Curriculum Integration - Students Linking Ideas across Disciplines

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Student Quotes

"It helped with other classes by giving us a hands-on approach to the math and sciences we were learning and by showing us that we will use this education once we get out of school."

"Integration of subjects is a great idea and saves time. Actually while taking physics and math I would go back and forth getting the application of math from physics and learning how to do something for physics from math."

"I enjoyed the integration of subjects because I enjoy seeing the big picture. I really need to see the big picture to understand things."

Foundation Coalition Students

Definition

Curriculum integration implies restructuring learning activities to help students build connections between topics.

A seminal study by Seymour and Hewitt concludes that one of the reasons students leave science and engineering is that they lose interest.[1] Building connections and establishing greater relevance is important.

Goal: Transferable Learning

Engineering graduates will be expected to transfer and apply their conceptual understanding in novel situations. However, transferring knowledge from one context and applying it in a different situation is a very challenging task.[2] Promoting successful transfer in engineering curricula depends upon students' prior knowledge and characteristics of their undergraduate experiences. Since prior knowledge is beyond curricular control, emphasis in promoting transferable learning should be on characteristics of engineering curricula.

During their undergraduate experiences students learn a number of topics simultaneously in different courses. In their courses students must actively extend their existing cognitive networks or construct new networks in which to hold the new information. They might more easily and effectively assimilate new information if topics presented simultaneously in different courses were closely related. Therefore, faculty members might coordinate topics across different subjects. Further, faculty members reasoned that they might facilitate assimilation if they constructed lectures and other learning activities that acknowledged other topics that students were learning and helped students build links between these topics. Research support for integrated learning activities can be found in multiple sources.

Source No. 1: Transferable Learning and Multiple Contexts

"The context in which one learns is also important for promoting transfer. Knowledge that is taught in only a single context is less likely to support flexible transfer than knowledge that is taught in multiple contexts. With multiple contexts, students are more likely to abstract the relevant features of concepts and develop a more flexible representation of knowledge."[3]

The use of well-chosen contrasting cases can help students learn the conditions under which new knowledge is applicable. Abstract representations of problems can also facilitate transfer. Transfer between tasks is related to the degree to which they share common elements, although the concept of elements must be defined cognitively. In assessing learning, the key is increased speed of learning the concepts underlying the new material, rather than early performance attempts in a new subject domain.

Curriculum Integration Example
Arizona State University Students Link Electromagnetics and Electronic Materials

Electromagnetics and properties of electronic materials are two of the most challenging areas of electrical engineering. At Arizona State University, Professor Ronald Roedel and co-workers use wave phenomena to integrate the material and offer students challenging and more realistic problems. Roedel unites concepts, like matter waves, electromagnetic waves, and lattice vibrations, to create a strong, interdisciplinary foundation.

Example Problem: Develop a nondestructive technique to examine regrowth kinetics of a silicon wafer implanted with silicon ions and the interface between the thin amorphous layer near the top of the wafer and the crystalline region below. Because amorphous and crystalline silicon have different relative permitivities, consider using a He-Ne laser to illuminate the wafer. As the interface moves, the thickness of the amorphous layer changes, and the reflectance should change. Set up the wave equations for normal incidence reflection from a two-interface dielectric system and solve these equations to determine the thickness of the amorphous layer. Then find the velocity of the amorphous/crystalline interface.

Instead of compartmentalizing material into either "solid state" or "electromagnetics" arenas, students who tackle problems like the one above see the need for thinking and problem solving skills at the analysis and synthesis levels.[4]

Roedel developed the Wave Concepts Inventory (WCI)[5] to measure students' conceptual understanding of the material. Using the WCI, Roedel has shown that students who have taken the integrated course have a stronger conceptual understanding of electromagnetics and electronic materials than students who take the separate courses.

Source No. 2: Student Perspective

Qualitative researchers at the University of California Berkeley interviewed 70 mechanical engineering students about their learning experiences in college. Although the researchers were aware of various integrated curricula that had been implemented across the country, they were interested in the student perspective of integration, as well as the pedagogical perspective. Data from the interviews tended to support the value of linking concepts. For example, "Of the 70 students interviewed, 60% commented on the benefit of linking concepts across disciplines."[6]

Source No. 3: Neurological Studies

Studies using functional magnetic resonance imaging show that activities in the "left prefrontal and temporal regions jointly promote memory formation"[7] for words in a list. Activity in the left prefrontal cortex may indicate that subjects must make some association between the new words that are being presented for recall and prior memories. Thus, studies of neurological processes support the necessity of building links between new stimuli and prior knowledge for subsequent recall.

Source No. 4: Concept Maps

Concept maps are graphs in which the nodes are concepts and the edges that connect the nodes are links that describe how the connected concepts are related.[8] Very roughly, concept maps may represent the knowledge of a person and the way in which the person has organized her/his knowledge. In general, faculty members would prefer that in a students' concept map that there would be many links between a concept and other concepts so that the student would be able to connect a particular concept to many possible applications. However, helping students develop more tightly interconnected concepts may require increased curricular integration.

References for Further Information:

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Curriculum Integration Example: Multidisciplinary Applications of Spectral Analysis at University of Alabama

At the University of Alabama, Sally McInerny, associate professor of aerospace engineering and mechanics, and electrical engineering associate professors Harold Stern and Tim Haskew have developed a junior-level multidisciplinary laboratory course on industrial applications of dynamic data acquisition and analysis. "By using a team of professors to teach the course," says Stern, "we could show the students how professors work in teams. And by using professors from different disciplines, we could help the students see concepts from different perspectives and how different disciplines share common principles." The instructors designed the course to integrate topics in digital signal processing, communications, acoustics, vibrations, electric machines, and power. Multidisciplinary teams of aerospace, electrical, industrial, and mechanical engineering students develop a qualitative understanding of time and frequency domains. "Interdisciplinary interaction in upper-level lecture courses is helpful to students," explained McInerny, "because it allows them to see some of the common principles and themes that run through all disciplines of engineering." Instructors use resources available via the Web and movies developed with MATLAB to help students develop a foundation for later work. With a conceptual foundation in place, students work to understand the breadth of possible applications, studying four laboratory modules: speech encoding and enhancement, machinery sound power measurement, machine condition monitoring, and motor condition monitoring. The course ends with a small design project.[9]

Curriculum Integration Example: First-Year Students at the Rose-Hulman Link Chemistry and Mathematics

Mathematicians and chemists at Rose-Hulman Institute of Technology introduce reaction kinetics simultaneously.[10] They present the general nth order reaction and the associated differential equation $A'(t) = k[A(t)]^n$, as well as first and second order reactions (n = 1 or 2), as important special cases. Obtaining solutions (analytical models) to the differential equations motivates antiderivatives (or indefinite integrals). Students acquire data from reactions in the chemistry laboratory and attempt to fit the data with these analytical models. An application in one discipline motivates theoretical exploration in another discipline. Models obtained from the theoretical exploration are used to interpret laboratory data. Students begin to see how a single concept appears in diverse contexts.

Curriculum Integration Example: Building Terminology Bridges

Differences in terminology (or nomenclature, as chemists prefer), units, or error analysis sometimes inhibit the ability of students to make links. For example, what physicists call torque is named moment of a force by faculty members teaching engineering mechanics. Chemists teaching reaction kinetics to first-year students often introduce the concept of indefinite integration before or at the same time as the students see the concept in calculus. However, chemists may be unsure of whether to call it indefinite integration or antidifferentiation. Terminology may not cause problems for faculty members who have mastered material, but different names for the same concept can hinder students' mastery. Helping students see the different names for the same concept can encourage deeper learning.

Whether you are just getting started or looking for additional ideas, the Foundation Coalition would like to help you improve integration across your engineering classes through workshops, Web sites, lesson plans, and reading materials. For suggestions on where to start, see our Web site at

http://www.foundationcoalition.org

or contact Jeffrey Froyd at froyd@ee.tamu.edu or 979-845-7574.