A Successful Experiment in Curriculum Integration: The Integrated Science and Technology Department at James Madison University

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Abstract:

In 1988, the Virginia General Assembly created the "Commission on the University of the 21st Century", which challenged each institution of higher learning in the Commonwealth to provide leadership in bringing about needed educational reform. In response to this challenge, James Madison University proposed an innovative new major in 1990 entitled "Integrated Science and Technology" (ISAT) that would embrace these reforms. The program focus was on using more effective pedagogical techniques, employing the latest instructional technology to enhance classroom learning, and integrating the curriculum to place emphasis on learning through applications. The first freshman class entered this new program in the fall of 1993.

ISAT integrates the study of science, mathematics, and technology in the context of societal and business concerns to uniquely qualify graduates to play a central role in creative scientific and technological problem solving. ISAT graduates are able to creatively solve scientific and technological problems in a real-world context with an appreciation for economic, social, political, and legal constraints. They communicate effectively and work productively in teams with individuals from a variety of disciplines.

ISAT is specifically designed to engage students in studying the sciences and technology, to lead students through examples of the practice of science, and to help them learn underlying methods and principles. Scientific theory is thus combined with hands-on experience designed to motivate and stimulate interest as well as impart learning. This is accomplished by the development of interdisciplinary, issue-based courses that address critical technology sectors of today's economy. These sectors include biotechnology, energy, environment, engineering manufacturing, information/knowledge management, telecommunications, and health systems.

ISAT has grown from an enrollment of 62 students in its first freshman class (1993), to graduating over 200 seniors in 2002. A listing of selected milestone events in the evolution of the ISAT program is shown in Table I. As can be seen from this table, ISAT has, by all measures, demonstrated a successful implementation of the original program vision.[1, 2]

TABLE I: Milestone Events in the Evolution of ISAT

TIME	MILESTONE EVENT
Spring 1993	State approves JMU's request to initiate ISAT BS program
Fall 1993	First ISAT undergraduate class enters the program (62 students)
Fall 1996	ISAT program enrollment grows to 500 students
Spring 1997	First ISAT class graduates (~$38,000 starting salary)
Fall 1997	ISAT occupies first new building
Spring 1999	State approves JMU's request to initiate ISAT MS program
Spring 2000	Fourth ISAT class graduates (~$46,500 starting salary)
Fall 2000	ISAT program enrollment grows to 800 students
Fall 2001	First ISAT graduate class enters the program (8 students)

The Department:

The ISAT Department educates students for positions that are often filled by graduates of traditional science, engineering, and business programs. The ISAT graduate, however, is professionally prepared in a broader sense. ISAT students are educated to be technological problem solvers, communicators, and life-long learners. They are unique in having:

- breadth of knowledge and skills across a variety of scientific and technological disciplines.
- formal training in collaborative and leadership methods, problem-solving techniques from many disciplines, and use of the computer as a problem-solving tool.
- the ability to integrate scientific and technological factors with political, social, economic, and ethical considerations.

Breadth is provided through study in several different strategic sectors that reflect national critical technologies, and currently include: biotechnology, energy, engineering manufacturing, environment, information and knowledge management, health systems, and telecommunications. Depth is provided through study in an area of concentration selected from among these sectors, and includes a comprehensive capstone thesis project.

One objective of the program is to educate students to solve problems in a "real world" context. Students learn to solve interdisciplinary problems using an integrated, collaborative, team approach. The societal, political, and economic impact of technological solutions is considered in a creative problem-solving environment. The goal is to develop a science generalist with intellectual coherence and a specific technological specialization. This balanced approach appeals to students who might otherwise have pursued a traditional science or engineering discipline except for the fact that they do not want specialize in one specific discipline at this point in their professional careers. This approach also attracts nontraditional students to the study of science and technology, including students interested in the societal, political, and business aspects of technology and groups that are traditionally underrepresented in the science and engineering disciplines.[1, 3, 4]

The Curriculum:

The ISAT curriculum is made up of five basic segments, as outlined in Table II. The Foundation Courses establish a basic introduction to science, mathematics and technology and are taken during the freshman and sophomore years. The Strategic Sector Courses allow a student to demonstrate interdisciplinary breadth by studying several different critical technologies, while the Concentration Electives allow a student to demonstrate depth in their chosen technology area. Finally, students have an opportunity to customize and broaden their educational experience through the universities General Education Program and the selection of a series of Approved Electives.

Table II: Five Basic Segments of the ISAT Curriculum

SEGMENT	CREDITS
Foundation Courses	33
Strategic Sectors	18-21
Concentration Electives	18
Approved Electives	18-21
General Education	30
TOTAL	*120*

The Foundation course sequence is made up of eleven courses that are grouped into four basic areas, as shown in Table III. The Analytical Methods sequence is made up of four courses that introduce basic mathematics, physical sciences, statistics, and computer programming using an integrated, just-in-time delivery technique. The Issues in Science & Technology sequence is made up of four courses that explore contemporary technology issues by applying the information learned in the Analytical Methods courses in an integrated, interdisciplinary fashion. Typical semester-long topics include the environment, modern production methods, living systems, and energy systems. The Connections sequence is made up of two courses that consider the ethical, economic, political and societal context of science and technology. Finally, the Instrumentation and Measurement course focuses on the use of laboratory instruments, measurement systems, data analysis, and the presentation of experimental results. Most of the Foundation courses have laboratory components that give the students hands-on experience in a team environment.

Table III: Four Basic Areas in the Foundation Course Sequence

COURSE SEQUENCE	CREDITS
Analytical Methods	13
Issues in Science & Technology	12
Connections	5
Instrumentation & Measurement	3
TOTAL	*33*

Note that the basic mathematics, science, and technology topics in the curriculum are integrated among the eleven different courses in the Foundations course sequence. Table IV attempts to separate the content areas covered in the Foundations sequence into traditional disciplinary headings in order to better describe the overall course sequence content.

Table IV: Foundations Course Sequence Content Areas

CONTENT AREA	**EQUIVALENT CREDITS**
Biology	3
Business/Economics	3
Chemistry	3
Computer Science	3
Engineering & Design	3
Environmental/Earth Science	2
Mathematics & Statistics	6
Physics	5
Science, Technology, & Society	5
TOTAL	*33*

In the junior year, students are required to take three different two-course introductory sequences in three of the seven Strategic Sectors offered in the department. These Strategic Sectors are listed in Table V, and represent interdisciplinary technology sectors that are critical to the global economy. The integrated breadth of exposure in these introductory sequences helps develop critical thinking skills and establishes a backdrop by which the student can select and concentrate in one of these Strategic Sectors in their senior year.

Table V: Two-Course Introductory Sequences Offered in the Seven Strategic Sectors
(students must select three of the seven available sequences)

STRATEGIC SECTOR	CREDIT S
Biotechnology	7
Energy	7
Engineering/Manufacturing	7
Environment	7
Health Systems	6
Information/Knowledge Management	6
Telecommunications	6
TOTAL	*18-21*

In the senior year, students must select one of the Strategic Sectors in which to concentrate. Students are required to complete at least 18 credits of upper-level work in their concentration area, including at least 12 credits of upper level courses and a six credit, year-long capstone senior thesis project.

In addition to the flexibility afforded by the selection of a concentration from among the seven different strategic sector areas, students also have between 18 and 21 credits of approved electives available in the junior and senior year. These electives can be "strategically deployed" in several different ways, based on the interests and aptitudes of the student. In general, these electives are used either to establish additional breadth of study or additional depth of study. Examples of using these electives for additional breadth would include completing a second concentration selected from among the Strategic Sectors, designing a second "Tailored Concentration" with the guidance of a faculty advisor, or completing a non-technical complementary minor of interest (e.g., foreign language, political science, economics, business, music, art, etc.). Examples of using these electives for additional depth would include taking additional courses in the original concentration area or completing a complementary technical minor (e.g., math, physics, biology, chemistry, materials science, etc.). The latter choice is often a precursor to graduate school application. In fact, approximately 15% of ISAT undergraduates go on to graduate programs ranging from business, law, and medical schools to basic science and engineering disciplines. Further variety in the curriculum is introduced through a wide-range of electives that are made available to the students through the university-wide General Education program.

Experiential Learning:

A hallmark of the ISAT program is the purposeful inclusion of experiential learning opportunities throughout the curriculum. Examples range from in-class active learning exercises and team-based laboratory experience, through summer internship opportunities and research experiences, to the team-based capstone senior thesis project.[3, 4]

The capstone senior project experience allows a team of students to work with a faculty mentor on an externally funded project with the intent of bridging the gap between the college experience and the world of work. The experience starts in the spring of the junior year, when the students are required to form project teams and meet with faculty mentors in order to select a topic and prepare a detailed proposal. This proposal, developed by the students under the guidance of the faculty mentor and the external sponsor, outlines the problem to be solved, and includes a proposed timeline, budget, and list of deliverables. The student team completes the work during the senior year, and presents the results (in oral and written form) in the spring of the senior year. This year, for example, approximately 70 different projects are underway, with student teams ranging from 1 to 5 in size. (Note: Honors Thesis projects are required to be individual.) A daylong Senior Symposium is held each spring in which the seniors present their work before their peers, the faculty, and the project sponsors. This symposium is held in a professional manner, in all respects emulating a typical one-day professional conference.

Another important experiential learning opportunity is the ISAT summer internship program. Approximately 70% of the ISAT students spend at least one summer working in industry, government laboratories, or other agencies/organizations. This work is typically paid, and not for credit. Through departmental resources, we assist students with resume preparation and assist the students in arranging interviews with companies and agencies that express interest in hiring ISAT students for internships and permanent positions.

Finally, many faculty maintain active research programs and regularly hire undergraduate students to work in their laboratories on sponsored grants and contracts in the summer and during the school year. In fact many undergraduate students have co-authored papers and conference proceedings with ISAT faculty and graduate students. This experiential learning opportunity is especially attractive to those students who express interest in continuing their studies in graduate school.

The Graduates:

Six ISAT classes have graduated since the inception of the program, and the recognition and reputation of the program is continuing to grow. ISAT graduates are highly sought after and valued by a wide range of employers, and are demanding relatively high starting salaries (~$46,500 average starting salary in 2000). Typically, ~75% of the class accepts employment offers and ~15% of the class goes on to graduate school. Many employers have made multiple hires and now come back to recruit on an annual basis. However, the fact that ISAT is a relatively new and unique program means that a large number of potential employers still do not know about the availability and capabilities of ISAT graduates. While there is strong regional demand in the mid-Atlantic region, we must do a better job of disseminating information about the program and its graduates to a broader audience of potential employers. It is anticipated that this task will become easier over time as more and more alumni are placed in jobs and as similar programs are developed at other institutions based on the JMU model.

The 2002 graduating class numbered more than 200, and represented the largest graduating class to-date. Faculty, space, and other resource limitations suggest a long-term target graduation rate of approximately 150 per year (on average) from the BS program with an additional 20 graduates per year (on average) from the MS program. These numbers represent a balance between graduating enough students to penetrate the market and increase recognition of the program, and keeping the job and graduate school placement rates acceptably high.

The Faculty:

The most precious resource in developing and sustaining a unique, interdisciplinary program like ISAT is the faculty. There are more than 40 faculty in the ISAT department, most with some practical experience in industry, government, or other agencies. The breadth of experience brought together to design and implement this curriculum is best demonstrated by the fact that this eclectic mix of 40 plus faculty completed doctoral studies in more than 30 different fields, as outlined in Table VI.

Table VI: Doctoral Areas of ISAT Faculty

Aerospace Engineering	Environmental Sciences	Natural Resources
Agricultural & Extension Education	Environmental Toxicology	Natural Sciences
Biochemistry	Genetics	Nuclear Engineering
Biomedical Engineering	Geography	Pharmacology/Neuroscience
Biophysics	Higher Education	Physics/Applied Physics
Botany	Industrial Engineering	Plant Pathology
Chemical Engineering	Jurist Doctor (Law)	Political Science
Chemical Physics	Logic & Philosophy of Science	Solid State Physics
Computer Engineering	Materials Science	Statistics
Computer Science	Mechanical Engineering	Technology Education
Electrical Engineering	Microbiology	Theoretical & Applied Mechanics
Environmental Engineering	Molecular Biology	Theoretical Biology

Managing such a diverse program is surprisingly easy; primarily because of the energy and enthusiasm exhibited by the faculty and students alike. Furthermore, we consciously emulate the cooperative team environment that we are trying to foster in our students in every aspect of curriculum development, course delivery, and departmental administration.

Contribution to Engineering Education:

We must keep in mind that the goal of the ISAT program is to graduate broadly educated science and technology generalists, not engineers. While the program is not associated with an engineering college, its departmental structure and curriculum design is an indication of the direction that traditional engineering programs are moving.[4,5,6] Take, for example, the most recent accreditation criteria published by the Accreditation Board for Engineering and Technology (ABET). In ABET's 2003-2004 "Criteria for Accrediting Engineering Programs",[7] the Program Outcomes and Assessment Criteria (Criteria 3) state:

"Engineering programs must demonstrate that their graduates have:
a) an ability to apply knowledge of mathematics, science, and engineering
b) an ability to design and conduct experiments, as well as to analyze and interpret data
c) an ability to design a system, component, or process to meet desired needs
d) an ability to function on multi-disciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively
h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
i) a recognition of the need for, and an ability to engage in life-long learning
j) a knowledge of contemporary issues
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."

It is clear that many of these criteria are exemplified in the structure and implementation of the

ISAT program. While the ISAT program addresses all 11 criteria to one degree or another. It is especially strong in those criteria with which traditional engineering programs have the most difficulty. Namely, criteria d, f, g, h, i, and j are central to the development of the ISAT culture. While criteria a, b, c, e, and k are, necessarily, covered less rigorously in an interdisciplinary curriculum like ISAT, the strength of coverage across all 11 criteria is much more balanced than in a more traditionally designed engineering curriculum.

ISAT was not designed to be is an engineering program, nor does it attest to educate students to the depth of a more disciplinary engineering curriculum. However, many elements of the ISAT program foreshadow the future direction of engineering.[4, 6, 8, 9]

Summary:

The ISAT Department at James Madison University provides a curriculum that integrates the study of science, mathematics, technology, society, and business to develop a graduate with unique professional qualifications. ISAT graduates will be able to play a central role in solving scientific and technological problems in a real-world context (with an appreciation of economic, social, political, and legal constraints), and communicate and work productively with individuals from a variety of disciplines. The use of the computer as a problem-solving tool is a central feature of the curriculum, along with an emphasis on the collaborative (team) approach to problem solving. The ISAT Program is specifically designed to engage students in studying the sciences and technology, lead students through examples of the practice of science, and help them learn the underlying methods and principles. Scientific theory is thus combined with hands-on experience designed to motivate and stimulate interest as well as impart learning.

While not an engineering program itself, ISAT contains many of the elements described in the "Program Outcomes and Assessment Criteria" of the Accreditation Board for Engineering and Technology, and may foreshadow the future direction of many engineering curricula.

For more information about the ISAT program, visit the departmental website at http://www.isat.jmu.edu. An anthology document describing the program in detail is also available in PDF form at http://www.isat.jmu.edu/anthology.PDF.

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