

**Contextual Learning Modules -  
A New Approach to Bioengineering Education**

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**Abstract**

A sequence of Bioengineering courses are under development at the State University of New York at Stony Brook, to be used as part of a minor program to introduce students in the College of Arts and Sciences to Bioengineering and as freshmen/sophomore level courses in a Bioengineering major. Each course is composed of a series of contextual learning modules (CLMs) with a common theme, which are 4-6 contact hour modules, each introducing one major engineering concept in a biological context. Approximately one hour is devoted to class discussion of the context, ~3-4 hours doing hands on experimentation coupled with didactic presentation and ~1-2 hours of group participation in a design experience. The intent is to more clearly indicate to the students how the engineering concept may be integrated into their existing "world map" and thereby motivate the students to learn to apply the new knowledge. Our experience thus far suggests that students are enthusiastic about the CLM approach, but future studies will determine whether or not retention of content is improved. One drawback, depending on one's point of view of the CLM approach is that by increasing discussion of the context within which the material fits and hands-on experiences of the concepts being presented, the amount of content which may be presented in a standard length course must be reduced.

**Introduction**

Engineering education has undergone several transformations over the last 50 years and we are currently in the midst of another effort to rethink how we train engineers. Following World War II, with the rapid influx of servicemen into engineering schools, curricula were redesigned with greater emphasis on analytical techniques in solid mechanics, fluid mechanics, thermodynamics, heat and mass transfer, electrical theory, and materials science, with a corresponding decrease in both hands-on and synthesis experiences (1,2). Throughout the 1960's, a continued shift in engineering curricula occurred in the direction of increased emphasis on analytical techniques, due in part to the explosion of knowledge in mathematics and the basic sciences. This represented a transition to the era of engineering science, an era which produced fine analytical engineers, but engineers who were required to learn most, if not all, of their design skills after securing their first engineering position. By the 1980's, the effect of these shifts was evident in a

report on the status of engineering education worldwide, which noted the students' remarkable lack of curiosity about the physical meaning of the subjects they were studying (3). Indeed over the last half-century, curricula have moved away from presenting students with an equal balance of the three major knowledge processes; the cognitive, perceptive and pragmatic. The shift in science and engineering education has been toward the cognitive, i.e. the analytical, linear, and rational skills, which are critical to defining a problem, gathering information, and diagnosis. While technical skills are an absolute necessity in engineering, organization leaders have noted that engineering graduates lack breadth of vision, flexibility, and a business orientation. These skills are not associated with cognitive processes, but with perceptive (i.e. intuition, insight and enthusiasm, leading to the ability to generate solutions and make decisions), and pragmatic (i.e. experiential/observational modes of thought which facilitate planning, implementation and evaluation) processes. In response to the perceived "over-correction" towards solely analytical thinking, the National Science Foundation has made significant investments in engineering education reform (4). In addition, the Accreditation Board for Engineering and Technology (ABET) has recently adopted accreditation criteria which require demonstration that graduates of accredited programs can do more than manipulate mathematical expressions (5,6).

In order to develop a curriculum that achieves the goal of producing a graduate with vision and flexibility, faculty need to incorporate hands on learning, develop communication skills, and instill a sense of creativity and innovation which the students will need throughout their engineering careers (7). To these ends, we have developed an approach to curriculum delivery composed of what we call Contextual Learning Modules (CLM).

### **Goals of the Contextual Learning Module Approach**

The goals of the CLM approach are:

- 1) To integrate physical science, life science, and engineering in each module.
- 2) To provide at least one "hands on" experience each day.
- 3) To use the module itself as an implicit model of how to tackle complex problems (i.e. break them down into sub-problems, review what one already knows, acquire necessary new knowledge, and practice new skills).
- 4) To provide explicit learning outcomes and opportunities for students to assess their own acquisition of knowledge and ability to apply that new knowledge.

### **Structure of the Contextual Learning Module**

The typical structure of a 4-day (80 minute class session) CLM is:

- 1) Day One: Introduce concepts within a broad contextual area with which the students have some familiarity by conducting a discussion with mandatory class participation, and use the student contributions to sketch a "knowledge map".
- 2) Days 2-3: Formally develop the new knowledge, using lecture, class discussion, demonstrations, audio visual aids and most importantly, hands-on experiences (eg mini-labs).

- 3) Day 4: Have students work together in teams to apply the new knowledge in some aspect of design.

### **Bioelectricity: An Example of a Bioengineering Course Designed around Contextual Learning Modules**

In a course on Bioelectricity, the engineering concept of modular design is explicitly introduced from an electrical engineering perspective. We cover the topics of sensing, passive devices, information processing, active devices, real time control, discrete logic, output transducers and power/energy concerns. At the same time, engineering thought processes including brainstorming for multiple solutions, estimation, modeling, and the principle that no unique best design exists, are covered in the context of bioelectrical design. The course consists of 8 CLMS:

#### **1 - Sensors and the role of electricity in sensing things**

- Discusses electricity in the context of biological sensors, explaining that electricity and magnetism underlies all of our senses, and that the transduction of various forms of energy, including temperature, pressure, chemical, and electromagnetic into electrical potentials and/or currents is not only nature's paradigm for sensing, but also the bioengineer's. Explores the students' experience with sensors and demonstrates the ubiquity of sensors.

#### **2 - Passive Devices/Circuits**

- In the context of excitable cell membranes, ocean current loops, wind, the global electrical circuit, and the work day, introduces the concepts of closed loops, things that move around them, and the forces which drive that motion
- Discusses conservation of carriers, conservation of energy, resistance to motion, generation of heat and light, storage of charge, energy, etc.

#### **3 - Information processing**

- In the contexts of sensory transduction in humans and detection of diagnostic bioelectric signals, intuitive and formal approaches are presented to gain understanding of what constitutes signal, noise, time and frequency domains, filtering, and simple designs of signal processing systems.

#### **4 - Active Devices**

- Introduces the concepts of amplification and non-linear circuit elements in the context of the electrical properties of the heart.
- Discusses the application of electrical signals to the body in the contexts of defibrillation and cardiac pacemakers

#### **5 - Real Time Control Systems**

- Starting from the context of how we are able to point at an object, or track a moving object, introduces the major concepts associated with linear control systems, including block diagrams, feedback, response times, stability and instability, and control system design techniques.

## 6 - Discrete Logic

- Introduces the concepts of digital signals, logic circuits, analog/digital converters, memory and recall, and computerized programming.
- Uses electronic gates to illustrate and harness Boolean logical operations

## 7 - Output transducers

- Starting from the contexts of muscles, fireflies, and electric fish, explores output transducers- devices which transduce electrical signals into other forms of energy, including mechanical, chemical, electromagnetic, and thermal.

## 8 - Energy and Power

- Starting from the context of biological energy transduction, including transduction of electromagnetic radiation into chemical energy (photosynthesis), and transduction of chemical energy into mechanical energy (the end point of respiration), explores issues of power, energy density, photocells, fuel cells, batteries, and power supplies.

### Sensors: An Example of a CLM Used in Bioelectricity

As an example, CLM #1 begins on day 1 with a class discussion of biological senses, exploring the means by which information is gathered from the environment and introducing the extension of our senses beyond their natural range via man-made sensors. Students are encouraged to identify man-made sensors with which they have everyday contact and speculate on the mechanisms used to sense everyday things. Examples discussed in the first running of the course included the presence of a car at a left-hand turn signal, the temperature of water in a water heater and the oil pressure in a car engine. Students then discuss how similar measurements may be made in medical settings, environmental applications and ergonomic design. Days 2-3 expand on more formal aspects of sensor technology. Attention is paid to the physical modalities of sensors, describing resistive sensors such as thermistors, phototransistors, strain gages, capacitive sensors including microphones and pressure transducers and various other physical modalities including photoelectric, piezoelectric and pyroelectric sensors. Important sensor concepts including sensitivity, accuracy, dynamic range, noise, hysteresis and linearity are discussed. Interspersed with didactic presentations and discussions are short hands on experiences, including using thermistors, phototransistors and strain gages to produce calibration curves. Finally, on day 4, students work together in teams to apply their new knowledge of sensors to determine how they would measure the value of a specific parameter necessary to address a Biomedical, Environmental or Biotechnological process.

For example, in the first year that we ran the course, students formed teams of 4-5 students, which then could choose from the following problems.

- a) Detect algae blooms in the Peconic Bay
- b) Identify whether or not a child has an ear infection
- c) Determine whether a diabetic, who has lost sensation in his/her feet, is developing an inflammation as the result of poor shoes or overactivity
- d) Detect the depth of anesthesia during surgery
- e) Measure soil water content

Groups were asked to identify one means to accomplish the sensor input requirements for one of the design problems.

1. Consider who is your customer?
2. Describe an appropriate size and cost of the sensors considered
3. Explain how the sensor would provide the needed information
4. Describe the working range of the selected sensors
5. Describe possible failure modes of the sensor (under what conditions might the sensor provide confusing information?)

Student groups worked together with guidance from the instructor and a graduate student TA for ~1hour, and then gave short oral presentations of their solutions before the class and finally were asked to write up their solutions as a homework set.

## **Conclusions**

The early experiences we have had with the contextual learning module approach have been mostly positive, and we are currently discussing what changes would be needed for these courses designed for sophomores and juniors taking a minor in bioengineering to also serve as freshmen and sophomore level courses for a major. On the first day of the second 300 level course offered in the series (Biomechanics), the instructor asked the students what they expected the course to contain. A majority of the students requested that the course maintain the CLM approach. We believe that there are several reasons for this. Students clearly felt daunted by both the amount and complexity of material presented in Bioelectricity. We suspect that the CLM approach made the complex problem of assimilating the physical science, biological science and engineering content of the course tractable by dividing it up into "bite-sized" chunks. This demonstration of modular design was, of course, one of the goals of the curriculum. By the time Bioelectricity finished, the students had realized that if they had gotten behind in one of the CLMs, the short duration of each CLM made it possible for them to effectively get caught up again. This appeared to diminish the fear factor often associated in difficult classes with the problem of falling ever farther behind.

Further, students clearly enjoyed the discussions on day 1 in which they had the opportunity to "personalize" the course by focusing the discussion on experiences they had actually had in life. We believe that many students were surprised to learn how much they already knew about a topic, which may have sounded daunting at first. After a period of coming to understand what the instructors wanted, we believe that students also enjoyed the "design day" experience. Working in teams generated friendships and collaborations which we believe have lasted past the end of the course, and realizing that they indeed could make use of what was very recently acquired knowledge seems to have led to an increase in confidence in several of the students. Student evaluations of the course were uniformly high in spite of the observations made by several students during the semester that Bioelectricity was the hardest class they were taking.

On the downside, the course preparation and presentation are work-intensive, and the amount of content that may be successfully delivered is smaller than in a traditional lecture-based course. This has proven frustrating to several of the faculty developing curricula in the program, and may prove a stumbling block in producing a uniform undergraduate curriculum based on CLMs.

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## Author Biographies

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