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Teaching thermodynamics in Engineering based on competences

Enseñanza de la termodinámica en Ingeniería con base en competencias

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Abstract

This paper shows an analysis of the activities carried out in the classroom on topics which involve thermodynamics. This proposal contemplates methodological aspects and competences of the subject on basic topics that involve the understanding of the phenomena involving the first and second laws of thermodynamics. The proposal aims for the student to develop a cognitive process which can be used as a tool to help improve their learning. This process is characterized by a feedback between the implementation of the changes concerning the teaching-learning process and the evaluation process of the achieved learning. The analysis of the evaluation is based on the phenomena that involve fundamental concepts such as energy, work and heat, as well as the need to develop assessment instruments according to the competence that the student needs to develop. The results show a significant progress, in terms of the level of learning achieved, by making an annual comparison of school performance based on a competency scheme.

Teaching, Thermodynamics, Competency

Resumen

El presente trabajo muestra un análisis de las actividades realizadas en el aula sobre temas que involucran a la termodinámica. Esta propuesta contempla aspectos metodológicos y de competencias de la materia sobre temas básicos que involucran la comprensión de los fenómenos que involucran a la primera y segunda ley de la termodinámica. La propuesta pretende que el alumno desarrolle un proceso cognitivo que pueda ser usado como herramienta que ayude al proceso de mejora en cuanto a su aprendizaje. Este proceso se caracteriza por una retroalimentación entre la implementación de los cambios referentes al proceso de enseñanza aprendizaje y el proceso de evaluación del aprendizaje logrado. El análisis de la evaluación se realiza con base a los fenómenos que involucran a los conceptos fundamentales como energía, trabajo y calor, así como en la necesidad de elaborar los instrumentos de evaluación de acuerdo a la competencia que el alumno necesita desarrollar. Los resultados encontrados muestran un avance significativo, en cuanto al nivel de aprendizaje logrado, al realizar una comparativa anual de aprovechamiento escolar basado en un esquema de competencias.

Enseñanza, Termodinámica, Competencias

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Introduction

In the development of the teaching practice, lack of analysis and reasoning of significant knowledge is manifested daily in students; memorization has been strengthen, largely replacing reasoning, fractioning learning on small islands, without relating the contents in a scientific way.

This pedagogical breakdown, with the development of skills and competences, leads the teacher and the student to an uncertain pedagogical process not in accordance to the needs of the labor market. Therefore, the model focused on competencies considers important aspects towards the student, such as: focusing on the student the responsibility of building and structuring their knowledge, leaving teachers the role of facilitators, guides and motivators of student learning, likewise, that of achieving coherence between the curricula and the training processes which involve the teaching-learning process, and that of obtaining a balance between the theoretical teaching activities with the objective of reaching the required skills and competencies of the student in their professional training and consequent labor insertion. It is also essential that students develop reading abilities that allow them to understand knowledge in all its magnitude and also incorporate a sense of social responsibility.

In this pedagogical context, and given the challenges of current education, it is believed that competences can be grouped in 3 domains: training and personal development, communication, and development of scientific thinking.

Selected knowledge, specific skills and values reflected in professional attitudes and behaviors concur during the development of the competences. For this, we carried out a pedagogical strategy which begins with the learning process in the field of thermodynamics; this was complemented with other techniques to ensure that students acquire the competence that the subject requires in order to define the areas in which the professional develops, thus delineating the skills from the domains of the subject.

Development

In the development of the aforementioned competences, it is necessary to recognize that the strategy, method, techniques and assistance must be focused on student learning, so inherently the teacher must surround the learning process with the necessary scientific information with an appropriate pedagogical strategy.

That is why the teaching-learning process is considered as a set of dynamic interactions which involve the teacher and students, where the former has as main purpose integral formation, including the knowledge of the subject, the skills for the teaching process and attitudes, all of them aimed at the student's own cognitive process, as well as an organized management which includes the knowledge acquired. To develop a competence, it is necessary for the teacher to guide by creating situations focused on reality within the work context, using strategies that give the best results to exchange, share, confront and debate ideas, making students form new structures. It is important to mention that the strategy to be used should consider reflection as an important part to deal with practical problems and thus face the discrepancy between reality and what was expected. When teaching with reflexive activity, not only do students get used to understanding the concepts, but they contribute new meanings and structure their ideas, analyzing the processes and expressing their thoughts in a better way.

For teaching the subject of thermodynamics, we chose to apply the cooperative learning strategy. It is an organized and structured method that includes team building activities, the preparation and formal presentation of the information acquired, practice in solving problems and the evaluation of each student. It is important to mention that the progress achieved by the students is very significant, since it encourages students to be self-taught, to be more sociable and that they try to generate their own learning in terms of the subjects they do not understand. Cooperative learning promotes collaborative work because it allows for better relationships between students, those who learn better, feel more motivated and, in addition, make their social skills much more effective by being part of a cooperative group.

It is relevant to point out that each of the teams strives to obtain recognition for the work done by each member, which translates into a noticeable improvement in their school performance.

Likewise, individual responsibility develops from the moment in which each of the members knows that they will have to be evaluated in relation to the proficiency of the subject presented. The team members prepare, practice together and explain to each other the topics that are not understood, since the grade of the team is based on the progress demonstrated by the students, a situation that forces them to pay more attention when the topic is explained by the teacher.

Result analysis

It is important to mention that not all work group is a cooperative learning group, since there are still traditional work groups in which the most skilled students assume leadership and benefit from the team experience; also there are students who only perform functions such as photocopying, drawing or capturing texts. In these teams, cooperative learning is forgotten and becomes very personal. This inappropriate distribution of activities usually causes problems such as struggle for power, division, distrust, selfishness and segregation of the group.

This type of situations is often reflected in the development of professional activities and is the reason why many people still do not believe in teamwork. That is why it is important to be aware of how much this happens, since it implies individualistic situations and there is no relationship between the objectives pursued by each student, because their goals are independent of each other. For cooperative learning, the action of cooperating represents the fact of working together to achieve shared goals and, for this, teamwork has very positive effects not only on academic performance, as evidenced by the fact that interpersonals relationships develop very favorably, as they increase respect and solidarity, as well as feelings of obligation and help.

Student name								
Date	**Subject**		**Total points**		**Points earned**		**Group**	
Indicators	**Autonomous (10)**		**Outstanding (9)**		**Satisfactory (8)**		**Deficient (7)**	
Evaporator 2.5 points	Cognitive area	Knows the evaporation process where the refrigerant changes phase, as it absorbs heat from the space to cool.	Cognitive area	Knows the evaporation process, but doesn't know the difference between superheated vapor and saturated vapor.	Cognitive area	Has little knowledge of the evaporation process, and confuses superheated vapor and saturated vapor	Cognitive area	Total ignorance of the evaporation process.
	Procedural area	Perfectly locates the evaporation point on the Mollier diagram, and uses correctly the thermodynamic tables to locate this point	Procedural area	Does not locate the point in the region of saturated vapor in the Mollier diagram, which is not correct and leads to misuse of thermodynamic tables	Procedural area	Does not know how to plot in the Mollier diagram	Procedural area	Does not know anything about Mollier's diagram
	Attitudinal area	Performs correctly the operations for the calculation of the COP, in addition to interpolating the functions in the thermodynamic tables.	Attitudinal area	Does not use the interpolation calculations correctly and miscalculates the COP	Attitudinal area	Does not know how to interpolate, which leads to the wrong calculation of the COP.	Attitudinal area	Des not know how to interpolate nor the COP formula.
Compressor 2.5 points	Cognitive area	Knows the compression ratio and perfectly locates the pressure in the suction and the pressure in the discharge.	Cognitive area	Knows the compression ratio, but does not know that the suction pressure is sometimes less than the evaporation pressure	Cognitive area	Does not know if the discharge pressure in the compressor should be higher than the room temperature.	Cognitive area	Has no knowledge of the compression process, does not understand that the fluid cannot enter the compressor as saturated vapor.
	Procedural area	Uses thermodynamic tables correctly in the superheated vapor region.	Procedural area	When performing the operations, locates the suction pressure in the compressor with difficulty on the Mollier diagram.	Procedural area	Has difficulty finding the compressor suction and discharge point in the superheated vapor table.	Procedural area	Total lack of knowledge of thermodynamic tables.
	Attitudinal area	When using the thermodynamic tables performs triple interpolation correctly.	Attitudinal area	Finds it difficult to perform triple interpolation.	Attitudinal area	Uses the thermodynamic table and perform triple interpolation incorrectly.	Attitudinal area	Does not know how to perform triple interpolation.
Condenser 2.5 points	Cognitive area	Knowledge of the change of phase of superheated vapor to subcooled liquid, correctly applies the condensation heat formula..	Cognitive area	Does not understand the process of de-heating, but does place the points on the Mollier diagram.	Cognitive area	Does not know phase change, locating the point at the condenser outlet as a vapor-liquid mixture.	Cognitive area	Total lack of knowledge of the process, locating the compressor inlet as saturated vapor.
	Procedural area	Uses the tables for condensation vapor calculations correctly	Procedural area	Confuses the regions of superheated vapor and saturated vapor for the calculation of condensation heat.	Procedural area	When interpolating, confuses the use of thermodynamic tables.	Procedural area	Has no idea how to use the thermodynamic tables for the calculation of condensation heat.
	Attitudinal area	Uses the interpolations correctly and applies the condensation heat equation correctly	Attitudinal area	Confuses which table to use to interpolate	Attitudinal area	Has problems to interpolate and confuses which thermodynamic table to use.	Attitudinal area	Does not know how to interpolate and what table to use.
Expansion valve 2.5 points	Cognitive area	Knows the iso-enthalpy process and also the quality of the refrigerant.	Cognitive area	Does not understand why it is necessary to know the quality of vapor.	Cognitive area	Does not know where the point is located at the outlet of the expansion valve.	Cognitive area	Ignores the iso-enthalpy process, and locates the outlet of the expansion valve as saturated liquid.
	Procedural area	Perfectly locates the points of the expansion valve in the Mollier diagram.	Procedural area	Uses the thermodynamic tables for the location of the points incorrectly.	Procedural area	Calculates de refrigerant quality incorrectly	Procedural area	Does not know the location of the points in the Mollier diagram, has no idea of the use of thermodynamic tables.
	Attitudinal area	Uses the thermodynamic tables correctly to calculate the quality.	Attitudinal area	Confuses the interpolation, but does get the points for the calculation of the quality of the refrigerant	Attitudinal area	Has a vague idea regarding the use of the equation of the calculation for the refrigerant quality	Attitudinal area	Does not know how to interpolate what is necessary to find the quality of the refrigerant.

Table 1 Rubric used for the evaluation of a refrigeration system
Source: Prepared by the authors.

The results achieved with the implementation of the competency approach can be discussed from different perspectives, the most relevant being the following: In relation to the training modality, it can be indicated that by implementing the competency method it is possible to clearly define which strategies, methodologies and activities should be used by the teacher so that students can reach the competences and abilities which obviously facilitate the evaluation process.

Regarding the students, there was an increase in their direct participation during the learning process. Approximately 30% of the teaching hours correspond to activities carried out by the students themselves. During their development, they expressed approval of the activities designed, since they could better visualize what they are capable of doing. The evaluation system was more varied and adapted to the new conditions, in which the relevant point is to check the achievement of competencies. A diverse range of assessment instruments were available, such as essay tests, laboratory work, reports, collaborative work, etc., which allow for a better decision regarding the passing or faling of a particular student in each unit, depending on whether or not they have developed the defined competencies. Table 1 shows a rubric used to evaluate thermodynamic concepts of a refrigeration system.

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Conclusions

The student has to know the professional and labor field in order to develop the skills and competencies essential in their professional development.

The development of competences is strictly related to the pedagogical strategy that focuses on the development of the student's scientific thinking, leaving behind the reduced vision of memorizing isolated and meaningless concepts.

The concrete expression of the development of the process-learning has to do with insertion success in the labor field. The dialogue between those who integrate and act in the learning process will be effective as long as it addresses and links capacity development, discipline, values, and cognitive processes which form and forge professionals capable of analyzing the circumstances and transform them into cognitive initiatives that lead them to professional success. The teacher as facilitator and generator of learning must master the scientific field of their area and propose the most appropriate pedagogical strategy for the student to develop skills and competencies.

Learning, assets and knowledge, when they are the product of joint work, collective and individual analysis, have more possibilities to build paradigms and projects that raise the quality of learning based on concrete-collective reality.

Future work

In a future work it is essential to systematically record the evidence which allows us to analyze and evaluate the progress attained.

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