Session IV

Consolidating Co-ordination and Integration Among Educational Institutions in GCC Countries

Engineering Education Excellence at King Abdul Aziz University

Dr. Youssef A. Shatilla
Faculty of Engineering, King Abdulaziz University
Jeddah, Saudi Arabia

ABSTRACT. Engineering education at King Abdul Aziz University (KAAU) is undergoing a powerful paradigm shift that is driven by the desire to achieve stronger ties with industry. One avenue through which this shift is going to materialize is the offering of a new course, Introduction to Engineering Design, IE201, which is mandatory for all engineering students. The goal of the new course is to introduce students to the Engineering Method (EM) which can be accomplished by focusing on 1) Self Regulation, 2) Communication, 3) Working Cooperatively and Collaboratively, 4) Problem Solving, 5) Modeling, and 6) Quality. These objectives are achieved by the use of Active Learning in class where student teams, continuous improvement of the learning process and constructivist learning exercises are routinely used. The course topics are delivered in three different learning environments which resulted in creating three different course sessions; 1) Concepts, 2) Laboratory, and 3) Modeling. One of the more important tasks of the course is to make the students familiar with work products assessment process which focuses on quality as perceived by the customer (instructor). In this paper, we present our experience with delivering the new course for the first time during the Summer Term of 2003 at KAAU.

Index Terms –Active Learning, KAAU, Engineering Method

Introduction

Engineering Employers (industry) who are the University's customers have tremendous impact on the engineering curriculum through the attributes they seek in their employees. In 1988 the U.S. Labor Department reported that employers were seeking employees with the following attributes:

- Learning to Learn.
- Listening and Oral Communication.
- Competence in Reading, Writing, and Computation.
- Adaptability: Creative Thinking and Problem Solving.

- Personal Management: Self-Esteem, Goal Setting/Motivation and Personal/Career Development.
- Group Effectiveness: Interpersonal Skills, Negotiation, and Teamwork.
- Organizational Effectiveness and Leadership.

Major corporations have common desirable employee attributes:

1. A good understanding of engineering science fundamentals
2. A good understanding design and manufacturing processes (i.e., understands engineering).
3. Possesses a multi-disciplinary, systems, perspective.
4. A basic understanding the context in which engineering is practiced: economics, including business practices; history; the environment; customer and societal needs.
5. Good communicator: written, verbal, graphic, and listening.
6. High ethical standards.
7. An ability to think both critically and creatively - independently and cooperatively.
8. Flexibility - the ability and self-confidence to adapt to rapid/ major change.
9. Curiosity and a desire to learn for life.
10. A profound understanding of the importance of teamwork.

There is an obvious overlap in industry between engineering and science which directly affects engineering schools curricula[1]. Engineering education is highly theoretical and emphasizes math and science. This emphasis is based primarily on the assumption that engineers are likely to learn the more applied portion of their field on the job while they are unlikely to learn math and science on the job. Students are expected to learn but never taught how to learn. They are expected to solve problems but never taught how to solve problems. All of this creates a gap between what engineering students learn at school and what practicing engineers really do on the job.

The School of Engineering at KAAU has recognized this gap between engineering education and the engineering profession and has taken ambitious steps to close it. One important step is the offering of a new course, Introduction to Engineering Design, for the first time during the Summer Term of 2003. The course material has been used in several classes at various universities such as Arizona State University (ASU). At ASU this material is used primarily in a course with the same title, Introduction to Engineering Design, ECE100, which is an engineering core course. In this paper, we will review the course material and discuss its underlying philosophy and how it meshes with College mission and objectives.

Course Goal - Engineering Method

Engineering education at KAAU is undergoing a powerful paradigm shift that is driven by the desire to achieve stronger ties with industry. One avenue through which this shift is going to materialize is the offering of a new course, Introduction to Engineering Design, IE201, which is mandatory for all engineering students. The goal of the new course is to introduce students to the EM which can be accomplished by focusing on the following objectives: 1) Self Regulation, 2) Communication, 3) Working Cooperatively and Collaboratively, 4) Problem Solving, 5) Modeling, and 6) Quality.

Borrowing from Koen's [2] definition of the EM and his heavy reliance on the use of heuristics, the EM definition becomes [3]:

The use of heuristics to cause the best change in a poorly understood situation with the available resources.

Course Objectives

The course goal is further defined with above-mentioned objectives. These objectives represent areas of interest that are needed for the student to become proficient at the EM.

Self Regulation

One of the course objectives is to produce self-regulated learners [4] who share the following characteristics:

- They plan, set goals, organize, self-monitor, and self-evaluate at various points of the learning process.
- They use self-oriented feedback.
- They proactively seek out and profit from the learning process. They are not only self-directed but also self-motivated.

In IE201, students' affective behavior is assessed to check if they are demonstrating self regulation. Instances of poor behavior or participation are recorded as Self Regulation Lapses (SRLs) which have negative impact on course final grade. SRLs include, but are not limited to:

- absences and/or lateness to class,
- being unprepared for class
- failure to participate and/or disruptive or unethical classroom behaviors,
- minor inappropriate use of KAAU properties and facilities,
- late submittal of an assignment (up to 1 week late is 1 lapse, between 2 to 3 weeks late is 2 lapses, more than 3 weeks late is 3 lapses),
- no credible effort (NCE) on an assignment.

Communication

Communication is a total of all the things said – and not said. It is the perception, not the intention, that counts. Therefore, communication (verbal and non-verbal) skills can not be overemphasized. A brilliant idea could never see the light if it is poorly presented. On the other hand, a not-so-brilliant idea could be a huge success if it is conveyed the right way at the right time. A successful engineer is not only technically competent but also able to transfer his ideas to people around him.

In IE201, students are exposed to the following concepts which they use in making presentations to small groups and to the entire class:

- Communications roadblocks,
- Listening skills and techniques,
- Communication tools,
  - Talking chips
  - Paraphrase for understanding
  - Constructive feedback, and
- Presentation of technical work

Working Cooperatively and Collaboratively

Most of the problems facing society today consist of divisible, optimizing, conjunctive tasks that will be solved only by teams of people, working together. Engineers work in teams to solve problems. When problems are ill-defined, teams help clarify the problems and generate potential solutions. When problems are clearly defined, they are generally too involved for a single engineer to solve. Teams of engineers, not single ones, are the building blocks for successful technical groups.

In IE201, students learn and practice, in semester-long teams, the following concepts:

- Stages of team development,
  - Orientation,
  - Conflict,
  - Cohesion,
  - Performance, and
  - Dissolution
- Team dynamics jigsaw exercise which is an active learning exercise where:
  - A general topic is divided smaller, interrelated pieces (like a puzzle)
  - Each member of each team is assigned to read and become an *expert* on a different piece of the puzzle
  - After each person has finished presenting their expert material to the rest of the team, the puzzle has been reassembled and *everyone* in the team knows something important about *every* piece of the puzzle.
- Team building issues,
- Team composition and roles,
- Types of team decisions,
- Guideline for productive meetings, and
- Team norms.

Problem Solving

The underlying approach to develop the solution to any engineering problem is practically the same regardless of the solution nature. IE201 uses a text book by Fogler[5] to teach students the following techniques:

1. Problem definition,
2. Solution generation,

3. Decision analysis,
4. Implementation, and
5. Solution evaluation.

Students, in teams, apply these techniques in mini projects as well as in a semester-long project to solve engineering problems which are not major-specific. Extra credit is given to students who apply these techniques in out-of-class situations.

Modeling

There is hardly any solution to any engineering problem that does not include modeling. Modeling can be conceptual, mathematical, physical, or visual. Mathematical modeling receives particular emphasis, and sketching is routinely practiced as it is important for representing visual models.

The course uses a text book by Starfield[6] to teach students the following techniques:

1. Solutions and resources,
2. Heuristics and spreadsheets,
3. Results presentation,
4. Stochastic modeling,
5. Information organization,
6. Introduction to optimization,
7. System dynamics,
8. Solution strategies and trade-offs, and
9. Expert systems.

The course development committee thought that Modeling can be offered as a stand-alone course, Modeling IE202, and decided to offer it for the first time in the Spring Term of 2004.

Quality

Quality is a term that has a wide range of meanings. It pervades all aspects of today's engineering work environment. In IE201, students are exposed to the following concepts:

- Customer needs,
    - Expected requirements,
    - Revealed requirements,
    - Exciting requirements, and
    - Customer satisfaction
- Quality culture,
    - Deming's [7] Total Quality Management (TQM)
- Improving quality,
    - Re-engineering – ishinsuru and
    - Continuous improvement – kaizen
- Flowcharts, and
- Process check.

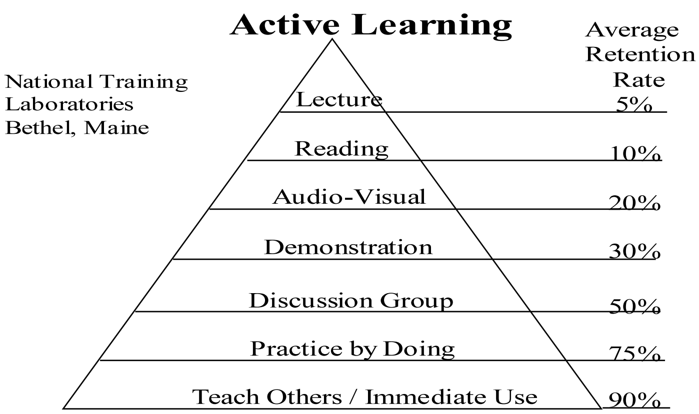
Quality is an essential part of all student activities. It affects the type of homework they submit; it defines the grade they receive in the class. Students strive hard to meet, or exceed, the customer (instructor) set of requirements (using Kano's model [8]) that is determined before class through the use of checklists. Students are given the chance to assess other students work products to learn how to appreciate and reward quality. They practice continuous improvement first hand by giving feedback on the learning process (process check) at the end of each class. They demand and expect instructors to follow up on their feedback to see if they "walk the talk". All this creates a quality culture that has been outlined elsewhere [9] and, therefore, will not be discussed here.

Management of the Course

Following are management issues that need to be presented to give a clear and complete picture of the course.

Active Learning

In a study done by the National Training Laboratories it was found that the learner's retention rate is highly affected by the learning environment as seen in the active learning pyramid below. To lecture is at the top of the pyramid and to teach is at the bottom. In conventional class, the instructor who prepared and delivered the lectures is the one who benefits the most. Through active learning we move the students closer to the bottom of the pyramid where the retention rate is higher. Active learning encourages information restructuring [10] when students integrate the new information with what they already have to form a new body of knowledge. It encourages the students to be mentally, emotionally, and physically engaged in the learning process.



One of the active learning techniques is the constructivist learning exercise where student teams are assigned a problem but are not given any suggestions on how the problem might be solved. The teams work until they are unable to proceed. At that time either some guidance is given by the instructor or teams share their views on how to proceed. The teams then continue working on the problem and the cycle is repeated.

The Three-Session Course

The course topics are delivered in three different learning environments and, therefore, there are three different sessions [3] in the course.

1. *The Concepts Session*

The important concepts are *first* introduced, examined, and tested in the Concepts Session; these are large classes. A mixture of short lectures, group work, quizzes, and videos is employed to deliver and assess the material. Generally, it is assumed that the students have read the material related to the topic *prior* to the class meeting; therefore, class time is used to assess what has been learned, clarify the reading, and, in small groups, test the ideas that have been presented in class. Thus, group work is required during class and individual work is required outside of the class. The Engineering (or Academic) Journal is also used in the Concepts Session to initiate the reflection process which includes both Self Regulation and Information Restructuring. This journal is designed to be used for recording, or documenting, *and continuously improving* the student's learning process through student reflection upon the assigned textbook reading.

2. *The Laboratory Session*

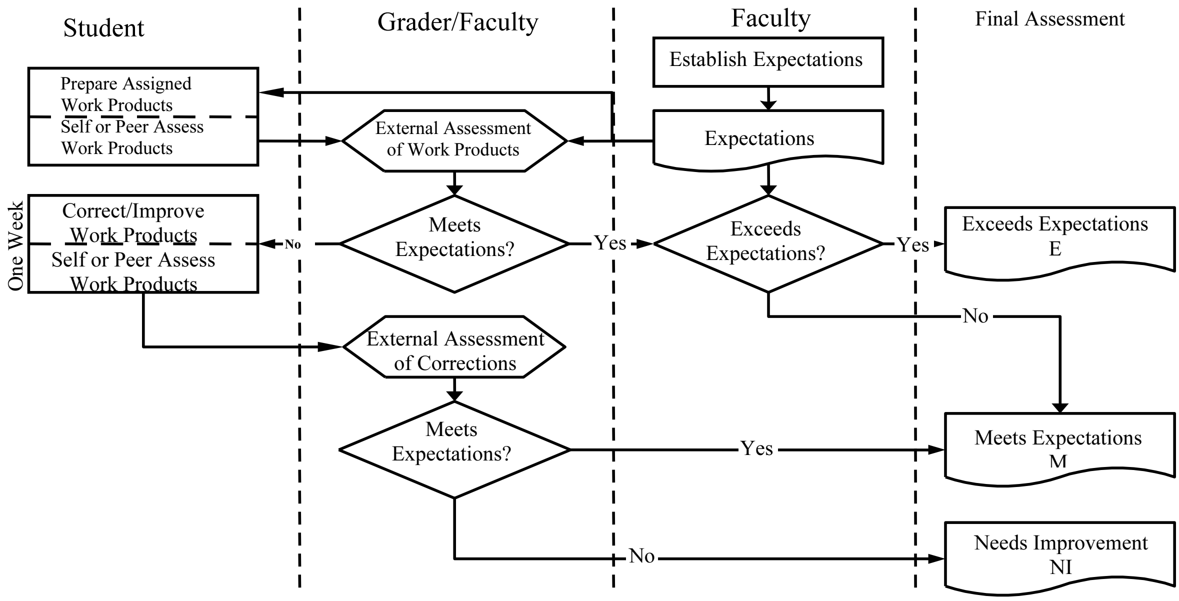
All of the work in the Laboratory Session is team based. In Laboratory, the teams are assigned a broad problem context and are then expected to work a number of smaller problems that are consistent with the specified context. The general problem provides a series of opportunities for the teams to practice and master the specific concepts introduced in the Concepts Session. The Laboratory Session is somewhat less structured than the Concepts Session. There are two general problems assigned; one that culminates in the development of a process (an assembly process), and one that culminates in the development of an artifact. As in the Modeling Session, the actual final work product (process or artifact) is not as important as the process the teams used to develop the work product. The students will be continually encouraged to reflect on and document their decision process; i.e., the reasons they decided to do what they did.

3. *The Modeling Session – to be offered as part of IE202*

The Modeling Session is the smallest class and is delivered in computer classrooms in which the ratio of students to computers is 2 to 1. The students are expected to work in small teams to build models and present intermediate work products to the class. A constructivist approach is used in which students are given a new problem and asked to start developing models that could be useful in solving the problem. The Modeling Session concentrates on encouraging the students to think about how they created their models, and why they created them; the final work product (model) is not as important as the process the students used to develop the work product or model.

Assessment

Work products are assessed, not graded, using the following terms [3]: meets expectations (M), exceeds expectations (E), or needs improvement (NI). This division into three distinct categories is used to assess: 1) submitted work products, 2) session activities (e.g., quizzes), and 3) session participation. The general process used in assessing an activity or work product is shown in the figure below. The figure shows the important tasks for the people associated with the course. The student is assigned the task of doing the work, self assessing the work, and correcting any work that needs improvement. The Grader/Faculty are assigned the task of assessing the work to determine if it meets expectations on the first submittal (or on subsequent re-submittal, if required). The Faculty are responsible for establishing the expectations and determining when a work product exceeds expectations.



Based on the above assessment process, it is very important for the faculty to *clearly and completely* define their expectations of any work product *prior* to its offering via a checklist. This eliminates expectations *creep* which de-motivates students considerably.

In the above assessment process, several features of the work product are assessed. However, there is one more item that needs to be assessed which is assessing what the student knows and how well he knows it i.e.; assessing the student's educational states. In 1956, a group of psychologist [11] divided the educational states into three domains; cognitive - Levels of Learning (LoL), affective – Degrees of Internalization (DoI), and psychomotor domains in which they further defined a cognitive taxonomy containing six major categories. They were: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. In 1964, a taxonomy was defined [12] for the affective domain. It had the following categories: Receiving, Responding, Valuing, Organization and Characterization by a value. In IE201, students are taught the importance of and trained to recognize the LoLs and DoIs for various work products. Each course session has its LoL clearly defined to the students to make them aware of not only the content of the lecture but also of the learning process involved to acquire this content. As with every concept in the course, students are rewarded if they can identify LoLs and DoIs out of their own personal life.

Conclusions

Engineering education at KAAU is undergoing a powerful paradigm shift that is driven by the desire to achieve stronger ties with industry. One avenue through which this shift is going to materialize is the offering of a new course, Introduction to Engineering Design, IE201, which is mandatory for all engineering students. The goal of the new course is to introduce students to the Engineering Method (EM) which can be accomplished by focusing on 1) Self Regulation, 2) Communication, 3) Working Cooperatively and Collaboratively, 4) Problem Solving, 5) Modeling, and 6) Quality. These objectives are achieved by the use of Active Learning in class where student teams, continuous improvement of the learning process and constructivist learning exercises are routinely used. The course topics are delivered in three different learning environments which resulted in creating three different course sessions; 1) Concepts, 2) Laboratory, and 3) Modeling. One of the more important tasks of the course is to make the students familiar with work products assessment process which focuses on quality as perceived by the customer (instructor). The course was offered for the first time during the Summer Term of 2003.

It has been the experience of the course faculty to observe a big change, on average, in students' attitude towards learning in general and towards this course in specific. Students have reported that the course experience have helped them conduct successful job interviews, organize their own way of thinking, increased their self-esteem, heightened their pride in the engineering profession, minimized their fear of talking to large groups of people, made them aware of the needs of people around them especially those whom they work with, made them recognize paradigms in their own personal life and how powerful they can be, and used a systematic way to solve personal problems and resolve conflicts. Faculty have also reported a very important finding which will be used as a rule of thumb from now on: set the standard high and students will always surprise you by meeting and occasionally exceeding your standards. It was very pleasing to see students change from hesitant and shy individuals into energetic and self-motivated team members.

Change is happening in the College of Engineering at KAAU and there is no going back. This change is supported by the University administration at the highest level and is meant to continue as long as it results in continuous improvement in the education process. The offering of IE201 is the first step that is soon to be followed by similar steps to achieve the desired goal. This will be the subject of later publications about the subject.

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تميز التعليم الهندسي في جامعة الملك عبد العزيز

د. يوسف شاتيلا

كلية الهندسة، جامعة الملك عبد العزيز، جدة، المملكة العربية السعودية

المستخلص: يمر التعليم الهندسي بجامعة الملك عبد العزيز بمرحلة تطوير جذرية نابعة من الرغبة الملحة لتوطيد العلاقة مع الصناعة. ويعتبر استحداث مادة " مقدمة في التصميم الهندسي – هـــ.ص. ٢٠١ " كمادة إلزامية لجميع طلاب الهندسة كعنصر هام وأساسي في تحقيق التغير المنشود. وللمادة الجديدة هدف رئيسي هو استيعاب الطالب "للطريقة الهندسية" والتي يمكن تعريفها بأنها القدرة على إحداث أحسن تغير ممكن لأي مشكلة بغض النظر عن مدى وضوح فرضياتها وذلك في حدود الإمكانيات المتاحة ويمكن تحقيق هذا الهدف عن طريق: ١) الانضباط الشخصي، ٢) تنمية مهارات الاتصال، ٣) تنمية مهارات العمل الجماعي، ٤) تنمية مهارات منهجية حل المشاكل، ٥) تنمية مهارات المحاكاة والنمذجة، ٦) إتقان مبادئ الجودة. وتستخدم أدوات التعليم التفاعلي والتحسين المستمر والتعليم الذاتي في تحقيق أهداف المادة الجديدة والتي تقسم محاضراتها إلى ثلاثة أقسام رئيسية: ١) قسم الأفكار الرئيسية، ٢) قسم المعمل، ٣) قسم الحاسب الآلي للنمذجة. وتحظى عملية تقييم الطلاب في المادة الجديدة باهتمام بالغ حيث تعتبر جزء لا يتجزأ من المواضيع التي يدرسها الطالب ويمارسها شخصيا وذلك لإرساء مفهوم التقييم في ذهنه وربطه بمبدأ إرضاء العميل (عضو هيئة التدريس) والذي يعتبر مبدأ أساسي في نجاح أي صناعة. كما تتعرض الورقة إلى خبرات أعضاء هيئة التدريس بالكلية منذ بدأ تقديم المادة في صيف ٢٠٠٣.