The Integration of Engineering Design Graphics (EDG) and Solid Modeling Related Content into Four-Year Industrial and Engineering Technology Majors

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INTRODUCTION

A new industrial data revolution is happening, and those who acquire expertise in engineering design graphics and computer-integrated manufacturing with emphases in computer-aided design or computer-assisted manufacturing are assuming important roles. In the future, students will increasingly learn how to integrate computer-related conceptual design, engineering design graphics, analysis and simulation activities, and engineering documentation functions.

The need for people in the aforementioned areas is great because industry cannot find enough people with training in this special technical area. Because manufacturing plays a key role in Michigan's economy, opportunities in the state are extensive. Automotive related design and manufacturing provides considerable opportunities for technology graduates.

3D graphical modeling and all its variations (solids and surfaces abstracted from solids) is increasing dramatically in real world engineering and design environments. Technologists involved with the design process will and are presently doing more with 3D graphical modeling. As a percent of time on the job it is the technologist and not just the engineer with increasing responsibility for the application of the 3D modeling technology.

The need for people knowledgeable in EDG and 3D modeling related concepts is great simply because industry cannot find enough people with educational and experienced background in this special technical area. The rapid development of sophisticated, but user friendly, applications software tends to point in the direction of technologists (not just engineers) having greater involvement in solid modeling, prototyping, analysis and simulation, and associated manufacturing technologies.

Technology students need to increase their abilities to rapidly analyze and synthesize 3D images necessary in the development of solutions to open-ended design problems. They need to have increased exposure to modeling technology in the context of solving poorly defined open-ended design problems. They need to have greater understanding of mechanical computer-aided engineering, computer-integrated manufacturing, finite element modeling/analysis, rapid prototyping, and various other simulation processes. This should be implemented in a hands-on learning environment and not in a pure abstract conceptual content.

The role of some students recently employed in EDG/CAD/CAM positions include: 1) planning, selecting and applying computer/automated systems for manufacturing or processing;
2) designing computer and automated systems machines, and equipment used in manufacturing or processing; 3) research and development leading to the creation of new or improved computer and/or automated equipment or processes; 4) developing common computer-related databases to be shared by engineering design, factory automation, and manufacturing planning functions; and 5) product design and development.

PROBLEMS AND ISSUES

There appears to be a reduction of EDG/drafting/design visualization courses available nationally in grades 7-12. Also, spatial related secondary school courses (i.e. Industrial Arts) have been reduced in availability and scope as educational philosophies and emphases change. Not only have secondary programs changed and decreased in number but so have the teacher preparation programs in associated areas. Fewer secondary school teachers have had preparation in the aforementioned visualization concepts. What appears to be happening is going to cause greater concern by technology faculties and certainly by employing organizations that so badly need the skilled workers (both technologists and engineers).

EDG/CAD PROGRAM AND COURSE EVOLUTION

Central Michigan University provided practical training in the applied sciences as early as 1903, which was part of the manual training movement. The intent of these courses was to provide students experiences that would allow them to introduce and teach students this (these) subject(s) in the public schools of the state. Early courses consisted of fine and applied arts, simple woodwork, bent iron, and mechanical drawing. The mechanical drawing course included "projection of shadows, instrumental perspective and plane geometry."

Early inclusion of CAD/CAM concepts were taught via Tektronix CRTs, digitizing tablets, joysticks, binary tape preparation devices, customized 2-D software, very early versions of NC software, all with output provided by a B-size plotter. By the early 1980s the CAD operation was upgraded to a large mainframe computer with remote dumb terminals located in cramped quarters. Software was Beta-site versions of drafting and surface modeling packages. By 1986, new facilities with very adequate space and equipment were being planned.

In 1987, the program was dramatically enhanced by the purchase of engineering workstations and solid modeling - based design and NC software. In January of 1989, the Department occupied a technically advanced facility where the program was further developed.

The current emphasis is being placed on 3-D solid and surface modeling techniques. There is a major shift occurring in the University's service region. Greater demand is developing for solid modeling, analysis and simulation, and associated manufacturing software usage. The nearly 95 years of evolution has been dramatic -- but, the greatest change has really occurred in the last 10 years.

PROGRAM STRUCTURE

As programs evolved there were critical programmatic factors to consider such as: 1) industrial needs and expectations, 2) staffing requirements, 3) financial resources, and 4) constant assessment and evaluation requirements. Course titles appearing in **bold type** are at least 50 percent EDG/CAD/CAM content- based. The resulting program structures as of 1997-98, follow:

Engineering Technology
B.S.E.T. degree

The engineering technology majors are designed to prepare students who aspire to careers related to electronic, manufacturing or mechanical engineering. Students who wish to pursue one of these majors must fulfill the following: 1) Basic Science and Mathematics (24-31 hours), and 2) technical courses (51 hours). The courses designated by an asterisk* may also be used to fulfill University Program and competency requirements. Students pursuing any of these majors must consult with a departmental advisor during their first semester at CMU.

1. Basic Science and Mathematics (24-31 hours)

All students pursuing a major in electronic, manufacturing or mechanical engineering technology must complete the following basic science and mathematics requirements:

MTH 130 (4) Pre-calculus Mathematics
* MTH 132 (4) Calculus I **OR**
* MTH 136 (5) Calculus I for Engineers and Scientists
MTH 133 (4) Calculus II **OR**
MTH 137 (5) Calculus II for Engineers and Scientists
* PHY 130 (4) College Physics I **OR**
* PHY 145 (4) University Physics I
PHY 131 (4) College Physics II **OR**
PHY 146 (4) University Physics II
* PHY 170 (1) College Physics Laboratory I **OR**
* PHY 175 (1) University Physics Laboratory I
PHY 171 (1) College Physics Laboratory II **OR**
PHY 176 (1) University Physics Laboratory II
* CHM 120 (4) Survey of Chemistry **OR**
* CHM 131 (4) Introduction to Chemistry
CPS 150 (2) FORTRAN Programming **OR**
* CPS 180 (3) Principals of Computer Programming

* These courses also fulfill University Program requirements.

2. Engineering Technology Majors (51 hours)

All engineering technology students are required to complete the following core courses. Additionally, all students must complete 21 required credits from one of three Technology Specializations. Students also need to select nine credits of Technical Electives in consultation with an advisor. **The specialization shall be the name of the major.**

Technology Core (21 hours)

IET 120 (3) Introduction to Engineering Technology
IET 170 (3) Metal Technology
IET 284 (3) Fluid Power Technology
IET 292 (3) DC Circuit Analysis
IET 365 (3) Plastics Technology
IET 375 (3) Robotics
IET 394 (3) Digital Electronics

Technology Specializations

Electronic Engineering Technology (21 hours)

IET 190 (3) Electronic Computer-Aided Design
IET 293 (3) AC Circuit Analysis
IET 390 (3) Discrete Device Theory
IET 392 (3) Linear Electronics
IET 492 (3) Interfacing with Programmable Devices
IET 494 (3) Data Acquisition and Control
IET 594 (3) Research and Development Electronics

Mechanical Engineering Technology (21 hours)

IET 154 (3) Engineering Design Graphics
IET 350 (3) Mechanism Design
IET 351 (3) Dynamics
IET 354 (3) Descriptive Geometry
IET 379 (3) Mechanics of Materials
IET 450 (3) Machine Design Graphics
IET 454 (3) Mechanical Design Problems

Manufacturing Technology (21 hours)

IET 225 (3) Manufacturing Process Planning
IET 326 (3) Manufacturing Methods Analysis
IET 377 (3) Numerical Control Programming
IET 426 (3) Plant Layout and Materials Handling
IET 428 (3) Manufacturing Quality
IET 477 (3) Computer-Assisted Numerical Control Programming
IET 500 (3) Production Concepts

Technical Electives (9 hours)
Select nine (9) semester hours of coursework from the following:

IET 154 (3) Engineering Design Graphics
IET 180 (3) Power and Energy Technology
IET 327 (3) Industrial Safety
IET 359 (3) Computer-Aided Drafting
IET 385 (3) Automotive Engines
IET 388 (3) Automotive Power Transmission
IET 425 (2-8) Industrial Internship
IET 427 (3) Product Liability and Safety
IET 455 (3) Tool Design
IET 457 (3) Computer-Aided Design
IET 458 (3) Advanced Computer-Aided Design
IET 475 (3) Metallurgy and Materials Testing
IET 500 (3) Production Concepts
IET 502 (3) Computer Applications in Industry
IET 592 (2) Electronics Technology

Total: 75-82 semester hours

Notes: MTH 130 may be waived based on the results of the Mathematics Placement Examination or permission of a mathematics adviser.

Computer-Integrated Manufacturing Major
B.A., B.S. degrees, Plan A or B

This major offers an interdisciplinary program of coursework for students planning CIM/CAD/CAM related careers. The student will have an adviser in both the Computer Science and Industrial and Engineering Technology Departments.

Required Courses (39 hours)

IET 154 (3) Engineering Design Graphics
IET 359 (3) Computer-Aided Drafting
IET 375 (3) Robotics
IET 377 (3) N/C Programming
IET 457 (3) Computer-Aided Design
IET 477 (3) Computer-Assisted N/C Programming
IET 502 (3) Computer Applications in Industry
CPS 170 (1) UNIX
CPS 180 (3) Principles of Computer Programming
CPS 181 (3) Introduction to Data Structures
CPS 210 (3) Assembly Language and Computer Organization
CPS 280 (1) FORTRAN
CPS 280 (1) ‘C’
CPS 340 (3) Advanced Data Structures and Algorithms
CPS 360 (3) Computer Design and Architecture

IET Electives (6 hours) selected with the approval of an IET adviser.

CPS Electives (6 hours) at CPS 280 level or above and selected with the approval of a CPS adviser.

IET 170 (3) Metal Technology
IET 190 (3) Electronic Computer-Aided Design
IET 326 (3) Manufacturing Methods Analysis
IET 350 (3) Mechanism Design
IET 354 (3) Descriptive Geometry
IET 379 (3) Mechanics of Materials
IET 425 (3-6) Industrial Internship
IET 426 (3) Plant Layout and Materials Handling
IET 450 (3) Machine Design Graphics
IET 455 (3) Tool Design
IET 458 (3) Advanced Computer-Aided Design
CPS 280 (1) ADA
CPS 280 (1) LISP
CPS 370 (3) File Manipulation Techniques
CPS 380 (3) Microcomputer Architecture
CPS 410 (3) Software Engineering
CPS 541 (3) Data Bases
CPS 565 (3) Computer Networks I
CPS 575 (3) Computer Graphics
CPS 576 (3) Digital Image Processing

TOTAL: 51 semester hours

The following mathematics courses or equivalent skills are prerequisites for some of the required courses on this major: MTH 132 (4) [OR MTH 136 (5)], MTH 175 (3) and MTH 223 (3). Students with incomplete high school preparation may find it necessary to complete additional mathematics courses.

Industrial Technology Management Major
B.A., B.A.A., or B.S. degree, Plan A or B

This major offers a program of coursework for students planning careers in industry with an emphasis on technology applications and their management. The major is available with five specified concentrations.

Required Core
(take 18 hours from the following):
IET 116 (3) General Drafting
IET 143 (3) Introduction to Graphic Arts
IET 170 (3) Metal Technology

IET 180 (3) Power and Energy Technology
IET 284 (3) Fluid Power Technology
IET 291 (3) Applied Electronics
IET 327 (3) Industrial Safety
IET 365 (3) Plastics Technology

Professional Sequence (9 hours):
IET 500 (3) Production Concepts
IET 501 (3) Application of Industrial Management Principles
IET 502 (3) Computer Applications in Industry

Additional Requirements (13 hours):
MTH 105 (3) Intermediate Algebra
STA 282 (3) Introduction to Statistics **OR**
PSY 211 (3) Introduction to Psychological Statistics
IPC 353 (3) Communication in Small Groups
CHM 120 (4) Survey of Chemistry **OR**
CHM 131 (4) Introduction to Chemistry I

Students must select one of the following Concentrated Areas of Study (30 hours). Notes: 1) *Courses are Required, 2) Selected from respective concentrations in consultation with the advisor.

Concentration 1: Mechanical Design and Engineering Graphics
* PHY 130 (4) College Physics I
* PHY 170 (1) College Physics Lab I
* MTH 106 (3) Plane Trigonometry
IET 154 (3) Engineering Design Graphics
IET 350 (3) Mechanism Design
IET 354 (3) Descriptive Geometry
IET 359 (3) Computer-Aided Drafting
IET 379 (3) Mechanics of Materials
IET 425 (2-6) Industrial Internship
IET 450 (3) Machine Design Graphics
IET 451 (3) Geometric Dimensioning and Tolerancing
IET 455 (3) Tool Design
IET 457 (3) Computer-Aided Design
IET 458 (3) Advanced Computer-Aided Design
IET 475 (3) Metallurgy and Materials Testing
CPS 105 (1) Word Processing Concepts
CPS 106 (1) Spreadsheet Concepts
CPS 107 (1) Database Concepts

Concentration 2: Manufacturing/Production Technology

- * PHY 130 (4) College Physics I
- * PHY 170 (1) College Physics Lab I
- * MTH 106 (3) Plane Trigonometry
- IET 225 (3) Manufacturing Process Planning
- IET 326 (3) Manufacturing Methods Analysis
- **IET 359 (3) Computer-Aided Drafting**
- IET 375 (3) Robotics
- **IET 377 (3) Numerical Control Programming**
- IET 425 (2-6) Industrial Internship
- **IET 426 (3) Plant Layout and Materials Handling**
- IET 428 (3) Manufacturing Quality
- IET 475 (3) Metallurgy and Materials Testing
- **IET 477 (3) Computer-Aided Numerical Control Programming**
- CPS 105 (1) Word Processing Concepts
- CPS 106 (1) Spreadsheet Concepts
- CPS 107 (1) Database Concepts

Concentration 3: Construction Technology

- * ECO 201 (3) Principles of Macroeconomics
- * PSY 336 (3) Industrial/Organizational Psychology
- Note: Prereq PSY 100 (3) General Psychology
- IET 160 (3) Wood Technology
- IET 294 (3) Residential Electrical Wiring
- **IET 357 (3) Residential Architectural Graphics**
- **IET 358 (3) Light Commercial Architectural Graphics**
- **IET 359 (3) Computer-Aided Drafting**
- IET 361 (3) Construction Technology
- IET 425 (2-6) Industrial Internship
- **IET 426 (3) Plant Layout and Materials Handling**
- IET 428 (3) Manufacturing Quality
- IET 561 (3) Light Frame Construction Workshop
- CPS 105 (1) Word Processing Concepts
- CPS 106 (1) Spreadsheet Concepts
- CPS 107 (1) Database Concepts

Concentration 4: Automotive Technology

- * CPS 105 (1) Word Processing Concepts
- * CPS 106 (1) Spreadsheet Concepts
- * CPS 107 (1) Database Concepts
- * MGT 310 (3) Small Business Management
- ECO 201 (3) Principles of Macroeconomics
- ACC 101 (3) Introduction to Accounting
- **IET 359 (3) Computer-Aided Drafting**
- IET 382 (3) Vehicle Control Systems

IET 385 (3) Automotive Engines
IET 388 (3) Automotive Power Transmission
IET 425 (2-6) Industrial Internship
IET 450 (3) Machine Design Graphics
IET 475 (3) Metallurgy and Materials Testing
IET 483 (3) Automotive Electrical Systems
IET 485 (3) Fuels and Lubricants
IET 486 (3) Automotive Testing

Concentration 5: Graphics Technology

* JRN 302 (3) Introduction to Graphics & Visual Communications
* CPS 108 (1) Computer Graphics Concepts
* BCA 210 (4) Survey of the Mass Media OR
ART 135 (3) Graphic Design I
IET 143 (3) Introduction to Graphic Arts
IET 154 (3) Engineering Design Graphics
IET 343 (3) Line Photography and Beginning Offset
IET 346 (3) Screen Printing
IET 349 (3) Typography
IET 359 (3) Computer-Aided Drafting
IET 425 (2-6) Industrial Internship
IET 443 (3) Process Color Procedures
IET 446 (3) Advanced Camera Techniques
IET 543 (3) Production Printing Methods

TOTAL: 70 semester hours

To satisfy the mathematics competency requirement, a student must earn a grade of "C" or better in MTH 105 or 106 or 107, or STA 282 or otherwise satisfy the requirements in the General Education Requirement section.

Minor: Minors are required on the B.A.A. and B.S. (Plan B) degrees but are optional on the B.A. and B.S. (Plan A) degrees. If a minor is selected, consult with major advisor.

Industrial Technology Minor
B.A., B.A.A., B.S., B.S. in B.A. degrees

Required Courses (21 hours):
Students may select courses appropriate to any IET major concentration with adviser approval:

Manufacturing/Production Technology
Construction Technology
Graphics Technology
Automotive Technology
Mechanical Design and Engineering Graphics Technology

TOTAL: 21 semester hours

A total of 86 undergraduate courses are currently offered by the IET Department of which 18 (22 percent) are engineering design graphics, CAD, CAM, and solid modeling related.

FUTURE EMPHASES

Possible suggested areas of greater emphasis for inductory EDG/CAD/CAM courses in university-level technology programs and secondary programs include:

1) Measurement and scale manipulation in at least British gravitational and metric (SI) units;
2) Mass properties to include volumes, surface areas, densities, mass and weights, centroids, and moments of inertia;
3) Coordinate systems to include 2, 2.5, and 3D variables (cartesian, polar, cylindrical, spherical, and vectors);
4) Constructive/boolean operations and sweeps applied to solids and 2D geometry (wireframe and sections/profiles);
5) 2D and 3D sketching skills that apply to constructive variational geometry and dimensional associativity as related to the aforementioned concepts;
6) 3D CAD/CAE modeling technology relating to the aforementioned concepts (1-5); and
7) Extensive use of open-ended poorly defined graphics/design problems.

PROBLEM AREAS

Developing, implementing and maintaining EDG and solid modeling programs can be a process loaded with difficulties:

1) Financial limitations are somewhat restrictive for departments/faculty just now making moves toward 3D modeling technologies. It should be noted though that software and hardware companies are very supportive and aggressive in supplying large discounts to school and students.
2) Hardware and software issues can be very difficult to deal with. Faculty need to be involved in benchmarking and testing of hardware and software. Ideally faculty could actually take formal vendor sponsored courses/seminars in order to more fully understand what they are buying into -- suppliers are most supportive.
3) Difficulty in staffing is currently at a near crisis situation as related to recruiting technology faculty. Local requirements plus accreditation guidelines (work experience and degree requirements) have made the task most difficult. A strong economy, poor communication skills, plus financial limitations are compounding factors.
4) Programmatic concerns are generally the result of honest and professional observation, philosophies, and teaching pedagogy. Open communications and a willingness to share information with all levels -- students, faculty, and administration.
5) Industrial involvement and support is imperative for success of any programmatic development, review and assessment. Industrial involvement, both formal and informal,

provides incentives and an anchor in terms of what is real. Advisory committee involvement, sources of internships/cooperations, research possibilities, and placement of graduates all result from industrial input.

6) Assessment issues and program reviews are currently tied directly to regional and professional accreditation, so technology faculty need to be involved at all levels -- program, major, departmental, school/college, and university. Assessment and program growth are increasingly interrelated.
7) Public and industrial relations can be facilitated by service activities, community and industrial-based developmental projects, résumé services, open houses, special workshops/seminars, and good personal communications via professional organizations/societies.

PROGRAM EVALUATION AND ASSESSMENT

The 1990s have required a greater emphasis on program evaluation and assessment. This has resulted from good curriculum and instruction guidelines, funding limitations, justifying faculty positions and equipment, maintenance expenditures, validity of industrial content, university-wide priorities and general program review requirements. There have been a number of evaluation and assessment strategies used in conjunction with the aforementioned EDG/CAD/CAM related programs to meet internal and external requirements.

The strategies utilized during this decade include:

1) Follow-up of graduates (1988-97) has provided detailed information relevant to former students' current status, relevant courses taken while a student, and their programmatic recommendations.
2) Manufacturing Engineering Certification Institute (SME/MECI) examination has been administered since 1988, and has provided normative data for nearly 100 concept areas.
3) National Association of Industrial Technology (NAIT) accreditation guidelines have been used to establish minimal requirements for the majors and degree requirements.
4) Technology Accrediting Council/Accrediting Board for Engineering and Technology (TAC/ABET) guidelines have been used to establish minimal requirements for the majors and degree requirements.
5) Transcript analysis of all graduates (1988-95) has provided considerable insight into program and course strengths and weaknesses.
6) Industrial ad hoc advisory committees have provided constant review of programs, internship opportunities and evaluations, instructional materials, design problems, and permanent employment opportunities for graduates.
7) Graduate placement feedback is provided almost weekly. Former students recognize the support of faculty and feel a strong responsibility for keeping faculty up-to-date in respect to future placement opportunities, corporate gifts, and technology trends.
8) Internship evaluations and reports are submitted weekly and reviewed by associated faculty. Each intern submits approximately 16 detailed reports per semester. Each report includes an evaluation by the student's supervisor.

All of the aforementioned evaluation and assessment methods are used to justify program growth, funding, and curriculum improvements. They have at times provided much needed leverage when discussing these issues with the dean, provost, and university-wide curricular authority committees.

SUMMARY

The Engineering Design Graphics/CAD programs described in the previous sections were introduced starting in the late 1970s and developed rapidly in the 1980s and 90s. They came about as a result of considerable effort by the Department of Industrial and Engineering Technology. They are some of the most successful technical programs in existence at what is defined as a liberal arts university. Placement has been nearly 100 percent with over two thousand graduates. There are presently over 250 students with authorizations in the associated majors. Faculty interested in learning more about the program should contact the author.

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BIOGRAPHICAL

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