DEVELOPING AN INTRODUCTORY ENGINEERING COURSE FOR LASALLIAN HIGH SCHOOLS

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KEY POINTS

- WHY– The need for the course
- WHO – Target student population
- WHAT– Overview of planned curriculum; LaSallian approach
- HOW – Planning issues; available models and resources, facilities, personnel, curriculum expansion

THE NEED FOR AN ENGINEERING ELECTIVE

STEM education for the 21st century needs to provide

- a frame work for creative analytical thinking

- problem solving skills that can adapt to a rapidly changing world

- global thinkers who can manage and improve their world ethically

- We are educating students who will live in a world that is changing exponentially.
- The international economic and political landscape is rapidly shifting. They will be global citizens.
- They will live and work with technologies we can barely imagine
- Teaching needs to focus more on portability of skills and frameworks for thinking

DID YOU KNOW?

The Committee on K-12 Engineering Education of the National Academy of Engineering states:

The potential benefits to students of including engineering education in K-12 schools can be grouped into five areas:

1. improved learning and achievement in science and mathematics;
2. increased awareness of engineering and the work of engineers;
3. understanding of and the ability to engage in engineering design;
4. interest in pursuing engineering as a career; and
5. increased technological literacy.

A January 2006 report of the NSF states that:

If the U.S. is to maintain its economic leadership and compete in the new global economy, <u>the nation must prepare today's K-12 students</u> better to be tomorrow's productive workers and citizens. Changing workforce requirements mean that <u>new workers will need ever more sophisticated skills in science, mathematics, engineering and technology</u>

... In addition, the rapid advances in technology in all fields mean that even those students who do not pursue professional occupations in technological fields will also require solid foundations in science and math in order to be productive and capable members of our nation's society.

WHY ENGINEERING?

Engineering can unify and reinforce all other STEM curricula.

Engineering encourages creativity.

Engineering imparts skills that are portable and transferrable.

Engineers can have a profound, beneficial impact on society.

NEED FOR AN ENGINEERING CURRICULUM

Most high school science electives are biology based. Students who are more interested in physics or chemistry have few options.

Traditional science classes often don’t appeal to hands-on learners or creative . As a result, many of them lose interest in science. These are the students we can least afford to lose if we hope to build a fluid, adaptable, technologically competent workforce.

All students benefit from the application of skills learned in math and science class.

WHY ENGINEERING ?

- Engineering focuses on problem-solving in much more realistic manner than core science and math courses. There is often more than one "correct" answer.
- Engineering involves team work. Students learn to appreciate the power of many minds versus one. They learn to cooperate rather than compete.
- Engineering requires creativity. Students who struggle with the formal framework of science can think "out of the box".

The word *engineer* has its roots in the Latin word *ingeniator*, which means ingenious.

"Scientists discover the world that exists; engineers create the world that never was." *Dr. Theodore Von Kármán*

- **Science stresses concepts, rather than skills.**
- **Science stresses discovery, not application.**
- **Science stresses adding to knowledge; engineering stresses using knowledge.**

From the National Academy of Engineering:

What attributes will the engineer of 2020 have?

He or she will aspire to have the ingenuity of Lillian Gilbreth, the problem-solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King,

and the curiosity and wonder of our grandchildren.

- Traditional math and sciences courses often diminish and downplay the creativity and curiosity that is most prevalent in young people.
- We are guilty of tossing aside an enormous amount of potential by forcing creative minds to follow one model, to seek one answer.
- As nation and as global citizens that is a luxury we can no longer afford.
- As teachers and learners, we cannot possibly keep up with the explosion of information. Students can only be productive if they are able to devise techniques to unify information and apply what they know.

A1989 report of the American Association for the Advancement of Science (AAAS), *Project 2061, Science for All Americans* presented goals for science, mathematics, and technology literacy.

The goals presented

- *offered multidisciplinary instructions in the real world,*
- *structured so students would use the discovery process to study issues that are multidimensional to arrive at alternative approaches*
- *and to be able to anticipate both positive and negative consequences of their choices.*

THIS IS ENGINEERING !!

TARGET POPULATION

What type of student can benefit from an engineering course?

- the student you see come alive in open-ended labs
- the student who is excited about the concept, but occasionally struggles with structured problem analysis
- the student who likes science and math, but is not interested in the health sciences
- Students who are under-represented in more advanced science classes

FORMAL PREREQUISITES

- Currently, 11^{th} and 12^{th} grades. Plans to possibly extend to 10^{th} grade.
- Concurrent or previous completion of Chemistry and/or Physics.
- Completion of Geometry and Algebra 1. Enrollment in Algebra 2 or pre-Calculus.
- Approval of current science instructor and Engineering instructor.

COURSE STRUCTURE

- The curriculum centers on design projects for each quarter.
- Overall focus on four essential questions:
  1. What is technology?
  2. What do engineers do?
  3. What do engineers need to know?
  4. How do technologies impact society?

- The projects serve to reinforce the unique and critical role of

  - *the engineering team*
  - *the design process*
  - *technical communication*
  - *process and material specifications and constraints*
  - *realistic considerations involved in moving from science to technology.*

- All units will involve relevant discussions of ethics, sustainability and appropriate technologies.

CURRICULAR UNITS

- There are four principal curricular units. Each focuses on a broad topic in engineering or technology.
- Each unit is organized around
  - relevant scientific principles
  - types of engineering and processes
  - specific projects

UNIT 1: WHAT IS ENGINEERING ?

- History of Engineering
- Engineering vs. science
- Types and roles of engineers
- The Engineering Design Process
- Manufacturing

Scientific topics

1. Forces, levers, torque
2. Aeronautics

Engineering focus

1. Aerospace
2. Mechanical
3. Industrial design
4. Biomedical

Projects

1. Simple product for everyday use
2. Glider design
3. Packaging design
4. Prosthetic hand

Engineering skills/topics:

1. isometric and orthographic drawing
2. introduction to CAD
3. manufacturing processes
4. quality control issues
5. cost/benefit analysis
6. appropriate technology
7. ENGINEERING DESIGN PROCESS

THE ENGINEERING DESIGN PROCESS

- Design is the approach engineers use to determine the best way to make a device or process that serves a particular purpose.
- Not a linear, step-by-step process. It is iterative; each new version of the design is tested and modified based on what has been learned up to that point.
- Finally, there is never just one “correct” solution to a design challenge. Instead, there are a number of possible solutions, and choosing among them inevitably involves a holistic approach

UNIT 2:Building the Future
Structures and Materials

- Mechanical Considerations
- Material Design
- Energy Efficiency Issues
- Issues of Sustainability and Growth
- Financial/Aesthetic Considerations

Scientific topics

1. Forces
2. static and dynamic loading
3. tension, compression, shear
4. Material characteristics: strength, ductility, elasticity
5. Failure analysis
6. bridge and skyscraper design
7. Urban planning

Engineering Focus

1. Civil engineering
2. Materials engineering
3. Mechanical engineering
4. Environmental engineering

Projects

1. Cardboard Chair
2. Why did Your Building Fail?
3. Design a City of the Future
4. Make and Test Concrete
5. Build a Better Bridge

Engineering skills/topics include:

- Allocation of resources
- Structural mechanics
- Failure analysis
- Material specification
- Sustainability/Use of renewable resources
- Efficiency
- Cost/benefit analysis
- User/visual appeal

UNIT 3
Putting Things in Motion:
Energy and Transportation

- Fluids
- Boat Design
- Alternative sources of Energy
- Implementing designs with renewable energy sources
- Challenges of an aging infrastructure; developing an infrastructure for growth

Scientific topics

1. Archimedes Principle
2. Bernoulli's Principle
3. Thermodynamics
4. Hydraulics and pneumatics
5. Generators/electromagnetism
6. Engine design and use.

Engineering Focus

1. Marine engineering
2. Mechanical engineering
3. Chemical engineering
4. Nuclear engineering
5. Automotive engineering.

Projects

1. Wind Power
2. Build a Putt-Putt boat; heat engines
3. Build a fuel cell car
4. Solar car races

Engineering skills/topics include:

- Patenting new designs
- Fuel cells and photovoltaic cells
- Power generation; the “grid”
- Infrastructure challenges
- Cost/benefit analysis
- Socio-political issues relating to the environment and issues of sustainability

Unit 4:
Electricity and Communication
Staying Connected

- Supplying Electricity
- Using Electricity
- Electronics
- Optics and Communications Concepts

Scientific topics

1. electric charge
2. current, Ohm's law, resistance
3. motors, generators
4. semiconductors
5. robotics

Engineering Focus

1. Electrical
2. Mechanical
3. Biomechanical
4. Nuclear
5. Software and communications engineering

Projects

1. Build a Scoreboard
2. Design a Communications System
3. Motor Design
4. Robotic Hand

Engineering Topics/Skills

- Power plant technology and design /Coal, nuclear, and hydro-powered plants
- Environmental impacts/ Appropriate technology
- Reverse engineering
- Electronics
- Digital and analog signals/ Encoding and decoding
- data storage and retrieval
- fiber optics

The LaSallian Engineer

Throughout the units we continually focus on three stewardship topics:

1. Appropriate technologies *“teach man to fish…”*
2. Environmental impacts; sustainability
3. Ethical design and decision

PLANNING ISSUES
Curriculum

- Engineering the Future
  - developed by the Boston Museum of Science and the NCTL

- Engineering by Design
  - developed by ITEEA
- Project Lead the Way

- The Infinity Project

Curriculum Development Resources

- American Society for Engineering Education (ASEE)
- Teach Engineering
- Try Engineering
- National Center for Engineering and Technology Education (NCETE)
- International Technology and Engineering Educators Association (ITEAA)

TEACHER TRAINING AND RECRUITMENT

- All science and math teachers can be taught to think more like engineers.
- Engineering by Design and Engineering the Future offer fairly low cost training
- Physics teachers have an advantage
- Can have a course be co-taught by science and math faculty
- Need teachers who are flexible and can adapt to a class where a wide variety of approaches and skills are encouraged

EXTERNAL SOURCES OF TRAINING AND PERSONNEL

- Utilize local engineering schools. Look for community/education outreach efforts; GK-12 fellowship programs.
- Utilize your alumni network. Enlist alumni in technical fields as speakers. Coordinate a forum of recent alumni pursuing engineering degrees.
- Utilize local industry and manufacturing. They have a vested interest in producing more technologically competent graduates.

FACILITIES AND EQUIPMENT

- Lab space with tables suitable for group work.
- Computer access is highly valuable.
- Can use form core and basic cutting tools in place of traditional woodshop
- Budget for consumables. Some materials can be obtained through local recycling resources, industry outreach
- Dual purpose physics and engineering supplies and equipment

FUTURE PLANS

- Curriculum will continue to be modified over the next 2 years
- Depending on student demand, 2 levels of the introductory course may be needed .
- Introductory course can be used as a pre-requisite for several one semester courses.
- Additional courses being considered are:
  - Engineering Materials
  - Manufacturing Processes and Products
  - Green Technologies
  - Technology and Society (ethics)
  - Engineering Design Project (capstone course)

Future Engineers