Innovation
2022; 3(2): 46-52
http://www.sciencepublishinggroup.com/j/innov
doi: 10.11648/j.innov.20220302.12

The Professionalization of Molecular Physics and Thermodynamics in the Training of Civil Engineers

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To cite this article:

Segifredo Luis Gonzalez Bello, Leonardo Orlando Mora Aguilera, Juan Carlos Martin Llano. The Professionalization of Molecular Physics and Thermodynamics in the Training of Civil Engineers. *Innovation*. Vol. 3, No. 2, 2022, pp. 46-52. doi: 10.11648/j.innov.20220302.12

Received: May 26, 2022; **Accepted**: June 13, 2022; **Published**: June 27, 2022

Abstract: Scientific results have been reported on the importance of Physics in the training of engineers, and applications in the solution of professional problems, but manifests as problematic the little existence of didactic proposals that articulate Physics with the specific sciences of the profession, highlighting inadequacies in the content professionalization. The objective of the work is to exemplify the professionalization of Molecular Physics and Thermodynamics in the Civil Engineering career, First year of Regular Course at the University of Holguín, and to assess the learning results of students, in the second semester of the 2020-21 school year. An exploratory and descriptive study was carried out with the use of theoretical, empirical and comparative analysis methods. The population was two natural groups of 22 students each. A random sample of 10 students (45.45%) from each group was taken. The results highlight the didactic development of the content professionalization, and value the learning of the students. It can be seen that the average of the grades in the frequent and partial evaluations of the experimental group is higher than the control group, which did not receive the influence of the didactic proposal (4.2-3.7). The results obtained show the feasibility of the application of the content professionalization in the training of Civil Engineers.

Keywords: Content Professionalization, Thermal Conduction, Physics Teaching Methods, Didactic of Physics

1. Introduction

This Civil Engineering has a strong organizational component that has its fundamental application in the administration of the urban and, frequently, rural environment; not only in relation to construction, but also to the maintenance, control and operation of what has been built; as well as in the planning of human activity in the designed environment.

The Civil Engineering career that is studied in Cuban universities, aims to train a professional with extensive knowledge and possibilities of application of basic sciences and engineering sciences, suitable for proposing rational and creative engineering solutions focused on buildings, structures of all kinds, land routes and hydraulics [1].

The experience provided by the educational practice in the teaching of General Physics for the Civil Engineering career at the University of Holguín, allowed to specify that among the insufficiencies that the teaching presents are:

1) Little link of General Physics with the Civil Engineering career, and with the specific disciplines of that career.
2) Limitations of students in the understanding of the discipline General Physics, and its application in the solution of professional problems of their career.

The theoretical study carried out, both abroad and in Cuba, allowed to verify the existence of works on the importance of Physics as a basic discipline in the training of engineers, and the professionalization that from the perspective of applications in engineering, it has in the solution of everyday professional problems [2-9].

These authors refer to the existence of few elements that allow to relate the General Physics with the specific subjects of engineering, highlighting the insuficiente professionalization of the content of the subjects in the curricula.

At the University of Holguín, scientific results related to the professionalization of General Physics for engineering careers have been synthesized, among them: [10-12], which addressed the teaching of Physics for Mechanical Engineering and Industrial Engineering, with a focus on professionalization.

From the previous study carried out, limitations are inferred in the students to use their contents and methods in the solution of professional problems of the career, shows that the professionalization of Physics in the training of civil engineers is insufficient, which makes it necessary to look for didactic proposals to perfect their teaching.

This paper synthesizes the results obtained in research with the aim of exemplifying the professionalization of Molecular Physics and Thermodynamics in the Civil Engineering career, at the University of Holguín, to contribute to the improvement of its teaching and obtain better results in the learning of students.

2. Theoretical Framework

2.1. Theoretical Considerations on the Science-Profession Relationship

An essential aspect of the approach to professionalization of teaching disciplines is the relationship between science and profession, identified by Leon, V. E. & Herrera, J. L. [13] as an objective manifestation of the epistemology of the professions, given the demands they make on the sciences, to unravel their respective objects, through processes of integration-differentiation.

In this study it is considered that to achieve the transformation of the student, it is necessary to include the methods of the science that is taught. The generalization of particular methods leads to the formation of logical skills in accorddance with Mestre, U. [14], which play an important role in the formation of modes of performance of the professional.

The authors Addine, F & Blanco, A. [15] consider that the relationship between science and profession makes possible an adequate characterization of the object of the profession, from a coherent articulation between the logic and methods of science and the logic of the profession, in a given historical context. While this precision is made in the context of initial teacher training, its level of generality transcends the training of engineers.

2.2. Particularities of the Science-Profession Relationship in the Training of Civil Engineers

Among the basic sciences that are part of the curriculum of the Curriculum "E" [16], of the Civil Engineering career includes the discipline General Physics, which is taught to students from the first year or starting with Physics I [17], in which the fundamentals of Mechanics, Molecular Physics and Thermodynamics are offered and precedes, from interdisciplinarity, to the subjects of the profession, which are based on engineering sciences.

From the perspective of the relationship between science and profession, there is an articulation between the basic sciences and the engineering sciences, which is singularized in the role of Physics, because it contributes to disciplines such as: Topography, Applied Hydraulics, Analysis and Design of Structures, Geotechnics and Foundations, Projection and Conservation of Communication Routes.

These disciplines related to the engineering sciences contribute to the Main Integrating Discipline of the career, which is responsible for establishing the links between the modes of performance of the professional that the students will demonstrate, and is nourished by the integrative projects of each academic year.

3. Methodology

Methods of the theoretical level were used: the historical-logical in the evolution of the investigated object, analysis and synthesis in the theoretical systematization carried out, as well as the induction and deduction in the elaboration of the didactic proposal; of the empirical level: the observation of the teaching-learning process and the pedagogical tests, in this case the partial tests and the final exam applied to the students.

The methodology used is based on an exploratory and descriptive study, based on the documentary analysis of previous contributions, as well as on the normative and methodological documents of the Study Plan “E” [17] for the Civil Engineering career.

Among the general objectives stated in Study Plan “E” [17], of the Civil Engineering career is the one that refers to the use of the knowledge of Physics, for the solution of common professional problems typified in the Professional Model.

Following the didactic guideline proposed by Gonzalez, S. L. & Campos, S. [18], where they consider that the professional problems typified in the Professional Model, have wide concreteness through the professionalization of the content of Mechanics in conferences, practical classes and laboratories, with specific exercises of a professional nature, the content of Molecular Physics and Thermodynamics was analyzed with the same perspective.

With the didactic proposal given by Gonzalez, S. L. & Mora, L. O. [19], the basic knowledge of Molecular Physics and Thermodynamics more related to the subjects of the profession, which students must acquire, was specified.

3.1. Example for the Didactic Development of Professionalization

As an example for the didactic development of professionalization, the topic of Molecular Physics and Thermodynamics was chosen, which is related to the disciplines Analysis of Structures; Design of Structures; Conservation of Constructions and Main Integrative Discipline.

In the didactic exemplification, the physical explanation of the phenomenon studied is first introduced, in this case, thermal conduction, where the concepts of heat and temperature and the laws of thermodynamics are involved, and then exercises are proposed as close as possible to real professional problems [19].

To analyze with the students and propose a medium-term solution, which mobilizes the search for new knowledge, an exercise related to the thermal conduction of materials was chosen.

The laws of thermodynamics apply to systems that are in equilibrium. These laws can predict, for example, the amount of energy required to change a system from one equilibrium state to another equilibrium state, but they do not offer information about how these changes occur.

In response to this problem and to complement the laws of thermodynamics, in the face of the professional problems that the civil engineer must solve, it is necessary to take into account the phenomenology that accompanies thermal conductivity.

For example, in the hotel facilities that are built in Cuba near the sea, under the sun and the tropical heat, they are used as typical materials: plasterboard ceilings (laminated plasterboard) of an approximate thickness of 13 mm, which allow to install both thermal and acoustic insulation; on the external walls concrete blocks (40x20x20 cm) are used, and on the interior partition plasterboard (of variable thickness) is used.

A physical situation consistent with the above is the transfer of solar heat through a flat wall of concrete blocks with thickness H. This situation is typical in the facilities indicated, however, it is little attended in the Physics classes.

Faced with this situation, in order to organize student learning, the teacher must specify the concepts and phenomena that are related to the identified professional problem. In this case they are significant: temperature; temperature gradient; heat transmission by conduction (typical in solid bodies); heat flow, thermal conductivity; laws of thermodynamics and Fourier's law of heat conduction, among others.

The comparative analysis of this knowledge, with those declared in the analytical program of the subject Physics I [17], allows to specify that the program does not include the following aspects: temperature gradient and the law of the conduction of fourier heat.

Given the conceptual need raised in the aforementioned topic, the focus of the exercise should be directed towards the search for the necessary elements, which allow the student to assess the influence of heat conduction from the outside to the area where people live, due to the effects they can cause on the quality of life.

These deficient theoretical aspects, far from being interpreted as a weakness in teaching, represent an opportunity, which being oriented so that they are located and used by students, promote the use of scientific methods, as an essential aspect in the training of the professional.

3.2. Approach to the Typical Exercise

The exercise prepared has the following statement:

"In a construction project of a hotel facility, it has been found that one of the external walls of thickness H, would be subjected daily for four consecutive hours to solar radiation. If as a consequence the temperature of the room limited by the wall can rise, develop a theoretical-experimental proposal that allows you to assess whether the amount of heat transferred to the enclosure without air conditioning installation, is significant enough to affect the people who use it".

Additional feedback is offered to the student: To solve this exercise, you need to take into account the following aspects: heat transmission by conduction, temperature gradient and Fourier's law of heat conduction.

This type of physical situation must be oriented so that its realization is framed in a reasonable period of time that allows the student to develop his capacity for autonomy in decision-making and in the use of the necessary resources, including time.

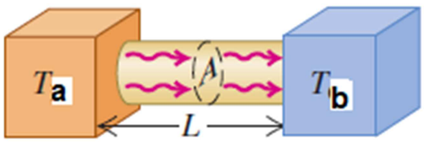
These aspects are important in the formation of the modes of action of the Civil Engineering professional, since they underlie the actions of: managing, designing, executing, controlling, and conserving civil works and researching and innovating in the construction sector [8].

4. Results

A first result refers to the proposal of didactic variant chosen for the application of the professionalization of Molecular Physics and Thermodynamics, when solving the physical situation posed that reflects a typical professional problem faced by civil engineers in Cuba.

The physical content of the proposed exercise is found in the basic text for the Civil Engineering career [20]. As a physical model of the situation posed, the ideas developed in Chapter 17 are used. Temperature and heat, §17. Heat transfer mechanisms.

In Figure 1, the elements that allow the understanding of the phenomenon of heat conduction are collected. It is shown that T_a is the highest temperature and T_b the lowest, A is the area of the cross section of the rod and L the length of the rod.



Source: [20] (Figure 17.23a, p. 571)

Figure 1. *Phenomenon of heat conduction.*

The temperature difference between the rod ends is the cause of an amount of dQ heat being transferred from the highest temperature end to the lowest temperature end, in a dt time interval. Heat flow velocity is defined as heat stream I_Q.

This important theoretical conclusion allowed a series of experimental studies in physics, which are concretized in the following ideas:

For a stationary flow of heat through a substance, it is true that:

1) The heat current I_Q is directly proportional to the area of the cross-section of the rod (A).
2) The heat current I_Q is directly proportional to the temperature difference between the ends of the rod:

$$\alpha\,(T_a - T_b).$$

3) The heat current I_Q is inversely proportional to the length of the rod (L).

So:

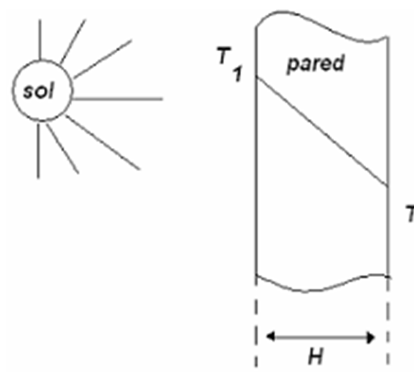
$$I_Q = \frac{dQ}{dt} = k\frac{A(Ta - Tb)}{L} \quad (1)$$

In (1) the ratio *(Ta-Tb)/L* is the temperature difference per unit length and is called the temperature gradient. Theconcept of gradient is important in the study of thermal and electromagnetic phenomena. The gradient of a scalar function is interpreted as a vector that points in the direction and direction in which the function varies most rapidly.

The constant of proportionality *k*, called thermal conductivity, is introduced, which depends on the material of the rod. Those high values of *k*, correspond to good heat-conducting materials, such as metals; while materials that are bad conductors of heat, such as wood, plaster, fiberglass, polystyrene foam, among others, have small values of *k* and serve as heat insulators.

For the thermal insulation of buildings, civil engineers use the concept of thermal resistance: $R = L/k$, so a plate of 5 cm of polyurethane foam has a value of R = 12; for a plate of 15 cm of fiberglass, R = 19. In severe cold climates R = 30, for exterior walls and ceilings. In the International System of Units, R is expressed in m^2. K/W.

Figure 2 shows that due to the Sun the outer part of the wall reaches a temperature T_1 which is the highest, and T_2 is the temperature of the inner surface of the wall that is lower, *A* is the area of the cross section of the wall and *H* the thickness of the wall.



Source: Own elaboration.

Figure 2. *Representation of the physical situation of the exercise.*

In the physical situation that occurs in the exercise to be resolved, it is not important that points *1* and *2*, in which temperatures T_1 and T_2 are taken, are not on a line perpendicular to the wall. Either way, the definition of gradient considers them that way.

When the student proposes the solution to the exercise, it will allow him to demonstrate modes of action that correspond to the demand of the professional problem faced, based on the knowledge about heat conduction, obtained through the research activity. The student is expected to perform the following sequence in their learning actions:

1. Applies the conceptual and procedural (experimental) contents, in the calculation the temperature gradient, for which it is necessary:
   1) Model wall-specimen, with the desired materials and thickness;
   2) Measure T_1 (T_a) and T_2 (T_b), at different times of the 4-hour interval, to average their respective values;
   3) Calculate the temperature gradient.
2. Calculate the heat transferred by the wall, for which it is necessary:
   1) Specify the area of the wall that receives solar radiation;
   2) Select in the manuals the thermal conductivity constant of the material;
   3) Apply equation (1) to get the value of the amount of heat entering the room through the wall.

For the calculation of the amount of heat, equation (1) is adapted to the situation that arises, and is equivalent to:

$$I_Q = \frac{dQ}{dt} = k\frac{A(T_1 - T_2)}{H} \quad (2)$$

Then:

$$dQ = k\frac{A(T_1 - T_2)}{H}\,dt \quad (3)$$

Solving equation (3), one obtains:

$$Q = k\frac{A(T_1 - T_2)}{H}\,t \quad (4)$$

Which will be the work equation.

5. Make Decisions Based on the Result Obtained

To decide what is related to the installation of air conditioning systems, based on the result obtained, it is necessary to compareit with a reference. As such, a person's body could be chosen, modeled as an ideal radiator. Thus, you can compare the heat provided by the wall, with the heat emitted by the body of the person.

The physical content of the ideal radiator is found in the complementary text for the Civil Engineering career [21].

A typical example of radiation from the human body is found in section 49-1. Thermal radiation, in problem 7:

"Show that a human body of 1.80 m^2 of area with an emissivity very close to the unit, whatever the pigmentation of the skin, and a temperature of 34°C, emits radiation at the rate of 910 W".

The solution is obtained from the knowledge of thermal radiation with the accompaniment of the teacher to the student's learning management.

A second result reflects the assessment of the learning outcomes of students in the subject Physics I, with emphasis on the application of professionalization in the subject of Molecular Physics and Thermodynamics.

The study was conducted in the second semester of school year 2020-21, in the first year of the Regular Course (RC). The time taken to perform it was 15 weeks from February 1, 2021, although it was extended a little more in time due to the measures taken by the occurrence of COVID-19.

The population consisted of two natural groups of 22 students each. In Group 1, 9 males (40.90%) and 13 females (59.10%), with an average age of 19.6 years; in Group 2, 14 males (63.64%), and 8 female groups (36.36%), with an average of 19.6 years. They were selected as a population, for having the same possibilities of meeting the objectives foreseen for the subject, and similar characteristics.

A sample was taken from the natural groups, using the table of random numbers to ensure the homogeneity of the characteristics of the students investigated. The sample was made up of 10 students (45.5%) from each group. Of Group 1 (experimental), 6 males (60.0%) and 4 females (40.0%), with an average age of 19.8 years; of Group 2 (control), equal composition by sex, with an average of 19.5 years. The sample reflects the characteristics of the population and the equivalence in terms of sexes and ages.

The reference subject is taught in the second semester of first year. It offers the fundamentals of Mechanics, Molecular Physics and Thermodynamics and precedes the subjects of the career, highlighting the applications they have in civil engineering.

The evaluation activities taken for the assessment of the students' learning were the following:

1) Laboratory Practice (PL). Experimental verification of the Boyle-Mariotte law.
2) Task 1 (T1). Exercises on thermal expansion and heat conduction.
3) Task 2 (T2). Exercises on the first law of Thermodynamics.
4) Task 3 (T3). Exercises on thermal machines.
5) Partial Test 2 (PP2).
6) Final exam (EF).

As a qualification criterion, the one established in [22], which establishes in Article 178, was followed: The results of the different forms of evaluation of student learning will be graded using the following categories and symbols: Excellent 5, Good 4, Regular 3 and Bad 2.

Tables 1 and 2 show the summary of the grades obtained by the students of the experimental and control groups.

Table 1. *Summary of the evaluations obtained by the sampled students of Group 1 (experimental).*

Names	PL	T1	Q2	Q3	PP2	Prom.	EF
YAV	3	4	4	4	3	3.6	4
LAV	4	4	4	4	4	4.0	5
YCB	4	5	5	5	4	4.6	5
DCR	4	4	4	4	3	3.8	4
LMF	3	4	4	3	4	3.6	4
REF	4	4	4	4	4	4.0	4
GGV	3	4	4	4	3	3.6	3
DEG	4	4	4	5	5	4.4	5
LVL	4	5	5	4	4	4.4	5
SPL	3	4	4	4	4	3.8	3
Prom.	3.6	4.2	4.2	4.1	3.8	3.9	4.2

Table 2. *Summary of the evaluations obtained by the sampled students of Group 2 (control).*

Names	PL	T1	Q2	Q3	PP2	Prom.	EF
AAR	3	4	3	3	3	3.6	4
KEF	4	4	3	4	3	3.6	3
FCM	3	3	3	5	3	3.4	3
LGF	4	4	4	4	3	3.8	4
LMP	3	3	3	4	4	3.4	3
CLF	4	4	4	4	4	4.0	4
YPB	3	3	3	3	3	3.0	3
JRD	4	4	4	4	4	4.0	4
LAL	4	5	5	4	4	4.4	5
MTR	3	4	4	4	4	3.8	4
Prom.	3.5	3.8	3.6	3.9	3.5	3.6	3.7

Partial Test 2 included a typical exercise on heat transfer in housing construction, which reflects the application of physicsin the solution of professional problems of the career. A similar physical situation was also included in the Final Physics Exam I.

From the comparison of the results, it can be seen that the average of the grades in the frequent and partial evaluations of the experimental group is higher than the control group, which did not receive the influence of the didactic proposal (3.98-3.66).

The average of the grades received in the Final Exam is also higher in the experimental group than the control group (4.2-3.7).

It was located in the Teaching Secretariat of the Faculty of Engineering, the average of the grades in the Final Exam of Physics I in the two previous school years. Also, the average obtained during the study exceeds them, not only in the experimental group, but also in the control group (4.2 and 3.7-3.6 and 3.4).

The results obtained in the learning show the feasibility of the application of the professionalization of the subject in the training of the students of the Civil Engineering career.

6. Conclusions

The study carried out allowed to establish the interrelation between Molecular Physics and Thermodynamics with disciplines of the training of future civil engineers: Analysis of Structures; Design of Structures; Conservation of Constructions and Main Integrative Discipline, which employ concepts, laws and formulations based on Physics.

The application of this knowledge was exercised and resources were offered that put into practice the research component of the training.

A first result obtained synthesizes the didactic proposal chosen for the application of the professionalization of Molecular Physics and Thermodynamics, by solving the physical situation posed that reflects a professional problem of the Civil Engineering career in Cuba.

A second result refers to the assessment of student learning. From the comparison of the results, it can be seen that the average of the grades in the frequent and partial evaluations of the experimental group is higher than the control group, which did not receive the influence of the didactic proposal (3.98-3.66). The average of the grades received in the Final Exam is also higher in the experimental group than the control group (4.2-3.7).

When comparing the average of grades obtained during the study, with the average of the grades in the Final Exam of Physics I in the two previous school years, they are superior not only in the experimental group, but also in the control group (4.2 and 3.7-3.6 and 3.4).

The results obtained in the learning show the feasibility of the application of the professionalization of the subject in the training of the students of the Civil Engineering career.

In future research, other topics of the General Physics discipline should be included in the Methodological Scientific Work that is carried out in the Discipline Collective to enhance the applications of Physics in the solution of professional problems of Civil Engineering.

Acknowledgements

The authors thank the Construction Department of the University of Holguín for the facilities offered by the Head of Civil Engineering Career, Master Silvia Campos Movilla to carry out the research.

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