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 introductory 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, and 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

JOHN G. NEE is currently a professor in the Department of Industrial and Engineering Technology at Central
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