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Using Goals Modeling in Educational Engineering: Application to Course Learning Outcomes Assessment (CLOs) at Aljouf University

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Abstract

This research study is inscribed in cycle improvement of training and of academic program for graduates at Aljouf University. So, in this paper, we show how to evaluate academic programs using the goals modeling to assess the course learning outcomes in this university. The academic program evaluation is a complex and multidisciplinary process. It relies on the technical process (requirement engineering that we use in computer and software engineering) and on the other human science activities. Here, we are only interested by the technical aspect of this process. In this study, we use the goal model like it is used by the requirement engineering methods, such as goals-based requirement analysis method (GBRAM), I* and collaborative requirement engineering with scenarios (CREWS) to identify the expected outcomes on the courses. As result, the model that we present here feeds well the process of Course Learning Outcomes (CLOs). For experimenting of our approach and model, we present the application of this evaluation process that is conducted at Al-Jouf University, in the department of computer sciences.

Keywords: Goals modelling, Educational engineering, Evaluation of Academic programs, Course learning outcomes assessment, Aljouf University.

1. Introduction

Objective-based education is the target of today's universities (Den Akker, 2006). It consists in giving training according to the exact demand of the labor market. To realize this target, universities adopt classical methods: Upstream of the training process, we find the explicit requirements of the labor market, and downstream, we define the courses to be provided during the training cycle. However, this approach often results in a divergence on the expected profile due to the rapidly changing labor market needs.In this paper, we will make our contribution to this problematic with proposing a model of courses contents of training according to the "GOAL" that express the labor market. It involves using goal modeling to assess Courses Learning Outcomes (CLOs) according to the profile expected by the labor market. To do, we use the "Goal Model" that is usually proposed by the goal-based methods of requirement engineering such as GBRAM (Anton, 1996). For us, it is the best manner to express and check the CLOs. We add to these outputs, the table of CLOs in order to evaluate the achieved rate of goal.This research is inscribed in the framework of elaboration academic courses reports: an aspect of courses outcomes. To experiment in this research work, we have worked on the process of LCOs assessment which is done by the faculty members at Aljouf University (Saudi Arabia).The paper is structured as follow: after this introduction, we deliver a global overview about educational engineering and requirement engineering research field, with basing on one goal-based method, where we were interested by the used goal's model. Then, we present our main contribution: the process of Course Learning Outcomes Assessment. For experimentation, we give an example of CLOs with indicators that we teach in the computer engineer training at Aljouf University. The paper ends with a conclusion.

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2. A global overview of related works

2.1 Educational Engineering

Educational engineering aims to improve the quality of education and professional training. It is a very old field of research in the humanities and techniques (Hoover, 1941), (Charters, 1945), but it is still a topical field (Laurillard, 2012), (Isaev, 2017).In the literature of this research field, we are interested by the different methodological processes. It consists on the framework for the majority of scientific research of educational engineering (fig. 1).

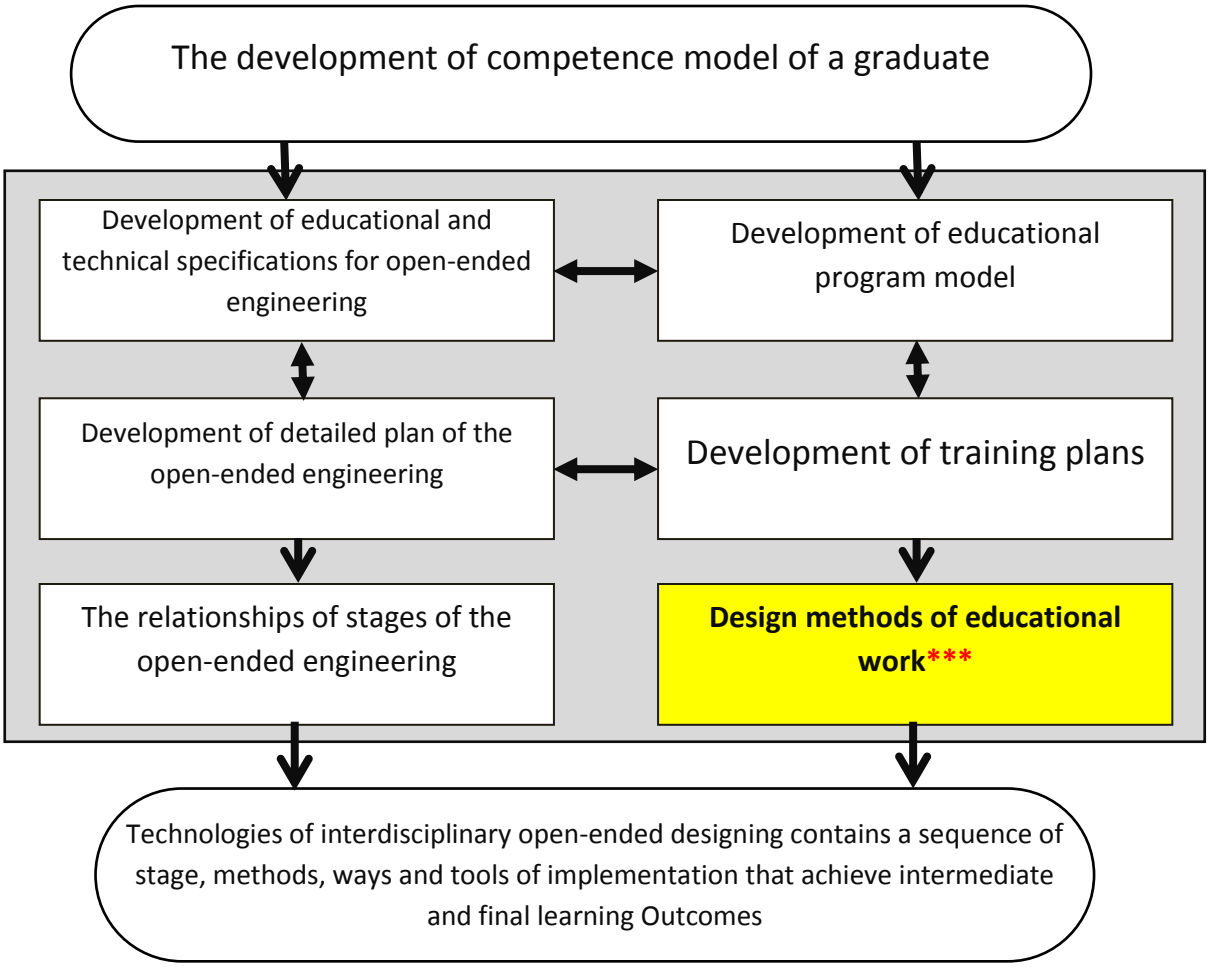

Fig. 1 The framework of research work in educational engineering

Our research is inscribed in design methods of educational work, or, it consists in proposing an approach for program learning outcomes assessment basing on goals modeling that is the purpose of software engineering research works. Our target is to improve the quality of academic training programs at Aljouf University.

2.2 Requirement Engineering and Goals modeling

Steave Easterbrook defines 'Requirements Engineering' (RE) as a set of activities concerned with identifying and communicating the purpose of a software-intensive system and the contexts in which it will be used. Hence, requirements engineering acts as the bridge between the real world (real-world) needs of users, customers, and other constituencies affected by a software system, and the capabilities and opportunities afforded by software-intensive technologies (Easterbrook , 2004).Several research studies have marked this field of research (Loucopoulos, 1995), (Brunet, 2007), (Rolland, 2003), (Kavakli, 2002), (Lamsweerde, 2000), (Ross, 1977). It consists in a research domain that proposes concepts, processes, methods and support tools that allows converting the needs of users (that are generally expressed as goals) to model or part of the system / process to be built. So, the concept "Goal" is always the kernel of this discipline. For us, the "Goal" in "educational engineering" is the main concept that we developed in this research. It is the element to be assessed by the course learning that we always define by the question "Why this

chapter/element of course?" We have also studied the proposed methods of this discipline that we grouped into three great classes.

- Goal-based methods: they are characterized by the link between actors and processes. For the goals achievement, it is generally carried out by the temporal logic (Yu, 1998), (Lamsweerde, 1998), (Bubenko, 1994);
- Scenario-based methods: they show the particular situations of the requirement, drive conceptual models from scenarios and allow reasoning about the choice of designs (Caroll , 1995), (Potts, 1997), (Dano, 1997), (Jacobson, 1999);
- Mixed methods: They use the <goal, scenario> couple to define a fragment of requirement (Tawbi, 2001), (Rolland, 2003).

As a result, the study of a goal-based method was essential for this research. And seeing its popularity, we have chosen the GBRAM method.

GBRAM - Goals Based Requirement Engineering Analysis Method

GBRAM is a goal-based requirement analysis method. It carries out two processes: goals analysis and goals evolution. For the first process, the work consists in the analysis of different goals and their document as they are expressed in each level of organization. Then, for each goal, we describe the different steps of its evolution until its achievement.This method uses a set of concepts: goal, requirement, operationalization, achieved goal, maintaining goal, agent, constraint, goal decomposition, and goal obstacle. We were interested by the concept "Goal" in this method because it coincides well with our occupation that consists of assessing of course learning outcomes. So we have developed the model of goal that uses GBRAM – the most useful model of goal –.

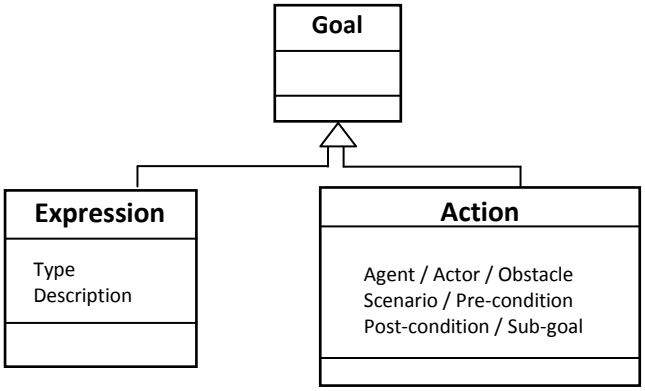

Fig.2 Goal's model of GBRAM

The model that we presented below may be reformulated by the following linguistic structure:

Goal= [{<Expression>, <Type>, <Description>}, {<Action>, <Agent>, <Actor>, <Obstacle>, <Scenario>, <Pre-condition>, <Post-condition>, <Sub-goal >}]

The choice of GBRAM method is imposed in this research because of two reasons:First (upstream of an academic program): in educational engineering, to provide training according to the demand of the labor market, the programs and the courses content are developed on the basis of the expressed requirements of the labor market which formulate in the form of a list of "goals". The goal of a program is a set of sub-goals (sub-goal of a program is a goal of one of its courses).Secondly (downstream of an academic program): the learning program assessment aims to measure the rate of achievement of the "goals" of each course (CLOs Assessment), which feeds the battle horse of this research. So using the concept "goal", it is easy to convert the result of CLOs to quantitative measures.

3. Our approach of CLOs assessment

The proposed approach of CLOs assessment articulates three steps. Each step uses a specific model, template or and table (Fig. 3).In the beginning, we express the goal of the academic program (GP) around of five axes that are called learning domains (Knowledge – Cognitive Skills- Interpersonal Skills and responsibilities, communication & information technologies, Psychomotor skills). And for each learning program domain (LPD), we express its expected results that we call LPOs). So, the requirement of the program is expressed as a couple (GP – LPs).

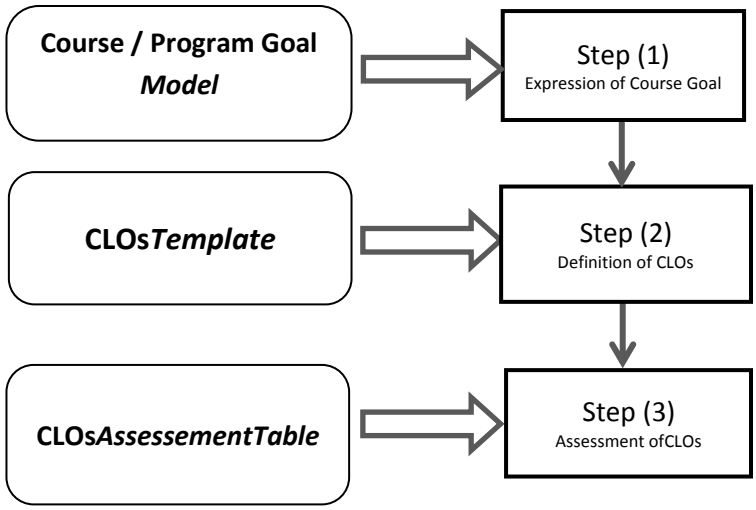

Fig.3 Global overview of CLOs Assessment Approach

We recall that the program and course are expressed using the same model of goal, but the different that we must underline is the level of detail. Or, the course is more detailed than the program.

- PG = PLDs + PLOs
- CG = CLDs + CLOs

3.1 Expression of Course Goal

Model of Goal in Course Learning Outcomes

Basing on the PLOs that we analyze, we get a list of sub-goals those express the goals of courses (CG). Each program sub-goal or (CG) is also expressed on the five learning domains that we above listed. Then, we obtain the list of courses like goals to which we will assign a set of results that we call Course Learning Outcomes – CLOs). In this paper, we will not present the mechanisms of goals program decomposition to get the courses goals, because it comes from another discipline (educational engineering). We only will be limited to the courses goals and the assessment of their outcomes (assessment CLOs) according to the fixed scale.

We formalize the CG with the following way (Fig. 4):

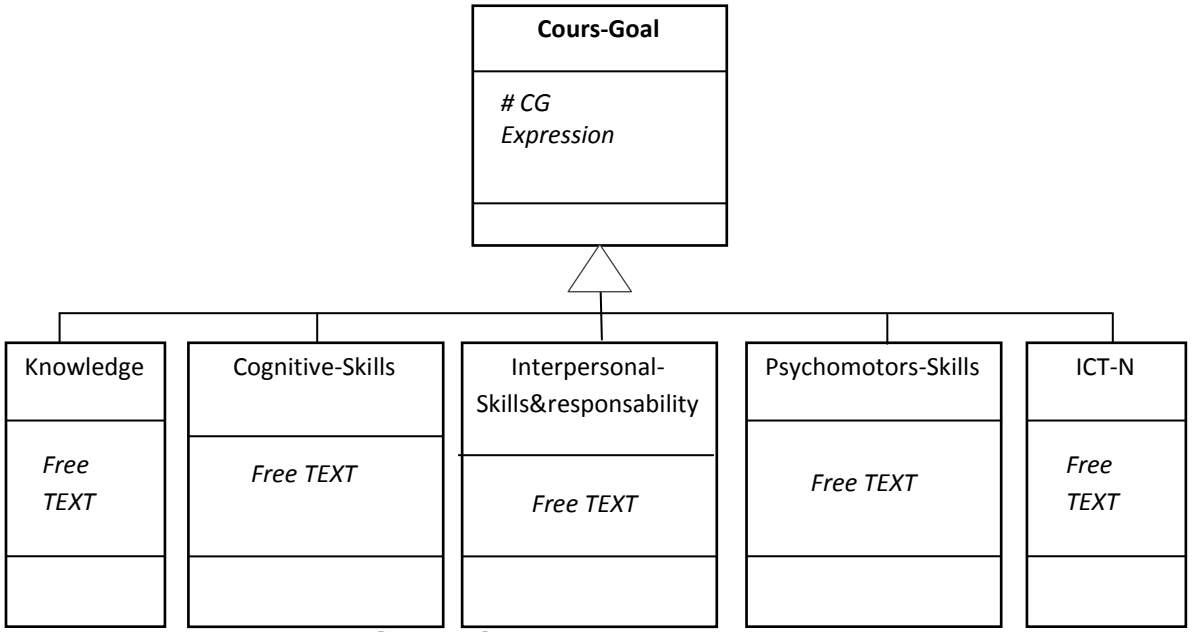

Fig.4 Couse's Goal model with UML annotation

The course goal expresses a global overview as a free text of the five learning domains of the course.

3.2 Definition of Course learning Outcomes

The course goal (CG) is expressed by five learning domains:

CG = {{Knowledge}, {Cognitive Skills}, {Interpersonal Skills & Responsibility}, {ICT & numeric}, {Psychomotor Skills}}.

The result expected by each learning domain defines the course learning outcomes (CLOs).

The next table (Table 1) presents a global canvas of CLOs. We have filled it exampling with Undergraduate Learning Outcomes – University of California at Santa Barbara Students graduating with a B.A. or B.S. in Physics –. So, the table shows what students should be able to do.

Table.1 Canvas of CLOs expression

Learning Domains	Learning Outcomes	Do	Don't
Knowledge	Apply basic mathematical tools commonly used in physics, including elementary probability theory, differential and integral calculus, vector calculus, ordinary differential equations, partial differential equations, and linear algebra.	✓	
	Apply the basic laws of physics in the areas of classical mechanics, Newtonian gravitation, special relativity, electromagnetism, geometrical and physical optics, quantum mechanics, thermodynamics and statistical mechanics.	✓	
Cognitive Skills	Apply more advanced mathematical tools, including Fourier series and transforms, abstract linear algebra, and functions of a complex variable.	✓	
	Use classic experimental techniques and modern measurement technology, including analog electronics, computer data acquisition, laboratory test equipment, optics, lasers, and detectors.	✓	
	Exercise the use of physical intuition, including the ability to guess an approximate or conceptual answer to a physics problem and recognize whether or not the result of a calculation makes physical sense.	✓	
	Recognize how observation, experiment and theory work together to continue to expand the frontiers of knowledge of the physical universe.	✓	
Interpersonal Skills & Responsibility	Communicate verbally, graphically, and/or in writing the results of theoretical calculations and laboratory experiments in a clear and concise manner that incorporates the stylistic conventions used by physicists worldwide.	✓	
	Convert a physical situation articulated in English to a mathematical formulation, and then analyze it quantitatively.	✓	
Communication, Information Technology, Numerical	Access information on a topic from a variety of sources, and be able to learn new things on one's own.	✓	
	Use basic laboratory data analysis techniques, including distinguishing statistical and systematic errors, propagating errors, and representing data graphically.	✓	
Psychomotor Skills	Collecting and analyzing appropriate data.	✓	
	Using of methods, tools, and instruments.	✓	
	Practicing routine methods of enquiry, investigation and research for a defined project	✓	
	Communicating in writing appropriately and effectively.	✓	
	Communicating verbally appropriately and effectively.	✓	

For CLOs expressing, we use the list of standard statement that are used in educational engineering (Benjamin, 1956), (Table 2):

Table.2 List of learning verbs

Know	Understand	Apply	Analyze	Evaluate	Create
Define	Articulate*	Act Administer	Analyze	Appraise Argue	Adapt Anticipate
Identify	Characterize	Apply	Arrange*	Assess	Arrange* Assemble
Inventory*	Cite examples	Articulate*	Break!down	Choose	Collect /Combine
List	Describe	Choose Compute	Calculate	Compare	Compose Construct
Locate*	Diagram*	Control	Categorize	Conclude	Create/
Name	Discuss	Demonstrate	Compare Contrast	Critique	Design
Recall	Explain	Dramatize	Correlate Debate	Determine	Devise/ Develop
Record	Express	Employ	Deduce Detect	Diagnose*	Diagram* Formulate
Repeat	Interpret	Generalize	Determine	Estimate	Generate Initiate
Restate*	Outline*	Illustrate	Diagnose*	Evaluate	Integrate Invent
State	Paraphrase	Imitate	Differentiate	Judge Justify	Model / Modify
Underline	Report	Implement	Distinguish	Measure	Negotiate / Plan
	Respond	Instruct	Discriminate	Prioritize	Perform* Predict
	Restate*	Interview	Examine Inspect	Rate /Revise	Prepare Produce
	Review	Operate	Inventory*	Score Select	Propose Reconstruct
	Translate	Perform*	Locate*	Support alidate	Substitute
		Practice Select	Outline* Question	Value/ Test	Synthesize
		Simulate /Use	Relate Separate		
		Utilize	Subdivide		

Here, we made in bold polices only the measurable verbs that we generally use in educational engineering.

3.3 Assessment of CLOs

The value of each sub-goal (total of achieved grades) is the average of the grades of students according to a fixed scale of a learning domain.

Table.3 Model of table Of CLOs assessment

Domaine of Learning		Total of achieved grades	Total / 100	Percentage
Code	ITEM			
1	Knowledge	G_1	S_1	G_1 /S_1 (%)
2	Cognitive Skills	G_2	S_2	G_2 /S_2 (%)
3	Interpersonal Skills & Responsibility	G_3	S_3	G_3 /S_3 (%)
4	TIC and Numeric	G_4	S_4	G_4 /S_4 (%)
5	Psychomotor Skills	G_5	S_5	G_5 /S_5 (%)
Total		Achieved Total (AT)	100	AT %

- S_i: fixed scale for learning domain;
- AT =$\sum_{n=1}^{nbr-LD} G_i$: achieved total;
- G_i = the average of the students grade in a learning domain.

The PLOs assessment is obtained by consolidating of all CLOs assessment.
In this paper, we present only the assessment of Information technologies course.

4. Experimentation

We have carried out our approach at Al-Jouf University. We were interested by the department of computer science and the unit of Quality and Academic Accreditation. After working the documents that we get, we remarked that computer engineering program aims

"to prepare students for careers that deal with computer and networks engineering who are able to contribute to the continued advancement in computer and networks engineering in order to serve to local, and regional communities, while maintaining the quality assurance standards (local and international)".

This text consists in the first goal of program that we discovered and elicited in the beginning. This goal will be detailed into sub-goals and will define the program learning outcomes (Table 4).

4.1 Expressing of course goal

Before expressing courses goals, we must to know in which program the courses will be given for students. So, in the beginning, we take to express the goals of computer engineering program at Al-Jouf University:

Table.4 Example of Goal Program (computer and Network engineering – Al-Jouf University)

Program Learning Goals	Program Learning Outcomes - PLOs
"Computer engineering graduates will be prepared to compete in the global engineering market".	1: Students will be provided with the basic concepts of science, mathematics, computation, and engineering to successfully apply them in their chosen endeavor.
	2: Students will be provided with knowledge and skills essential to engineering processes, including design, analysis, synthesis, fabrication and experimental techniques.
	3: Students will be prepared for professional interaction and leadership including multi-disciplinary collaboration, and effective oral and written communication.
	4: Students will understand their professional and ethical responsibilities.
	5: Students will understand technology within a global. Societal and economic context.
	6: Students will be prepared for lifelong learning

Basing on analysis of the program learning outcomes that are presented in table 4, we conclude that these goals are achieved by teaching the following courses (table 5).

Table .5 Couse's Goal 'IT 101 Information technologies'

Level 1		**Level 2**	
# Course	**Label**	**# Course**	**Label**
ARAB 101	Linguistic Skills		Computer Programing
COMM101	Communication and high studies Skills	CSC 102	Writing Skills
ENGL100	English 1	ENGL 102	Introduction to Islamic
IT 101	**Information Technologies**	IC 100	cultures
MATH100	Math 1	MATH101	Introduction to Diff
		STAT104	Calculating
			Principles of Stat and Proba
Level 3		**Level 4**	
		CSC 216	Logical designing
ARAB 103	Arabic redacting	CSC 217	Data structures
CSC 104	Computer Programing	CSC 225	Computing organization -
CSC 316	Computer and society	ENGL 124	society Ling
ENGL 123	Listening Skills	IC 103	Translating in computer
IC 102	Islam and society building	MATH231	studies field
MATH112	Integral Calculating		Islamic Economic system
			Calculating of integrals and differential
Level 5		**Level 6**	
CSC 353	Operating systems	CSC 325	Databases

CSC 337	Principles of programing languages	CSC 328	Computer building
CSC 351	Management of computer center	CSC 343	Software engineering
CSC 383	Date Structure	CSC 363	Artificial intelligence
IC 105	Principles of human rights	CSC 375	Human and machine interaction
MATH242	Laniary Algebra	OPER 201	Operational research
Level 7		**Level 8**	
CSC 338	Ontologies designing	CSC 403	Internet technologies
CSC 422	Computer network systems	CSC 413	Algorithms analysis & designing
CSC 426	Advanced databases	CSC 491	Selected topics (2)
CSC 447	Management of programing projects	CSC 492	Distributing Sys and Prall.
CSC 490	Selected topics (1)	CSC 495	Process
CSC 494	Research project (1)		Research project (2)

Here, we describe only the goal of the course 'Information Technologies' as it is taught at Aljouf University in 'Computer engineering' program, during the academic year: 2018/2019.

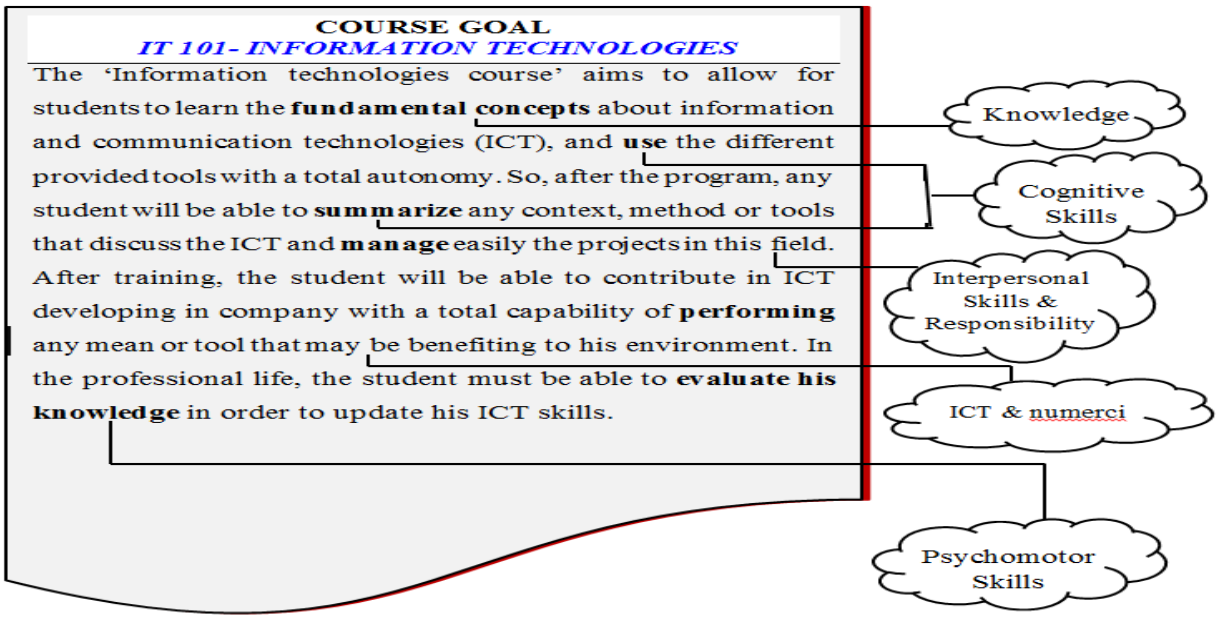

Fig.5 Couse's Goal 'Information technologies'

4.2 Definition of CLOs

We get the list of CLOs basing in goal course analysis. In this step, we are supported by the use of the verbs list those express the learning statement as they are proposed in table 2 (bellow), by Benjamin Bloom3. This step is the most difficult stage of our approach because the faculty member who uses this approach must have a well experience in educational engineering. In order to simplify reading, we present in this experimentation, only one course learning outcome (CLO) by course learning domain (CLD) of "information technologies" as it is assessed, because in fact, each CLD mays group more than one CLO.

[3]**Benjamin Samuel Bloom** (1913 - 1999) is an American educational psychologist who made contributions to the classification of educational objectives and to the theory of mastery learning.

Table.6 Table of courses learning outcomes ("Information technologies" – Aljouf University)

CLD	CLOs
Knowledge	**Acquire** and learn different concepts (MIT, ARPA, ARPANET, INTERNET, HTML, XML, WWW, http, htpps, ftp, FAQ, CHAT) and IT tools (email, FAQ, Forum, broadcasting tool, social network).
Cognitive Skills	**Use** the all of ICT tools with a total autonomy.
Interpersonal Skills & Responsibility	**Summarize** content of IT concept and tools; **Manage** any ICT Project.
TIC and Numeric	**Perform** any ICT mean or tool in a company.
Psychomotor Skills	**Evaluate** acquired knowledges.

4.3 Course Learning Outcomes assessment

The task consists in average calculating of the grades of students in different examinations, and their distribution on the five learning domains. The result is presented in table 7.

Table.7 Table of grades distributing of students according to the Learning Model "Course: Information Technologies"

CLD	CLOs	Assignments	Midterm Exam	Exercises	Final Exam	Total of achieved grades
Knowledge	**Acquire** and learn different concepts (MIT, ARPA, ARPANET, INTERNET, HTML, XML, WWW, http, htpps, ftp, FAQ, CHAT) and IT tools (email, FAQ, Forum, broadcasting tool, social network).	1	5	2	8	16
Cognitive Skills	**Use** the all of ICT tools with a total autonomy	2	5	1	10	18
Interpersonal Skills & Responsibility	**Summarize** content of IT concept and tools; **Manage** any ICT Project.	2	6	2	8	18
TIC and Numeric	**Perform** any ICT mean or tool in a company.	2	4	1	6	13
Psychomotor Skills	**Evaluate** acquired knowledges.	2	3	1	7	13
Total		10	30	10	50	100

At the end, the assessment is a simple comparison operation between the fixed total to the achieved result of each learning domain.

Table.8 Table of CLOs Assessment of "Information Technologies Course"

Course Learning Domain	CLOs	Total of achieved grades	Total	Achievement in Percent %
Knowledge	Acquire and learn different concepts (MIT, ARPA, ARPANET, INTERNET, HTML, XML, WWW, http, htpps, ftp, FAQ, CHAT) and IT tools (email, FAQ, Forum, broadcasting tool, social network).	14	20	70
Cognitive Skills	Use the all of ICT tools with a total autonomy	12	22	54.54
Interpersonal Skills & Responsibility	Summarize content of IT concept and tools and Manage any ICT Project.	9	16	56.25
TIC and Numeric	Perform any ICT mean or tool in a company.	13	22	59.09
Psychomotor Skills	Evaluate acquired knowledges.	10	20	50
Totals		**58**	**100**	**58**

The following graphic illustrates the achieved percentage of each learning domain.

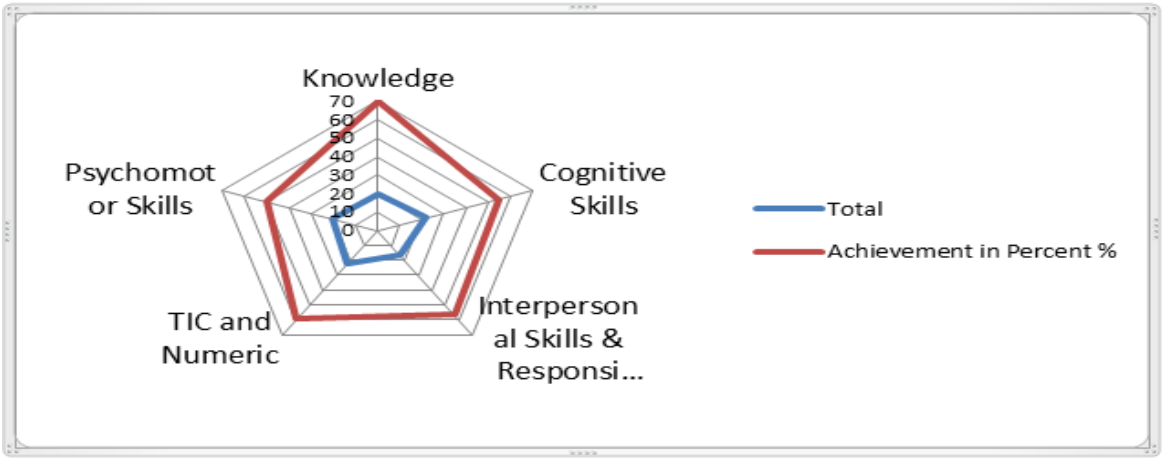

Fig.6 Percentage of achieved total on learning domain

Comment: the knowledge acquisition is the most part of achieved Information technologies course goal, because it groups the easier chapter of this course. However, the psychomotor skills take the last place in this distribution of the achieved goal rate because it needs more experience with the use of ICT in a professional environment. The following graphic presents the distribution of achieved total of LCOs.

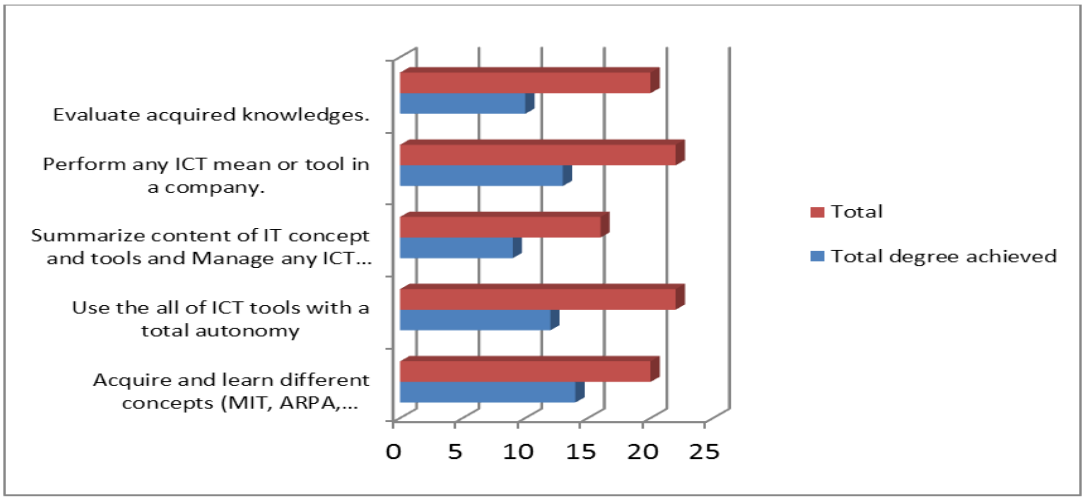

Fig.7 Repartition of achieved CLOs than fixed total

Comment: the achieved scores of CLOs are more than the average. And the goal of this course is achieved at 58%. So, we say that this course interests well the students of the computer engineering program.

5. Conclusion

The evaluation of academic programs is the vocation of educational engineering, which consists in defining the programs according to the labor market requirements. The practices in this area still have limitations and shortcomings because of the labor market needs those are changing during elaborating or updating of academic programs. This is the axe where our approach contributes. It consists to help better the academicians in evaluating of the results of their courses, when the faculty members are assessing the program outcomes. In this paper, we defined an approach for course assessment using goal modeling as it is used in requirements engineering.

Our approach allows to:

- Express the goal of the course;
- Define the course outcomes that it is expected to feed well a program;
- Fix the course learning outcomes in order to assess it as well as possible;

In our approach we have proposed a process for academic program analysis to accord it well with the needs of the labor market. This process exploits:

- A Course Goal Model to express the requirement of a course in a program;
- A Learning Outcomes Model for program evaluation;
- An assessment table for course learning outcomes.

Our approach is experimented at Al-Jouf University in accordance according the guidelines that are proposed by the National Commission for Academic Accreditation & Assessment in Kingdom of Saudi Arabia (NCAAA, 2011). We have assessed the courses outcomes of the Computer Engineering Program as it is provided at Al-Jouf University during the first semester of the 2018-2019 academic years. We found a very favorable echo to use our approach by the faculty members. As a rest to do of this research, we proposed to detail more the mechanisms academic programs analysis according to the requirements of labor market.

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