Evaluation of the teaching of physics areas in university engineering programs

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Abstract. Relevance studies provide a vision of the impact and degree to which an academic offer responds to the needs of an environment. In this research it was possible to analyze the context of the existing technological level programs with respect to the offer of physics branches linked in their curricula, in order to determine the correlation between these areas and the contribution they represent in the development of competences and skills for the exercise of the profession of Technologists in areas of Engineering knowledge. A descriptive methodological approach was used, through the application of instruments and tools that allowed synthesizing the findings in relation to the formulated study hypothesis. It was concluded that the fields of physics at the technological level allowed establishing the bases to articulate the knowledge towards the disciplinary study in each of the programs studied; likewise, it was evidenced that the behavior of the proportion of physics courses within the curricular structures are corresponding among the programs under study; and finally, it was demonstrated that the areas of physics are mostly addressed in the programs whose specific field demands the application of electronic, mechanical, electromechanical, manufacturing, instrumentation, automation and control systems.

1. Introduction

Relevance studies provide a clear vision of the purpose and future impact of an academic program and help to identify the efficiency of a program with respect to the fulfillment of its educational purposes and objectives, evaluating its impact from different points of view. The pertinence study is the development of actions in search of knowing the convenience of something. In relevance studies, it is necessary to establish an action logic that allows the systemic management of the necessary information to carry out a relevance study that enhances and scientifically supports its results [1]. It has been shown that academic relevance supports the construction of an educational offer adjusted to the geographical, demographic, economic and social environment of the institution [2].

Regarding Social Relevance, it should be noted that changes are constantly occurring in society, and individuals are responsible for improving the environment in which they live. This relevance is understood to represent for universities a high degree of commitment and involvement of scientific communities with the ongoing perspectives of contemporary societies [3]. Social relevance is not only a greater university-society linkage in the sense of taking up social problems as a source for the production of knowledge, but also shows the coherence between the mission, objectives and profiles
with the needs of the environment to generate alternatives in the social, economic and productive development of a country [4].

Academic relevance refers to the capacity of an institution or programme to respond to the needs of the environment in a proactive manner, based on the institution’s relations with its environment. [5]. The curricular structure must respond to several properties for the training of professionals, not only focused on standards but also on the reality of the context and social development over the years. Academic relevance is defined as a correspondence between the academic purpose of the project, course, subjects with teaching, research, knowledge transfer and strategies, human resources and instruments that are handled in practice for the academic fulfillment of the proposed objectives [6].

Likewise, the case of technological programs is considered, which correspond to a group of programs whose training level is oriented to the development of competencies, mainly of doing and knowing how to do. At this level of training there are a large number of programs in the area of engineering knowledge, whose academic and social relevance must be constantly evaluated, starting from their curricular structure as the basis for all processes.

It stands out the fact that all engineering programs at the technological level have a curricular structure based on the areas of basic sciences, highlighting physics as a transversal science that supports the formative development of several disciplines. The analysis of the academic and social relevance in turn requires studying the way in which each of the curricular components that make up these curricula are coherent with the educational purposes; for this reason, the offer of physics courses is analyzed as a protagonist of the formative process.

2. Methodology

The type of research used in this project is descriptive, with a quantitative-qualitative approach. The information was collected through comparative analysis exercises of validated sources from sources available in governmental databases.

2.1. Methodological approach

The methodology developed for the analysis was qualitative and quantitative [7,8], since the data were collected and filtered based on the following criteria: currently active university academic programs that belonged to the technological level and whose denomination corresponded to thematic areas related to engineering.

2.2. Instrument design

The main instrument used to collect the information was a structured analysis matrix that made it possible to evaluate the criteria indicated in Table 1.

| Table 1. Criteria for evaluating the curricular relevance of the physics courses offered in the programs under study. |
|---------------------------------------------------------------|
| Indicator | Interpretation |
|------------------|----------------|
| Curricular participation of physics subjects (%) | Proportion of existing physics courses in the curricula of the programs studied. |
| Analysis of physics offerings by course or topic (%) | To identify the prevalence and coincidence of the main thematic areas of physics in the curricula analyzed. |
| Congruence between the professional profiles and the academic offer of physics (%) | Thematic and disciplinary contribution of physics courses to the development of professional competencies stated in the different profiles of the academic programs. |

2.3. Population and sample

For the application of the instruments, a number of 103 active academic programs in the information system “Sistema Nacional de Información de la Educación Superior (SNIES)” of “Ministerio de Educación Nacional”, Colombia, was considered; based on the characteristics of this finite population, where the total number of observation units that comprise it is known, it was necessary to determine a
representative sample, taking as a basis the statistical method set out and whose formula is presented in Equation (1) [9].

\[
n = \frac{N \times Z^2 \times p \times q}{(N-1) \times e^2 + Z^2 \times p \times q},
\]

where, \( n \) is the number equivalent to the sample size to be calculated; \( N \) is the total number of active academic programs related to the study problem (103 careers); \( Z \) is the corresponding confidence level of 95%, with a \( Z \) of 1.96 reliability in the results; \( p \) is the proportion of occurrence (50%); \( q \) is the rejection ratio (50%); and \( e \) is the error or maximum difference between sample rate and population rate (5%).

Once these parameters were applied, a result of 82 academic programs (careers) subject to analysis of the research objective was obtained. The methodological process for developing the research is presented in Figure 1, which shows each of the phases of the study that made it possible to fulfill the proposed aim.

![Figure 1. Methodological process [10].](image)

3. Results and discussion

When analyzing the existence of physics subjects in the different curricula of the academic programs that were analyzed, a significant behavior of these areas of knowledge was found within the training component of Engineering at the technological level, so that an academic relevance of physics subjects can be appreciated, as shown in Figure 1. This level of participation was calculated from the review of academic credits in each program associated to the fields of knowledge described in Table 2; data that were analyzed from the official sources of “Ministerio de Educación Nacional de Colombia”.

| Field of knowledge                                      | Total physics courses | Total courses |
|---------------------------------------------------------|-----------------------|--------------|
| 1. Agro-industrial, food and related engineering        | 2                     | 92           |
| 2. Biomedical and related engineering                   | 0                     | 96           |
| 3. Chemical engineering and related                    | 44                    | 781          |
| 4. Chemistry and related                               | 6                     | 104          |
| 5. Electrical engineering and related                  | 33                    | 523          |
| 6. Electronics, telecommunications and related engineering | 199                  | 2754         |
| 7. Industrial engineering and related                  | 160                   | 3144         |
| 8. Mechanical engineering and related                  | 169                   | 2181         |
| 9. Systems engineering, telematics and related areas    | 8                     | 297          |
The data referring to the participation percentages of the physics subjects shown in Figure 2 were calculated by taking as numerator the total number of academic credits invested for these areas in each academic program over the total number of academic credits of each curriculum.

![Figure 2. Percentage of curricular participation of physics subjects in the analyzed careers.](image)

It was possible to validate that the curricular structures of the technological programs in engineering represent between 2.2% and 7.7% of participation or academic relevance for the case study of Colombia, being the programs of the specific area of knowledge of mechanical engineering and related areas, in which the physics courses represent a majority participation with respect to the others. Likewise, in the area of Electronics, telecommunications and related areas, physics represents a participation close to 7.2%. Figure 2 also showed that engineering programs belonging to other basic knowledge cores adopt physics courses within their curriculum in a smaller proportion, depending on their professional field and the skills and competencies established in their profile. Physics is a basic science that participates in the formative process of all engineering programs, a situation that was congruent with the academic panorama previously known in the country in this regard. The background showed that the teaching of physics in national universities is part of the basic training of all engineers and is part of the minimum standards required by the State, so that the field of physics is always present [11]. The teaching of the area of physics at the university level for engineering programs is based on a thematic distribution, from which the different subjects are derived. This distribution of contents of the area, in most cases, is done in five subjects, namely: mechanical physics, physics of electricity and magnetism, physics of fluids and thermodynamics, physics of waves and modern physics [11].

Recognizing the global participation of physics in most of the engineering programs at the technological level, it was also necessary to classify and weight the topics that represent the greatest importance for the careers that were the object of study. Figure 3 shows the percentage of specific topics in the area of physics studied in the academic programs, with the field of mechanical physics being the most addressed by the engineering programs. To determine these percentages it was necessary to analyze each of the curricular plans of the 82 academic programs under study, managing to validate those in which courses in mechanical physics, electricity and magnetism, wave physics, physico-chemistry, fluid physics and thermodynamics were observed.

Some fields derived from physics that are more specific in the disciplinary environment, such as physico-chemistry and thermodynamics, are present in smaller proportions, and are immersed in academic programs whose focus and professional profile is oriented to address problems of this nature, for example in careers such as chemical technology, industrial process technology, industrial production technology and chemical process technology. Electromagnetic physics and its associated topics are especially important in curricula of technologies related to instrumentation, automation, mechanics, electronics and mechatronics.
This is especially important if we take into account some experiences on the subject of study that had been discussed, in which physics is a tool within engineering that contributes to the scientific and technological development of a country [12], and since the technological level programs are part of engineering, they would not be alien to this reality.

It is possible to infer that at present, teaching in the areas of physics in its different disciplines is a fundamental aspect for the academic processes of engineering programs, especially those at the technological level.

4. Conclusions
It was possible to demonstrate that in the current academic contexts of technological engineering programs, physics continues to be a science whose study allows acquiring the basis for the development of any engineering model or system. All the fields of engineering that were studied are focused on the solution of diverse problems that require the development of new technologies that in many occasions are based on a solid knowledge of physics.

It is concluded that the incursion of physics in the different curricular plans depends on the profile and professional focus that each academic program wishes to strengthen.

Curricular contents, pedagogical aspects, thematic units, time intensity and other aspects related to the teaching of physics within engineering programs should be reviewed and updated periodically to ensure social relevance within the academic programs and the solution of problems in their environment.

It is concluded that the level of academic relevance of physics courses in technological engineering programs is significantly high, due to the fact that the curricular participation of these subjects has been maintained. Although the processes of academic self-evaluation have brought with them the need for curricular modernization of university academic programs, the teaching of physics has been maintained and has continued to play a leading role in the basic training component.

The need to determine the sufficiency of the physics curricular contents offered or dictated by each of the engineering programs, in order to contrast their applicability with the fields of professional practice, is proposed for future research.

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