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Engineering education – New needs for an old profession

Formación em ingeniería – Nuevas necessidades para uma antigua profesion

Formation de l'ingénieur - de nouveaux besoins pour une profession ancienne

A formação do engenheiro – Novas necessidades para uma velha profissão

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Abstract

This writing aims to identify and analyze needs and reasons in the meaning of the Vector concept in the Civil Engineer profession, delimited by the following issue: what are the necessary confrontations in the training of an Engineer, considering the conceptual significance of Vector, for a professional performance which contemplates the indicatives proposed by the DCN? For that, we considered as analysis instruments a questionnaire and a semi-structured interview with Civil Engineering Course students. The questionnaire was sent via Google forms to all Civil Engineering Course graduates registered in the Graduate Program of an Educational Institution since 2015. The semi-structured interview was carried out with five academics of the course, which was carried out via Google Meet, and the transcripts constituted the second instrument of analyzing this production. Both instruments – questionnaire and interview transcripts – were analyzed considering the stages of the ATD by Moraes and Galiazzi (2016). The theoretical basis of this study was Leontiev's Activity Theory (1978). The analyzes carried

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out indicated that, in order to face the needs of training that contemplates the new curricular guidelines and that enables a training process with conceptual significance, it is necessary that the educational activity, restructure and adapt to new market demands, providing a process of more significant teaching, with articulation between the disciplines and proposition of activities that mobilize the concepts in situations of professional practice.

Keywords: Vector concept, Work, Activity theory, Pedagogical action, Civil engineering, Conceptual signification.

Resumen

Este escrito tiene como objetivo identificar y analizar necesidades y razones en el sentido del concepto Vector en la profesión de Ingeniero Civil, delimitado del siguiente tema: ¿Cuáles son los enfrentamientos necesarios en la formación del Ingeniero, considerando la trascendencia conceptual de Vector, para un profesional? ¿Desempeño de manera de contemplar los indicativos propuestos por las DCN? Para ello, se consideró como instrumentos de análisis un cuestionario y una entrevista semiestructurada con estudiantes de la carrera de Ingeniería Civil. El cuestionario se envió vía formularios de Google a todos los egresados del Curso de Ingeniería Civil inscritos en el Programa de Posgrado de una Institución Educativa desde 2015. La entrevista semiestructurada se realizó con cinco académicos del curso, la cual se realizó vía Google Meet, y el las transcripciones constituyeron el segundo instrumento para analizar esta producción. Ambos instrumentos, cuestionario y transcripciones de entrevistas, fueron analizados considerando las etapas del ATD por Moraes y Galiazzi (2016). La base teórica de este estudio fue la teoría de la actividad de Leontiev (1978). Los análisis realizados indicaron que, para enfrentar las necesidades de formación que contempla los nuevos lineamientos curriculares y que posibilita un proceso formativo con significación conceptual, es necesario que la actividad educativa, se reestructura y se adapta a las nuevas demandas del mercado, brindando un proceso de docencia más significativa, con articulación entre las disciplinas y proposición de actividades que movilicen los conceptos en situaciones de práctica profesional.

Palabras clave: Concepto vectorial, Trabajo, Teoría de la actividad, Acción pedagógica, Ingeniería civil, Significado conceptual.

Résumé

L'objectif de cet article est d'identifier et d'analyser les besoins et les motivations dans la signification du concept de vecteur dans la profession d'Ingénieur Civil, à partir de la problématique suivante : quelles confrontations sont nécessaires dans la formation des

Ingénieurs, compte tenu de la signification conceptuelle du vecteur, afin d'exercer la profession d'une manière qui contemple les indications proposées par la DCN ? Pour ce faire, nous avons analysé un questionnaire envoyé à des diplômés et un entretien semi-structuré proposé à un groupe d'étudiants d'un cours de génie civil. Le questionnaire a été envoyé via Google Forms à tous les diplômés de la filière Génie civil inscrits depuis 2015 au programme d'études supérieures d'un établissement d'enseignement. L'entretien semi-structuré a été réalisé avec cinq étudiants du cours, via Google Meet, et les transcriptions ont été le deuxième outil utilisé pour analyser cette production. Les réponses aux questionnaires et les transcriptions des entretiens ont été analysées en tenant compte des étapes de l'ATD de Moraes et Galiazzi (2016). La base théorique de cette étude est la théorie de l'activité de Leontiev (1978). Les analyses réalisées ont montré que, pour répondre aux besoins d'une formation qui prenne en compte les nouvelles lignes directrices du curriculum et permette un processus de formation avec une signification conceptuelle, l'activité éducative doit être restructurée et adaptée aux nouvelles exigences du marché, en fournissant un processus d'enseignement plus significatif, avec une articulation entre les disciplines et en proposant des activités qui mobilisent les concepts dans des situations de pratique professionnelle.

Mots-clés : Concept de vecteur, Travail, Théorie de l'activité, Action pédagogique, Génie civil, Signification conceptuelle.

Resumo

Essa escrita tem por objetivo identificar e analisar necessidades e motivos na significação do conceito Vetor na profissão de Engenheiro Civil, delimitado a partir da seguinte problemática: quais os enfrentamentos necessários na formação do Engenheiro, considerando a significação conceitual de Vetor, para uma atuação profissional de forma a contemplar os indicativos propostos pelas DCN? Para tanto, consideramos como instrumentos de análise um questionário enviado a egressos e uma entrevista semiestruturada proposta a um grupo de estudantes de um Curso de Engenharia Civil. O questionário foi encaminhado via formulários Google para todos os egressos do Curso de Engenharia Civil cadastrados no Programa Egresso de uma Instituição de Ensino desde 2015. A entrevista semiestruturada, foi realizada com cinco acadêmicos do curso, a qual foi realizada via Google Meet, e as transcrições constituíram o segundo instrumento de análise desta produção. As respostas dos questionários e as transcrições das entrevistas foram analisadas considerando as etapas da ATD de Moraes e Galiazzi (2016). A base teórica deste estudo foi a Teoria da Atividade de Leontiev (1978). As análises realizadas apontaram que, para enfrentar as necessidades de uma formação que contemple as novas diretrizes curriculares e que possibilite um processo formativo com significação conceitual, é preciso que a atividade educativa, se reestruture e se adapte às novas demandas do mercado, proporcionando um processo de ensino mais significativo, com articulação entre as disciplinas e proposição de atividades que mobilizem os conceitos em situações da prática profissional.

Palavras-chave: Conceito de vetor, Trabalho, Teoria da atividade, Ação pedagógica, Engenharia civil, Significação conceitual.

Engineer education – New needs for an old profession

According to the Higher Education Census (2019), civil engineering is one of the five courses Brazilians seek the most. The growing demand for professionals in this area is due to the expansion of civil construction, socioeconomic development, and diversification in the field of action of this professional, which goes far beyond civil construction. According to the National Curriculum Guidelines [Diretrizes Curriculares Nacionais – DCN] (BRASIL, 2019), the civil engineer can work in the following fields: *construction* – the most traditional area of civil engineering, responsible for all construction processes from design to execution, ranging from the choice of materials used in the foundation to the finish; *structures* – responsible for the entire structure scheme, for the calculation of deformations, efforts and loads, calculation and definition of the structural elements and the detailed design of the project; *geotechnics* – concerns everything that involves excavations and soil mechanics; the civil engineer works to prevent crashing down, collapses, landslides, and contamination of water tables, acts to minimize these situations in a sustainable and safe way without degrading the environment; *water resources and sanitation* – operates in projects to explore the use of water and in basic and general sanitation works, which include sewage, water, drainage, and waste; *transport* – plans, constructs and implements several transportation systems and organizes all traffic logistics.

Civil engineers' field of action is vast and requires ownership of knowledge for them to act and develop their professional activity, their work. The civil engineering professional plays a broad role in modern society as an articulator of the technique for the population's well-being (UNIJUI, 2017, p.7). As a society, we are in constant transformation; we live in a globalized world characterized by the remarkable speed with which information is produced and consumed, and professions, in general, must adapt to this new reality. Technological advances marked by the emergence of digital technologies, such as automation, artificial intelligence and Big Data, impact different sectors, from agriculture to industry, largely changing the way production is produced, how value chains are organized, how it is marketed and the way people live and relate to each other (CNI, 2020). In this sense, the job market has become increasingly competitive and demanding, looking for professionals who value excellence and who are in constant qualification of their professional practice, in addition,

> The civil engineer is at the forefront of an immense range of articulated professionals to transform ideas, projects, and materials into real estate capable of lasting, allowing their use and economic exploitation. [...] There is a growing demand for civil engineers' actions in the development, production, and control of materials used in construction and other areas of civil engineering. Also in the infrastructure sector, civil engineers

> have played an increasing role as managers of human and material resources that are intensely involved in the activities of construction, use, and maintenance of this infrastructure. One can also mention the activities of designing new projects, in the field of buildings, infrastructure, and industrial assemblies, where civil engineers appear as the main actors in a scene in constant development (UNIJUÍ, 2017, p.7)

The complexity of the civil engineer's work currently requires professionals with a vision of the needs and expectations of the market, committed to the quality of their work, and open to change, having teamwork skills. The civil engineer must also be a leader, showing initiative to make critical, creative, ethical, and responsible decisions and evaluate and validate information, besides working with digital tools and mastering other languages.

Higher education courses are responsible for enabling a formative process capable of developing complex thinking, relating theories and practices, being a space that enables subjects to develop skills and abilities related to their professional activities. It should allow them to acquire knowledge at a conceptual level, based on interpretation, action, analysis of situations, and outlining strategies, in addition to producing efficient and sustainable solutions. The concepts learned in the academic formative process become necessary cognitive tools as support to solve problems in the professional context.

The societal demand for new needs interferes with graduates' profile, that is, in the curriculum and the way educational institutions promote the teaching and learning process. The professional formative process ends up becoming increasingly complex, demanding from higher education institutions, and consequently from teachers, intentional actions regarding the teaching and learning process of knowledge that integrate the curriculum of the process.

The curriculum guidelines that guide the organization of undergraduate courses consider the needs and requirements of society to provide subjects with a comprehensive formation that makes them able to act in this complex and technological context. The DCN of engineering courses is an example of this. Article 4 of the CNE/CES Resolution (2019) presents a series of competencies and skills that the initial engineering education needs to enable the academic to develop, considering the current context. We highlight some of them:

> II – Analyze and understand physical and chemical phenomena through symbolic, physical and other models, verified and validated by experimentation;
> [...]
> III – Conceive, design and analyze systems, products (goods and services), components or processes;
> [...]
> IV – Implement, supervise, and control engineering solutions;
> [...]
> VI – Work and lead multidisciplinary teams.

> VIII – Learn autonomously and deal with complex situations and contexts, keeping up-to-date with advances in science, technology, and the challenges of innovation:
> a) be able to assume an investigative and autonomous attitude, with a view to continuous learning, the production of new knowledge, and the development of new technologies;
> b) learn how to learn. (Brasil, 2019)

Therefore, the challenges are not presented only to professionals and future professionals in the civil engineering area but to all sectors/institutions involved in their formative process. In this context, Roncaglio, Battisti, and Nehring (2020, 2021) point out important characteristics related to the initial education of this professional, especially in relation to the appropriation of mathematical concepts, considered essential tools in the process of professional constitution and how this must be dealt with in a meaningful way during the formative process.

The educational process as a condition for human development

Every human being is constituted human to the extent that they appropriate the objectified knowledge in the world. The appropriation of this knowledge results from one's activity on objects and the context in which they is inserted, a process mediated by instruments and signs.

> [...] the subject's relationship with the other and/or with the world is not a direct relationship, it is mediated by mediation elements: instruments and signs. All relationships are mediated; likewise, the relationship between thought and language is not direct, it is mediated by meaning. In this way, in the activity the subject is constituted by semiotic mediation from processes of signification.
> Both Vygotsky and Leontiev consider the idea of mediating elements, but from different perspectives. Vygotsky stressed the emphasis on the sign as a fundamental element in the construction of a person's relationship with the world. Leontiev was particularly concerned with the concept of internalization and the role of culture in the development of human capabilities, emphasizing interactions in the appropriation of the meaning of instruments (artifacts/situations of intervention in nature), starting from the category of work, which supports the idea of the activity. (Battisti; Nehring, 2020, p. 41)

Therefore, from the understanding of the cultural-historical approach, we can say that in the interaction with the other, mediated by signs and instruments, we can appropriate the objectified knowledge in the world and humanize ourselves. For Leontiev (1978b), this process of humanization is an education process, that is, a process in which culture and knowledge historically produced through activity are transmitted and assimilated.

The educational process is the central point in the development of humanity, since it allows us to progress with each new generation. On the contrary, we would always have to reinvent the knowledge impregnated in the surrounding world and always start from scratch.

Marques (2006, p. 26) corroborates the discussion by pointing out that learning takes place as the singular subject enters into an active relationship with his world through the mediation of procedures, ways of acting, objects, and language socially elaborated and recognized by a collective, organized, specific, and differentiated subject in each historical situation.

In other words, according to this author:

> The subject is constituted in the process of enunciation, of production of meaning, which transcends both extra-individual mechanisms (economic, social, and cultural) and intrapsychic ones (physiological systems, systems of sensitivity, perception). It transcends these different instances, placing them in connection, circulating between them, conforming to them in a relation of subjection and/or constituting them in relations of expressiveness and resignification, in a process of singularization. (Marques, 2006, p. 35)

In the cultural-historical approach, as we defend in Roncaglio, Battisti, and Nehring (2021), the process of human development occurs through main activities, which are structured depending on the place that man occupies in social relations and are directly related to awareness. They are: playing (pre-school phase); studying (school phase); and working (adult stage).

> **Working** is the activity through which one not only materially architects society, based on their capacities to ideate and objectify, but also makes the foundations so that they become humanized, become authentic social beings (Lessa; Tonet, 2011). In this materialist perspective, work does not refer to a concept equivalent to employment, paid activity, profession, or any other concepts associated with the typical exchange process of capitalist society, as is commonly heard today. It brings us back to a key concept because it deals with a **practical activity**, one **productive activity**. (Araújo, 2015, p. 36, emphasis added)

Concerning the work activity, Marques (2006, p. 81) contributes by highlighting that the subjects' occupational activities "are organized in the form of professions by combining the configurations of the new organizational principles of symbolic and material reproduction of the world objectified by men, advances in science and technology and the political intentions of defined social groups".

We mark, then, the fundamental role of educational institutions of higher education, which, in a way, participate in the social organization of work, being responsible for enabling subjects to learn theoretical and practical knowledge that will allow the appropriation of essential cognitive tools to life in society, especially in the scope of professional performance. Through the process of internalizing objectified knowledge in the surrounding world, we learn and develop.

In this sense, the development of the human psyche stems from the relationships established with other humans, which are mediated by objectified knowledge in the world (instruments and signs). This process is effective in learning in general, and in some specific cases, when there is an intentionality that is objective in the formal organization and/or systematized in the process of transmitting this knowledge, in which case, we have learning resulting from an educational activity.

To Leontiev (1978b, p. 273):

> The more humanity progresses, the richer the socio-historical practice accumulated by it, the more the specific role of education grows and the more complex its task. This is why every new stage in the development of humanity -and that of different peoples- inevitably calls for a new stage in education development: the time society dedicates to the education of generations increases; teaching establishments are created, instruction takes on specialized forms, the work of the educator and the teacher is differentiated; study programs are enriched, pedagogical methods are perfected, pedagogical science is developed. This relationship between historical progress and the progress of education is so close that one can safely judge the general level of historical development of society by the level of development of its educational system and vice versa.

Formal education spaces, whether in the scope of basic or higher education, are social places responsible for fostering the appropriation of historically produced knowledge and allowing the deepening and advancement of this knowledge. We understand that such appropriation only occurs when this educational action is organized and intentional. We highlight, in this article, the teaching developed by higher education institutions, which is responsible for enabling the professional academic formation of the subjects, the appropriation of cognitive tools from theoretical and practical knowledge, the subjects' development, and the realization of specific activities when they act in the field of work.

In this context, we understand the academic-professional formative process as a human activity, as it is through this process that the subject can develop skills that qualify them for specialized work. In addition, it is a means for scientific research to advance, for new knowledge to be developed, for new technologies to emerge at all times, placing society in constant transformation. In this scenario, the professional formative process, through formal and intentionally organized education, is increasingly necessary and complex. In the cultural-historical perspective:

> [...] men are constituted through work, understandood as a human activity suited to an end and guided by objectives, so teachers constitutes themselves as teachers through their work – the teaching activity – i.e., teachers become teachers in the teaching activity. In particular, by expressing their need to teach and, consequently, organize teaching to favor learning. (Moretti, 2007, p. 101)

Teachers' teaching activities must mobilize students' study and create reasons for students to want to learn. By putting themselves into teaching activity, the teacher continues to appropriate knowledge, specific, pedagogical, curricular contents, contexts, and educational purposes, which support them in organizing potential actions to enable students to put themselves into the activity of study and, thus, appropriate scientific concepts and develop theoretical thinking. According to Moura et al. (2016), teachers' actions in the organization of teaching allow learning to occur in a systematic, intentional, and organized way.

The teaching developed by the teachers:

> [...] should aim at bringing students closer to a particular knowledge. Hence the importance for teachers to understand their teaching object, which should become a learning object for students. In addition, it is essential that, in the teaching process, the object to be taught is understood by students as a learning object. For the cultural-historical theory, this is only possible if that same object constitutes a need for them. Thus, "theoretical knowledge is both object and need in the learning activity" (Moura et al., 2016, p.105)

From the perspective considered here, the activity:

> [...] is capable of transforming the activity developed in the pedagogical work into those that allow qualitative changes. Thus, it must be organized in such a way that individuals can develop themselves as transforming subjects in their social context, not only because they know the complexity of the current social practice, but because they also understand the limits of their contribution to the process of transforming themselves and the context that surrounds them. (Cedro, 2008, p. 22)

The teacher's teaching activity needs to enable students' acquisition of scientific concepts, which will be internalized as the students engage in study activities. In other words, the appropriation of scientific concepts promoted by the teacher's activity takes place through systematic and intentional teaching. The teacher is responsible for organizing teaching, defining actions, selecting tools and evaluating the process, in order to generate reasons for students to want to learn. In this regard, we emphasize that:

> [...] there are essential actions that need to be assumed by the teacher when organizing the teaching, which aims at the formation of concepts by the basic education student and/or by the academic in higher education. These actions should include content analysis, perceiving the basic relationships that support the content and identifying the core concept, and considering students' motives; that is, students engage in learning activity if they have social and individual reasons to learn. Content analysis is strongly linked to the consideration of students' motives for learning content. This articulation "[...] does not only consist of taking into account students' interests and motivations, but intervening in their motives, training them for significant, desirable reasons" (Libâneo, 2009, p. 33). The way of organizing teaching, the form and content of teaching

> activities constitute a motivational factor, and one of the teachers' roles is to form in students, both in basic and higher education, reasons for learning to take effect. (Battisti; Nehring, 2020, p. 55-56)

Specifically considering teachers' work, their teaching activity, their need consists of organizing actions so that their activity occurs efficiently and effectively, since it is in the teaching activity that the teacher becomes a worker by exercising his/her function as an organizer and promoter of learning, enabling students to engage in study activities. We understand the educational process as central to human development and, as such, responsible for promoting the development of the subjects' superior psychological functions, enabling the appropriation of concepts so that they become cognitive tools that expand the conditions of the subject to act in society. In this context, the study presented here considers the formative process and focuses on a mathematical concept mobilized in engineering courses, in particular, in the civil engineering course, the concept of vectors.

Vector is a concept used by several areas as a tool to explain and/or represent situations. In mathematics, they have specific meanings for the area (RONCAGLIO; BATTISTI; NEHRING, 2021b). In the civil engineering course, as already discussed in studies carried out by Roncaglio, Battisti and Nehring (2021a, 2021b, 2021c), this concept is mobilized in several specific course topics.

In addition, such studies present a range of conceptual relationships that articulate the vector concept to a series of situations in which it is needed to analyze, discuss, and solve problems in civil engineering. The meaning engineering students give to vectors enables them to establish relationships, articulating the concept to situations in their professional field and allowing them to appropriate significant cognitive tools. This allows them to develop competencies and skills that can become a differential in the educational process and professional performance.

Thus, in this writing, we aim to identify and analyze needs and reasons for the meaning of vectors in civil engineering professionals, delimited from the following question: What are the necessary confrontations in engineers' education, considering the conceptual meaning of vectors for a professional performance, to contemplate the indications proposed by the DCN?

Methodological procedures

This study employs a qualitative research methodology, focusing on a case study of a university that has been offering a civil engineering course for over 30 years. The data produced consider a questionnaire sent to professionals in the civil engineering area and a semi-structured interview with civil engineering students. All participants in this study are current or former students of the educational institution where the primary researcher is pursuing her doctoral studies. Furthermore, the research advisors are faculty members specializing in mathematics. Thus, the selection of this institution was not intentional. The questionnaire was organized via a Google form and emailed to all graduates registered in the institution’s egress program since 2015. The responsibility for keeping the data (e-mail address and telephone) updated in the program rests with the graduates; many forwarded e-mails were outdated and ended up returning to their senders. The questionnaire was emailed to 387 graduates, out of which 30 responded. One respondent chose not to participate in the survey, resulting in 29 participants who completed and returned the questionnaire. This questionnaire was open for 15 days. Graduates who agreed to participate in the research did so by agreeing to the consent form sent along with the questionnaire.

The questionnaire consisted of three sections: one with the purpose of the research and the consent form with the possibility of accepting or not participating in the research; a second session introducing the graduate, with name, e-mail, year of graduation and if he/she is working in the area of training; and the third section asked the graduates’ field and time in the activity. It also presented two images representing situations related to the engineer’s performance, in which the graduates were asked about which concepts of mathematics, physics and engineering could be used to explain and/or solve the presented situations.

Figure 1 below shows the images presented to the graduates.

Figure 1.

Images presented to graduates (Research production)

The second movement for data production included interviewing students in training who were enrolled in the 8th semester of the course and had already taken the topics: Analytical Geometry and Vectors, Physics I, General Mechanics I, Strength of Materials I, Structural Analysis I, Hydraulics, Soil Mechanics I, Phenomena of Transport, Reinforced Concrete Structures I, Steel Structure, Foundations and Wood Structure, that is, subjects that had already been identified and that mobilize the vector concept. Based on these criteria, a previous survey with academics was carried out with the assistance of the course secretariat. The students were invited through contact via WhatsApp in groups of topics, through individual contact by a scientific initiation scholarship holder and also by an engineering student who participates in a research project of the advisors.

The interview was conducted via Google Meet. The link was created and forwarded to the WhatsApp groups of the subjects/topics. The students who agreed to participate in the survey, five in total, signed the informed consent form. The interview was recorded on video, transcribed and carried out collectively among the students. The interview was divided into two moments: first, the students were asked about how the vector concept had been presented to them, the way it was worked in the classroom, whether this concept was mobilized in different specific topics of the course, whether they established a relationship between the vector concept and the topics already taken, and whether they managed to appropriate the concept. After that, three images of situations in the context of engineering were presented (Figure 2). Students were asked what they saw and what concepts were involved in the situations. They were also requested to solve the problem presented in the images.

Figure 2.

Images presented to students (Research production)

The images presented to graduates and students were different; however, the context of both shows the relationship between the subjects in the professional field of civil engineering,i.e., the images represent situations to be experienced in professional practice. To understand the images, professionals must consider concepts from mathematics, physics and engineering to perform a technical analysis of the conceptual field. These concepts will enable an in-depth understanding and/or analysis of the images.

During the writing, the subjects are identified as E1 through E5, in the case of students in the training process and the graduates are identified as Eg1 through Eg29.

Data analysis is based on the methodological framework of discursive textual analysis (DTA) by Moraes and Galiazzi (2016). DTA is structured in three stages: unitization, categorization, and metatext. The first stage of the DTA, unitization, is the initial movement of the analysis, which requires a careful and deep reading of the data produced. It is marked by disorder, the moment of data deconstruction, in which the researcher, when analyzing the data, performs several interpretations. From this movement, the units of meaning emerge.

The analyses considering the instruments produced allowed us to define the units of meaning, the categorization, the second stage of the DTA, marked by a constructive movement.

> Categorization is a moment of synthesis and organization of information related to the investigated phenomena. These elaborations are the researcher's theorizations, produced from the implicit theoretical perspectives of the research subjects and the researcher, always in dialogue with other theorists. They require continuous improvement, adequacy, and refinement during the process of analysis and written production. The categorization process constitutes a research movement strategy that goes from the empirical to the abstract, from the data collected to the theories constructed or reconstructed by the researcher. (Moraes; Galiazzi, 2016, p. 112-113)

Table 1 presents the units of meaning and categories considering the DTA framework and, to examine better the research intentionality, the propositions defined from the analyzed *corpus*. The proposition is structured by capturing the emergent in which the new understanding is communicated and validated, considering the empirical/theory relationship. It is the researcher's construction of a metatext, making remarks about the categories of analysis he built and the units of meaning identified in the data produced. It is a writing that seeks to present clearly and objectively the researcher's understanding of the data analysis related to the foundation that sustains the study.

Table 1.

Units of meaning, categories, and propositions (Research production)

Units of meaning	**Categories**	**Propositions**
- Theoretical part and exercises. - Bunch of exercises. - Passed the concept and then examples. - Application in the area you are studying. - Application in practice, in the area itself.	- Mathematical concepts and their approach in topics of the civil engineering course.	- The educational activity as a central point in the relationship between the subject and the engineer's professional development.
Fields of action of the civil engineer - Construction works. - Structural calculation. - Elaboration and execution of technical project. - Paving and infrastructure. - Supervision, coordination, and technical guidance. **Concepts studied during the civil engineering course** - Materials of construction. - Sanitation. - Acting forces. - Materials strength. - Tensions, deformations, and displacements. - Efforts and moments. - Static mechanics. - Calculation of structures. - Trigonometry. - Cartesian coordinates. - Reinforced concrete structures. - Bending moment.	- Field of professional performance of the civil engineer, their needs and challenges.	- The engineer's role requires an interlocution between mathematics, physics, and engineering concepts and can potentially create reasons for students to want to learn.

In the next items, we will bring the discussions, understandings and foundations of the propositions presented, considering the problem presented for this production in light of the theoretical framework and data analysis.

The educational activity as a central point in the relationship between the subject and the engineer's professional development

Based on the references provided, we define an educational activity as encompassing all facets of scientific knowledge's teaching and learning process facilitated by educational institutions and various agents. A class development, for example, is an educational activity, since its accomplishment needs organization around intentionality with clear and well-defined objectives. It consists of a conscious and interactive action, open to questioning and dialogue between the subjects involved to enable the institution of processes that aim, among others, at the meaning of concepts. Bernardes (2011, p. 324) contributes to the discussion by pointing out that:

> The actions and operations carried out in the educational activity necessarily aim to relate the objectives of education with its purpose. In other words, they meet the need for communication to overcome teachers' and students' particular conditions, enhanced by the appropriation of historically elaborated human cultural production.
> [...]
> Under these conditions, we understand educational activity as a human activity whose purpose is the appropriation of human cultural production by the subjects in interpersonal relationships through education in a broad way, whether between family members or in a social group with a shared purpose. Thus, education, in general, is understood as a means whose purpose is to appropriate and enhance what is universal in individual subjects. It aims to create conditions for subjects' appropriation of everything that belongs to the human race, constituted from the historical movement of hominization and humanization. We understand the educational processes as mediators of human production in the relations between the human race and the active subjects belonging to a society.

The educational activity, then, is developed not only by the teacher but also by the relationships they establish with the students and scientific concepts. However, the teacher is fundamental in this process, as they are responsible for transforming historically constructed scientific knowledge into knowledge to be taught, that is, into teachable knowledge. Being a teacher requires mastering scientific knowledge in their area of expertise, being able to make their pedagogical activity meaningful without losing the scientific rigor of knowledge and having the sensitivity to perceive students, to consider their experiences and prior knowledge and how they learn. In addition, it is important to highlight that being aware of educational purposes and mastering scientific concepts, curricular, didactic and pedagogical aspects allows the teacher to develop teaching based on a conceptual system, articulating different notions and allowing the relationship and mobilization in different contexts.

An educational model based on actions rather than activities tends to promote alienation, given that personal meaning is not associated with social significance (education). Students' focus is often not on the subject of the activity, which is studying. This means that the motive and the object are not related, because there are two roles to be developed at school: that of the teacher, as an agent of education, whose main activity consists of teaching, and that of the student, the target of education, that of studying. (Grymuza; Rêgo, 2014, p. 129-130)

The teacher's teaching activity, when assumed as the core of the educational activity, presents two dimensions: one of teacher education, by organizing and reorganizing their actions when proposing their classes; and the other of the students, by placing themselves in the movement of apprehension of the scientific concepts already produced and, through them, to develop necessary competencies for their professional performance. Therefore, the educational activity must be developed in such a way as to allow students' appropriation of concepts, expanding the levels of meaning through the attribution and negotiation of meanings.

Formal education is a means organized by society to satisfy the need of new generations to appropriate the knowledge already produced. This interpretation suggests that work, a purposeful human endeavor, inherently creates such a necessity. Through this work, teachers impart education as part of their professional activities, which is an integral component of a social and collective organization. Therefore, teaching, as a product of physical and mental activity, can be considered an objectification of the teacher's work. (Battisti; Nehring, 2019, p. 545)

In this context, to meet the objective and guiding question of the investigation presented in this writing, we bring fragments of the semi-structured interview carried out with students. The questions addressed several aspects related to their participation in the educational activity. One of the questions was related to the concept of vectors in the course topics. At first, the students soon identified the subject in which the concept is introduced in the course, as can be seen in Table 2.

Table 2.

Responses to how the vector concept was introduced to students (Research production)

(Line 1) E1: *I forgot the name of that one. It's Analytical Geometry and Vectors, right?* ***(Line 2) E2:*** *In geometry classes.* ***(Line 3) E3:*** *It's Analytical Geometry and Vectors. But I think it's first, second semester. I think it is* ***(Line 4)*** *very early, the vectors.* ***(Line 5) E4:*** *That's it. Me too.* ***(Line 6) E1:*** *I remember doing it, I think, in the first [semester].* ***(Line 7) E5:*** *For me, it was the second, I think. It was Analytical Geometry and Vectors.* ***(Line 8) E1:*** *Yeah, I think it was the first time it appeared.*

.

The students soon identified the topic of Analytical Geometry and Vectors as the subject that works or introduces vectors in the course. These speeches demonstrate that students relate the name of the subject or remember activities carried out in it. After these answers, new questions were asked. One of the questions was how the concept had been worked on in the topic, whether it was through a problem situation, a definition or another form. Table 3 below presents the students' responses to this question.

Table 3.

How students remember the presentation of vectors (Research production)

(Line 1) E5: *The teacher gave the concept, which I remember, and then, examples. Like, in the form of*
(Line 2) *examples.*
(Line 3) E4: *I did it with XXXX, he gave me the theory and I don't forget that he drew the 3D*
(Line 4) *in the corner of the wall. Like, xy z. It's the thing I remember most from Analytical Geometry.*
(Line 5) *But it was the theoretical concept and the practice, he passed as he could. Because it's kind of complex*
(Line 6) *list the vector practically.*
(Line 7) E5: *I remember this drawing xy z. I remember that Prof. XXXX passed too. That I*
(Line 8) *remember.*
(Line 9) E1: *I remember doing this article with Prof. XXX, and if I'm not mistaken, it was either on the*
(Line 10) *board or it was on the slides. I can't remember...*
(Line 11) E3: *Yes. We were classmates, right?*
(Line 12) E1: *I think so. But it was a bunch of exercises.*
(Line 13) E5: *For us, XXXX would print the sheets and not show slides or anything. I think*
(Line 14) *that was only oral presentation. That I remember.*
(Line 15) E4: *I did it with the XXXXX and it was a handout. Then he gave exercises and explained.*

Students' responses mark the way teaching is generally developed in HEIs, an approach already pointed out in Roncaglio, Battisti, and Nehring (2021a, p. 40):

> One of the most common approaches in the teaching process in higher education, especially in exact sciences, has been the presentation of the definition of the content to be taught and the teacher's explanation about it, some examples that are mostly solved together with the students so that they can follow step by step the treatments the teacher uses to find a solution, and lists of exercises as application and/or systematization of the studied concepts.

This form of teaching developed in HEIs, mainly considering the area of exact sciences, has been a "natural" practice and the students themselves already consider that teaching in these institutions/areas is –or should be– like this. We see this in E4's speech on Lines 5 and 6 of Table 3. This way of teaching has already become a "standard" in institutions, and, when performed without including the student in the pedagogical activity, without providing processes of meaning, it can become an empty and mechanical process, not allowing the production of meaning by those who need to appropriate such knowledge. Luzzi and Philipp Jr. (2011, p. 124) contribute to this discussion by pointing out that:

> Students of that future need much more than repetitive information and techniques. It is necessary to develop metacognitive, complex thinking styles, open to uncertainties and constant changes to deal with a world in constant transformation. They need to learn to learn and learn to think.

That is, much more is needed than presenting definitions, solving examples, and making lists of exercises. It is necessary to make the teaching process meaningful, enabling students to establish relationships with already elaborated knowledge, thus, between the concepts so that they are actually inserted in the educational activity and expand the levels of meaning of the approached concepts. We agree with Luzzi and Philipp Jr. (2011, p. 140) when they point out that:

> Higher education cannot go on ignoring the profound social changes that are taking place at a dizzying pace in this historic moment. We must understand the professional profile that the current reality demands have changed. Today, it is more important to train professionals who can elaborate creatively autonomous solutions that learn to learn and think, that learn to capture the complex web of interrelationships present in the various phenomena of the object of study. For this, education must also change, using as a basis for its transformation the approach to the complexity of the teaching and learning process and the context that situates, means, and determines it through a multi-referenced interdisciplinary vision. Therefore, it is urgent to move forward.

The educational activity needs to be rethought to consider the complexity of society and, thus, of the teaching and learning processes. As companies look for professionals who develop their professional practice with quality, with critical and creative skills, who know how to face different and complex problems and seek efficient and sustainable solutions, educational institutions also need professionals who are open to changes and value the quality of their practice. The curriculum of an undergraduate course consists of several disciplines planned and organized to provide complete and quality professional training. They are subjects that, together, in an articulated way, constituting a unit, allow the appropriation of an essential theoretical and practical framework in the training process. It is on:

> [...] mediation of teaching in the classroom that formal and systematic learning takes place and their contents acquire life when they are assumed as determined elements of knowledge achieved in the understanding shared by teachers and students, subjects/agents of their own teach and learn. The students, with their knowledge of life and the teacher and the knowledge of their own lived experience, with organized and systematized knowledge, under the school form and according to it, in culture and science. (Marques, 2006, p. 111)

It is important that, besides having relationships between the different topics, students perceive these relationships and understand and mobilize the concepts in the context of professional practice through educational activity. In other words, there is an urgent need for articulation between concepts based on joint labor between disciplines and not their isolation, promoting interdisciplinary approaches that consider the complexity of teaching and learning processes.

> [...] interdisciplinarity implies a process of interrelation of processes, knowledge, and practices that transcend scientific disciplines and their possible articulations. A process that, from an educational standpoint, surpasses and transcends curricular contents, permeating educational practices as a whole, in a kind of multi-referenced approach.
> An approach that articulates theories from different fields of knowledge makes it possible to reveal the complexity of the teaching and learning process, generating differentiated didactics. Teaching that, as a theory of practice, considers the classroom a space where specific and unique groups, tasks, research, communication, and power relations are formed, reflecting and dramatizing the configurations of the institutional dynamics that permeate it. A space where relationships with knowledge are organized and where tensions, individual desires, social representations, values, beliefs, and motivations intersect. (Luzzi; Philipp Jr., 2011, p. 126)

In this sense, another question proposed during the interview was about mobilizing the vector concept in other course topics. Table 4 below presents the students' responses.

Table 4.
Mobilization of the vector concept in other disciplines of the course
Source: Research production.

(Line 1) E5: *Now in Steel [topic], we have the vectors.*
(Line 2) E3: *Yeah, but before that comes Physics.*
(Line 3) E4: *Physics and one Calculus subject too.*
(Line 4) E1: *Linear Algebra, isn't there a little bit? I don't think so.*
(Line 5) E4: *Yes, there is, too.*
(Line 6) E1: *Yeah, there are vectors in Linear Algebra.*
(Line 7) E4: *And in one of the Calculus classes, I don't know whether 1 or 2. I think it's the 2, that has the temperature business, right?*

The analysis of students' answers about the mobilization of the vectors in other disciplines of the engineering course, besides Analytical Geometry and Vectors, which introduces the concept, makes it possible to perceive that the students cite two more topics related to mathematics, physics and a specific subject of the course, Steel Structures. However, in studies already developed by Roncaglio, Battisti, and Nehring (2021c), we identified several subjects that use vectors as tools to represent or solve specific situations of civil engineering, such as, for example, General Mechanics I, Strength of Materials I or Structural Analysis I, among others. It is worth remembering that the students who participated in the interview were attending the 8th semester. Therefore, they had already taken specific course subjects that consider the mobilization of the vector concept.

> The relationships established with the concepts are part of the vector conceptual system that makes it possible to mobilize it in different situations and other areas of knowledge. Mathematics has a language that enables articulating different registers of semiotic representation and physics uses this language. For example, the vector language to represent phenomena such as force, displacement, velocity and acceleration, and magnitudes that need a module, a sense and a direction to be defined. The vector is a

> mathematical concept used as a language by physics and engineering to describe phenomena that, in order to be defined, require a direction, a direction and a module (intensity), generally used to describe a displacement or situations involving vector magnitudes, such as the vector quantity force. A vector magnitude is defined by its sense, module, and direction –elements that constitute the vector, which need to be given meaning in the teaching and learning process and which mark the delimiter of the scalar magnitude and the need for a vector magnitude. (Roncaglio; Battisti; Nehring, 2021b)

Another question asked in the interview was about how the notion of vectors was worked on in the Analytical Geometry and Vectors topic and whether it contributed to the mobilization of the concept in other subjects/topics of the course. The answers were:

Table 5.

Articulating concepts (Research production)

(Line 1) E3: *It's just that actually, in terms of vectors, you can't teach a class, I believe,*
(Line 2) *with practice. Do you understand? It was more the theoretical part and exercise of calculation and situations. Like,*
(Line 3) *I would set up the story there and calculated.*
(Line 4) E4: *That's exactly what he said. I totally agree, with the same words... I*
(Line 5) *I think it's complex to explain vectors in a practical, visible way like that. I think it is complex. The*
(Line 6) *easiest [thing] is the sum issue, of vectors that you can observe, but otherwise... Kind of*
(Line 7) *vector concept, I think complex.*
(Line 8) E3: *In fact, you can consider an ascending [line]. Let's assume: Geometry, you*
(Line 9) *learned that as a value. And then in physics you learn by applying some*
(Line 10) *velocity in a car, you apply another vector. So this was a crescent of values of*
(Line 11) *concept that helped, in a way, solve the calculations.*
(Line 12) E1: *And it depends on the teacher. Because sometimes, we go through a topic in which such and such*
(Line 13) *teacher didn't even say to us, "Look, this has to do with vectors. This right here is a vector but*
(Line 14) *you are not seeing it as a vector". So there could be a lot of things that we applied*
(Line 15) *in engineering that has to do with vectors but we don't even know.*
(Line 16) E5: *And that because it is a knowledge of the previous subjects, from the beginning, even the teachers*
(Line 17) *sometimes pass by, they don't explain clearly what it is.*

The students' responses point to the isolation of subjects in the curriculum. In the considered context, it is impossible to identify dialogue/relationship between the subjects and this, unfortunately, makes the students not perceive the connection between the concepts being apprehended so that the training process expands the conditions of professional performance. Here, again, the way teaching is presented in higher education appears when E3 tries to explain how the vector concept was worked on in the discipline of Analytical Geometry and Vectors, Lines 2 and 3. E4 understands that the vector concept is complex, but points out one of the operations with vectors as "easy" to understand, Lines 4 to 7.

The development E4 points out in Lines 6 and 7 is the sum of vectors considering the geometric representation of vectors when this operation is performed through the law of the parallelogram or the law of the polygon. These are mathematical procedures for calculating the sum when the vectors are in the geometric representation in the figural register. This operation is used in several disciplines of the engineering course to calculate the addition of forces. Even so, students cannot relate vectors with the specific topics of the course, as we saw in Table 4.

In Lines 16 and 17, E5 points to the isolation of subjects that make up the curriculum. The vector concept is a fundamental mathematical tool mobilized in different topics, i.e., it is fundamental knowledge in several topics and essential for a subject's professional formation process. When trying to exemplify the relationship between concepts and mobilization in other school subjects, E3 relates vectors to a scalar quantity, Lines 8 to 11. Here, the student associates the scalar magnitude velocity with a vector magnitude, which indicates that he has not appropriated the vector concept as representative of a vector magnitude, which consequently causes him not to recognize the elements of the constitution of the vectors and the difference between a scalar magnitude and a vector magnitude. Furthermore, if the student cannot appropriate the vector concept, he will not be able to mobilize it in other disciplines that need it.

This difficulty presented by E3 may reflect the work developed in the GAV discipline, in which vectors are treated only considering the mathematical context and thus limiting their exploration in other situations, such as, for example, in the representation of situations involving the concept of strength. Exploration in other contexts, especially in situations where the force concept is applied - a concept mobilized in several topics of the engineering curriculum - can broaden the understanding of vectors beyond the mathematical perspective, contributing to the production of understanding of specific concepts in engineering courses. This idea is foreseen in the DCN (Brasil, 2019) when indicating that the student must be able to model physical and chemical phenomena and systems using, among others, mathematical tools.

Another question involves the approach given to the concept of vectors and its relationship with concepts from other areas of knowledge. From students' standpoint, it would have been significant if an application situation had been considered in the context of engineering in the introduction of the study of the concept of vectors.

Table 6.

Approach given to the vector concept (Research production)

(Line 1) E1: *We have everything very ready nowadays, I think both in software, that we*
(Line 2) *use to do as many projects as [unintelligible], all that part. We end up not*
(Line 3) *seeing so much because now it is very practical. We do practically nothing by hand, nothing*
(Line 4) *too calculated, we calculate. So I think some teachers end up not*
(Line 5) *addressing this, a bit because there is no time and a bit because we won't need to*
(Line 6) *use it so much, as well as other subjects that we learn at the beginning of college and*
(Line 7) *in the end, we know that we needed to learn that, but we don't apply it*
(Line 8) *in those subject matters, you know?*
(Line 9) E3: *And there is also the issue of passing on the content, for example, every student always likes it,*
(Line 10) *that you are learning the content, but it is good for the teacher to bring a practice that is*
(Line 11) *really from our course. Okay, there's physics, and mathematics, but as we said,*
(Line 12) *average velocity, it is not related to our course. So every student seeks*
(Line 13) *a form of application to what will be in the future.*
(Line 14) E5: *And sometimes it is very difficult to relate something. Because, for example, who didn't*
(Line 15) *make concrete still won't know what to relate to, or other topics where we use*
(Line 16) *vectors. It's really hard to make a connection.*
(Line 17) E3: *It's easier to remember because you relate.*
(Line 18) E1: *I always say this, that actually we have these subjects that are for the*
(Line 19) *engineering, at the beginning, so if they are for engineering, they should bring not only*
(Line 20) *mathematics, they should mix the two things, because many times we had*
(Line 21) *subjects that were pure mathematics. Then I know that XXX, she asked for some works with*
(Line 22) *application in the area you're studying, I didn't do any topics with her, and my actual*
(Line 23) *teacher, I didn't have that. So people came up to me with "oh, I did*
(Line 24) *a work, with derivatives and integrals", I was like, "okay, but where did you apply it?"*
(Line 25) *because I couldn't see an example. And we use this a lot in concrete,*
(Line 26) *integrals and derivatives, we know we have them and when the teacher says it, it's really ours.*
(Line 27) E5: *It was an area calculation that we had in this work with XXXX.*
(Line 28) E4: *Exactly, that is it. As it is about the common core that you mentioned there, these matters, the*
(Line 29) *teacher conveys the concept in a general way, for us he didn't apply, like, these subjects*
(Line 30) *that have to do with electrical engineering, or mechanics, not to apply in just one, and some*
(Line 31) *students will feel like, ah, it didn't apply in my field. In this case, with XXXX, you*
(Line 32) *apply the derivatives and integrals in a work in your area. I think that'd be good.*
(Line 33) *a visible application, in practice, in the area itself.*
(Line 34) E2: *I agree. It is even something that the university is proposing now, but these*
(Line 35) *more general topicss at the beginning of the course, it's not cool, the student gets really lost in this*
(Line 36) *situation. They end up acquiring minimal knowledge of what they can list from their course*
(Line 37)*, because they enter and have hope -hope is not the right word- but you think that*
(Line 38) *you're already going to run into the specific knowledge of your course, and it ends up that you only have*
(Line 39) *contact with this from the 5th, 6th semester, and this is very bad.*

The analysis of the responses presented in Table 6 highlights aspects such as technological advances and how this influences all sectors, including education and the role of teachers in this new scenario. In E1's response, there are indications of this fact in Lines 1 to 4. Another aspect that we can highlight in the analysis of students' answers concerns the isolation of the subjects and the lack of connection between the concepts, especially the subjects, which do not work with situations of application of the concepts in the students' training area, that is, in the context of the professional area or field of work of the civil engineer. E1, in Lines 18 to

26, indicates the fact, unveiling a weakness in the teaching process that can generate a problem for learning in higher education.

In addition, it marks the need to work with the articulation between theoretical knowledge, practice, and the professional context in the professional training of the learners. The questions raised here point directly to the teacher's work or the educational activity, in which the teacher has a fundamental role in educating. The teacher's action, or the way they develop their teaching, interferes significantly with the process of appropriation of concepts by students.

> Teaching that, as a theory of practice, considers the classroom a space where specific and unique groups, tasks, research, communication, and power relations are formed, reflecting and dramatizing the configurations of the institutional dynamics that permeate it. A space where relationships with knowledge are organized and where tensions, individual desires, social representations, values, beliefs, and motivations intersect. (Luzzi; Philipp Jr., 2011, p. 126)

We understand that considering situations and/or contexts related to the engineer's field of activity in the educational activity during the training process can expand the possibilities of meaning of the concepts and the establishment of relationships between the concepts of the different areas, such as, for example, mathematics, physics and engineering, as is the case of the civil engineering course. In this sense:

> [...] effective teaching can help in the eventualities of the construction of meanings by the students; therefore, teaching is leading the student to understand something, an object of reality or content. [...] The teacher's approach in the classroom will directly interfere with student learning. (Grymuza; Rêgo, 2014, p. 132)

In the formative process, these articulations between different concepts should occur, providing future professionals with consistent cognitive tools to analyze different contexts, outline strategies, and find solutions. We understand that this articulation takes place in and through the educational activity; it is in the teacher's work in the classroom that these articulations must occur. The student alone cannot make such connections. Therefore, the student must engage in study activities. The teacher organizes teaching in such a way as to enable the student to engage in study activities.

The role of the engineer requires an interlocution between mathematics, physics, and engineering concepts and can potentially create reasons for students to want to learn

Discussions regarding this proposition consider, in particular, the analysis carried out by students and graduates of images that represent situations in the professional context. Three images (Figure 1) were presented to the students so that they could analyze and indicate mathematics, physics and engineering concepts that could be related to facing those situations. In the questionnaire sent to the graduates, images (Figure 2) of the professional context were also presented, and they were asked, based on their understanding, their professional experience, to indicate which mathematics, physics, and engineering concepts were involved in coping with the situations presented. Here, to carry out a more in-depth analysis of the situations, students must mobilize concepts that were -or should have been- learned throughout their training, and an effective relationship between them. The articulation between mathematics, physics, and engineering concepts allows a technical analysis of the situations presented, which portrays the contexts of the professional area. In Table 7, we present the responses of students and graduates.

Table 7.

Analysis of students and graduates in relation to images of the professional context

Source: Research production.

	Students	**Graduates**
Mathematics		Trigonometry, structure calculation, algebra, geometry, integral and differential calculus, Cartesian coordinates, Pythagorean theorem, concept of proportionality.
Physics	Vector force, friction force, gravity, weight force.	Acting forces, loads and overloads, bending moment, tension, deformation, displacement, bending, static, torsion, traction, efforts, static mechanics, the balance of rotation, and center of gravity.
Engineering	Support beam, distributed load.	Material resistance, structural calculation, dimensioning of reinforced concrete structures, traction, shear moment, beams, structural mechanics, foundations, planning and execution of works, settlement, soil survey, and expert evaluation of structures.

In the students' answers, the vector concept appears linked to that of force, "force vector", which may show evidence of a possible understanding of the force concept, when it refers to a vector magnitude, definitions present in the books of the basic bibliography of the discipline of Physics I, one of the subject matters that are part of the common core of the engineering courses, which were analyzed in Roncaglio, Battisti, and Nehring (2021b). In addition, another possibility for understanding the "vector force" answer is that the student is suggesting the vector as a mathematical concept that represents force.

Regarding the concepts of the professional area, students could make two connections only: one related to a distributed load and the other related to a support beam. In the students' analyses in the formative process, considering that they are in the 8th semester of the course, the articulation between mathematics, physics, and engineering concepts did not occur, and it was not possible to identify mobilizations of concepts from the specific area of engineering. The lack of arguments against the contexts presented may indicate a fragile level of meaning of the concepts and the lack of articulation between them.

In the analysis carried out by the students, mathematics does not “appear” at all. That is, they do not present mathematical concepts in their analyses. This fact is a strong indication that students did not understand the concept of vectors when working in the first semester of the course, which would justify their lack of perception of the mobilization of the vector concept and other mathematical concepts in their analyses that approached the situations presented in the images. Table 7, previously exposed, brings the speech of a student who relates vectors and velocity, remembering that velocity is a scalar, not a vector magnitude. This fact indicates the non-significance of the vector concept and, consequently, its non-relationship with the force vector magnitude discussed in physics and the specific engineering course topics.

Table 7 reveals that the graduates present a relationship between mathematics, physics, and engineering courses that are higher than the list of concepts that the students could present when faced with situations related to the professional context. Based on the analysis of the situations, the graduates relate the mathematics, physics, and engineering concepts to the contexts presented in the images. In the graduates' answers, mathematics appears; that is, they are able to perceive some mathematical concepts present in the profession. However, the concept of vectors does not appear in the answers, even though they cite concepts such as geometry, Cartesian coordinates, and trigonometry, concepts that may be related to vectors. This fact may be related to the fragility of the teaching and learning process the students indicated, considering isolated topics, pure mathematics subjects, and failing to identify the application of mathematical concepts in engineering courses, including the vector concept.

The graduates' answers highlight some of the relationships between mathematics, physics, and engineering areas that are fundamental for the engineer's performance in the job market. Professional practice may have had a powerful influence on the graduates' responses. Unlike the students who, in the training process, pointed out few or no concepts, as is the case of mathematics, a fact that may indicate gaps in connections between theory and practice.

The articulation between the theoretical and practical concepts discussed in the subject matters that make up the curricula of undergraduate courses, especially the civil engineering course, is the first condition for the teaching and learning process to become meaningful and capable of enabling the development of competencies and skills necessary for professional performance in a globalized and complex world in which we live. The document supporting the implementation of the DCN of engineering courses, in Article 6, item 2, contributes by highlighting: “Activities that simultaneously articulate the **theory, practice, and context of application**, necessary for the development of competencies, established in the graduate’s profile, including extension actions and company-school integration” (CNI, 2020, p. 26, emphasis added).

If we consider Figure 1, presented earlier, for example, however much the image allows a superficial analysis of the situation, several aspects may be raised. A pathology is observed, a problem in the bridge that may be related to the pillar or the beams forming the bridge. Finding the causes of the pathology observed requires a precise analysis of several aspects involved in the bridge, whether related to the foundation, structure, dimensioning considering the load and/or support effort, and the flow of the bridge. To this end, precise examination of the structure, pillars, beams are needed, involving the analysis of the amount and dimension of steel, concrete strength, effort, and support load, sizing, among other specific concepts in the area of engineering that can help us calculate the extension of the problem, its origin/cause, and its solution.

Such engineering concepts involve the concept of force, a physical concept, a vector magnitude, fundamental in physics and the basis of the study of mechanics. A concept that can only be mobilized through geometric or algebraic representation, that is, through the vectors. It is through the geometric and/or algebraic representation of situations involving force that it is possible to explore, analyze, define variables, find the problem and/or point out solutions. Therefore, the concept of vectors is essential in this process; it is the concept that allows the representation of situations involving force.

In this context, we understand that the articulation between theory and practice and the interlocution between mathematics, physics, and engineering concepts are crucial to creating reasons for students to want to learn. Problematizations that consider professional practice contexts can generate the need to mobilize concepts and, thus, create reasons to learn. In addition, such contexts allow the production of meanings and the insertion of new concepts into a network already being elaborated by the students. Grymuza and Rêgo (2014, p. 130) contribute to the discussion by pointing out that:

> The teacher's activity should be focused on the needs of their students so that they can build a system of operations aimed at an action that motivates them to study and, consequently, to learn, giving them favorable conditions for teaching, transforming the "stimuli-motives" into "meaning-forming motives". Thus, the student's object is defined in the act of studying, and the teacher's object is reached.

The exploration of situations in the professional context generates needs in students, among which the appropriation of concepts, especially in subject matters considered fundamental, as is the case of mathematics subjects. Situations in the professional context are relevant elements to be considered in the organization of teaching so that they generate needs and, thus, the creation of motives on the students' part. As the students point out, these topics are *"pure mathematics"*; that is, they do not explore mathematical concepts in professional practice situations. E2 contributes to the discussion when he says: *"*[...] Because he (the student) comes in and has hope. Hope is not the right word, but you think you're going to come face to face with the specific knowledge of your course, and it turns out that you only have contact with it from the 5th, 6th semester onwards and that's really bad". E3 confirms: "But it is good for the teacher to bring a practice that is really part of our course". In this regard:

> [...] interaction between mathematical contents and between them and other school subjects and the social context is necessary so that the purpose of the school is not lost. In this sense, the activity is the main point, as it will ensure this interaction occurs. Only through activity and awareness will practice in the classroom, in the desired molds of insertion and social integration, be possible. (Grymuza; Rêgo, 2014, p. 137)

The application and/or mobilization of the concepts in situations of the professional context is a way of giving meaning to the concepts, of making one realize the importance of appropriating this knowledge and of mobilizing in the student the need for a specific knowledge necessary to work in the professional field. The way teaching has been developed, according to the data analyzed in this writing, does not allow the production of meanings by the students. This form of teaching organization promotes students' alienation regarding the learning process, which makes teaching mechanical and does not allow the meaning of concepts, only the improvement of resolving techniques by manipulating formulas. Therefore, there is no potential to put students in study activity, as the reason and object of the activity are not related. The student here only mimics techniques and/or procedures in which the teacher presents the resolution of issues that do not require complex thinking.

Final Considerations

In this production, the research problem was: What are the necessary confrontations in the formation of the engineer, considering the conceptual significance of vectors for a professional performance to contemplate the indications proposed by the DCN? For that, we considered two analysis instruments: a questionnaire sent via Google Form to civil engineering graduates and an interview carried out via Google Meet with students attending the 8th semester of that course. The analysis of this material allowed us to construct two propositions. The first, "Educational activity as a central point in the relationship between the subject and the professional development of the engineer", and the second, "Enginners' performance requires an interlocution between mathematics, physics, and engineering concepts and is a potentiator of the creation of motives so that students want to learn", which were based on Leontiev's theory of activity (1978b).

From the analysis, we concluded that the educational activity is the central point in the formation process, not only professionally, but of the subject in general. Also, the way the teaching and learning process occurs directly influences the constitution of the professional, a fact that was evident in the analyses carried out. The students' speeches during the interview mark the way the process happens: *"The teacher passed on the concept, which I remember, and then examples"*, or yet, *"[...] it was a booklet. Then he (the teacher) gave exercises and explained"* and was *"a bunch of exercises"*. Presentation of the definition, examples, and resolution of exercises, that is, the classes follow an organization pattern, and this way of developing teaching, among other aspects, may be responsible for causing the distance between the subjects that make up the curriculum, especially concerning the subjects of the common core, as is the case of the subjects of Mathematics and Physics with the specific ones. This distance between the subjects and, consequently, between the concepts discussed in them, does not consider the complexity of the teaching and learning process, makes it fragile, with gaps, without application and without meaning for the student, that is, this distance does not provoke needs and reasons why students want to learn.

The graduates' analyses of situations/images explain how professional practice requires the mobilization of mathematics, physics and engineering concepts and how much work in the professional field requires that the concepts be worked on in initial training. Therefore, it reinforces our understanding, including what official documents such as the DCN bring, of the development of activities in the training path that combines theory and practice. The professional practice may have strongly influenced the graduates' responses, unlike the students who, in the training process, had few or no concepts when analyzing the situations/images.

In general, we conclude that to face the needs of an education that contemplates the new curriculum guidelines and that allows a formative process with conceptual meaning, it is necessary that the educational activity – and by that, we mean the institution, the PPC of the courses, to the teaching plans and the form of teaching organization – to restructure and consider the new demands of the market, providing a more meaningful teaching process, with articulation between the topics, and the proposition of activities that mobilize the concepts in situations of professional practice.

References

Battisti, I. K.; Nehring, C. M. A formação acadêmica do engenheiro: produto de uma atividade coletiva. **Revista Ibero-Americana de Estudos em Educação**, v. 14, n. 2, p. 543-558, abr./jun. 2019. Disponível em: https://periodicos.fclar.unesp.br/iberoamericana/article/view/11434/8598#info. Acesso em: 20 jan. 2020.

Battisti, I. K.; Nehring, C. M. **Mediações na significação do conceito vetor com tratamento da Geometria Analítica em aulas de Matemática**. 1. ed. Curitiba: Appris, 2020.

Bernardes, M. E. M. Atividade educativa, pensamento e linguagem: contribuições da psicologia histórico-cultural. **Revista Semestral da Associação Brasileira de Psicologia Escolar e Educacional**, v. 15, n. 2, p. 323-332, jul./dez. 2011. Disponível em: https://www.scielo.br/j/pee/a/wDmmMhJ3jTqmKTmrxn87Pxt/?format=pdf&lang=pt. Acesso em: 21 jun. 2021.

Brasil. **Resolução CNE/CES nº 02, de 24 de abril de 2019**. Institui Diretrizes Curriculares Nacionais do Curso de Graduação em Engenharia. Brasília, 2019. Disponível em: https://www.in.gov.br/web/dou/-/resolu%C3%87%C3%83o-n%C2%BA-2-de-24-de-abril-de-2019-85344528. Acesso em: 12 fev. 2021.

Cedro, W. L. **O motivo e a atividade de aprendizagem do professor de Matemática**: uma perspectiva histórico-cultural. 2008. 242f. Tese (Doutorado) – Faculdade de Educação, Universidade de São Paulo, São Paulo, 2008.

CNI – CONSELHO NACIONAL DA INDÚSTRIA. **Documento de apoio à implantação das DCNs do Curso de Graduação em Engenharia**. Brasília: CNI, 2020. Disponível em: https://www.portaldaindustria.com.br/publicacoes/2020/6/documento-de-apoioimplantacao-das-dcns-do-curso-de-graduacao-em-engenharia/. Acesso em: 03 jun. 2021.

Grymuza, A. M. G.; Rêgo, R. G. Teoria da atividade: uma possibilidade no ensino de Matemática. **Revista Temas Em Educação**, V. 23, N. 2, P. 117-138, Jul./Dez. 2014.

Leontiev, A. N. **Actividade, consciência e personalidade**. 1978a. Disponível em: http://www.dominiopublico.gov.br/download/texto/ma000004.pdf. Acesso em: 12 jul. 2017.

Leontiev, A. N. **O desenvolvimento do psiquismo**. Lisboa: Livros Horizontes, 1978b.

Luzzi, D. A.; Philipp JR., A. Interdisciplinaridade, pedagogia e didática da complexidade na formação superior. In: **Interdisciplinaridade em ciência, tecnologia & inovação**. São Paulo: Manole, 2011.

Marques, M. O. **A aprendizagem na mediação social do aprendido e da docência**. 3. ed. rev. Ijuí: Ed. Unijuí, 2006.

Moraes, R.; Galiazzi, M. C. **Análise textual discursiva**. 3. ed. rev. ampl. Ijuí: Ed. Unijuí, 2016.

Moretti, V. D. **Professores de Matemática em atividade de ensino**: uma perspectiva histórico-cultural para a formação docente. 2007. 206f. Tese (Doutorado em Educação: Ensino de Ciências e Matemática) – Universidade de São Paulo, São Paulo, 2007.

Moura, M. O. et al. A atividade orientadora de ensino como unidade entre ensino e aprendizagem. In: MOURA, M. O. (coord.). **A atividade pedagógica na teoria histórico-cultural**. 2. ed. São Paulo: Autores Associados, 2016.

Universidade Regional do Noroeste do Estado do Rio Grande Do Sul. Projeto Pedagógico de Curso de Engenharia Civil. 2017.

Roncaglio, V.; Battisti, I. K.; Nehring, C. M. Aulas de Mecânica Geral I em um Curso de Engenharia e a mobilização do conceito vetor. In: SANTOS, M. P. (org.). **Tópicos especiais no ensino e na aprendizagem de Matemática**. Ponta Grossa: AYA, 2021a.

Roncaglio, V.; Nehring, C. M.; Battisti, I. **Conceito força**: Uma grandeza vetorial mobilizada pela mecânica e base dos cursos de engenharia. Revista Ibero-Americana de Estudos em Educação, Araraquara, v. 18, n. 00, e023010, 2023. e-ISSN: 1982- 5587. DOI: https://doi.org/10.21723/riaee.v18i00.16208

Roncaglio, V.; Battisti, I. K.; Nehring, C. M. Formação do engenheiro: o conceito vetor no programa curricular de um Curso de Engenharia Civil. **Educ. Matem. Pesq.**, v. 23, n. 1, p. 263-296, 2021c. Disponível em: https://revistas.pucsp.br/index.php/emp/article/view/ 49595/pdf. Acesso em: 25 abr. 2021.