Reflections on Essential Student Learning for Graduates of the Industrial and Manufacturing Engineering Department 2013-2014 Academic Year

A. Introduction

The Industrial and Manufacturing Engineering (IME) Department within the College of Engineering offers two programs: Industrial Engineering & Management (IE&M) and Manufacturing Engineering (MfgE). In addition to these two B.S. degrees, the Department offers two M.S. degrees in Industrial Engineering & Management and Manufacturing Engineering as well as a Ph.D. degree in Industrial and Manufacturing Engineering. The IME Department is served by nine faculty, two laboratory instructors/technicians, one IME extension specialist, one administrative assistant and one student services coordinator. During the second half of the 2013-2014 academic year, the department was served by eight faculty members (due to probationary faculty non-renewal). A search is currently underway to fill this open position. During the 2013-14 academic year the department housed 123 (IE&M) and 51 (MfgE) undergraduate students; awarded 35 B.S. degrees in IE&M and 12 B.S. degrees in MfgE.

B. Accreditation Status and Assessment of Student Learning

Both programs, IE&M and MfgE, received reaccreditation by the Engineering Accreditation Commission of ABET in August 2013, following an extensive review, including a campus visit by the reviewers.. This accreditation will be up for renewal in six years, 2019. Reaccreditation of the MfgE program required submission of an Interim Report in June 2014. During the 2013-2014 academic year, the IME Department developed an Assessment Manual for each program to enhance our assessment of student learning outcomes. The Assessment Manual defines program educational objectives, student outcomes and performance indicators for assessing each student outcome. The Assessment Manual also includes curriculum mapping tables which show courses where each student outcome is covered and assessed; direct and indirect tools to use in the assessment of student outcomes; and rubrics or scoring guides which describe varying quality levels of student work with targets for acceptable levels of student work. Also included is an assessment matrix which is used to summarize important pieces of the assessment elements for each outcome. A six-year assessment schedule is also included in the manual. The new assessment manual adopted by the IME Department in Spring 2014 is designed to focus our assessment efforts on evaluation and continuous improvement of student outcomes. During each academic year we assess three to four student outcomes so that outcomes assessed in year 1 are evaluated in year 2 and recommendations are implemented in year 3. Within a six-year cycle each outcome will be assessed twice. Moving from assessing every student outcome annually to assessing only three to four outcomes will allow more thorough, effective assessment and continuous improvement of student learning outcomes. During the 2013-2014 academic year, we worked to assess three student learning outcomes. Starting Fall 2014 assessment data collected during the 2013-2014 academic year will be evaluated by the IME Department faculty and our Industrial Advisory Board members.

C. Student Learning Expectations

Specific program objectives have been presented to constituents and discussed at various levels among faculty, students, and department alumni to ensure consistency with ABET accreditation criteria and the mission of NDSU CoE.

Program Educational Objectives for the IE&M Program. Within a few years of their formal commencement, graduates of the IE&M at NDSU will be expected:

1. to have engaged in advanced study or effective life-long learning in topic areas relevant to professional advancement and to enhancing the quality of personal life in today's global and social context.
2. to be productive citizens who become involved in their community and seek leadership roles in professional and community organizations.
3. to have established themselves as practicing engineers/professionals in their careers and to effectively and economically employ and integrate technology and people in organizational environments in industrial, healthcare, logistics, service and/or governmental settings, with appropriate consideration for current and future environmental factors, health and safety, manufacturability and ethical, economic, social and political issues.
4. to have participated effectively in multi-disciplinary teams in both leadership and followership roles throughout their career and have worked with and welcomed diversity.
5. to have developed expertise to solve advance problems relevant to modern production, commercial, social and/or governmental organizations, with principal emphasis on quality, productivity, continuous improvement and enterprise integration with demonstrated ability to effectively communicate complex technological concepts and advances, issues and professional details to a variety of audiences.

Program Educational Objectives for the MfgE Program. Within a few years of their formal commencement, graduates of the Manufacturing Engineering program at NDSU will be expected:

1. to have become established as practicing career engineers/professionals/managers, exercising effective problem-solving and creative design skills for technologically relevant, economically sound and socially responsible world-class manufacturing activities.
2. to have developed sound decision-making capability that effectively and efficiently employs and integrates lean principles, technology, materials, machinery, processes, people and monetary resources in progressive modern manufacturing environments.
3. to have developed the capacity to contribute effectively in multi-disciplinary teams in both leadership and followership roles, with an appreciation for the value of ethical responsibility and cultural diversity.
4. to have continued to expand professional knowledge and competencies through effective life-long learning attained through formal advanced study, job-skill development and personal initiative, enhancing both professional capabilities and personal life in a relevant societal and global context.
5. to have developed advanced expertise for communicating complex concepts of the technologies and organizational structures of manufacturing within contexts of both engineering and business constituencies and the general public.
6. to be productive citizens, involved with and seeking both service and leadership roles in their communities and profession.

Expected Student Learning Outcomes for the IE&M and MfgE Programs. The student learning outcomes for IE&M and MfgE programs are:

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 within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
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, economic, environmental, and social 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

The student outcomes listed above describe the measureable knowledge and skills that students are expected to acquire by the time of graduation. The IE&M and MfgE curriculums have been formulated to ensure that students in the program meet these outcomes, which are intended to provide graduates with the necessary preparation to attain the corresponding program educational objectives defined by the department. Specifically, each of the objectives has one or more outcomes linked to it that directly represent knowledge or skills that graduates must possess in order to meet that objective within a few years of graduation. Table 1 summarizes how the IE&M and MfgE student outcomes align with NDSU Undergraduate Learning Outcomes approved by Faculty Senate in May 2013. As can be seen from Table 1, student learning outcomes for both IE&M and MfgE align with all of the NDSU Undergraduate Learning Outcomes. Tables 2 (for IE&M) and 3 (for MfgE) map learning outcomes to the required IME courses for each of the programs.

Table 1.Mapping University Learning Outcomes versus IME Programs Student Outcomes

NDSU Approved Undergraduate Learning Outcomes	**IE&M and MfgE Student Outcomes**										
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
Communication				X			X				
Critical thinking, creative thinking, and problem solving	X	X	X		X						X
Understanding and applying technology	X	X	X		X						X
Understanding natural and physical worlds	X							X			
Understanding human societies			X	X				X		X	
Personal and social responsibility						X		X	X	X	

Table 2. Curriculum Map for IE&M Program (Learning outcomes versus IE&M core courses)

IE&M Learning Outcomes	111	311	330	440	450	456	460	461	462	470	472	480	482	485	489
a. Applications of mathematics, science, and engineering		I	I	I	R		E	E	R	E	E	R		R	M
b. Data design, experimentation, analysis, and interpretation		I	I		R	E	E	E			E			R	M
c. Design of system, component, and process		I	I			E				E	E		R		M
d. Teamwork	I	I	I		R	E			R			R		R	M
e. Engineering Problem Solving	I	I	I		R	E			R	E	E	R	R	R	M
f. Professional and Ethical Responsibility	I	I				E		E	R					R	M
g. Communications		I			R	E			R			R		R	M
h. Broader Education	I	I		I	R	E								R	M
i. Life Long Learning	I	I				E									M
j. Contemporary Issues	I	I	I			E		E					R	R	M
k. Techniques, skills, and modern engineering tools	I	I	I		R	E	E	E	R	E	E	R	R	R	M

I: Introduced E: Emphasized R: Reinforced M: Mastered

Table 3. Curriculum Map for IE&M Program (Learning outcomes versus MfgE core courses)

MfgE Learning Outcomes	111	311	330	380	430	431	432	440	456	460	461	480	482	489
a. Applications of mathematics, science, and engineering		I	I	E	E	E	R	E		E	E	R		M
b. Data design, experimentation, analysis, and interpretation		I	I	E	E	E			R	E	E			M
c. Design of system, component, and process		I	I	E	E	E	R		R				R	M
d. Teamwork	I	I	I	E	E	E	R		R			R		M
e. Engineering Problem Solving	I	I	I	E	E	E	R		R		E	R	R	M
f. Professional and Ethical Responsibility	I			E		E			E					M
g. Communications		I		E	E	E			R			R		M
h. Broader Education	I	I				E		E	R					M
i. Life Long Learning	I	I		E	E	E			R					M
j. Contemporary Issues	I	I	I	E		E	R				E		R	M
k. Techniques, skills, and modern engineering tools	I	I	I	E	E	E	R		R	E	E	R	R	M

I: Introduced E: Emphasized R: Reinforced M: Mastered

D. Student Learning Environments and Support Services

IME students are provided a variety of learning environments and support services. These include:

I**nstruction and Laboratories.** Student learning in each course is monitored by the course instructor in lecture courses through homework assignments, exams and quizzes, classroom participation; in laboratory courses through laboratory reports; and in capstone and project based courses through oral presentations and project reports. Most IME courses include a laboratory component (2 credits of lecture and 1 credit of laboratory) where students work on problem based hands-on activities individually or in smaller groups at least two hours a week. Most IME courses include guest speakers and company tours. Student performance in each course is monitored by the course instructor in lecture courses through homework assignments, exams and quizzes, classroom participation; in laboratory courses through laboratory reports; and in capstone and project based courses through oral presentations and project reports. The Faculty Course Assessment Report (FCAR) is used to provide faculty a mechanism for keeping track of classroom performance and to allow for reflection and self-assessment based on student feedback and to plan for improvements in each course. An FCAR is generated for each course taught in our department since Fall 2005. Faculty members assess courses they teach based on the parameters they see important for student learning. These classroom assessments are for faculty purposes and recommendations are summarized and reported as part of the FCAR.

Facilities. Students have access to an IME computer cluster through card key access 24/7. The computer cluster has 25 computers, two laser printers (one color), and a 3D printer. Again through card key access, IME students working on their capstone projects also have access to a separate laboratory and additional computers and printers at all times. Students also have access to computers within the Manufacturing Process Laboratory. During the 2013-14 academic year we have

enhanced the Automation Laboratory through the addition of new machine vision equipment. We are in the process of creating a new Additive Manufacturing Laboratory to support a number of IME advanced manufacturing courses including the newly developed IME 433 - Additive Manufacturing Course.

Student Organizations. The student chapter of Institute of Industrial Engineers (IIE) organizes an annual two-day tour of companies in the region. The goal of the tour is to increase students' exposure to the profession. The tour also includes a formal meeting with IME alumni. Additionally, IIE organizes several events though out the year featuring talks by industrial and manufacturing engineering professionals, they discuss different career opportunities, directions, and give advice. The IME Department funds the annual company tour as well as the student travel to regional and national IIE Conferences, and HIMMS Annual Conference.

Faculty Advisors. Once admitted to one of the programs, students are assigned to an official faculty advisor. However, the department utilizes an open approach to advising in order to foster personal growth and a sense of responsibility by creating a climate of support. Faculty welcome student inquiries on their plan of study and encourage questions about how to achieve academic, career, and personal goals. The department seeks to meet with each student at least once a semester. The department uses registration holds to ensure that students meet with their advisor before they can register for next semester's courses. After an advising session, faculty record a brief note of advice given. in the official student file kept in the main IME office.The same faculty member normally advises the student until his/her graduation, however, students may request a new advisor if they so desire. To monitor the effectiveness of the academic advising, the IME Department developed an advising survey during the 2013-14 academic year. Additionally, as part of the department chair exit survey/interview, students are asked to rate the quality of advisement they received in the program.

Introductory Courses. Introductory courses such as UNIV 189: Skills for Academic Success, and IME 111: Introduction to Industrial and Manufacturing Engineering, provide students with academic advice as well as exposure to the profession. As part of course requirements, students develop a plan of study; learn strategies for academic success; learn about the IE&M curriculums; gain exposure to industrial and manufacturing engineering professions; and attend the annual Engineering and TechExpo attended by employers from many engineering and technology-related industries. The TechExpo provides students an excellent opportunity to discuss or interview for current and/or future career-related employment and co-op/internship opportunities.

Advisory Board. The departmental Advisory Board consists of 26 members representing various industries in the region. Since the majority of the Advisory Board members are also IME graduates, the Board has a good representation of the primary constituencies of various industries and alumni. This constituency helps keep the program content relevant to current and emerging industry needs. The Advisory Board meets twice a year, normally in April and October. The Advisory Board provides input regarding the IE&M Program Educational Objectives and Program Outcomes. Makeup of the Advisory Board is diverse and includes representation from academia, area industry, out of state companies, and multi-national companies. Meetings of the board include time with students to hear their perspectives and needs. Many of the members serve as judges for capstone project presentations and guest speakers for various courses. They also help faculty arrange company tours, and identify course projects and guest speakers.

Cooperative Education and Internship Program. All IME students before completing their degree requirements are expected to participate in the Cooperative Education and Internship Program to gain career-related, work experiences. Cooperative Education and Internship Program can be taken for academic credit. However, these credits no longer count toward meeting degree requirements. According to the NDSU Career Center, about 90% of IME students (157 IE&M, 27 MfgE) attended the 2014 Engineering & Technology Expo (over 200 companies participated in the 2014 Expo). Although NDSU Career Center records show that only 23 IME (16 IE&M and 7 MfgE) students have participated in cooperative education & internship the during the 2013-14 academic year, many more have arranged internships through other means.

Capstone Course. During their senior year, students take the capstone course that includes engagement of students in real world projects performed on behalf of business and industrial clients. Such projects involve analysis of client needs, determination of engineering requirements, design, development, documentation, and presentation addressing clients' needs. Capstone students work with many regional firms in developing solutions for company problems that require them to draw upon the entire curriculum. In the current format, students in capstone courses apply for projects. The project teams concurrently conduct multiple projects in various industrial engineering subject areas. Student's benefit greatly from this Capstone experience as it focuses on gaining expertise in the following areas: experience and confidence in engineering and management practice; application and integration of concepts and tools from multiple industrial and manufacturing engineering topics; team work in a multi-disciplinary setting; presentation and documentation skills, and interaction with field engineers and managers. Many graduates and employers have stated that the capstone experience puts IME students on a high value-added path to accelerated advancement and career success patterns.

Student Services Coordinator. The IME department maintains hard copies of student records. The department uses a curriculum grid organized by year and semester in the program and a flow chart of courses to monitor student progress in meeting IE&M degree requirements. At the end of each semester the IME department student services coordinator ensures

that student progress toward program requirements is posted in student files. At least once a semester, faculty advisors meet with students and check their records to ensure the proper courses are taken in the correct sequence and that prerequisite requirements are satisfied.

E. Reflections About Essential Student Learning

The IME Department met bi-weekly between August 23, 2013 and May 22, 2014 (13 meetings). Almost every meeting included discussion items on the IE&M and MfgE curriculums, IME courses, and assessment of student learning. Most faculty members and staff attended these hour long meetings. Additionally, the IME Industry Advisory Board meetings in the Fall 2013, Spring 2014, and Fall 2014 included extensive discussions on program evaluation and student learning. Students are involved in reflective conversations about learning expectations through participation in advisory board meetings, formative assessment surveys, and finally through Exit Surveys and Interviews**.** Every graduating senior takes part in an exit interview with the department chair to collect their opinions and suggestions for improvement in the program. Since 2005, students are expected to complete an exit survey as part of the exit interview process.

During the 2013-2014 academic year, these discussions have resulted in several significant improvements. These changes were identified through extensive discussions within the Department including discussions with our Advisory Board members. Following departmental faculty voting and approval, some of these curriculum changes were also voted and approved at the College and University levels. Below is a list of changes made to the IE&M and MfgE programs:

1. Developed a new course: IME 433 - Additive Manufacturing (3 credits, elective for MfgE): A synchronized approach considering functional design, analysis and manufacturing that support seamless integration of geometry with performance. The course will address computational geometry, reverse engineering and additive manufacturing principles and their concept. Pre-requisite: IME 330.
2. The MfgE program increased the total number of technical elective credits to nine by making IME 432 - Composite Materials Manufacturing an elective course.
3. The IE&M program increased the total number of technical elective credits to nine by making IME 462 - Total Quality in Industrial Management an elective course.
4. Moved IME 456 - Program and Project management course from senior year to junior year.
5. Changed course title, bulletin description, and pre-requisite requirements of IME 485 - Facilities Layout and Design (required for IE&M, elective for MfgE).
6. Introduced a laboratory component to IME 460 - Evaluation of Engineering Data to give students more opportunities for solving problems. The course meets for two hours of lecture and two additional hours for weekly laboratory sessions.
7. Updated pre-requisite requirements for seven IME courses:
   - Courses required for both majors: IME 311 - Workstation Design, IME 440 - Engineering Economy.
   - Courses required for MfgE (technical elective for IE&M): IME 380 - CAD/CAM for Manufacturing. IME 431 - Production Engineering.
   - Courses required for IE&M (technical elective for MfgE): IME 450 - Systems Engineering. IME 462 - Total Quality in Industrial Management and IME 472 - Simulation of Business and Industrial Systems.
8. Restructured our capstone experience courses so that IME 489 – Industrial and Manufacturing Engineering course is offered both fall and spring semesters.
9. Enhanced the laboratory component of IME 427 – Electronics Manufacturing by partnering with NDSU Center for Nanoscale Science and Engineering (CNSE). Through this partnership we have secured access to CNSE facilities, including professional-grade equipment in the clean rooms, and technician support for the laboratory portion of IME 427.

As mentioned earlier the assessment data collected during the 2013-2014 academic year will be evaluated by the IME Department faculty and our Industrial Advisory Board members in order to assess student learning as well as to identify areas where our students struggle as learners. Early discussions with faculty and Advisory Board members have identified oral communication, in particular interview skills, resume writing, and the ability to explain lean concepts as areas where our students need more emphasis placed. As the academic year progresses the IME Department is working on strengthening not only our current students but also our program as a whole in these areas of concern. The Department has already implemented a Boston Scientific Lean training workshop this semester, and there were a large number of students who participated. Within the course of the next month the Department will be inviting the NDSU Career Center staff to work with the capstone students on their presentation skills. The Department will also be promoting the mock interview sessions which the Career Center provides for all NDSU students. It is the hope of the Department that our students will soon begin to excel in these current areas of concern.