Open Innovation Laboratory: Education 4.0 Environments to improve competencies in scholars

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Abstract– With the widespread adoption of emergent technologies, productive sectors have evolved in leaps and bounds This has generated a breach between what is needed in the Industry and what is expected in Academia to be taught. Traditional education focuses on the development of hard skills in students, nonetheless, current technology developments mainly in the fields of artificial intelligence and automation pose a threat to technique and repetitive jobs. Soft skills on the other hand are to remain active and desired in the near future as they are needed for tasks that machines cannot replicate yet. Complex problems require the integration of multidisciplinary teams where decision-making and communication abilities are enhanced by its individual parts. Mass adoption of Information and Communication Technologies in every sector of society demands an evolution of the education model. Consequently, universities throughout lecturers and infrastructure must develop guidelines for students to improve their skills and generate the competences needed. The open innovation concept has brought institutions a framework to develop multidisciplinary and multi entity projects to provide valuable experiences and competencies development to college students. This has led to the development of Open Innovation Laboratories where learning techniques, design methodologies and product realisation platforms fuse to provide a state-of-the-art concept to cope with the demands toward the educational model. This allows joint efforts from industry, government and institutions on the creation of collaborative projects to provide innovative solutions whilst enriching experience and boosting competences in students. Thus, the idea of gathering emergent technologies for training, open innovation for generating end-to-end solutions and methodologies to foster strengths in students becomes an educational environment to promote the use of active and collaborative learning techniques to enhance soft skills and development of competences facing society challenges as part of the education 4.0 context.

Keywords– Collaborative and Active Learning, Education 4.0, Educational Innovation, Higher Education, Integrated Product, Process and Manufacturing System Development, Learning Environments, Open Innovation Laboratory.

I. INTRODUCTION

Social, economic and environmental changes driven by information technologies are defining today's society. Productive sectors (primary, secondary and tertiary) are in constant evolution and there are at least two new sectors that must be included into this classification [1]. This increasing complexity exhibits the evolution of all social structure. For instance, the primary sector is under high pressure to find new practices in order to preserve and protect these non-renewable resources. New regulations seem to conflict with the increased needs of population growth entailing a rational speed up of exploitation. Even new trends in human feed patterns [2], including the demand of organic food represent a challenge to this sector requiring new responsible ways of production. On the other hand, the industrial sector is the maximum representative of the innovation that is being carried out thanks to the constant evolution of technology. Both extraction and transformation are experiencing deep changes easily observable as their flagship corporations lead the transformation into Industry 4.0 [3]. For the service sector, there is ongoing work to make the most of new production models and technologies. Widespread use of the internet has enabled the creation of new business models, growth of e-commerce and transformation of services thanks to fog and cloud computing [4]. To this extent, all sectors are constantly evolving and require professionals able to deal with current and future problems by means of specific skills and competences to propose innovative solutions that break the paradigm of the traditional way of doing things.

Formation of new generations must be in accordance with new educational techniques allowing professionals to face current and forthcoming challenges [5]. Much of this instruction is still carried out in conventional spaces even on the most prestigious institutions. Although there has been a constant evolution in different sectors of society, educational methods and learning techniques remain roughly the same as a century ago. Grads finishing their formation will encounter a demanding environment whether they want to enter the workforce of a company or, on the contrary, adventure themselves into the world of entrepreneurship. For universities around the world there is a continuing effort to improve their curricula to allow the development of the most demanded skills in students [6]. This step forward in learning culture is becoming known as Education 4.0 (Ed 4.0).

The purpose of this article is to show how disciplinary and transversal skills in scholars are improved through Ed 4.0 environments, such as Open Innovation Laboratories. A space which brings together industry and academia collaborations to share experiences about challenging engineering projects, promoting an integral development for students. To address these challenges of the productive sectors, students make use of technologies, methodologies and tools. The present paper is structured as follows. In Section II, there is divulged the conception of Ed 4.0 observing the advances of technology and their impact on future professionals. Then, in Section III, there are described the Open Innovation Laboratories (OIL) and current efforts of Universities to develop competences in students through them. Soon after, in Section IV, the educational environment to foster competences in the context of Ed 4.0 using OILs is exposed. Thereupon, in Section V, there are uncovered three case studies developed in the educational environment at Tecnologico de Monterrey.

II. EDUCATION 4.0 CONCEPTS AND TRENDS

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There is technology that was invented or conceived almost in the mid twentieth century but had not reached the necessary maturity to be implemented on a large scale until a decade ago. Mainly driven by the increased and exponentially growing computational power, this accelerated evolution has allowed technologies such as artificial intelligence (AI), data analysis, robotics and cloud computing, to benefit more and more sectors of the population directly and indirectly.

This massive implementation and creation of technologies rushes to reinvent things. Germany conceived this integration in 2011 on what they called Industrie 4.0 [7], seeking a major evolution on manufacturing processes. One of the great challenges faced in this fourth transformation is to align the technologies and tools used in the industry with education. For Demartini and Benussi, the term Education 4.0 is coined to the relation of technologies and tools applied to Industry 4.0 and the demands for graduates who will be employed in those sectors [8]. There are also efforts to define Ed 4.0 in terms of the dawn of novel methodologies and state of the art educational spaces that allow changing the paradigm of traditional education [9]. A common shared axis is that learning processes must strengthen the development of new skills and competences in future professionals.

Skills and competences are commonly divided between hard and soft. Hard skills comprise all the knowledge that professionals must have for the development of their activities and are job dependent. They are obtained through traditional classes over time. For instance, hard skills comprise almost the whole curricula of what is generally known as STEM (Science, Technology, Engineering & Mathematics) disciplines [10]. Soft skills are related to the person and refer to those that support the inner process of information, logic and interpersonal abilities and behaviours that allow to interact with the society. The Soft skill set for a professional is unique and its development is of paramount importance in order to reach a higher level of integration on any labour. There is intense research on the skill set that is required for any graduate student and the different methodologies and learning techniques to develop them. Mehmet [11], defined the skill set to be promoted in the second decade of the 21st century according to the demands of the industry. Nevertheless, the continuing transformation of the productive sectors drive a constant transformation on the qualifications needed of the workforce. The World Economic Forum (WEF) in 2016 enlisted the skills that will be required within the industry by 2020 [12]. The survey collected data of about 13M people and hundreds of corporations, the results summarized the growing need of soft skills as technologies are taking over many hard-skilled activities.

There is a growing discussion about the inclusion of AI and its impact on jobs. This is closely studied as a challenge and as an opportunity [13]. AI, together with other technologies such as robotics, machine learning and data analytics will lead to the automation of duties within different jobs. While this will bring medium term consequences such as the disappearance of some occupations that are highly repetitive, it will also provide the opportunity for the creation of new jobs where AI along with automated processes will facilitate and enhance the work of many people. On the other hand, the aforementioned technologies will have a direct influence on the hard skills and competences requirements for employment as computers will be capable enough to handle duties that were previously of exclusive human domain, such as reasoning and problem solving. However, those professions that make extensive use of soft skills will tend to grow in the future because this type of dynamics is very complex to perform yet even with new technologies.

Educational institutions are aware of these trends and endeavour on considerable efforts for students to develop and enrich the different skill sets that modern industry demands. Therefore, novel learning techniques are consolidating new technologies, methodologies and tools to allow the integral development of students. Some of these models allow education personalization focusing on the knowledge that all persons are different and have different learning styles. This has led to the creation of innovative learning spaces just as SCALE-UP [14]. A proposal born at the University of North Carolina that has gradually found application in some of the most prominent educational institutions in the USA including MIT. Active-based learning (ABL) and problem-based learning (PBL) are the main characteristics of such spaces and according to the evaluations being carried out, there is a significant improvement compared to traditional spaces on regard to hard and soft skills. Tecnologico de Monterrey is making constant efforts to transform its educational model to offer a system that is consistent with the current changes and challenges of the productive sectors. In this regard, it has created the Tec21 educational model which radically transforms education and aims to the development of what it’s called disciplinary and transversal skills [15].

Learning spaces and disruptive methodologies stand as the leading way to improve education. The use of the internet has been of paramount importance since it allows more flexible scheduling and ubiquity presence by lecturers and students as physical classrooms are exchanged by meeting software with personal laptops to take remote classes. This in turn brings up the opportunity to provide continuing education by online platforms like Massive Online Open Courses (MOOC). Concepts like Open Innovation [16], have encountered a niche of opportunity in education as includes the relationship between different entities (government, enterprises and education institutions) to provide solutions through the share of expertise each one can provide. Collaborative programs with external agents have played a very important role in creating new skills in students.

III. Open Innovation Laboratory

Open Innovation is a powerful concept as it contributes to the flow of knowledge between their entities. However, it stands in a blank canvas if no infrastructure and framework is provided. To this regard, institutions like Harvard, Berkeley, Yale, Tecnologico de Monterrey to say some, have created what is called Open Innovation Laboratories (OIL). Contrasting with technological parks around the world, OIL aims for the creation of collaboration hubs where not only knowledge and expertise is shared, but also facilities that can provide solutions to any external actor. These shared physical spaces provide solutions that otherwise could not be possible or would result costly for a single entity. A natural evolution of this model was to endeavour into collaborative projects where vantage points about benefits depend on the entity itself. For educational institutions the scope is centred on competences development, research relationships and talent linkage. Collaborative programs within OIL are created to solve real life problems of companies, government (including society) or both. OIL improves competences by enriching knowledge in a daring environment where attitude is boosted through ABL techniques and skills enhanced with collaborative and challenge-based learning. OIL is based on three pillars: i) learning methods and techniques, ii) design methodologies and a iii) rapid product realisation platforms [17].

A. Learning techniques and methods

Two main learning techniques have been used to enhance learning experience: Collaborative learning and active learning. Collaborative learning gathers people to interact in groups to cooperate, individual skills are highlighted to create unique environments in which participants share knowledge among their partners. There are some principles that rule the behaviour in this type of technique: i) understanding overcomes what occurs if members had worked independently, ii) interactions contribute to the increasing understanding of the whole group and iii) participation is voluntary. Collaborative learning involves engagement of a group of individuals to solve a complex problem. Besides, a large amount of information is available for participants to overcome the presented problem. Structure and guidance are provided by lecturers to complete their learning tasks. This learning technique is enriched with the use of emerging technological tools, with successful results rather than conventional approaches [18]. Active learning aims at complementing the learning process through thinking. Common activities involve analysis, practical experience and creativity. It makes use of feedback from peers and lecturers. This type of learning requires active stimulation and constant knowledge sharing to refine concepts. Furthermore, active learning enriches the traditional learning process with the use of digital platforms to allow students to be in contact with their peers.

B. Design methodologies

Novel educational methods such as Problem-Based Learning, Project-Oriented Learning, Case-Based Learning and Online Learning, make use of design methodologies in order to produce a straight solution for a given problem whilst these generate valuable activities to learn actively. A prevailing requirement when dealing with projects is product development. Integrated Product, Process and Manufacturing System Development (IPPMD) Reference Framework (See Fig. 1) [19] has been developed to interactively explore opportunities (diverge), analyse best options (structure) and materialize ideas (converge) when designing new products.

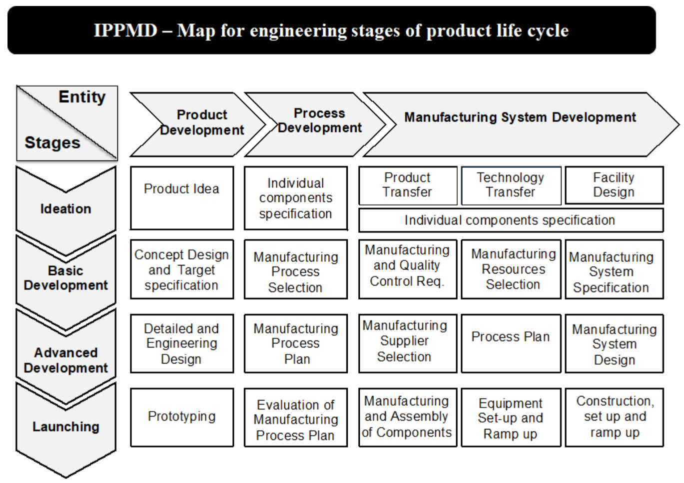

Fig. 1 Integrated Product, Process and Manufacturing System Development Reference Framework.

The IPPMD is comprised of entities, stages and toll gates that integrate the Product Life Cycle. The three components of the model are as follows:
1) Entities: Entities are developed during engineering projects. They indicate the type of deliverable acquired at the end of the four stages to be carried out. They are either Product, Process or Manufacturing System.
2) Stages: Stages are evolutionary levels of the entities. There are four stages along the designing processes: Ideation, Basic Development, Advanced Development and Launching
3) Toll gates: Toll gates are results obtained at the end of each stage for every entity. That is, every intersection of the map requires a toll gate. They sum up the information developed in the entity per stage and conform the documentation needed in an engineering project. Toll gates require additional engineering activities. These activities are i) analysis, ii) synthesis and iii) evaluation. Thus, toll gates are the conjunction of previous engineering activities to refine the deliverable including feedback for developers.

C. Rapid product realisation platform

Workspaces are a backbone of utmost importance for the OIL. In them the synergy of the other two pillars gets materialized. Its objective is to provide the necessary tools for the practical application of challenges that result after the application of learning techniques and design methodologies. They consist mainly of physical spaces such as: i) laboratories: industrial (ergonomics, CAD-CAM, CAE, PLM), science (Data analysis, programming, thermodynamics), creativity (arts, audio and video editing and production), electronics (test benches, PCB design, electrical analysis). ii) Machines such as: large scale CNC, precision CNC (micromachines), additive (sintering and 3D printing), subtractive (lathe, mill, drill) and transformative (trimming, shaping, laser, soldering, melting, painting, sanding) machines. iii) Facilities such as: makerspaces, decision theatres, video conference rooms, Gesell chambers, etc. Until now, they had been traditional laboratories. However, ICTs have played an increasingly role allowing their direct integration with the other OIL pillars transforming them from physical laboratories to learning platforms. This evolution has allowed the creation of some innovative spaces that live in digital worlds that together with the internet allow them to be accessed remotely and permanently 24/7. There are many practical approaches but one of them focuses on the creation of products. Then, it is possible to have a platform focused on competence development for the creation of inventions that give way to new start-ups and future companies. Together, physical spaces, virtual spaces and online learning platforms provide the OIL with a solid foundation for the development of skills in students.

IV. EDUCATION 4.0 ENVIRONMENT

In accordance with new trends, pillars of OIL and Tec21 educational model, learning techniques have been adapted to develop the competences required in the 21st Century [11]. Figure 2 shows the three main aspects that comprises a competence. Skills could be natural or trained on learner by practice of knowing and doing things. Knowledge is commonly acquired in classrooms, however, nowadays with large amounts of data available, material could be provided to access anytime and anywhere.

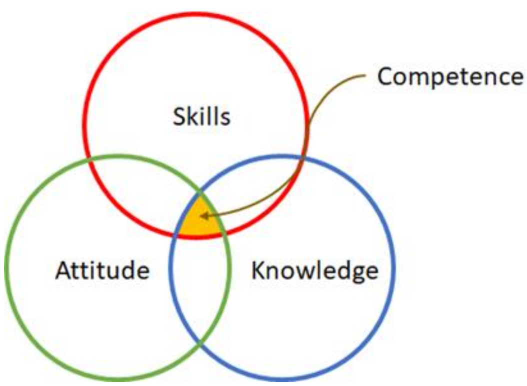

Fig. 2 Competence development in the educational environment.

This paradigm represents a breakthrough in the manner new generations conceive education. And that is why attitude is shown in the scheme. Even with the skills and knowledge to face complex challenges, learners must understand the advantage of having access to higher education. The work of the lecturers is to foster motivation in learners for them to relate knowledge acquired, improve skills and technique and, realise their capabilities of changing paradigms for their own and other people's needs. Then, a competence is understood as the conjunction of these three aspects to face actual problems in society

Educational institutions make efforts to conjugate ICTs into emerging educational methods, techniques, laboratories and formational experience for students. ICTs have proved successful results while developing competences in students [20]. Emerging technologies such as Virtual Reality, Virtual Immersion, Augmented Reality, AI, Big Data, Eye and Voice control have developed new skills, increase of retention, training for real scenarios, comprehension of complex systems and comprehension of data treatment among others in learners. However, among the technologies available, physical digitalization mainly represented by Digital Twins and Cyberphysical Systems has gained special attention among the projects that relate industry with academia [21]. This technology allows learners to simulate and study multiple scenarios. Hence, competences and knowledge conjugate in the analysis of multivariable processes that could achieve a feasible solution in short periods of time, increasing productivity whilst developing critical analysis in students. This has evoked a variety of initiatives to develop multiple competences in different platforms. Related work identified chat rooms, collaborative platforms, multidisciplinary sessions and social software [22], have had a positive impact in different areas such as creativity, focus in relevant aspects of society and increasing strategy for innovation on learners and participants.

The CEDETEC building (where all laboratories are located) act as one of the rapid realisation platform available on campus and was created with the objective of offering an open environment where everybody could make use of the facilities to rapidly run tests and put into practice their knowledge. Therefore, students are highly motivated to collaborate and test their own skills in practice. In traditional education, laboratories were focused on developing hard skills, the proposal of this article is taking the experience offered by these laboratories to develop soft skills in students. This proposal is accomplished with the infrastructure available on campus, the emergent technologies adoption and the methodologies imparted by lecturers. The activity could be seen in three different levels of interaction. First, students are taught in the hard skills to understand the concepts and interaction, second, students are trained in the laboratories to understand what is available and capable of being developed in the laboratory and third, students are challenged to propose solutions to complex problems.

Collaborative learning targets soft skills whilst active learning aims at increasing individual skills and knowledge of the participants. Both techniques make extended use of methodologies and frameworks to guide students into the steps needed to accomplish the objective with a more dynamic collaborative and individual learning process.

These techniques are based primarily on collaboration and active learning [23], [24]. These types of learning aim at producing graduates with skills, experience and knowledge to face actual and future society problems.

V. CASE STUDIES

As part of the ongoing efforts to provide experiences through Ed 4.0 environments and in hand-to-hand collaboration with the OIL at Tec de Monterrey, during 2019 and 2020 there has been remarkable case studies where internal and external actors have collaborated in order to achieve a solution to a given problem. Hereunder are some of the results that have been obtained.

A. Punching module

During summer of 2019, a research stay was carried out at Tecnologico de Monterrey. Students from the interior of Mexican republic attended the Inter-institutional Program for Strengthening Research and Postgraduate Studies in the Pacific or "DELFIN" program, which provides resources to attend a research stay with highly distinguished professors. As part of this stay, they had the objective of testing the IPPMD for the development of didactic modules for reconfigurable micromachines [25]. Aided by OIL rapid product realization platform diverse improvements to current technology were developed at the institute. During the stay, learning techniques applied to these Ed 4.0 environments resulted in a novelty module: punching machine for the development of badges aimed to eye impaired persons by the generation of automatic CNC Braille punched tags. The process is summarized into four stages (see Fig. 3).

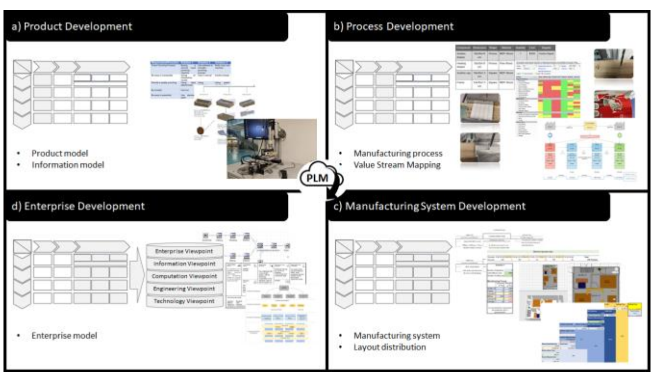

Fig. 3 Integrated Manufacturing System of the Punching Module.

1) Product Development entity: The student was asked to develop a functional module applying the methodology. The module to be developed was defined as the punching module.
2) Process Development entity: The student identified the manufacturing needed to develop the module and adapt existing parts of the machine. The process development for manufacturing the module was defined.
3) Manufacturing System Development entity: The student designed the facility where the component could be manufactured and sent to assembly lines of the micro-machine. The plant design was realised using layout, cost estimation and design of the value stream.
4) Enterprise conceptualization: Using the information generated in previous entities, some guides were provided to structure the business model of the component.

Methodology applied allowed the definition and creation of a product but most important the design of a facility to manufacture the module along with a business model to commercialize it. All in all, the challenge along with the the pillars of OIL allowed forging new competences in the student from other universities. While developing the final products, the student has had different impressions about the methodology followed. According to the surveys and final thoughts of the project, the competencies developed during this project are reflected in table 1. The evaluation is qualitative and done through the *Escala i* platform. *Escala i* has been validated by experts in education and it is comprised of the reference framework, methodology and evaluation to carry out the registration and set of instruments for the generation of evidence.

B. Plastic Extruder module

During the second semester of 2019, students from sixth semester of Industrial and Systems Engineering (ISE) along with two students with a major in mechatronics attended the course Integrated Manufacturing Systems (IMS) at Tecnologico de Monterrey. Thus, the idea of creating machines arose immediately to incorporate both industrial and mechatronics knowledge. Every semester they are challenged to work in teams in areas not previously explored in their career to develop novel solutions to face specific problems. This time they were asked to develop a machine capable of processing plastic to reduce or recycle scrap generated by 3D Printing process giving a second life to the waste material used in rapid prototyping for testing ideas. During this course students are encouraged to go beyond product development and design the manufacturing system. At the end of the course they present the physical product, the documentation of the manufacturing system and the business model associated with the production of it.
Notwithstanding the efforts to accomplish the mechanics of the course, students integrate their knowledge in one final product and confirms their skills to solve problems with successful results. The learning dynamics for the class make use of active and collaborative learning throughout the semester. Lecturers make use of the IPPMD reference framework and guide students during the semester. Also, they were encouraged to use the different manufacturing laboratories available in the campus where they could design, create, refine and even generate advertising for their idea. The challenge to the student was launched as "create machines to process plastic" and the machines were developed during the course. Constant feedback was provided to improve their entities, product (machine), process, manufacturing system and business model. A functional machine was the final delivery. The activities done

to realize the plastic extruder (See Fig. 4) are summarized as follows:

1) Product Development entity: The students defined the machine that was going to be produced. Functionality and positive environmental impact were considered during this phase. Plastic collection and swarf were defined as raw material for the machine. The core of the development was identified as: i) an extruder module and ii) a mould to create plastic goods.

2) Process Development entity: The students understood the plastic transformation process before proposing a machine, therefore, students focused on components that could add value to the machine. Once identified the components needed to develop the machine, components were proposed and selected to comprise the machine. Hence, the manufacturing process development was the selection, adaptation or generation of components to assemble the machine.

3) Manufacturing System Development entity: The students designed the facility where the component could be manufactured and sent to assembly lines of the module to process plastic. The plant design was realised using layout, cost estimation and design of the value stream.

4) Enterprise conceptualization: Using the information generated during the project, identifying the real problem society faces and with the value proposition of the machine, students structured the business model to commercialise the plastic extruder module.

Fig. 4 Plastic extruder machine. At left there is observed the module of plastic extrusion. copper must be covered and coupled with resistance (as observed in picture at top right) to melt plastic, finally, melted plastic is pressured into a mould (see bottom right picture) to form the plastic product

While developing the final products, teams have had different impressions about the course and the methodology followed. According to the surveys and final thoughts of the projects, the competencies developed during the semester are reflected in table 1.

C. Discrete event simulation

From the start of 2020 to the present, this case study addresses the competences obtained in a graduated student currently doing a major in Instituto Politécnico Nacional (IPN), Mexico, during an academic stay at the Tec de Monterrey with the purpose of enriching thesis content. The adoption of the OIL in the latter allows the collaboration between two institutions and the private sector (manufacturing facility) to embrace a project based on Discrete Event Simulation (DES) for decision making and optimization proposal to a manufacturing line on the automotive sector. In this case a different approach is made as goals differ from a product development, however the persecution of enriching competences in the student prevail and a suitable educational environment is provided by the use of the other pillars in OIL. The summarized steps followed are: i) induction, ii) training, and iii) project development

Induction: The IPN sets objectives and goals together with Tec de Monterrey research group. During the first week of the stay proper guidelines and introductory material is given for the first steps into DES training. Therefore, the student is asked to develop project scheduling of a real case on the industry sector. Work plan, objectives and expected results are reviewed by the advisor. A commitment is made as for the last week of the academic stay, the student presents the project in a postgraduate seminary remarking the results obtained and optimization proposals to the real case project.

Software training: DES is carried out with Tecnomatix Plant Simulation part of the PLM solution portfolio by Siemens. The first approach to the software is by a small exercise mainly aimed at the development of discrete events logic, conceptual and practical use of the software. After this, the student endeavours into an autodidact style where learning continues with project-oriented interaction with the software and becomes familiar with the interface, using tutorials, advice from professionals and the software manufacturer knowledgebase. Activities include basic simulations to be solved so that the student can develop at his discretion the optimal way to solve the exercise. At the end of this stage the instructor assesses knowledge and if needed suggests more exercises in order to get proficiency from the trainee.

Project Development: At this stage, the student can self-manage the activities whilst still fulfilling the schedule proposed on the induction stage. In this case, the development of the proposed project, follows the steps below as observed from the student diagram:

1) Data collection: During an industry stay, Value Stream Mapping (VSM) analysis is made from a production line on a Mexican company dedicated to the manufacture of urban buses. Diagnosis was supported by the company and the academy after obtaining the necessary data from the lamination process on the production line. This data is used to simulate the process in the Tecnologico de Monterrey.

2) Model creation: Data and metadata from the lamination subprocesses are then mapped to create the model using the necessary objects (e.g. work-stations, robots, workers, assembly stations, conveyor, buffers, sources), moving parts (e.g. parts, containers, transports), see Fig. 5.

3) Results analysis: After running the model, a comparison between the real world and the simulation is made. Herein, the student was able to obtain results that provided a deep insight to expand the particular scenario knowledge using DES. These results were supervised by the research team and advisor through feedback.

4) Creation of scenarios: A proposition of diverse scenarios is made to study "what if?" conditions in the assessment of optimization using design of experiments. Results are intended to provide better decision making to the shareholders of the company. The results are evaluated by the instructors.

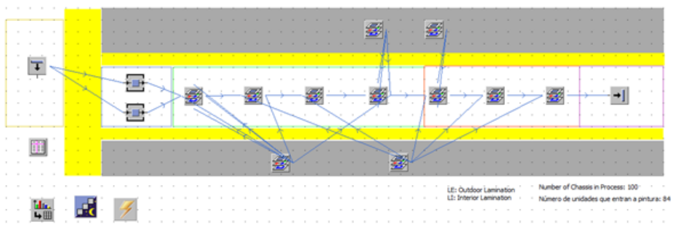

Fig. 5 General Mapping of process lamination using Discrete Event Simulation.

As stated, a final evaluation is made through a project report and oral presentation of the findings. While developing the project, the student has had different impressions about the methodology followed. According to the surveys and final thoughts of the project, the competencies developed during this project are represented in table 1.

TABLE I
SKILLS DEVELOPMENT

Competencies		Punching Module		Extruder module		Simulation	
		before	after	before	after	before	after
Soft	Critical Thinking	45%	80%	35%	85%	30%	85%
	Communication	5%	15%	25%	55%	10%	25%
	Entrepeneurship and innovation	35%	65%	20%	45%	25%	50%
	Collaborative work	5%	20%	45%	70%	5%	15%
	Creativity on using ICT'S	50%	75%	30%	55%	35%	85%
Hard	CAD	35%	55%	20%	35%	25%	85%
	CAM	15%	35%	30%	45%	5%	75%
	Design of experiments	35%	75%	40%	80%	35%	80%
	Bussiness (model and pitch)	50%	80%	30%	65%	10%	30%
	Manufacturing	30%	65%	50%	80%	5%	20%
	Other software (DES)	5%	25%	10%	25%	0%	80%

VI. FINDINGS AND CONCLUSIONS

The case studies were developed under the Open Innovation Laboratory concept using Ed 4.0 environments approach. These initiatives comprise the Tec21 educational model to promote the 21st century competencies in students. Results show that in short periods learners are able to propose innovative ideas or target an actual problem and face it following a guideline to integrate their knowledge demanding both collaborative and active learning from students to develop skills and competences desired in challenging environments. In addition, for the first two cases, the use of IPPMD supported the learning experience by providing a proven methodology for product realisation. The third one expressed the capabilities of the OIL in addition to collaborative projects among institutions and industry by working on a project in a two-month stay without practice in Discrete Event Simulation. Last but not least, OIL provides students from other universities a collaborative framework that can be used to complement the training of students with DES whilst strengthening their skills and responsibilities in decision making in the world of industry with emerging technologies.

Final comments by participants of the second case study are: "*This model makes the presentations available to students before classes, so they can review them prior to the class and ask specific questions if necessary. The students can prepare themselves before class, put in practice the knowledge while developing the project and learn how real works are done in the jobs*", "*this model is challenging however, there is a lot of satisfaction while seeing the project being applied and having good acceptance with potential customers and users*", "*There are things I had to learn by myself, so I had dedicated a lot of time doing so, it is very satisfying to see the project product of your effort working at the end of the course*". This model represents a challenge but with successful results for participants.

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