

## A Roadmap to the Development of Key Competencies of Engineering and Technology Graduates

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**Abstract**—The world of employment is impacted by major trends that are imposed by the on-going industrial advances. The changing labor market and the future of work calls for a paradigm shift in teaching and learning to equip graduates with competencies they need for current and future jobs, and in particular, those of the engineering and technology programs. The purpose of this study is to discuss previous work in the subject matter, to outline a set of teaching and learning strategies, and to create a roadmap for main players to work through to arm graduates with the intended competencies skills. To achieve this objective an extensive literature review was carried out to identify what teaching and learning strategies are currently in-place, and what skills are anticipated. However, still, the education institutions not been able to provide the workplace with competent graduates. A proposed set of intended competencies skills along with teaching and learning strategies for properly preparing future engineering and technology graduates was developed; and a roadmap was built to show the roles of college administration, professors and students to ensure an effective way to support students gaining these skills. It is recommended that these sets of strategies including the facilitation of the roles of the main players to be incorporated in the educational programs learning outcomes.

**Keywords**—Pedagogical landscape, teaching and learning strategies, intended competency skills, changing labor market.

### 1 Introduction

Today's educational and pedagogical landscape is facing major changes, particularly, the engineering and technology programs. The changing labor market and the continuous challenges call for innovative teaching and learning methods to equip graduates with competencies they need for current and new jobs. The necessary knowledge, skills, and competencies for entry into the practice of engineering and technology professions should be incorporated into the curricula, and teaching and learning strategies should be designed to achieve them. It is well recognized that millions of students graduated

every year and tens of millions are looking for jobs worldwide. On the other hand, as a matter of fact, millions of job vacancies are unfilled, and employers complain of not finding qualified people. Employability of graduates has become an issue that is not easy to be ignored in the global change.

Education institutions should give more attention and affairs to help their students to gain skills to enable them to meet the employment requirements [1], [2], [3].

With the continuous technological developments, the work environment has become to a large degree dependent on technology. The content has been adapted to global trends, and the way the content is taught has fundamentally changed. Technology, for instance, is one of these global megatrends that describe these changes in the working environment. According to this trend, the workplace from now to the future will be more dynamic and knowledge-intensive than in the past. Thus, adaptations are needed to cope with all these global changes [4].

Engineering and technology students have to pay more attention to gain technology skills; specifically, digital skills (use digital technologies) and digital navigation skills (finding information, ranking information and assessing the quality and reliability of information) [5]. Graduates should have in mind not only the demands of the present workplace but should be able to continuously learn and adopt new technologies. Moving to the workplace, it is expected to deal with a dynamic environment, to solve problems and bring creative solutions. Utilizing new technology tools will improve their achievements.

The workplace uncovered the lack of skills that are expected from new graduates. In addition to the weakness in negotiation and decision-making skills, it also was found that graduates of engineering and technology programs struggle to well-apply the technical knowledge they have gained [6], [2]. There is thus a need for employability skills to be valuable assets to enhance employability amongst graduates and meet employers' expectations [7].

The situation in developing countries is more complicated. The students enrolled at universities with a serious lack of digital and interpersonal skills. A good number of students find difficulty in using basic Microsoft applications beside a noticeable weakness in the English [6], with a consequent not to be able to easily gain the proper skills [8], [6], [7], [3]. As graduates, they do not adopt smoothly to work environment including even those who have the excellent technical knowledge, but not to be able to apply due to lack the support of their educational institutions and professors as to weaknesses in teaching strategies [9], [10]. To improve students' achievements, professors should use new methods of teaching along with the original strategies [11]. The teaching and learning in higher education is a shared process, with responsibilities on both students and teachers to contribute to their success [12]. In order to assist students to gain and build future competencies, a set of innovative teaching and learning strategies should take place. This is highly recommended taking into consideration the rapid technological development in today's dynamic and complex environment of digitization and artificial intelligence.

A university diploma and a well-written resume do not matter a lot to employers. The proven use of technical knowledge and interpersonal skills is the indicator of a competent employee that the employer would like to have. This is a need for a set of

teaching and learning strategies as well as a roadmap, which is the main purpose of the current paper, for properly preparing future engineering and technology graduates, not only to practice the profession as it is at the present but as is expected to be tomorrow.

The learning outcomes for engineering and technology programs are focused on three main domains: knowledge, skills, and competence. It is for the institutions and professors to provide the set-up and employ effective teaching strategies to enable engineering and technology students to be competent, i.e. to enhance their career readiness skills to face the challenges of employability in the digitalization era.

## **2 Literature Review**

Engineering and technology graduates apply the principles of science and mathematics to develop economical solutions to technical problems. Misra [13] links between scientific discoveries and commercial applications that meet societal and consumer necessities. In addition, the graduates have to meet the requirements of users within an organizational and societal context. They have many tasks such as; selection, creation, application, integration, and administration. Therefore, engineering and technology graduates must gain certain knowledge and skills to get proper positions in the workplace [13].

### **2.1 Interpersonal skills**

The employers are looking for skillful expertise in scientific knowledge along with the interpersonal skills. For example, the ability to communicate clearly, the ability to manage complex and big projects with varying indicators and deadlines, and the ability to manage budgets and cope with the needs of peers in other departments [14]. Singh and his co-author [15] state that there is increasing pressure from the industry, and government on the higher education institutions to provide graduates with useful interpersonal skills. The authors present the role of collaborative learning strategies in getting generic skills at the higher education level. Skills such as basic/ fundamental skills, people related, personal skills, thinking / conceptual skills, business-related, community-related are of great importance. These skills will back up graduates to become confident to move and interact in the society, to acquire new knowledge and information, to adapt according to demands of the workplace and to continue to be competitive.

AlMunifi and his co-author [2] aim at finding out to which extent the employability skills are available to engineering graduates. They collected comprehensive data through questionnaires and interviews that focus on the issue if the new graduates have the knowledge and interpersonal skills to meet the requirements of the labor market from the perception of graduates and employers. The output of the analysis shows that graduates gained sufficient technical knowledge, but missed on early preparation to meet the challenges they may face in the workplace particularly project management and key transferable skills. The study concluded that there is a need to look into the curricula contents and strategies of teaching and learning to ensure well-rounded graduates. Harry and his co-authors [7] study final-year students' perceptions of factors that

affect employability at a rural university in South Africa. The results showed a set of six factors were perceived to influence employability based on students' experiences:

- A poor socio-economic status
- A poor education system
- Curriculum issues
- The choice of higher education institution
- The social networks the student belonged to

On the other hand, Gerek and his co-author [3] went to study the employment ads. They represent the results of an investigation of the skills and competencies required by today's construction companies in ads in Turkey, with a particular focus on technical, computer, language, and interpersonal skills. According to their analysis, employers mention technical skills most often in job advertisements. The most important skills are computer skills, language skills, and interpersonal skills. Gerek' study presents the importance of foreign language skills for Turkish civil engineers. In the same trend, Kaushal [16] discussed and addressed the apparent gap between academic programs for engineering students and industry skills requirements. The author determines that the combination of both employability skills along with an engineering knowledge should help students to meet the high expectations of the workplaces. He listed a number of skills instance communication skills, teamwork, problem-solving skills, initiative and enterprising, planning and organizing, managerial skills/leadership skills, interpersonal skills, adaptability or flexibility, creativity or innovation, negotiation skills, commercial awareness, and lifelong learning. Whereas Warnick [17] described some of the challenges of transitioning from a lecture-based approach to an experiential learning approach. He described the associated benefits related to engineering and technology student' leadership outcomes. He listed some skills as follow: self-awareness, integrity, and ethical decision making, interpersonal skills, communication, problem-solving, project management, teamwork and team development, conflict resolution, planning, organizing and strategy formulation, coaching and mentoring, time management and prioritization, cultural awareness, global agility.

Aasheim and Williams [18] investigate if there is a difference in skill requirements for IT employees in the IT area versus other areas. In order to know how to prepare graduates in IT degree programs for jobs, employers in several industries were surveyed. The results show that IT programs that seek to tailor their curricula to better meet the needs of IT firms should focus on learning outcomes that support a higher level of skills. Moreover, Misra and the co-author [13] proposed the set of skills important for employability of IT professionals in this division. There are upon six skills: technical skills, higher order thinking skills, personal skills, social skills, generic skills, and self-perceived employability skills.

## **2.2 Teaching and learning strategies**

Teaching is the process of learning people what they need to learn and know [19]. Moreover, teaching and learning strategies are the methods used to help students learn

the desired course contents. M. C. Vorster [9] addresses the balance between teaching and learning. He discovers the notion that “we teach too much and our students learn too little”. On the other hand, Osakue and Graham [20] present a learning experience in which project assignment, a case of Project Assisted Learning (PAL), was used to improve the learning experience of the students and what they think about it.

Mocinic [11] indicates the method of lecturing is the dominant one on the respondents' studies, but with frequent use of guided conversations and discussions. The author illustrates that the leader of these changes is the professor who must be able to implement various different teaching methods and procedures and to alternate them strategically encouraging creativity, and problem-solving. Moreover, the author ensures that the faculty in the STEM disciplines face a number of challenges in seeking to become more effective teachers. Some of these challenges are common to all teaching and learning, while others are endemic to these disciplines. Instance, some of the more challenges include improving the assessment of learning outcomes. More discipline-specific challenges include teaching a broad range and large numbers of students, providing engaging laboratory and field experiences, and encouraging students to undertake original research that increasingly is highly sophisticated and technical.

Furthermore, Fox and Hackerma [21] address some of the more challenges include improving the assessment of learning outcomes. More discipline-specific challenges include teaching large numbers of students, providing engaging laboratory and field experiences, and encouraging students to undertake original research that increasingly is highly technical.

Much of the newest and most valuable knowledge involves more than one subject. Integrated STEM education can encourage students to careers in STEM fields and may improve their interest and performance in mathematics and science. Effective STEM education is very important for the future success of students [22]. The authors' emphases on the importance of the preparation and support of teachers of integrated STEM education is essential for succeeding these goals.

Zhou, Chunfang (2012) [23] aims to answer the question; what strategies can be applied to develop creativity in engineering education. The author emphases that to developing creativity, strategies such as using thinking tools, solving problems and building learning environment conducive to creativity have been recommended in engineering education. The author discussed in his research the Problem-Based Learning (PBL) to enhancing group dynamics thinking. He defined the strategy as ‘Problem-Based Learning (PBL) offers a framework for structuring and facilitating learning and group processes based on creative problem-solving.

Creative thinking tools (read: analogical thinking, brainstorming, idea checklists, mind mapping, and morphological analysis) have been discussed by Zhou, Chunfang (2012) [23] and (Liu and Schoenwetter, 2004 [24]); Thompson and Lordan, 1999 [5].

It is noticed from reviewing previous work in the subject area, that a set of interpersonal skills are listed as graduates' attributes. However, a number of researches stressed the existing gap between graduates' capabilities, especially of engineering and technology programs, and employers' expectations as well as employment requirements. In this study, the researchers attempted to emphasize the need for key competencies skills that fit the expectations of employers in dynamic work environments.

### **3 Research Problem and Methodology**

Traditional colleges and universities have always been interested in designing courses that equip students with the right thinking. Without any doubt, the students think well, and the challenge is how to enable students who think well to work well in this new rapid development environment.

With the rapid development of technology, there are many new skills required from graduates of scientific colleges. From the review of previous studies, as to form the personal experience of the authors, it has been noticed that students graduated from STEM disciplines especially those coming from developing countries, are lacking key competencies skills. This makes it difficult for them to perform efficiently, and even in many situations no able to show and apply the gained scientific knowledge efficiently in the workplace. A good number of graduates, including those who are excellence in science, suffer from adapting to the work environment.

Employers have been increasingly demanding that graduates should not only have knowledge and skills but should be able to use them well as proof of competence. The skills gap is still the same as it was many years ago. Not only should the education providers to be blamed for this but on the other hand, students also take more responsibility for their own learning process. Students need to know how to influence technology and have the right digital skills that will prepare them for a variety of work environments, whether physical or virtual.

Although we cannot ensure or predict the types of jobs that will be in the future, we know that today's graduates will need a variety of skills. If we agree upon this, we must ask ourselves what are the best ways to provide all graduates with authentic, unique, and innovative learning experiences that will foster the development of essential knowledge and skills to make them competent? How can we prepare graduates for jobs which may not exist yet in our ever-changing world?

The current paper aims to find out answers of the following questions:

- What are competencies skills for engineering and technology graduates to meet the challenges of employment?
- What is the teaching and learning strategies that will enable students to gain these competencies skills?
- What are the responsibilities of the main players, Professors, College Administration, and Students to support gaining these competencies skills?

The authors will follow descriptive and analytical methodologies to identify the problem by investigating the previous studies that dealt with some aspects of the problem. Then the intended competencies skills that support graduates will be identified with a focus on the skills required for graduates of engineering and technology disciplines as the challenges of the recruitment requirements are more. A set of teaching and learning strategies that will enable students to acquire these skills will be discussed. A roadmap will be created to present the responsibilities among the all involved parties, instance, college administration, professors and students to ensure an effective way to support students gain the intended skills.

## 4 Discussion

The previous studies have addressed many of the necessary attributes for higher education graduates. Lists of competencies skills from various domains are outlined in the above-mentioned studies that their purpose is to qualify students to the labor market. These studies were analyzed and filtered into homogeneous groups as shown in table no. (1).

**Table 1.** Competencies Skills

No.	Competencies Skills	Description
1	Teamwork and Leadership Skills	The most effective teamwork happens when individual contributors match their efforts and work toward a common goal. Good teams do not typically happen by chance; hard work, commitment and some amount of struggle are usually involved in making successful teams [26]. Leadership is the art of motivating a group of people to act towards achieving a common goal [16]
2	Problem-solving and Decision-making Skills	The process of working through details of a Problem-solving may include mathematical or systematic operations and can be a measure of an individual's critical thinking skills. Making a decision and the ability to choose the best option is vital skills in solving problems [27], [23]
3	Creative thinking Skill	Creative thinking is a way of looking at problems or situations from a fresh perspective to conceive of something new or original, it is the very definition of “thinking outside the box [28] [23]
4	Analytical and Critical thinking Skills	Analytical thinking is a critical component of visual thinking that gives one the ability to solve problems quickly and effectively. It involves a methodical step-by-step approach to thinking that allows you to break down complex problems into single and handy components [29] Critical thinking is the logical, sequential disciplined process of explaining, analyzing, evaluating, and interpreting information to make informed findings and/or decisions [28]
5	Technical writing and communication Skills	Technical writing is the writing of those involved in the technical fields. Including write technical reports, write technical proposals, write a business plan, and various forms of technical communication [30]
6	Self-learning Skill	Self-learning is an instructional strategy where the students, with guidance from the professor, decide what and how they will learn. It can be done individually or with group learning, but the overall concept is that students take ownership of their learning [31]
7	Digital and Navigation Skills	Digital skills are technical skills required to use digital technologies, whereas digital navigation skills are a broader set of skills needed to succeed in the digital world. These include finding information, ranking information and evaluating the quality and reliability of the information [5]

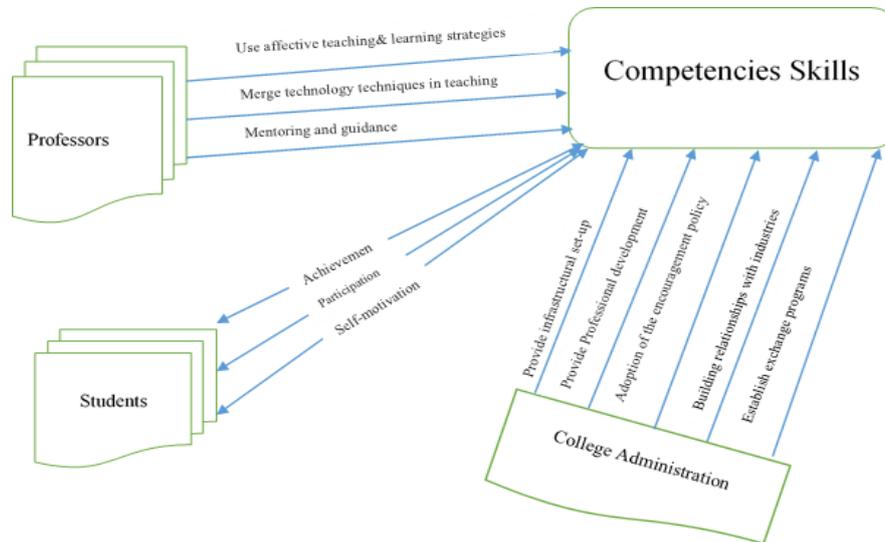
A set of teaching and learning strategies that will enable students to acquire these skills are proposed, Table no. (2). It is here to emphasize the importance of including a set of courses in the curriculum, as necessitated, to enable students to respond effectively to these strategies and gain the required skills.

**Table 2.** Teaching and Learning Strategies and the intended competencies skills

No	Teaching and Learning Stra.	Process	The intended competencies skills
1	Case Method	The study of real cases, discussion and evaluation of solutions that have already been made and provide alternative solutions help students touch the reality and expect the real situations to be faced in the labor market	Creative thinking Analytical and Critical thinking-Digital and Navigation Skills
2	Creative Thinking Tools (CTT)	Some complex problems can be discussed by brainstorming and motivating everyone to participate and the trigger mug to find new solutions and invent new solutions. Can be suitable for software and programming problems	Creative thinking Teamwork skills Problem-solving, and decision-making skills
3	Integrating Technology (IT)	The professor had to use technological tools, and encourage students to learn and use modern tools including, active presentation, online questionnaires, cloud personal storage and effective application for advanced data analysis	Creative thinking Analytical and Critical thinking Self-learning Digital and Navigation Skills
4	Self-learning	The professor should direct the students to two kinds of self-learning ability, first of all, to prepare the subject in advance and explain it to his colleagues and then complete what may be lacking. The second method, request reports on recent relevant topics that can be done through various sources, including the Internet	Self-learning Technical writing and communication Digital and Navigation Skills
5	Problem-Based Learning (PBL)	Teamwork helps students to work together, demonstrate responsibility and respect different views. The professor or assistants must follow the work of the groups and make sure that everyone participates and reviews technical reports	Problem-solving and decision-making Teamwork skills
6	Project Based Learning (PBL)	Students work on open-ended assignments that engage them in solving a real-world problem or answering a complex question. They validate their knowledge and skills by developing a public product or presentation for a real audience	Creative thinking Analytical and Critical thinking Tech. writing and communication Digital and Navigation Skills
7	Research-Based Learning (RBL)	Semi research based on up to date topics should be asked for each student and a good report should be presented. The good steps of research should be followed and the ethics rules are applied	Creative thinking Analytical and Critical thinking Technical writing and communication Digital and Navigation Skills

#### 4.1 The roadmap

To ensure effective delivery of the teaching and learning strategies and to realize the intended competencies skills, a roadmap that shows, *who should do what* was created.



**Fig. 1.** The roadmap outlines the necessary efforts of concerned parties to enable graduates to gain Competencies Skills

#### 4.2 Professors’ responsibilities

New teaching methods and approaches are expected into engineering higher education towards competency development of the students. Also, it is essential for the professors to build a new mindset and to develop competencies that enable them to be prepared for teaching the new generation [32]. Professors should understand that they are facing difficult times with new generations that were born surrounded by technology [33]. Table no. (3) presents professors’ responsibilities.

**Table 3.** The main responsibilities of the Professors

No	Responsibility	Description
1	Use effective teaching and learning strategies	Use effective teaching and learning strategies dependent on their subjects
2	Merge technology techniques in teaching	To ensure their students benefit from these technical tools and get a good understanding
3	Mentoring and guidance	To help their students to be self-learning and build good creative thinking and ability to search and get the knowledge by themselves

#### 4.3 College administration’s responsibilities

There is evidence which indicates the differences between the graduates' skills developed by institutions of higher education, perceived by graduates and expected by employers [32], [34]. The college administration should provide the infrastructural set-up, staff professional development, adoption of the encouragement policy, and establish

exchange programs, and building good relationships with industries to get feedback and a clear understanding of the employment' requirements, as in table no. (4).

**Table 4.** College Administration's responsibilities

No	Responsibility	Description
1	Provide a suitable infra-structural set-up	Provide the equipment that is required in teaching and learning Provide essential software, programs and labs
2	Provide Professional development	Provide refresh training for professors and educators to encourage them to follow the effective strategies of teaching Provide teaching assistants for the professors especially with large classes Adoption of peer to peer evaluation to take advantage of a note of preaching and improve performance
3	Adoption of the encouragement policy	Encourage professors to share the activities and projects of their students and to spread competition and motivation Adoption of the competitions policy amongst students from the alike colleges in the universities
4	Building good relationships with industry	Enabling students to train during summer vacations Invite some privileged people to give students lectures on the nature of work and what the graduates encounter when they employment Arrange visits during the semester to related companies to see what has been explained theoretically with the applied reality Enabling and encourage students to volunteer in these institutions during the graduation project and after graduation to learn about the nature of the actual work
5	Establish exchange programs	Invite Professors from other local and international universities to give some related courses Adopted exchange programs to allow students to get different skills and knowledge from different universities

#### 4.4 Students' responsibilities

The efforts of professors and even the efforts of the college administration cannot be fruitful if the student is not responsible for the follow-up, diligence, and keenness to participate effectively. Table no. (5) presents students' responsibilities.

**Table 5.** Students' responsibilities

No	Responsibility	Details
1	Integrity and honesty	Demonstrate academic integrity and honesty Respect group work and diverse ideas
2	Participation and Commitments	Attend classes, labs, and seminars Participate in an effective way during lectures and academic activities Complete the assigned work in a timely manner with attention to the quality of work
3	Self-motivation	Ability to do what needs to be done, without influence from other people or situations Identify, develop, and implement a plan to achieve educational goals and improve their self-learning

## 5 Conclusion

This study aims to find out answers to questions related to what competencies skills graduates need to meet the challenges of the employment; and what are the teaching strategies that will enable students to gain these competencies skills; and what is the roles of the main players to support gaining these skills. Learning outcomes of educational programs are designed to focus mainly on knowledge and transferable skills. Also, most of the current's researches have been discussing the missing interpersonal skills in higher education programs and came up with recommendations to fill the gaps.

The current study's point of view is that graduates may have the appropriate knowledge and interpersonal skills, but they lack the ability to efficiently use them, as the attitude to deal with demanded situations. A set of technical knowledge capabilities, transferable skills, abilities, and attitude are fundamentals for a competent graduate.

To advance knowledge in the subject area, this study proposes a set of intended competences skills along with teaching and learning strategies for properly preparing future engineering and technology graduates. A roadmap was created to show the roles of college administration, professors and students to ensure an effective way to support students gaining these skills. It is recommended that these sets of strategies be incorporated in the education programs document, and the roles of the main players to be facilitated.

The future of the research should go further to guide educational establishments in designing new programs with sets of competencies skills that take into consideration the shift happens in the labor market.

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