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An Expert System for Assessment of Learning Outcomes for ABET Accreditation

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Abstract**—**Learning outcomes of a course (CLOs) and the abilities at the time of graduation referred to as Student Outcomes (SOs) are required to be assessed for ABET accreditation. A question in an assessment must target a CLO as well as an SO and must represent a required level of competence. This paper presents the idea of an Expert System (ES) to select a proper question to satisfy ABET accreditation requirements. For ES implementation, seven attributes of a question are considered including the learning outcomes and Bloom's Taxonomy level. A database contains all the data about a course including course content topics, course learning outcomes and the CLO-SO relationship matrix. The knowledge base of the presented ES contains a pool of questions each with tags of the specified attributes. Questions and the attributes represent expert opinions. With implicit rule base the inference engine finds the best possible question satisfying the required attributes. It is shown that the novel idea of such an ES can be implemented and applied to a course with success. An application example is presented to demonstrate the working of the proposed ES.

Keywords**—**Expert system, student outcomes, course learning outcomes, question attributes.

I. INTRODUCTION

ABET accreditation [1] is quite common in US and other parts of the world. ABET accredits academic programs in the disciplines of applied science, computing, engineering, and engineering technology [2]. ABET specifies a set of general criteria as well as program criterion for each discipline. An academic program seeking accreditation must demonstrate that these criteria are satisfied. Based on these criteria, a critical issue for an academic program seeking ABET accreditation is to demonstrate that the set of Student Outcomes (SOs) [3] specified by ABET are being assessed and attained at the required Bloom's Taxonomy Level [4] with continuous improvement plans to bring them to the satisfactory level.

The SOs that point to a set of general abilities in the students at the time of graduation are actually attained through Course Learning Outcomes (CLOs) specified for all courses in a curriculum. A question in direct assessments in a course always targets a given CLO. These CLOs are mapped to SOs through a CLO-SO Map [5]. Therefore, a question in an assessment addresses a given CLO explicitly and one or more SOs implicitly.

With the present state of the art, selecting a question for assessment of a CLO is done intuitively by the instructors. No methodology or algorithm has been presented in the published literature that may lead to an Expert System (ES) for the selection of a proper question targeted to assess a given outcome. In Engineering Education, expert systems have been used [6], [7], but they do not deal with the issue of assessment design involving selection of proper questions that target given CLO and SO.

To design and implement an ES, a methodology for the selection of the most appropriate question from a set of questions is required. This paper presents such a methodology to select a question to assess students' abilities for a given CLO and SO. Its implementation for an ES is also presented.

In Sections II and III of this paper, Blooms Taxonomy and CLO-SO Map are described. These have been described elsewhere in the published literature [4], [5] but are included here because they are important elements of the presented ES and will help the reader to understand the presented methodology. Other aspects of the methodology and the ES are described in Sections IV-VIII.

II. BLOOM'S TAXONOMY

For the implementation of assessment design in an ES, each SO must have a "Level of Learning" (LOL) assigned to it. LOL actually represents the competency a learner is supposed to achieve. It is a key issue in assessment design. An assessment and instruction plan must aim at a certain LOL. Various taxonomies have been used for defining the LOLs. Bloom's Taxonomy [4] is the most common in engineering education and therefore has been used in the presented ES. The LOLs of Bloom's Taxonomy are shown in Table I. The first level refers to the lowest cognitive learning skill while the sixth refers to the highest level. A newer version of Bloom's Taxonomy [8] has minor modifications to the original version but has not been used. Each level of Bloom's Taxonomy is further elaborated through a set of "action verbs" for each level. Table II shows such action verbs. In the presented ES, each question in the Knowledge Base (described in Section V) is tagged with a Bloom's LOL.

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TABLE I
BLOOM'S LEVELS OF LEARNING

LOL ID	LOL Name
1	Knowledge
2	Comprehension
3	Application
4	Analysis
5	Synthesis
6	Evaluation

TABLE II
ACTION VERBS OF BLOOM'S LEVEL OF LEARNING

Level		Action Verbs
1	Knowledge	define; describe; enumerate; identify; label; list; match; name; reproduce; select; state
2	Comprehension	classify; cite; convert; describe; discuss; estimate; explain; generalize; give examples; paraphrase; restate (in own words); summarize
3	Application	Administer; apply; calculate; chart; compute; determine; demonstrate; implement; prepare; provide; relate; report; solve; use
4	Analysis	analyze; break down; correlate; differentiate; discriminate; distinguish; formulate; illustrate; infer; organize; outline; prioritize; separate; subdivide
5	Synthesis	Adapt; combine; compile; compose; create; design; develop; devise; facilitate; generate; integrate; modify; plan; reconstruct; revise; justify
6	Evaluation	Appraise; compare and contrast; conclude; criticize; defend; evaluate; judge; justify

TABLE III
ABET STUDENT OUTCOMES (EAC)

(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
(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 IV
A TYPICAL CLO-SO MAP

CLOs	Student Outcomes										
	a	b	c	d	e	f	g	h	i	j	k
1	1	0	0	0	0	0	0	0	0	0	0
2	1	0	1	0	1	0	0	0	0	0	0
3	1	0	0	0	1	0	0	0	0	0	0
4	1	0	0	0	1	0	0	0	0	0	0
5	0	1	0	0	0	0	0	0	0	0	1

III. CLO-SO MAP

Since the example application of this paper deals with a course for an engineering program, the discussion in this paper will use SOs for engineering program only. The SOs for engineering programs specified by ABET are listed in Table III taken from [3].

While SOs represent a set of general abilities to be attained by the students, Course Learning Outcomes (CLOs) specified for a given course in a curriculum are specific to the course content. A CLO represents course-related abilities students will acquire at the end of a course. A question in direct assessments always targets a given CLO. Since CLOs are related to SOs through a CLO-SO Map as shown in Table IV, a question implicitly targets one or more SOs. The CLO-SO Map shown in Table IV uses a 0/1 relationship. Instead, a "Low", "Medium" or "High" relationship may also be used to signify how strong is the relationship between a CLO and a corresponding SO. The presented ES has CLO-SO Map for each course in the Knowledge Base described in Section V.

IV. QUESTION ATTRIBUTES

The first element of the Knowledge Base for the presented ES is a common set of attributes for each question. It is necessary for making the ES work. Considering ABET accreditation requirements, the following attributes were considered as important:

1) Topic of syllabus it addresses
2) CLO to be addressed by the question (each question will address only a single CLO)
3) The SO the question addresses
4) Bloom's level of the question
5) Whether the question requires a student to draw a figure
6) Type of question: Whether it is a multiple choice, fill in the blank, descriptive, numerical or True/False question
7) Time required to solve the question

The above set of attributes is an integral part of the proposed ES. Since it is built in the ES, the instructor using the ES does not have to specify these attributes for designing assessments but only needs to answer certain queries that the ES will ask as described in Section VI. It may be noted that such a formalized set of attributes of a question are not found in published literature.

V. KNOWLEDGE BASE

The Knowledge Base used for the proposed ES consists of a pool of questions with the tags of the attributes described above. The Knowledge Base is designed to be machine readable with automated deductive reasoning to obtain the solutions. The Knowledge Base is shown in Fig. 1. In addition to a set of questions, it also contains the CLO-SO Maps and Course Contents for all courses. The Knowledge Base is supported by an interface for the course coordinator responsible for creating, adding and updating the information based on the input from the instructors and other experts.

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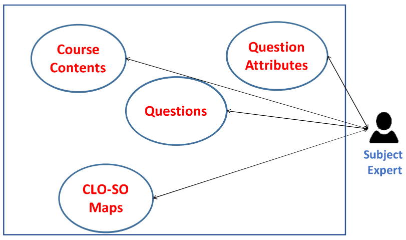

Fig. 1 Knowledge Base

VI. Interaction with Instructor

The proposed ES will interact with the instructor to determine instructor's preferences and will prompt the instructor with the following queries:

1) Which topic of the course you want to test?
2) Which CLO would you like to target?
3) Which SO do you want to target?
4) What Bloom's level is required for this question?
5) Should the student draw a figure to answer the question?
6) What type of question would you like to select from (a) MCQs, (b) fill in the blank, (c) descriptive, (d) True/False, (e) requiring the students to draw figures?
7) How much time should the question should take to answer?

Based on instructor's response to the above queries, the ES will find the best question from the pool of question already stored in the Knowledge Base. In case there are more than one question from the pool of questions satisfying the instructor's requirement, the ES will help the instructor in choosing one of them based on the properties displayed by the ES.

VII. Inference Engine

The rule base of the presented ES cannot be stated explicitly because of the huge number of rules arising due to the large number of choices available to the instructor. The rule base is implicit and is built into the code representing the inference engine. The inference engine of the presented ES will use search and match techniques to find the questions in the Knowledge Base that match the criterion of the user.

The proposed ES has been described in the block diagram of Fig. 2. Following are the main components of such a system:

1) A Knowledge Base representing a pool of questions tagged with attributes for each course.
2) An inference engine that interacts with the instructor through a user interface. It has two main components/jobs:
   a. It queries the instructor to ascertain the required attributes for questions to be selected.
   b. The interpreter interprets the answers from the instructor and interacts with the Knowledge Base to get the questions that would have the desired attributes.
3) A subject expert that interacts with the Knowledge Base through the user interface. The Knowledge Base grows when the subject expert adds new questions. This subject expert can also modify existing questions or delete questions in the Knowledge Base if needed.

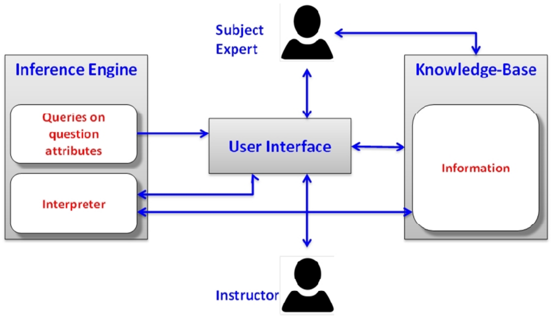

Fig. 2 Proposed Expert System

The ES interacts with the instructor and responds to instructor's queries by suggesting appropriate questions for the assessment. The Knowledge Base is dynamic and can continue to grow as the subject expert adds more and more questions to it based on the instructor's feedback.

VIII. Example Application

The proposed ES was tried on a course of Circuit Theory. A set of questions was collected. Attributes were assigned based on expert opinion. The instructor interface started the queries as follows:

1) All topics for the course were displayed from the database, so that the instructor may select a topic as shown in Fig. 3. The instructor selects Topic 4.

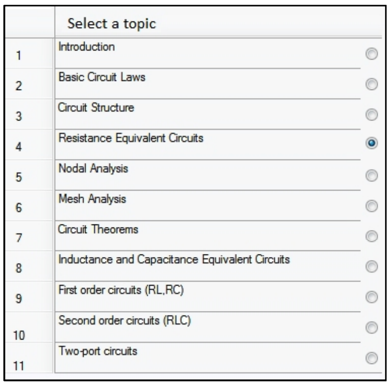

Fig. 3 Topic selection

2) ES displays CLOs of the course and asks the instructor to select one as shown in Fig. 4. Instructor selects CLO 2.

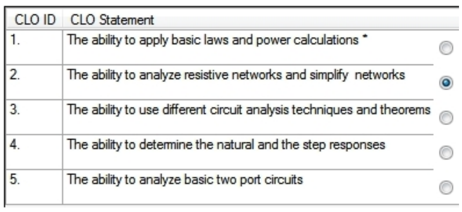

Fig. 4 Selection of a CLO

3) ES displays SOs of the course and asks the instructor to select one as shown in Fig. 5. It is worth noting here that the ES will pick only the relevant SOs from the CLO-SO map that has been shown in Table IV. The instructor selects SO (a).

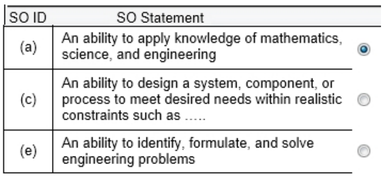

Fig. 5 Selection of a CLO

4) ES displays the Bloom's Taxonomy levels as stored in the database. The instructor selects the third level i.e., Application, as shown in Fig. 6.

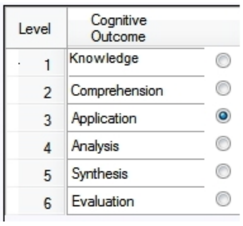

Fig. 6 Selection of Bloom's LOL

5) ES lets the instructor choose whether the selected question must require a figure to draw or not. As shown in Fig. 7, the instructor chooses "Figure not required".
6) ES lets the instructor choose from various types of questions. As shown in Fig. 8, the instructor chooses "Numerical".

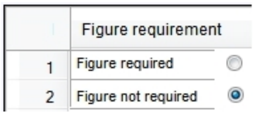

Fig. 7 Figure related choices

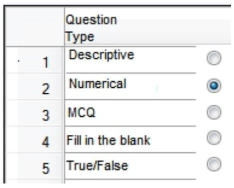

Fig. 8 Selection of question type

7) ES lets the instructor choose the time required for the question. As shown in Fig. 9, the instructor chooses from the displayed combo box "20 minutes".

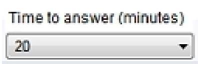

Fig. 9 Required time

8) Based on the above queries of the ES interface and the response of the instructor, the inference engine searches for a match from the pool of questions in the knowledge base. The ES then returns the best choice of question from the knowledge base. In this particular case, the displayed answer is as shown in Fig. 10.

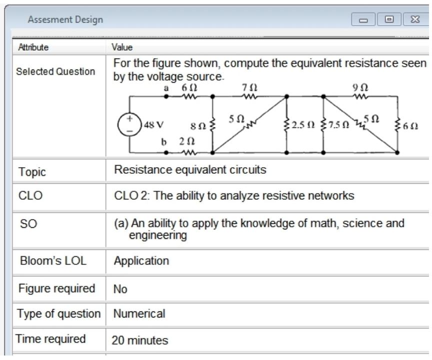

Fig. 10 Selected question with attributes

IX. Conclusion

A novel idea of an Expert System for assessment design for ABET accreditation has been presented. The ES has been implemented and tested in a cloud implementation on a course of Circuit Theory. However, the interfaces are quite crude at this stage and are being developed. A natural direction of future research is the application of Fuzzy Logic in the CLO-SO Maps of the courses. Also a relevance score must be investigated to provide the instructor with more meaningful choices in assessment design.

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