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Gap Analysis of a Newly Developed Electrical Engineering Program using NCEES FE Exam

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***Abstract* - In this paper a methodology to identify gaps in a newly developed Electrical and Computer Engineering program, using Fundamentals of Engineering (FE) exam administered by the National Council of Examiners for Engineering and Surveying (NCEES), is presented. The methodology is applied to selected course in Electrical and Computer Engineering. This paper demonstrates that the methodology succeeded to identify gaps in course learning outcomes and corrective actions to topics covered is consequently proposed. The proposed methodology is adequate for programs under development or already developed and is recommended as a continuous improvement and review method for engineering curriculum.**

Keywords* - *Engineering Curriculum Development, FE exam, ABET and Course Learning Outcomes

I. INTRODUCTION

One of the widely accepted practices in assessment of degree student outcomes for the purposes of ABET accreditation is to survey graduating seniors FE Exam results. The FE Exam is administered in the USA by the NCEES [1] and [2]. Engineers with undergraduate degree are eligible to take the FE Exam starting the last semester prior to graduation without any additional requirement. However, some states has specific rules on eligibility such as New York State where engineering students are eligible to take the exam within 20 credits of graduation [1]. Upon successful completion of the FE Exam, Engineers receive a certificate of Engineer in Training (EIT) or Engineer Intern (EI) status upon the completion of additional requirements such as submitting a final transcripts documenting graduation from the program.

The EIT/EI is the first step (prerequisite) towards Professional Engineer licensure (PE licensure) [2].

The NCEES FE exam used to be an all-day test with two sessions; a morning and afternoon session and offered only twice a year. Recently, however, the exam has changed to be a computer based approximately 6-hour exam long with a 25 minutes break [2]. NCEES site lists all topics for the morning and afternoon FE sessions for engineering majors. The new FE online exam started in January 2014 has changed the topics slightly. A list of the 2014 topics can be examined at the NCEES [1].

II. METHODOLOGY

This paper is based on the methodology proposed by Tanbour et. Al [1]. The proposed methodology for identifying course learning outcomes (CLOs), syllabi, and Program Learning Outcomes is represented graphically in Fig 1 [1]. The steps are:

1. Identify FE Exam topics related to the course offered in the curriculum.
2. Map course description against FE exam topics
3. Identify any gaps
4. Redefine the course description to meet or exceed FE Exam topics
5. Revise Course Learning Outcomes based on redefined course description
6. Update course syllabus according to revised CLOs
7. Aggregate revised CLOs to revise Program Learning Outcomes (PLO's)

III. METHODOLOGY DEMONSTRATION

The proposed methodology is applied to one Electrical and Computer Engineering (ECE) course from the School of Engineering Technology (SET) at Eastern Michigan University (EMU) [3].

The newly under-development undergraduate ECE program curriculum at EMU is currently championed by one the authors, M. C. Greenfield. The course selected to demonstrate the methodology is "ECE 341: Engineering Electronics I".

EMU Course: ECE 341- Engineering Electronics I

Step One: Identify FE Exam Topics Related to ECE 341- Table 1 lists the subjects covered by each FE Exam session for the topic of "Electronics". Seven major topics are tested under the FE exam for the subject of "Electronics". Examples of subtopics related to these areas are listed in the table between parentheses.

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Table 1: Electronics Topics in FE Exam

FE Exam Fluid Mechanics Topics
A. Solid-state fundamentals (e.g., tunneling, diffusion/drift current, energy bands, doping bands, p-n theory)
B. Discrete devices (diodes, transistors, BJT, CMOS) and models and their performance
C. Bias circuits
D. Amplifiers (e.g., single-stage/common emitter, differential)
E. Operational amplifiers (ideal, non-ideal)
F. Instrumentation (e.g., measurements, data acquisition, transducers)
G. Power electronics

Step Two: Map ECE 341- Engineering Electronics I Courses Descriptions Against FE Topics- ECE 341 is a core course in the program of Electrical and Computer. The FE Exam tests the knowledge subject of Electronics for all Electrical Engineers or Electrical and Computer Engineers. These topics are shown in Table 2.

Step Three: Are there any gaps? - Current EMU SET Engineering Course Descriptions for ECE 341:

ECE 341: Engineering electronics I: This course presents analysis and design of analog electronic circuits such as diodes, transistors, and IC op-amps for their use in systems. Physical operation, characteristics, biasing, and modeling are also presented. *Prerequisite***:** C or better in MATH 120, MATH 121; C or better in PHY 223; C or better in CET 151 or COSC 246, or COSC 111; C or better in ECE 212

Results of the Demonstration

- Current course description of ECE 341 does not cover the topic of "Instrumentation (e.g., measurements, data acquisition, transducers)". As a result, graduates of Electrical and Computer Engineering degree program will lack such basic knowledge and face a challenge in passing that portion of the FE exam.
- Graduates of Engineering and Computer Engineering degree program will rely on scattered learning opportunities within the program to acquire knowledge of topic F in the above two tables.
- Graduates of Electrical and Computer Engineering will have the opportunity to acquire advanced knowledge in topic G: "Power Electronics". This is a delayed introduction in the program since ECE 430 is a senior class. It is recommended that ECE 341 add an introductory topic to "Power Electronics" so that ECE 430 will serve to emphasize the learning outcome at the senior year level.

Step Four: Redefine The Course Description to Meet or Exceed FE Exam Topics- The following are recommended actions:

- Revise the course description of ECE 341 "Engineering Electronics" to reflect learning objectives in line with A to G in the FE Exam topics. In specific, the Instrumentation topic.
- Revise the course learning outcomes of ECE 341 to target "Instrumentation" topics.

Suggested Course Description For "ECE 341: Engineering Electronics I"

This course presents analysis and design of analog electronic circuits such as diodes, transistors, and IC op-amps for their use in systems. Instrumentation, Physical operation, characteristics, biasing, and modeling are also presented. *Prerequisite*: C or better in MATH 120, MATH 121; C or better in PHY 223; C or better in CET 151 or COSC 246, or COSC 111; C or better in ECE 212

Step Five: Define Course Learning Outcomes Based on Course Redefinition- The suggested revised CLOs for ECE 341 are shown in Table 3.

Step Six: Develop Course Syllabus According to Revised CLOs - Based on the new CLOs for ECE 341, the following is a proposed syllabus outline:
Suggested Syllabus outline for ECE 341: Engineering Electronics I:

- Introduction to Electronics Design
- Introduction to Amplifiers
- Introduction to Op-Amps
- Diodes 4 classes
- Applications of Diodes
- Amplifying Devices (BJTs)
- Amplifying Devices (MOSFETs)
- Active Current Sources
- Differential Amplifiers
- Frequency response of amplifiers
- Instrumentation, measurements and data acquisition

Sample Supplemental Textbook to Cover Instrumentation: Electronic Instrumentation and Measurements. Author, David Bell, latest edition

Step Seven: Aggregate Revised CLOs to Revise Student Outcomes- The Student Outcomes for Electrical and Computer Engineering are mapped against 2016-2017 ABET (a) to (k):

(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 multidisciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

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(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 societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 4 presents the alignment of ECE 341 CLOs with the applicable POs (ABET [4] a to k).

IV. CONCLUSIONS

The paper used the Fundamentals of Engineering (FE) exam to evaluate the content of the courses and a methodology to evaluate the curriculum. The methodology is applied to selected courses at two universities. The methodology succeeded to identify gaps in course learning outcomes of these courses and corrective actions to topics covered is consequently proposed. The proposed methodology is adequate for programs that are already developed. It is also recommended as a continuous improvement and review method for engineering curriculum. In addition, it is recommended to use the FE exam topics as the minimum requirements for any topics in the curriculum. Finally, the topics has to be reevaluated based on the recent changes in the FE exam.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

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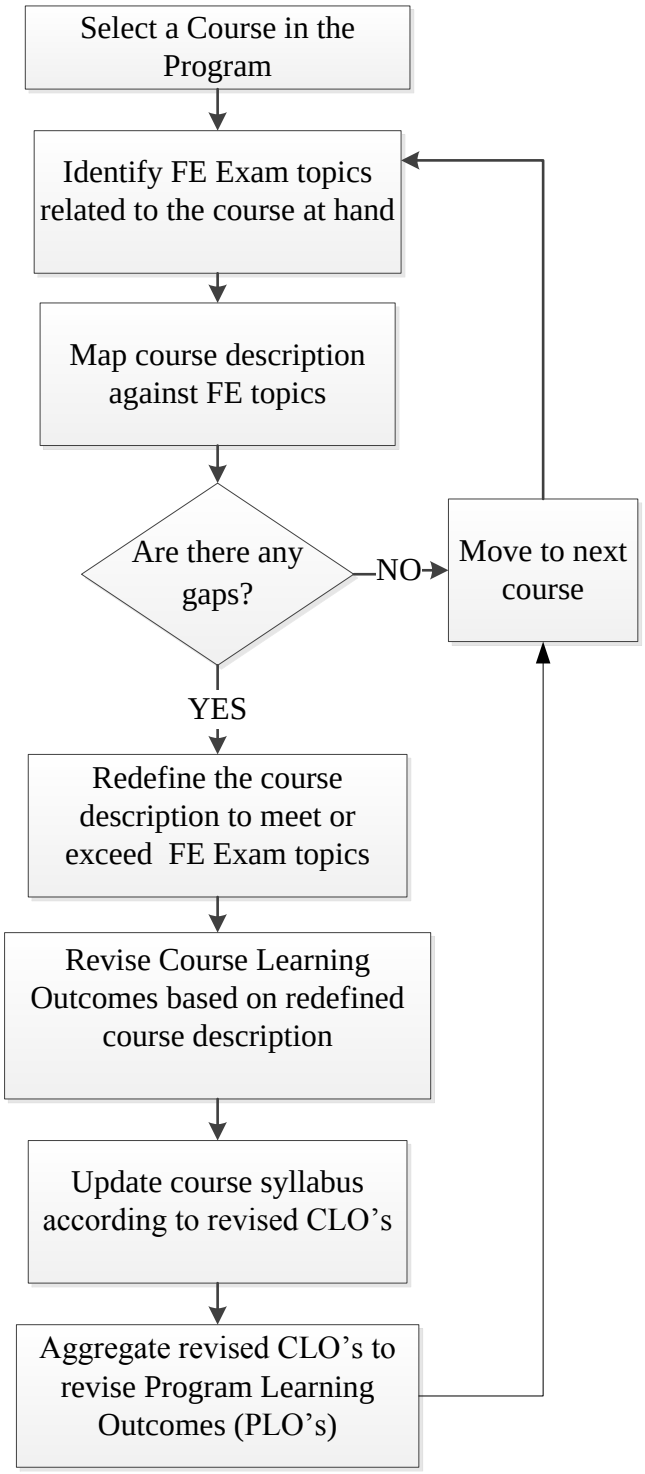

Fig. 1: Methodology Flowchart [1]

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Table 2 - Fe Exam Electronics Subjects Required By All Engineering Majors

Fluid Mechanics Knowledge Subject	Required for Electrical Engineering and Electrical and Computer Engineering graduating seniors	Covered in ECE 341	Conclusion
A. Solid-state fundamentals (e.g., tunneling, diffusion/drift current, energy bands, doping bands, p-n theory)	√	√	**Covered**
B. Discrete devices (diodes, transistors, BJT, CMOS) and models and their performance	√	√	**Covered**
C. Bias circuits	√	√	**Covered**
D. Amplifiers (e.g., single-stage/common emitter, differential)	√	√	**Covered**
E. Operational amplifiers (ideal, non-ideal)	√	√	**Covered**
F. Instrumentation (e.g., measurements, data acquisition, transducers)	√	**X**	**Missing**
G. Power electronics	√	**X***	**Missing**
* *This topic is comprehensively covered in a stand-alone course ECE 430*			

Table 3: ECE 341- Engineering Electronics I Revised Course Learning Outcomes (CLO)

Course Learning Outcomes
1) Provide basic analog electronic circuit design techniques and analytical skills using diodes, op-amps, MOSFETs, and BJTs.
2) Introduce the characteristics, biasing techniques, and circuit models of semiconductor devices.
3) Develop student ability to: (a) to apply basic engineering sciences to the design, analyses and operation of electronics devices and circuits, (b) to use modern simulation tools such as MULTISIM for the design, analyses, and performance evaluations of electronic circuits, (c) to practice problem solving
4) Design electronic circuits to meet desired specifications.
5) Introduce Instrumentation, measurements, data acquisition and transducers

Table 4: ECE 341 Clos Alignment to ABET a-k POS (Abet [4] a to k)

ECE 341 Course Learning Objective	Alignment to ABET a-k
1) Provide basic analog electronic circuit design techniques and analytical skills using diodes, op-amps, MOSFETs, and BJTs.	a, b, c
2) Introduce the characteristics, biasing techniques, and circuit models of semiconductor devices.	a, c
3) Develop student ability to: (a) to apply basic engineering sciences to the design, analyses and operation of electronics devices and circuits, (b) to use modern simulation tools such as MULTISIM for the design, analyses, and performance evaluations of electronic circuits, (c) to practice problem solving	a, e, j, k
4) Design electronic circuits to meet desired specifications.	b, c
5) Introduce Instrumentation, measurements, data acquisition and transducers	c, k