Educational model based on competencies: Performance Assessment in Mechatronics Engineering.

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Abstract:

The learning evaluation process has traditionally been one of the most common means to obtain academic credits from the knowledge or skills that a person provides to solve a challenging situation; however, society demands an evaluation centered on performance. The positivist paradigm led us to postulate that knowledge emerges through observation and the construction of a systematic process of prediction, whereas Hermeneutics explains the world and its phenomena from the interpretative capacity of the individual. As part of the quality validation process in graduates of the Mechatronics engineering at Tecnológico de Monterrey, it was carried out the evaluation of graduation competencies through the exercise called Assessment Center, an approach focused on performance rather than in knowledge.

This exercise, that included the participation of academics and industrial leaders with extensive experience, allowed to measure the performance of students in semi-structured circumstances like those that will be presented to them in real work scenarios, where quantitative and qualitative methodologies were combined with the objective of measuring the performance of each of the future graduates. At the closure of the Assessment Center the evaluators gave feedback to the students both on their performance related to their decisions and solutions to the previously defined challenge, and in relation to their attitudes towards their teammates.

From the Assessment Center the following conclusions were achieved. The students generated a greater confidence to have control over the results of their performance and the evaluation took relevance and significance and allowed them to reflect on their strengths and opportunity areas. The academics were able to detect the level of progress of the students, and the industrial leaders allowed them to have a greater understanding of the competencies that the students possess and consistency between the graduation profile and the skills attained by the student.

Keywords: assessment center, authentic evaluation, mechatronics engineering**.**

I. Introduction

World has become a complex, dynamic and interconnected global village that demands well-planned long-term effective solutions to crucial problems. Economic, energy and ecological crises are critical challenges of humanity. The current, rapidly evolving environment motivates expeditious and decisive responses with multiple interrogations and simultaneous actions, leaving little room for sequential and partial analysis of the candidate solutions in the action plan. Moreover, decisions require a reasoning that goes beyond current approaches that in most cases:

considers complex underlying dynamics, supports a short-term thinking with gratifying practices of immediate but unsustainable solutions that often lead to unwanted consequences or unexpected effects that could exacerbate problems (Probst and Bassi, 2014). Faced with this situation, universities play a leading role in developing professionals with competencies to solve actual and future challenges.

In 2013, Tecnológico de Monterrey began a transformation process to generate a new educational model. This innovative perspective should be capable of responding to the challenges posed by the changing and uncertain world, and at the same time should consider the characteristics of the new generations; digital natives that have access to technology in early childhood. The educational model must have distinctive characteristics in terms of learning and cognition, and learning evaluation is a key element to consider.

The process of assessing learning has traditionally been one of the most common ways of giving credit about the knowledge or skills. The idea is to assign a credit level based on the person´s skills to provide information or solve a problematic situation. The first records of assessments related to learning have been dated from the Middle Ages. However, it was until the modern age when the evaluation of learning was formally included in school education, with the insertion of various assessment processes to evaluate learned outcomes.

Modern evaluation processes have undergone some changes. The characteristics of academic instruction during the nineteenth century and the early years of the twentieth century were shaping the evaluation as currently known. In this context, two statements about evaluation are: “A unified process to determine the scope of the trainees, under the same criteria, standards and circumstances, expressed with a value numerical” (Díaz-Barriga and Hernández, 2002; Escudero, 2003), and “The current trend marks the value of performance evaluation as a predominant element given the fact that it has quantified knowledge for many years” (Hattie and Timperley, 2007; Palm, 2008; Shute, 2008).

As cutting-edge educational approaches, two visions about the evaluation in the formative process were developed. On the one hand, the positivist paradigm led to postulate that knowledge emerges through observation and the construction of a systematic prediction process, permeating the quantitative methodology in all sciences, including social sciences (Perrenoud, 1990; Sacristan, 1982). On the other hand, the hermeneutic principle explained the world and its phenomena from the individual interpretative capacity and the understanding of their environment. Regarding the learning evaluation processes from this perspective, Díaz-Barriga, and Hernández (2002) believe that the evaluation must be continuous, while considering the procedures and variables that were presented at the time of learning and that allowed the construction of knowledge.

To complement the assessment effort, performance evaluation involves the observation, monitoring and measurement of student behaviors at the time they are performing any action related to the learning process, either individually or collectively (Hancock, 2007). In this respect, exams are valuable tools to assess knowledge and procedures in terms of memory and reasoning. However, it is also necessary to evaluate the application of knowledge by solving problems, making decisions, collaborating as a team, generating new products, etc. These requirements must be supported by an evaluation method that allows docents to observe student performance. At Tecnológico de Monterrey, different efforts and innovations have been historically made in order to holistically evaluate student performance to determine case studies

comprehension and efficient application of knowledge to propose a solution. This way complements the traditional exam evaluation.

From the semester August-December 2018, Tecnológico de Monterrey has carried out assessment exercises with senior undergraduate students. For instance, students enrolled in their last semester of the Mechatronics Engineering academic program participate in an activity titled "Assessment Center". This action has allowed teachers to observe the students' performance in semi-structured and unstructured circumstances like those that will be presented to them in future real work situations. The main challenges in the implementation of this activity have been: the paradigm change, as well as the planning, instrumentation, evaluation and meta-evaluation processes required by its practice.

II. Development

Social and labor needs change at great speed. The approach and application of knowledge are carried out in emerging disciplinary areas, with the support of technologies that did not exist before. Therefore, Tecnológico de Monterrey, through the innovative educational model Tec21, seeks to train students with the necessary competencies to perform successfully in a dynamic world and to face the challenges of the 21st century (Garza, 2016).

The Assessment Center developed by docents at Tecnológico de Monterrey in Sonora Norte campus allowed to conform a heterogeneous team of evaluators. Managers, advisors, consultants and academics, experts in their field of study and with extensive experience in the labor field, defined a performance evaluation framework where students were able to: create, produce and provide solutions based on their knowledge, in a context and with a specific purpose, for which they can execute high level thinking processes. The judgments that are emitted from a performance evaluation process must be enriched with diverse points of view, beyond the academic: potential clients, employers, citizens, etc. (Morrow et. Al, 2015).

It should be noted that the choice of the scenario chosen by the academics varies according to the degree of control over the learning situation and the degree of desired immersion for the students to experience. The designed scenario contained semi-structured elements and real-life situations. It is important to remark that a semi-structured scenario refers to a previously documented context where a real-life situation is used. The context includes a situation where students are immersed in activities of personal and work life outside the classroom.

For the assessment design, docents considered the declared competencies for the Engineering Mechatronics educational program at Tecnológico de Monterrey. The administrative process for the competencies is performed through the technological platform System for the Administration of the Evaluation of Academic Programs (Sistema para la Administración de la Evaluación de Programas Académicos – SAEP, in spanish). The 7 declared competencies are listed in Table 1.

Table 1. Declared competencies for future students graduated from Mechatronic Engineering at Tecnológico de Monterrey

1	The student designs, builds and implements innovative mechatronic products and systems.
2	The student proposes mechatronic engineering solutions that improve quality, productivity and efficiency in industrial processes.
3	The student designs and conducts experiments, extrapolating the results towards the development of a product or mechatronic engineering process.
4	The student communicates efficiently both orally and in writing.
5	The student demonstrates the capacity for self-learning.
6	The student participates effectively in multi and interdisciplinary teams
7	The student develops the ability to analyze the global and local impacts of mechatronic engineering on individuals, organizations and society to provide their professional services in an ethical and responsible manner.

As part of the assessment design, 3 project stages were declared. The first stage was the problem definition, the second activity included the analysis of the possible solutions, and the third and final stage was the preparation of solutions and implementation.

The rules established for the development of the activity indicated that the instructions would be provided throughout the process. The instructions were given one single time. Students´ activities and presentations were carried out individually and in team; moreover, English and Spanish were both official languages during the assessment. The previously defined agenda was followed as stated; academics made use of a stopwatch to mark the beginning and end of each exercise. During the exercise, the evaluators observes the process and avoid asking questions, until indicated. It was mandatory to stay in the room during the exercises, and the use of cellphones was prohibited.

The project presented to the students was titled: “Exoskeletons: robotic assistants for rehabilitation and for the elderly”. The next section explains it in detail.

II. Challenge

The description of the Challenge went as follows: Imagine that you are in the first stage of the personnel selection process to enter the Mexican company IRFMN Robotic, a start-up created by professors and graduates of the Mechatronics Engineering career of Tecnologico de Monterrey for the development of robotic rehabilitations assistants. In this exercise, you will be asked to provide creative ideas for the development of a new motion assistant proposal. Whether you go to next stage of the selection process or not will depend on what you propose in terms of design, feasibility, innovation, and the environment.

Description of the need

The IRFMN Robotic Company wishes to create an exoskeleton proposal for any part of the body that is feasible to introduce into the Mexican market with two basic requirements: a) the

price of the prototype needs to have a lower price than those already existing in the market and that arrive to Mexico through importation; and b) the prototype must have the versatility to meet the needs of movement rehabilitation of people with bone or muscle-tendon injuries, or burned, or paraplegic, or with arthritis, or the elderly, or tired of posture. The innovation factor of this proposal lies in the addition of an artificial intelligence system to detect brain activity that allows the exoskeleton to move without necessarily having the user's biomechanical action.

Main design requirements

1. A refined and discrete aesthetic that does not draw too much attention to the user if it has to be used outside the hospital, and that it takes into account the ergonomic aspects of anthropometry and biomechanics typical of the Mexican user.
2. Incorporation of an electroencephalographic headband to detect brain activity that results in impulses to the exoskeleton movement system.
3. Consider a high performance auxiliary power system (actuators, battery, etc.) that guarantees support for user movements without adding too much weight to the exoskeleton.
4. A lightweight and very resistant structure whose components can be designed to suit the user and be obtained by 3D printing to ergonomically customize the test prototypes.
5. A cost less than one fifth of those currently sold in the national market (all imported).
6. Adhere to current international regulations and standards in manufacturing, materials, and health.
7. Consider in the proposal the necessary infrastructure and investments that the project requires.

The instructions offered to the students to start the project were the following:

1. Identify what an exoskeleton is, what are its parts based on the assistance it will provide, who the final users are, and to what market do they belong.
2. Detect a specific problem or opportunity area for a product proposal.
3. Develop a proposal for a product concept that includes the mechanical, electric/electronic, computer, and industrial design aspects that allow this company to have a prototype whose concept is feasible to introduce into the Mexican market.
4. Describe how is the experience for different types of exoskeleton users, from the way of installing it, what happens when being used, include possible problems that may arise, and with that information, explain the impact of engineering solutions in a global and social context.
5. Specify the types of tests and validations that must be done in order to test the capabilities of the prototype, using policies and procedures standardized by an international agency or organization.
6. What ethical and environmentally responsible design aspects would need to be considered in the proposal to make an ethical and sustainable project?
7. Make a Gantt diagram of the development of the prototype with a six-month planning, where the last scheduled activity is testing and validation of a first prototype; include an estimate of prototype costs.

The rubrics used for the evaluation are shown in the table 2 and 3.

Table 2. Rubrics used in the evaluation of competencies in the Assessment Center (career)

1. The student will design, build and implement innovative mechatronic products and systems			
Subcompetence	**Domain level A**	**Domain level B**	**Domain level C**
1.1 The student determines the design needs and selects and evaluates among various technologies, the components that integrate a mechatronic design based on technical standards.	It does not identify design needs, nor does it select or evaluate the various necessary technologies based on technical standards	Identifies some of the design needs but does not properly select the various appropriate technologies based on technical standards	Identify the design needs correctly and select and evaluate the various technologies, the components that integrate in case of study based on technical standards
1.2 The student identifies and solves mechatronic engineering problems by proposing and validating models based on the process of research, innovation, design and improvement of technological projects .	It identifies some problems that the case describes, but does not use mechatronic engineering tools to analyze and structure the information. Proposes but does not validate the model based on investigations, patent investigation	Identify some problems that the case describes and use some mechatronic engineering tools to analyze and structure the information. Proposes and validates the model based on investigations, but does not perform patent research	It correctly identifies the different problems that the case describes and uses mechatronic engineering tools for the analysis and structure of the information. Proposes and validates the model based on investigations and performs patent research
	It does not define an appropriate mechatronic design methodology to solve the client's need	Defines a mechatronic design methodology without highlighting the variables most appropriate to the client's needs	Defines an appropriate mechatronic design methodology to solve the client's need, highlighting the most important variables of the problem presented
1.5 The student carries out integrating projects that promote creativity and innovation.	It proposes an alternative solution without following a methodological process (without sustenance)	It proposes a solution to the problem following a methodological process of hierarchy of solution alternatives but does not mention the required resources, activities to be developed or assignment of responsibilities	It proposes a solution to the problem following a methodological process of hierarchy of solution alternatives, identification of required resources, activities to be developed and assignment of managers.
6. The student will participate effectively in multi and interdisciplinary teams			
6.1 The student works satisfactorily in a team reaching the objectives set in the projects, in accordance with previously established compliance criteria	It does not build agreements or interact collaboratively with the other members of the team and imposes its ideas authoritatively	He suggests ideas to team members and listens to others but does not reach agreements because a behavior of imposition of his ideas prevails	Build agreements and interactions, through a collaboration that takes into account differences, as well as the skills of others.
	A work plan with defined activities and commitments is not generated	It generates a work plan but there is no follow-up for compliance with it	It generates a work plan with activities and commitments of each member with the aim of seeking the collaboration of all team members.
	Does not demonstrate open and purposeful behavior for conflict resolution.	It demonstrates an open and proactive behavior for the resolution of conflicts but does not allow the personal development of the members of the team so that no agreements or commitments are reached.	It demonstrates an open and purposeful behavior for the resolution of conflicts (negativity, imposition of ideas, apathy, disinterest, etc.) that allows the personal development of the team members and punctuates agreements and commitments.

At the end of the Assesment Center exercise, the evaluators gave feedback to the students both on their performance related to their decisions and solutions to the problem, and relative to their attitudes towards their teammates. Among the advantages found in the application of the Assesment Center exercise we have:

For the student

- Generation of greater confidence in the students by letting them have control over performance results. Through the active participation of the student, the evaluation took relevance and meaning.
- Increased motivation and commitment by having frequent evaluations and timely feedback, unlike having just one evaluation at the end of the process, which could generate a greater pressure for the student.
- It allowed the students to have a clearer idea of what they need to do to improve their skills.
- It led the students to self-regulate their learning. The student reflected on his strengths and opportunity areas, allowing the student to self-assess him.

Table 3. Rubrics used in the evaluation of competencies in the Assessment Center exercise (transversal)

4.- The student will communicate efficiently both orally and in writing			
Subcompetence	**Domain level A**	**Domain level B**	**Domain level C**
4.1.-The student makes satisfactory oral presentations in laboratory practices or projects, according to previously established compliance criteria.	It does not demonstrate knowledge of the subject and its ideas are not well defined by what goes into contradictions	Demonstrates an adequate level of knowledge of the subject but enters contradictions by not expressing ideas in a concise and solid way.	Demonstrates a good level of knowledge of the subject and develops ideas in a solid way without going into contradictions
	It does not maintain adequate voice management or use adequate technical terminology	Maintains proper voice management (volume, nuances, pronunciation) but does not use the appropriate technical terminology.	Maintains proper voice management (volume, nuances, pronunciation) and uses technical terminology appropriately.
	Successful, accurate and complete information regarding the subject is not provided, so it does not meet the required presentation time.	They present sufficient information on the subject and do not structure the information in an appropriate and logical way.	They provide accurate, accurate and complete information on the subject in compliance with the requested time and the structure of the presentation is orderly and logical.
4.2.-The student writes technical reports satisfactorily on laboratory practices or projects, according to previously established compliance criteria	They present in an unprofessional way by not taking care of the spelling, font and font size so that it can be seen by the audience. The information is unclear and understandable, so the critical aspects of the presentation are not highlighted.	They present the information partially complying with the characteristics of a professional presentation (some spelling mistakes, inappropriate font sizes are observed, the critical aspects of the presentation are not highlighted)	They present in a professional way: without spelling mistakes, with adequate type and size of the letter so that it can be seen by the entire audience; the information is presented in a clear and understandable way; Highlights the critical aspects of the presentation.
	They do not use appropriate nonverbal language (use of hands, gestures, security, posture, movements in the classroom, etc.) during their presentation.	They use a nonverbal language that needs improvement because although it presents certainty in the subject presented, the posture, gestures, displacement in the classroom and use of hands is not adequate.	They use appropriate nonverbal language (use of hands, gestures, security, posture, etc.) during their presentation.

For the professor

- It allowed the professor to detect the level of progress of the students in order to carry out preventive, remedial, or reinforcement activities.

- It led to multiple and varied opportunities to observe and document learning, with the intention of improving the performance shown by the students.
- It allowed to supervise, self-evaluate, and improve evaluation practices.

For the achievement of learning

- Clarified the purpose of learning, especially in situations where there is a complex network of knowledge that has its origins in various disciplines.
- It allows to focus on complex skills such as the management and solution of intellectual and social problems.
- Considers contextualized problems that account for attitudes and shown ethical values.
- Evaluates the ability of the student in action where the played role can be observed, as well as the interaction and cooperation forms with other students.
- It values the thinking processes of students, as well as the products they make.

For the evaluators of the different participating companies

- Provides a greater understanding of the competencies that the students possess, as there is consistency between the graduation profile and the skills achieved by the student.
- It allows them to contribute with their experience in the evaluation and validation of the student skills.

Finally, we came to the conclusion that the consolidation of this exercise as an excellence evaluation system depends on two primary factors. The first one is the institutional support to propitiate the necessary changes and from their evaluation policies (generally reflected in the educational model and academic regulations). The second one is the professor's work to achieve the operationalization of this system of excellence. For the professor to be able to attain the latter, it is necessary:

- Knowledge of the graduation profile as a starting and ending point of the training process.
- Understanding the meaning and scope of disciplinary and transversal competences to know their essence and how they integrate into professional practice.
- Design of feasible and challenging activities and projects with the purpose of exercising teaching and evaluation processes, aligned with disciplinary and transversal competences, consistent with the levels that the students must reach and demonstrate according to their progress in the academic curricula.
- Feedback on student performance based on a varied and sufficient collection of learning evidence, which allows for solidly supported judgements.
- Improvement of our own methods for assessing and performing teaching practice, based on a critical analysis of the results.

IV. Conclusions

The Assessment Center application allowed the students to have a clear knowledge of the expectations of achievement and the quality standards that are expected to guide their future performance, additionally it was achieved that the students commit themselves to the monitoring of their learning process, and work towards reversing your mistakes.

The evaluators allowed us to monitor the progress and fulfillment of the individual objectives and goals of each student, which in turn are aligned with the objectives of the

mechatronics engineering program as well as being able to measure student performance and based on that be able to provide objective and quality feedback to promote the continuous improvement of the graduate in both skills and attitudes.

Identify the strengths and weaknesses of each student and measure the level of mastery of competencies. Additionally, it allowed us to detect the need to strengthen skills to reinforce the skills and knowledge necessary for the future graduate. Finally, with the application of the Assessment Center to candidates for graduation, the mechatronics department ensures that each of the students has the knowledge, skills and competencies required to function successfully as an engineer.

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