

Analyzing How University Is Preparing Engineering Students for Industry 4.0

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Abstract: Industry 4.0 is causing a lot of changes related to the way people work, bringing a demand for a new worker profile, mainly for engineers, that need to have not only technical skills but also methodological, social and personal skills. So, there is a need to study and identify how the university prepares engineering students for Industry 4.0 jobs. To achieve this objective a literature review was made, twenty-nine skills of Industry 4.0 jobs were identified, and eight active learning methodologies were selected like paths that universities can use to develop skills for the Industry 4.0. To analyze how a university can use active learning methodologies to develop Industry 4.0 skills in engineering students, a questionnaire was applied in four engineering classes of the University of Brasilia, where the professors answered about the active learning methodology used and what skills were developed in the students, and the students answer the questionnaire with what skills they developed. A correlation analysis was applied to detect the different points of view between professors and students. Then, a decision tree was used to identify what skills were most developed by the active learning methodology used by the professor. The results show that are some divergences between the two points of view, and the questionnaire needs to be adaptable to measure with more reliability the skills that the professor wants to develop in each engineering class.

Keywords: transdisciplinary systems; engineering education; active learning; Industry 4.0.

Introduction

Information security, internet of things, augmented reality, big data, autonomous robots, simulations, additive manufacturing, 3D printing, integrated systems and cloud computing, are examples of technologies that brings up a new industrial scenario and are used in an integrated way to solve problems and generate flexibility so that companies can meet customers' needs [1].

This scenario distinguishes the Fourth Industrial Revolution, represented by Industry 4.0 and characterized by digitalization, high level of technological innovation, real-time information, flexibility and connectivity which, like previous industrial revolutions, has a transformative impact on society, reaching the economy, business models and, consequently, the guidelines of the work environment and the professional profile [2].

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The implementation of the Industry 4.0 scenario is strongly related to collaboration between people who are able to develop new knowledge, concepts, tools and techniques shared by researches from different families of disciplines (social, science, natural science, humanities and engineering), working in a collaborative process to generate knowledge and implement solutions to unstructured problems [3].

This involvement of professionals from different disciplines, with different ways to work and think about ill-defined and complex problems relevant to Society is characterized by transdisciplinary systems, that combine both technical and social disciplines to implemented new technologies, process, practices and knowledge [4].

In this scenario, engineering institutions are restructuring their curricula and teaching models, moving from a purely technical scope to one that considers problem-solving, projects, critical thinking development among other approaches that integrate different forms of teaching and non-traditional engineering knowledge, such as business, finance, management, politics, social studies, and others, in order to develop skills and competencies that form professionals capable of acting in different situations and contexts [5].

Transdisciplinary systems in engineering requires the involvement of people with open mind to other disciplines [4]. Engineering education should incorporate courses whose curriculum prepare students with the knowledge and skills needed to understand and collaborate with people from other disciplines, in other words, the need of not only hard skills but also soft skills [6].

Some courses have been designed to achieve this goal especially those that use active learning methodologies like flipped classroom, problem-based learning (PBL), cooperative learning, peer-led team learning (PLTL), collaborative learning, game-based learning, inquiry-based learning, blended classroom. These are some examples of methodologies founded in literature that aim to implement transdisciplinary in engineering institutions.

Many challenges exist to implement a transdisciplinary approach in a training process, manly in engineering courses. In the traditional curricula was rarely the opportunity to leave the purely technical scope and have contact with real problems, extracting its essence and applying the respective analyzes that lead to decision making and generating solutions, engineering education should be more inclusive, also addressing the development of social, personal and methodological skills [6].

One of these challenges found in literature are how to measure and verify that the transdisciplinary approach implemented by active learning is preparing engineering professionals with Industry 4.0 skills?

This article aims to analyze if the application of an active learning methodology is efficient to collaborate with a transdisciplinary engineering approach to train professionals for Industry 4.0. To achieve this goal first was researched about the set of skills that needed to be developed in an industry 4.0 engineering professional. Secondly a research about active leaning method was made and, based on literature, the skills developed by each method was presented. Then a case study was developed in University of Brasilia (UnB) to compare the information of literature review with a practical situation, considering the point of view from the professor and undergraduates. The tools used to analyze and compare the different viewpoints were correlation analysis and decision tree.

1. Industry 4.0 and the need of a new engineering profile

The Fourth Industrial Revolution brings many changes in the business, in the way people think, the speed of changes and others facts that requires not only a different way to manage a business but also impact in different activities and functions to perform the work [7]. By this scenario is possible to notice that its need to develop new skills to survive the new Industrial era, mainly for the engineers [1].

The engineer must be able to combine technical, social, methodologic, and personal knowledge to work the Industry 4.0. Maffioli and Augusti [8] denote that only the aggregation of pure science knowledge, that includes all knowledge assumed by traditionally technical areas of engineering, like mechanical, mechatronics, robotics, and others are no longer enough to for future professionals.

Lemâitre [9] denote that industries demand skills related to innovation capacity and performance, that can vary from static to dynamic state. Companies that have a static state are characterized by a low level of innovation and long-life circle products, for example, tend to demand professionals with solid technical knowledge. On the other hand, companies with a dynamic state are characterized by high levels of competition, short life circle products and are constantly testing a new process, products, and clients. In this case, the uncertainty is a strong factor in all process, so, the company needs professionals who master technical knowledge and can combine this with different areas to understand and create new solutions to solve ill-defined and socially relevant problems.

Bughin, Manyika and Woetzel [10] declare that professionals will need to developed skills related to sensorial perception, cognitive abilities, problem-solving, planning and optimize activities. They also will need to be creative, own emotional intelligence and know-how to articulate and coordinate teams from different knowledge areas.

To train an Industry 4.0 engineer is necessary to synchronize cognitive, technical, methodological, and social skills development in the learning process. Such combination can impact in the integration of several learning ways content from different knowledge areas and help undergraduates to develop the ability to apply them in different situations and contexts, as well as to continue learning [11].

For future professionals is necessary interpersonal skills development, the engineer must be able to work in teams, consider different perspectives, understand and respect different opinions, and to recognize the experience of professionals from different areas. Consequently, it's necessary to communicate and present new ideas and results, understandable by professionals from other areas[10].

Hecklau *et al.* [12] introduce a set of future professional skills that were clustered into four main categories: methodological, technical, social, and personal. Methodological competencies are related to the knowledge of methods and tools to solve problems, conflicts, make analysis, researches, and to be creative. Technical competencies are related to technical knowledge and experience. Social competencies are related to the ability of teamwork besides understanding and collaborate with different knowledge and viewpoints. Personal competencies are related to the ability to be flexible, tolerant and able to constantly learn. Each skill is presented on Table 1.

Industry 4.0 brings challenges to training new professionals and consequently, the educational institutions and universities need to prepare professionals with the set of skills and competencies of the future industry. The way universities are structuring themselves to this scenario is covered in the next section.

Table 1. Set of future professional skills as proposed by [12].

Methodological	Technical	Personal	Social
Problem solving	Media skills	Flexibility	Leadership skills
Entrepreneurial thinking	State-of-the-art knowledge	Motivation to learn	Team work skills
Creativity	Technical abilities	Complacency	Intercultural skills
Analytical skills	Understand new processes	Sustainable mindset	Ability to commit and cooperate
Research skills	Programming skills	Tolerance	Communication skills
Efficiency in problem solving	Understanding information security	Ability to work under pressure	Ability to transfer knowledge
Decision-making	State of the art knowledge	Flexibility	Master more than one language
			Networking skills

2. How universities are preparing themselves to provide professionals for Industry 4.0

In response to changes in the market as well as the way people think and demand products and services, universities and institutions of education need to review the training process for new professionals. They need to allow undergraduates to apply knowledge to real, ill-defined and society-relevant problems, providing a transdisciplinary approach that engages and enables students to develop the technological knowledge, practical experiences, perspectives, and strategies drawn from a diverse range areas [13].

The transdisciplinary education approach is a way to create opportunities in the curriculum for undergraduates to experience and practice solutions to realistic problems, not simply academic knowledge. This is a student-centered method that involves dynamics classroom approaches with the objectives for students to achieve deeper knowledge through active exploration of real-world challenge and problems[4].

The transdisciplinary approach has seven key features that can be connected to engineering domain as follow [4]:

1. Problem oriented: ill-defined, society-relevant problems are dealt with in a transdisciplinary approach.
2. Involvement from academia and practice: to solve ill-defined, society-relevant complex problems both academic and non-academic stakeholders need to be involved.
3. Both research and practice need to benefit from a transdisciplinary process.
4. Research goals need to be defined by technical (transdisciplinary or inter-multidisciplinary) and social science goals (like business management, human resources, or team composition and culture).
5. Practice goals need to be defined, by different functional goals, like technical, as well as human resources and management goals.
6. Project goals need to be defined, which may shift in the course of the project, because of the dynamic nature of project and unexpected situations that may emerge.
7. Measures need to be defined for the various outcomes of the project.

To implement transdisciplinary education, institutions and universities can use active learning methodologies. Characterized by the student-centered approach, the active learning aims to involve the student in a dynamic process of knowledge construction based on theoretical and practical experiences of real-world situations [3]. Also consider situations to solve working problems with multidisciplinary teams, to promote the collaboration between teams from different disciplines with different viewpoints follow [4].

When the topic active methodologies is researched the main results appointed in the literature are the following methods: Flipped Classroom, is about the dissemination of content outside the classroom, in digital format [14][15][16]; Problem-based learning (PBL), is the application of the content to solve a real problem [17][18][19][20]; Cooperative learning, is the application of strategies that promote cooperation between students to solve a problem [19][18][21]; Peer-led team learning (PLTL), is about solving problems collaboratively, with the help of peers/mentors [22][23]; Game-based learning that brings a proposal of a scenario in which the application of games with certain contents, environments and challenges for solving problems [24][11][25]; Inquiry-based learning, provides students with opportunities to improve their understanding of content and practices covered during teaching [26][27]; Blended classroom is learning within the classroom, complemented with activities and virtual content, which can be accessed outside of class hours [28][29].

Each one is indicated in the literature to provide the learning process by experiences and consequently, develop skills and competencies that probably cannot be achieved by a non-centered-student method and compose the set of Industry 4.0 skills [30]. To analyze those methods in practice and find out if the application of active methodology results on the development of future skills, a case study was applied in some engineering classes of the University of Brasilia (UnB). The applied methodology is presented below.

3. Methodology

The case was implemented by a survey forms, structured based on two main points of the literature review: i) the set of twenty-seven skills introduced by Hecklau *et al.* [12]; ii) the inclusion of two more skills in this set, that were present in literature review that compose the important skills to Industry 4.0: a) critical thinking, characterized by an intentional judgment process that results in interpretation, analysis, evaluation and inference [31]; b) creativity, which includes divergent thinking, generation of innovative ideas, originality, inventiveness, ingenuity and the ability to see opportunities to solve problems [25]. The final classification is presented below:

1. Methodological: M1) Problem solving; M2) Entrepreneurial thinking; M3) Efficiency in problem solving; M4) Decision-making; M5) Creativity; M6) Analytical skills; M7) Research skills; M8) Critical thinking; M9) Systemic thinking.

2. Technical: T10) State of the art knowledge; T11) Technical abilities; T12) Understand new processes; T13) Media skills; T14) Programming skills; T15) Understanding information security.

3. Personal: P16) Flexibility; P17) Complacency; P18) Tolerance; P19) Motivation to learn; P20) Sustainable mindset; P21) Ability to work under pressure.

4. Social: S22) Leadership skills; S23) Ability to commit and cooperate; S24) Master more than one language; S25) Ability to work as a team; S26) Communication

skills; S27) Networking skills; S28) Intercultural skills; S29) Ability to transfer knowledge.

The classes from the engineering department that already used any active methodology were chosen for this case study. To identify these classes was applied an unstructured questionnaire was applied to interview professors and select those classes which use active methodologies and had availability to participate in the research. Having made this selection, the survey forms were applied.

First the forms were submitted to professors, to identify what was planned to develop in students during the semester. Secondly, the same form was submitted to undergraduates, to collect what skills do they identify that have been developed in the course. For both, the development of twenty-nine skills was analyzed by five possible answers: The skill was very well developed (note 5); The skill was partially developed (note 4); I cannot identify whether this skill was developed (note 3); The skill was poorly developed (note 2); The skill was not developed (note 1).

To analyze the answers, identify the development probabilities of each skills and conclude what dimension were more “successfully developed”, a decision tree method was used, and an overview was proposed to synthesize the answer. And to analyze the correlation between professor and undergraduate viewpoints, the results were plotted by dimensions in radar charts. The case study and the conclusion about what Industry 4.0 skills are developed by active methodologies, are presented in the next section.

4. A case study in the University of Brasilia

To identify what Industry 4.0 skills are developed in the undergraduates, four disciplines from engineering degree was analyzed: Products Systems Projects 1 (PSP1), Products Systems Projects 2 (PSP2), Products Systems Projects 6 (PSP6) and Special Product Engineering Topics (SPET). Both disciplines use the PBL as the main methodology during all semester.

The objective of these courses is to develop solutions to problems based on specific disciplines that are related to each one. For example, in PSP1 students need to solve real problems using statistic disciplines as the anchor approach; in PSP2 students need to solve real problems using, as the anchor approach, informational systems; in PSP6 students need to prototype physical solutions to real problems based on product development as it's anchor discipline; in SPET, students also need to prototype solutions based on product development, but with a low complexity level when compared to PSP6 (PSP 6 is more technical and focused in applying one specific methodology to solve a problem and develop a product). It's important to mention that both courses (PSP6 and SPET) prototype solutions to solve one problem introduced in the semester.

The first step was applying the questionnaires with the four professors, to understand their main expectations related to what was planned for the discipline and what they believe would be developed in undergraduates. About the undergraduates, a universe of 138 students participates in the research in the period of November 24 to December 13 of 2019. Figure 1 shows the results.

To PSP6 class, which had a total of 46 responses, students consider that in the methodological dimension, all skills were very well developed, except creativity and critical thinking (47%). In the technical dimension, students identified that the skills of state-of-the-art knowledge, technical skills, and understanding of new processes were very well developed, in contrast, media, programming, and understanding of information

security skills were identified as undeveloped by 36%, 73% and 52% of students respectively. Following the personal dimension, all skills were identified as very well developed. In the social dimension, practically all skills students are well defined.

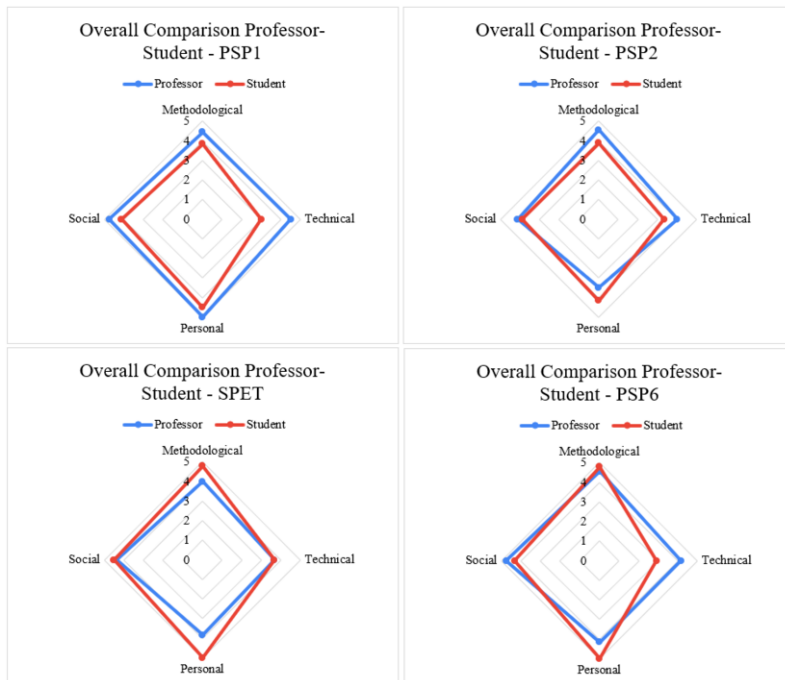


Figure 1. Overall comparison professor and student answers by discipline.

Analyzing the SPET class, in the methodological dimension, almost all skills are very well developed, except for entrepreneurial thinking and research skills, which were identified as partially developed by 67% and 47% of students respectively. In the technical dimension, 47% of the students point out that the programming skill was not developed, as well as the media skills and understanding of information security that did not have their development identified by the students. In the personal dimension, all skills were identified by 70% of the students as very well developed. This fact is repeated in the social dimension, except for the ability to develop a domain over more than one language.

The PSP1 has all methodological skills pointed out as partially developed (61%), except the ability of systemic thinking, whose development was not identified by the majority. In the technical dimension, state-of-the-art knowledge centers, understanding of new processes and media skills were indicated as partially developed. Technical skill was indicated as poorly developed. Programming and information security skills were indicated as undeveloped (62% and 38% respectively). In the personal dimension, all skills were identified as very well developed, except for flexibility, tolerance and motivation in learning, identified as partially developed. In the social dimension, the ability to develop a new language was identified as undeveloped, while for the skills for networking, intercultural and knowledge transfer, they were identified as partially developed and the rest were indicated as very well developed.

PSP2 discipline has all methodological skills pointed out as partially developed, except the ability to be creative. In the technical dimension, 37% of the students agree that the state-of-the-art knowledge was well developed, and about understand new processes and media skills, 40% agree that was partially developed. The majority pointed out that programming skills and understanding information security weren't developed. In personal dimension the majority was identified like partially developed, the same occurred for the social dimension, except for the ability to develop a domain over more than one language.

Looking at these answers it's possible to observe that exist some differences between what the professor identifies like "developed" and what the students really identify like "developed". To analyses and compare the differences between the two viewpoints and look at the relationship level of each ability answer, a correlation analysis was developed and was implemented a decision tree to identify what was the probability of development of each skill based on the answers. This analysis is presented in the next topic.

5. Comparing two viewpoints: professor and students

Having completed the analysis of the students and professors' perspectives, the decision tree method (Table 2) was used to classify the development probabilities of each skills, which shows that the most developed dimension in the four courses analyzed was the personal and social. The technical dimension was not much developed, except in PSP1. The methodological is the dimension with the lower level of development. The course with the biggest answer number was chosen to be detailed bellow (PSP6).

Table 2. Decision tree results: development probabilities of each dimension.

	PSP6	PSP1	PSP2	SPET
Methodological	20,75%	23,37%	21,35%	21,76%
Technical	24,62%	26,99%	22,50%	22,94%
Personal	27,64%	25,00%	27,88%	28,43%
Social	27,17%	24,64%	27,31%	27,84%

The PSP6 decision three results show that the dimension with the biggest development probability is the personal, with 28% of development chance of tolerance skill. With 27% of development probability is the social dimension and the ability to work as a team. With 25% is the technical dimension, with the probability of failure the develop programming skills. The methodological dimension had 21% of chance to develop the decision-making skills.

Analyzing the PSP6 discipline had the professors' perspective surpassed by what was actually developed by the students. In the methodological dimension, for example, only the creativity skill had a different professors' perception than the one expressed by the student, where the professor identified the skill as very well developed and the students pointed it as partially developed. In other dimensions the same fact occurs for understand new processes, media skills, understanding information security, networking skills and intercultural skills, and the greatest divergence occurred to media skills, pointed out by the teacher as partially developed and by the students as undeveloped.

6. Discussion and research agenda

In this paper the impact of Industry 4.0 in education and training of new professionals, mainly engineers, was evidenced by the understanding of the new skills that compose the ideal professional profile to future and the identification of how universities are preparing themselves to provide the skills needed by them.

A case study was applied in the University of Brasilia (UnB), to analyses four disciplines that use a transdisciplinary approach with the application of active learning as a method to develop the Industry 4.0 skills. The tools used for the analysis were the correlation level and decision tree.

Through these analyses and results of undergraduates answers, it's possible to conclude that even though the methods used to apply the transdisciplinary education in engineering training to developed skills for Industry 4.0 aimed to contribute in all four dimensions (methodological, technical, social and personal), some dimensions are more developed than others. In general, the skills development must be balanced and probably, if considering that during engineering graduation the disciplines, programs and courses have different development skills objectives, there are chances of developing all related Industry 4.0 skills, but this study does not allow to conclude this fact.

This last cited fact is not considering in the survey form used to analyze Industry 4.0 skills, they were generic, especially about the methodological and technical dimensions, maybe this is the cause of the differences between professor and student viewpoints since it could exist different interpretations about the meaning of each skill, once considered that they were generic.

Future work could be developed to propose a methodological application and analyses of Industry 4.0 skills in courses that use an active learning approach, considering skills development during all graduation and application of indicators that can prove undergraduates learning.

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