	NO COURSE			CED	ETES 5110B/7110B	Engineering Design II	3

The USU New Program more technology system focused

The Proposed Model more engineering design focused

Comparison: The proposed program offers more engineering design and experiment courses that correspond to courses in regular undergraduate engineering programs. The USU program has the merit of using popular Project Lead The Way curriculum (It is recommended to conduct additional comparative study of Project Lead The Way curriculum, and of the courses under UGA's current program plus the courses developed under my previously proposed model for infusing engineering design into K-12 curriculum, in Appendix A1).

All 3 (The Proposed Model, USU New Program, UGA Current Program) are moving in the same direction of increasing engineering analysis skills.

Comparison Chart (Cont.)

Utah State University Program: Engineering & Technology Education (T&E in STEM) Degree in Engineering and Technology Education (To Start Fall 2009)				My Proposed Program: Bachelor of Science in K-12 Engineering & Technology Teacher Education			
Note	Course #.	Course Name	Hrs	Note	Course #.	Course Name	Hrs
Composite Major (64 credits)							
Communication (3 credits)							
	ETE 3050	Computer Sys & Networking	3	ETCD	ETES 5020	Communication Systems	3
Manufacturing (6 credits)							
	ETE 1030	Material Processing Systems	3	E&T	ETES 5090B	Principles of Tech. II: Material Strength/Selection	4
	ETE 2030	Wood-Based Mfg Systems	3	MS*	ETES 5030/7030	Manufacturing Systems	3
Energy, Power, Transportation (3 credits)							
	ETE 1020	EPT Systems Control Technology	3	FETR	ETES 5060	Energy Systems	3
Construction (6 credits)							
	ETE 1040	Construction and Estimating	3	E&T	ETES 5040	Construction Systems	3
PLTW	ETE 2220[5]	Civil Engineering & Architecture	3		NO COURSE YET (CAN BE REQUIRED FROM EXISTING COURSES AVAILABLE AT UGA)		
Comparison: No major differences. Again, the USU program has the merit of using popular Project Lead The Way curriculum.							
Related Professional (7 credits)							
	ETE 10001	Orientation to Engineering Ed.	1	TER	ENGR 1920	Introduction to Engineering	2
DSC	ETE 3440	Science Tech & Modern Society	3	E&T	ETES 5010&5100	Appropriate Engineering & Technology in Society	4
CI	ETE 5220	Program & Course Development	3	TER	EOCS 4350	Curriculum Planning in K-12 Engineering and Technology Studies	3
	NO COURSE			E&T	ETES 5140/7140	Laboratory Planning, Management, and Safety	3
	NO COURSE			ETCD	ETES 2320	Creative Activities for Engineering & Tech Teachers	3
	NO COURSE			ETCD	ETES 2320B	Digital Simulation for K-12 Engineering & Technology	3
Comparison: The proposed program has the benefit of offering courses related to engineering and technology classroom management, development of K-12 engineering and technology learning activities, and digital simulation technology for engineering design.							

The USU new program more technology extensive

The Proposed Model more engineering extensive

All 3 (The Proposed Model, USU New Program, UGA Current Program) are moving in the same direction of increasing engineering analysis skills.

Comparison Chart (Cont.)

Utah State University Program: Engineering & Technology Education (T&E in STEM) Degree in Engineering and Technology Education (To Start Fall 2009)				My Proposed Program: Bachelor of Science in K-12 Engineering & Technology Teacher Education			
Note	**Course #.**	**Course Name**	**Hrs**	**Note**	**Course #.**	**Course Name**	**Hrs**
Electives (7 credits)				**Engineering Analysis and Technology Options (9-12 Hours/Option)** Additional options could be developed according to needs. Each student is required to choose one Option of 3 courses:			
	NOT SPECIFIED			**Mechanical Design Option (12 Hrs)**			
	NOT SPECIFIED			MD	ETES 5020B	Tech Design Graphics: 3D Solid Modeling/Design	3
	NOT SPECIFIED			MD	ETES 5090C	Principles of Technology III: Fluid Mechanics & Aerodynamics	3
	NOT SPECIFIED			MD	ETES 5090D	Principles of Technology IV: Heat Transfer & Thermodynamics	3
	NOT SPECIFIED			MD	ETES 5090E	Mechanism Design & Selection	3
				Manufacturing System Option (9 Hrs)			
				MS	ETES 5030/7030	Manufacturing Systems	3
				MS	ETES 5090F	Robotics and Automatic Systems	3
				MS	ETES 5090G	Production Enterprises	3
				Electrical and Electronics Option (9 Hrs)			
				E&E	ETES 5090H	Electronics Circuitry & Component Selection	3
				E&E	ETES 5090I	Advanced AC and DC Circuits	3
				E&E	ETES 5090J	Digital Electronics	3

Comparison: The Electives (7 credits) from USU's program obviously could be filled with 2-3 engineering analysis and design courses. The proposed program has the benefit of offering well-selected Options of engineering analysis and mini-design courses (3-4 courses/Option, 9-12 hours).

The USU New Program offers Electives

The Proposed Model requires Engineering Analysis & Technology Option/Major courses

All 3 (The Proposed Model, USU New Program, UGA Current Program) are moving in the same direction of increasing engineering analysis skills.

Comparison Chart (Cont.)

Summary and Conclusion	
Utah State University Program: **Engineering & Technology Education (T&E in STEM)** Degree in Engineering and Technology Education (To Start Fall 2009)	**My Proposed Program:** **Bachelor of Science in K-12 Engineering & Technology Teacher Education**
Program Characteristics	
• More focused on technology and pedagogy (Reflective of traditional **American pragmatism**). • Very feasible within the current system of educational logistics.	• More focused on engineering analysis and design (A "**Lite Version**" of **regular undergraduate engineering programs**); • A "**Heavy Duty**" **model** designed for the United States and other advanced English-speaking nations, reflective of the Anglo-American philosophy of "**Continuity + Change**."). • Feasible with some strengthening of the current system of educational logistics as well as some readjustment of curricular structure, to be addressed in this study.
Potential Program Outcome	
• K-12 Engineering & Technology teachers well-trained in ○ K-12 pedagogy and in ○ K-12 appropriate engineering technology and "Technology Education Design Process," ○ Fully dedicated to K-12 teaching career.	• K-12 Engineering & Technology teachers ○ Adequately trained in K-12 pedagogy, but ○ Well-trained in K-12 appropriate engineering analytic skills and in "Engineering Design Process," ○ Fully dedicated to K-12 teaching career and at the same time ○ Able to work for industry as practical product and system design engineers ○ (An "Educator + Practical Engineer" model designed to solve the problem of shortage in engineering graduates in the United States).

The USU New Program a modified technology program integrating engineering analysis courses. Good technology teacher training.

The Proposed Model a "Lite Version" of regular engineering program. Training practical engineers able to teach at K-12 level.

All 3 (The Proposed Model, USU New Program, UGA Current Program) are moving in the same direction of increasing engineering analysis skills.

Comparison Chart (Cont.)

↑ Summary and Conclusion (Continued) ↑	
Utah State University Program: **Engineering & Technology Education (T&E in STEM)** Degree in Engineering and Technology Education (To Start Fall 2009)	**My Proposed Program:** **Bachelor of Science in K-12 Engineering & Technology Teacher Education**
Relationship with Undergraduate Engineering Programs	
• Good training on engineering technology (CAD/CAM, etc.). • Slight inclusion of hard core engineering analysis courses (limited to Statics, Dynamics, EE for Non-Electrical Majors), and of engineering design process (Principles of Engineering). • Limited link with undergraduate engineering programs; and limited possibility for inter-transfer between the program and any regular engineering program.	• Good training on engineering technology (CAD/CAM, etc.). • Extensive inclusion of hard core engineering analysis courses (3-4 courses in each of several engineering Options or majors, in addition to foundation engineering subjects such as Statics and Dynamics, Materials Strength and Selection), and of engineering design process (Engineering Decision Making, Research and Experimentation in Technology Studies, Engineering Design I and II). • Strong link with undergraduate engineering programs; and greater possibility for inter-transfer between the program and any regular engineering program, through change of major, or double-major).

The USU New Program More Technology extensive

The Proposed Model More Engineering extensive

All 3 (The Proposed Model, USU New Program, UGA Current Program) are moving in the same direction of increasing engineering analysis skills.

The Proposed Model's Potential Benefits

Academic and pedagogic:

- **Relationship with math and science curriculum:** Reinforcing mathematics and science (physics and chemistry, etc.) curriculum, not competing with it, by matching both sides seamlessly.
- **Engineering design process:** Matching design expectation with K-12 students' developmental and cognitive maturity level;
- **Engineering analytic knowledge content:** Proceeding from simple to complex, combining traditional and modern methods (pencil-and-paper computations, lab experiment and digital simulation) in knowledge content delivery;
- **Logical sequence:** Increasing both analytic and creative abilities of K-12 students step-by-step.

A new paradigm in engineering and technology education:

- **Structure:** A systematic, holistic and viable solution grounded in engineering and technology educators' past experience with a version for the near future.
- **Guiding principles:** Progressive but not radical. "Continuity + Change." → within the time-tested philosophical framework of Utilitarianism, Positivism and Pragmatism.
- **Impact on students:** Equal Access to Engineering & Technology Literacy for All K-12 Students + Academic Upward Mobility for High Achievers, or a synthetic, non-dichotomous paradigm of Democracy (Dewey) + Efficiency (Prosser).
- **Change within traditions:** ABSOLUTE respect for the time-proven pedagogic traditions and conventions.

Logistics:

- **Cost effectiveness:** Little or no long-term increase in K-12 education funding; only a small amount of start-up investment needed for curricular structural adjustment.
- **Continuation of existing programs:** No disturbance to existing programs (incremental improvement is the only thing needed).
- **Teacher happiness:** ABSOLUTELY NO new burden on current generation of K-12 STEM educators.
- **Stability of educational institutions:** ABSOLUTELY NO change in current political and administrative structure governing the current K-12 STEM curriculum (the only change needed is in strategic thinking and in necessary curriculum re-structuring).

The Proposed Model and the Southern States

Impact of Globalization:

- **An emerging new international division of labor:**

1. **Low-end and mid-range consumer product manufacturing:** U.S. corporations outsource to China, Vietnam, Bangladesh and other Third World countries (K-Mart, Sears and Wal-Mart sores, etc.)
2. **Technology service:** India (800-number service for computer system trouble-shooting, etc.).
3. **Robotic-driven manufacturing:** USA and Japan (high tech products, weapons systems, etc.).
4. **Science, engineering research and innovation:** USA is still leading in new technologies such as genetic engineering; has best educational facilities, but needs to recruit more domestic students (US shortage in engineering graduates is around 25% on the average. For Georgia, it is around 50%).

- **Southern Advantage in the Process of Globalization:**

1. **Agriculture and related science and engineering:** Food sciences, genetics, etc., are well developed in the Southern economy and institutions of higher education and research (UGA a good example).
2. **Construction and agricultural equipments and consumer products design and manufacturing:** Need more scientists, engineers and designers.

- **Strengthening Southern economic cooperation with African countries for mutual benefit:**

1. **African-Americans:** A great human resource for connecting USA and African countries. Compared with other developed countries, the United States enjoys the advantage of having a well-educated African-American population, and thus, greater opportunity to participate in African economic development that would be mutually beneficial.

2. **Abundance of natural and human resources in Africa:** Waiting for exploration for Global peace and prosperity. The African continent south of Sahara Desert is generally bountiful in natural resources but need foreign capital investment. The English-speaking African countries usually have better social-economic infrastructure to support industrial development.

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The Proposed Model and the Southern States (Continued)

Solution for the Global and local problems of shortage of engineers and scientists:

- **The academic dimension of Affirmative Action:** A new focus on academic attainments in science, engineering and technology, equal opportunity to education in these vital fields of national interests for all K-12 students.
- **Teacher-friendly curriculum:** Matching K-12 Engineering Career Pathways with K-12 Engineering and Technology Teacher Education program.
- **Student-friendly learning process:** Matching K-12 Engineering Career Pathways pedagogy with K-12 students' different stages of cognitive development maturity.

Acknowledgement

Special thanks to Drs. Robert Wicklein, Roger Hill and John Mativo at College of Education, Sidney Thompson and David Gattie at Driftmier Engineering Center, University of Georgia, for their help in making corrections to and streamlining this PowerPoint presentation.

Gratitude is extended to Dr. Myra N. Womble at the College of Education, University of Georgia, and Drs. Kurt Becker and Cameron Denson at Utah State University, for their advice, comments and feedback on the Proposed Model explained in this presentation.

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Louisville, Kentucky ITEA 2009