Modelagem Computacional na Perspectiva Ciência, Tecnologia e Sociedade: Cenário dos Currículos dos Cursos de Engenharia Mecânica em Instituições Federais.

RESUMO

Novas tecnologias têm incentivado o debate sobre a necessidade de suas integrações no processo de ensino e aprendizagem, permitindo a formação de profissionais aptos para atender as demandas da sociedade e as exigências de um mercado de trabalho cada vez mais dinâmico. Somando-se a isto tem-se o surgimento de um novo perfil de estudantes, com a necessidade de uma educação voltada para a realidade em que estão inseridos. O presente artigo tem como objetivo analisar a presença da modelagem computacional (MC) como metodologia de aprendizagem nos currículos das graduações em engenharia mecânica em Instituições de Ensino Superior públicas federais, buscando verificar a existência de conexões e articulações com a área da Ciência, Tecnologia e Sociedade (CTS). Para tanto foi realizado um estudo descritivo, por meio de uma abordagem qualitativa a partir de uma pesquisa documental. Os resultados permitiram identificar que os conceitos relacionados à MC e à abordagem CTS nos currículos dos cursos de engenharia mecânica não trabalham de maneira integralizada e contínua ao longo do curso. Constatou-se que não houve relação direta entre os conceitos analisados com os desempenhos das instituições em exames de avaliação de curso. Concluiu-se que juntamente com a necessidade de reformulação e adequação dos currículos dos cursos de engenharia mecânica, existe a necessidade de implementação de novas metodologias de avaliações. Buscando uma formação onde se trabalhe de forma articulada os conceitos de MC e o enfoque CTS de forma a atender os anseios dos estudantes e as demandas do mercado atual por profissionais capacitados.

PALAVRAS-CHAVE

Aprendizagem por modelagem. Abordagem multidisciplinar. Conteúdo curriculares. Curso superior de tecnologia.

Computational Modeling from the Science, Technology and Society Perspective: Scenario of the Curriculum of Mechanical Engineering Courses in Federal Institutions

ABSTRACT

New technologies have encouraged the debate on the need for their integration in the teaching and learning process, allowing the training of professionals able to meet the demands of society and the demands of an increasingly dynamic job market. In addition to this, there is the emergence of a new profile of students, with the need for an education focused on the reality in which they are inserted. This article aims to analyze the presence of computational modeling (CM) as a learning methodology in the curricula of undergraduate mechanical engineering in federal public Higher Education Institutions, seeking to verify the existence of connections and articulations with the area of Science, Technology and Society (STS). For this purpose, a descriptive study was carried out, using a qualitative approach based on documental research. The results allowed us to identify that the concepts related to CM and the STSapproach in the curricula of mechanical engineering courses do not work in an integrated and continuous way throughout the course. It was found that there was no direct relationship between the concepts analyzed and the performance of institutions in course evaluation exams. It was concluded that together with the need to reformulate and adapt the curricula of mechanical engineering courses, there is a need to implement new assessment methodologies. Seeking a training where the concepts of CM and the STS approach are worked in an articulated way in order to meet the desires of students and the demands of the current market for qualified professionals.

KEYWORDS

Learning by modeling. Multidisciplinary approach. Curriculum contents. Technology higher education course.

Modelado Computacional desde la Perspectiva Ciencia, Tecnologia y Sociedad: Escenario del Curriculo de las carreras de Ingeniería Mecánica en Instituciones Federales.

RESUMEN
Nuevas tecnologías han propiciado el debate sobre la necesidad de integración del proceso de enseñanza y aprendizaje, permitiendo la formación de profesionales capaces de atender las demandas de la sociedad y las exigencias de un mercado dinámico. A esto se suma el surgimiento de un nuevo perfil de estudiantes, con la necesidad de una educacíon centrada en lá realidad en la que están insertos. Esta investigación tuvo como objetivo analizar la presencia del modelado computacional (MC) como herramienta de aprendizaje en los planes de estudio de los cursos de ingeniería mecánica en instituciones públicas federales, buscando verificar la existencia de conexiones y articulaciones con el área de Ciencia, Tecnología y Sociedad (CTS). Como metodología se realizó un estudio descriptivo, utilizando enfoque cualitativo basado en la investigación documental. Los resultados permitieron identificar que los conceptos relacionados con el MC y el enfoque CTS en los planes de estudio de los cursos de ingeniería mecánica no funcionan de manera integral y continua a lo largo del curso. Se encontró que no existía una relación directa entre los conceptos analizados y el desempeño de las instituciones en los exámenes de evaluación de cursos. Se concluyó que junto con la necesidad de reformular y adecuar los planes de estudio de los cursos de ingeniería mecánica, existe la necesidad de implementar nuevas herramientas de evaluación. Buscando una formación donde se articulen los conceptos de MC y el enfoque CTS con el fin de satisfacer los deseos de los estudiantes y como demandas del mercado actual de profesionales cualificados.

PALABRAS CLAVE

Aprendiendo modelando. Enfoque multidisciplinario. Contenidos curriculares. Curso de tecnología superior.

Introduction

Modern trends in the development of manufacturing industries must impose new requirements on engineers. Due to technological advances in the field of mechanical engineering, one of the main requirements for the successful professional activity of technical specialists is the mastery of tools in the area of information technology (KURENNOV, 2020). Motyl (2017) adds that future mechanical engineers will work and deal with an increasingly globalized, automated, virtualized, networked and flexible world. They will compete for jobs in a global market, so new skills and abilities will become more important.

Following global changes in engineering education, statements from the industry and the Brazilian government indicate that engineering and science education need to prepare students to deal with real-world problems in a realistic social, environmental and financial context (CAVALCANTE, 2018).

In this way, mechanical engineering courses should prepare students for the world of work, providing them with diversified experiences to face the challenges that reality will impose. To assist in this training process, there is a need to use new methodologies that help in the learning process, contributing to allow the student to build their practice, associating it with theory to produce results. This articulation can be made possible by computational modeling (CM), through the representation of conditions of practical reality, investigations through numerical simulations, actions that occur in reality, interacting and modifying system parameters that will lead to different situations and results to meet the desired requirements (KHALIL, 2012).

CM consists of the human activity of building models on the computer using, for this purpose, the representation and simplification resources offered by the machine, with the objective of achieving some specific result (OLIVEIRA, 2015). Therefore, the study of CM acts as a relevant strategy, allowing the improvement of the learning of concepts and the development of new knowledge necessary for the challenges that arise.

The contemporary job market has increasingly demanded qualified professionals with critical capacity for articulated action in the areas of science, technology, society, environment and engineering. Moran (2004) highlights that among the main concerns on the part of students in universities is the format in which the disciplines are taught, which highlights the need for changes that combine the insertion of technology in the teaching-learning process. Faced with this demand, the current change in the profile of students entering undergraduate courses also stands out, whose characteristics are high cognition and low ability to deal with emotional problems (TWENGE, 2017). Thus, the need for changes in the pedagogical practices of undergraduate courses is evident.

Linked to this need for change is Education in STS (Science, Technology and Society), which represents “a change of view”, where technology is no longer focused on distant and fragmented contents based on supposedly neutral and autonomous scientific knowledge and starts to be approached in a contextualized way, based on everyday situations experienced by students (LINSINGEN, 2007).

On the national scene, in April 2019, the National Council of Education (NCE) of the Ministry of Education (MEC) published the new National Curriculum Guidelines for the Undergraduate Course in Engineering (Engineering NCGs) aiming to "meet future demands for more and better engineers" (BRASIL, 2019b), bringing current concepts such as competency-based training, encouraging practical activities for the exercise of creativity and the spirit of innovation, the adoption of active learning methodologies and greater flexibility in the constitution of the curriculum.

The central points presented in the NCGs stimulate the modernization of engineering curricula, emphasizing their relationship with the STS approach, by encouraging studies of social issues involving science and technology, with the proposal of building a teaching focused on the student, valuing social and human aspects, preparing them for life in society and for the job market.

In this context, the present study aims to analyze the scenario of mechanical engineering courses, in federal educational institutions, with regard to the CM approach in the curriculum composition and its articulations with the STS approach, seeking to verify the existence of correlations with their performance in assessment exams for existing courses in Brazil.

Methodology

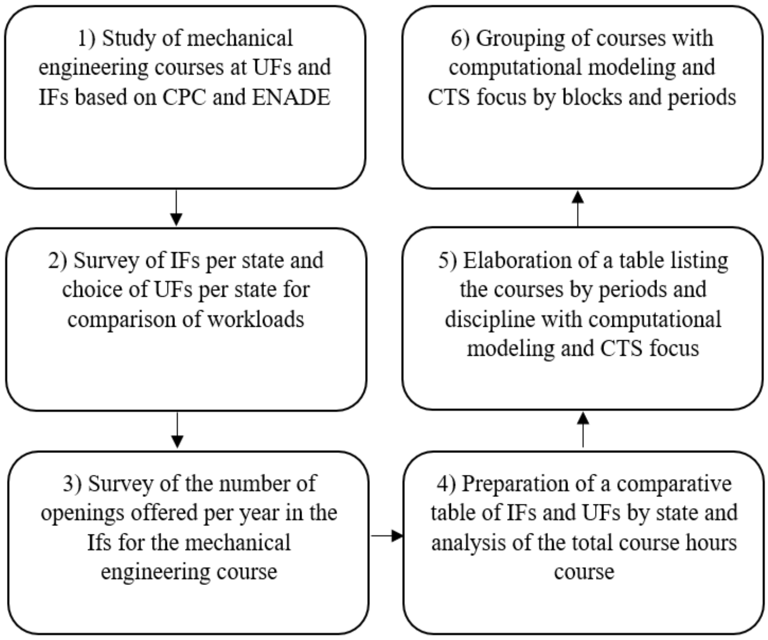
The present study is classified as descriptive, through a qualitative approach based on documental research, as it seeks to identify the characteristics of a certain group or phenomenon, being able to establish relationships between the variables researched (GIL, 2002); and its choice was due to the need to present, in relation to the mechanical engineering courses analyzed, whether CM and the STS theme are included or not in the courses.

The choice of data collection method through document analysis, in which the collection source is restricted to documents, written or not (MARCONI; LAKATOS, 2003), is justified because the method is used when it is intended to complement information obtained through other studies to reveal new aspects of the problem (LUDKE and ANDRÉ, 1986) and in the analysis of the curricular structure the method allows the association of the results obtained with other studies in progress.

The research was developed in three stages: 1) pre-analysis, 2) exploration of the material and 3) data analysis. In the pre-analysis, the ideas were systematized, making them operational in the analysis plan, the research objectives were defined and the selection of documents was carried out from available data sources that provided the necessary information, in this case, the Pedagogical Projects of the Courses (PPCs) consulted on the websites of universities, the Nilo Peçanha platform (NPP), the Synopsis of Higher Education (BRASIL, 2019c) and the Registry of Institutions and Higher Courses System (BRASIL, 2019a).

In the exploration of the material, coding and data decomposition operations were carried out, that is, the raw data were transformed to allow the description of the content characteristics. Data were recorded in spreadsheets for further categorization. In the final stage of treatment, the data obtained were interpreted, in order to make the raw data meaningful and valid (Figure 1).

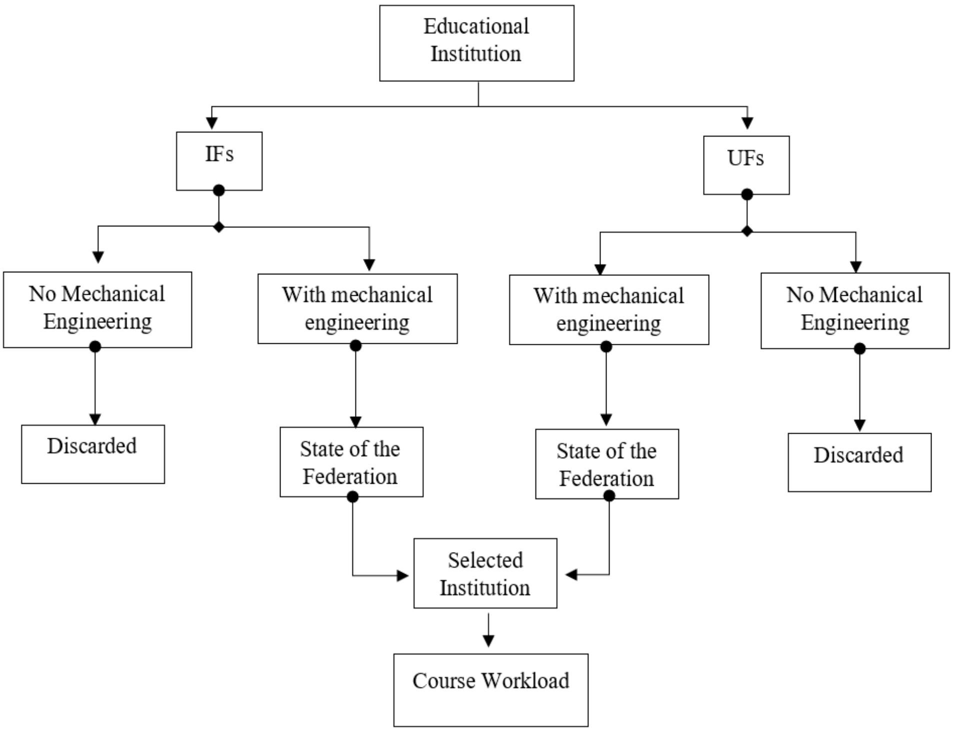
Figure 1. Methodology for interpreting research data



Source: [The authors, 2020]

Initially, a study was carried out with the main information about mechanical engineering courses at Federal Universities (FUs) and Federal Institutes (FIs). Through the analysis of the results of the 2017 evaluation cycle (BRASIL, 2018), it was possible to rank the mechanical engineering courses of the FUs and FIs that obtained higher and lower performances according to the ENADE grade and the Preliminary Course Concept (CPC). At this stage, the FUs that offered mechanical engineering courses with half-yearly workloads were selected for analysis following the criterion of the existence of FIs that offered the mechanical engineering course in the same state of the federation and with a half-yearly workload, in order to facilitate verifications and comparisons (Figure 2).

Figure 2. Methodology for choosing FUs and FIs



Source: [The authors, 2020]

It is noteworthy that only the Federal Technological University of Paraná (UTFPR) was selected without the criterion of the existence of a mechanical engineering course in a Federal Institute in the same state of the federation, as it is the federal institution that offers the most vacancies for the degree in mechanical engineering and has the second highest CPC among federal Higher Education Institutions (HEIs). Subsequently, a survey was carried out on the number of annual vacancies offered by the FIs (PNP, 2018) in order to analyze their objective of internalization.

Subsequently, all FIs and FUs selected for the research were tabulated by state and their workloads were analyzed, defining in sequence for each course and periods, by consulting the PPCs, the subjects with CM and STS approach. To define the courses that used the CM, a study of the syllabus of the curricular components was carried out and the subjects that presented the study of languages and mediation environments for the development of simulations were selected, analyzing the access/use of computational tools for modeling processes and simulations, teaching programming and components that stimulate computational logic in students.

The criterion for defining a discipline with an STS focus involves several variables directly related to its structural possibilities and teaching proposals, as presented by several authors (YAGER, 1990; HEATH, 1992; ZIMAN, 1994; AIKENHEAD, 1994; CACHAPUZ, 2000; SANTOS; MORTIMER, 2002; AULER, 2007; ROEHRIG; CAMARGO, 2014). Therefore, the study was carried out seeking to identify teaching characteristics where scientific content is studied together with technological and social aspects. The subjects were analyzed in order to identify the following dimensions: focus on the application of science; vocational focus, interdisciplinarity; historical focus; philosophical approach; sociological approach and problematization, presented by Ziman (1994). To identify the STS approaches addressed in the curricular components, a set of keywords were used according to Table 1 below:

Table 1. STS approaches with their respective keywords

STS Approach	Keywords
Philosophical	Scientific methods, validity, absolute truths
Historic	Contributions, understandings, evolutions
Sociological	Production of knowledge, interests, influences in society
Problematization	Consequences, everyday, visualization
Application of science	Practices, applications and technologies
Vocational	Critical study, responsibilities, decision making
Interdisciplinary	Integration, learning, relationships

Source: [The authors, 2020]

The CM and STS-focused subjects were categorized into blocks defined according to the contents covered (Table 2).

Table 2. Grouping of disciplines focusing on STS and CM

Groups - STS Approach	Groups - CM
IE - Introduction to Engineering	IP - Introduction to Programming
LL - Languages and Leveling	CAD - Computer Aided Design
ELH - Ethics, Law and Humanity	AP - Algorithms and Programming
ESE - Education, Science and Environment	ADS - Algorithms and Data Structure
PI -Integrating Projects	EE - Electronics and Electrotechnics
SPM - Scientific and Project Methodology	SM - Systems Modeling
SHQ - Safety, Hygiene and Quality	NM - Numerical methods
EA - Entrepreneurship and Administration	APC - Automated Process Control

Source: [The authors, 2020]

A study of the workloads of the CM components and STS focus of the FIs and FUs was carried out, relating in sequence the workloads of the curricular components with an STS and

CM focus with the ENADE and CPC assessments, aiming to identify a correlation between these concepts with the component hours.

Results

In this section, the results and analyzes generated in the studies of the FUs' and FIs' curricula referring to mechanical engineering courses are presented.

Current scenario of mechanical engineering courses at FUs and FIs

In the national scenario, according to the Statistical Synopsis of Higher Education (BRASIL, 2019c), in all Brazilian states there is at least one FU and one FI. Initially the FUs were implemented in capitals and later expanded their radius to medium-sized cities. The FIs, although they took advantage of the existing structure of the Cefets or technical schools, promoted an internalization of MEC actions for small municipalities.

The mechanical engineering course is offered in FUs and FIs, and the offer of vacancies in FIs is established by Law nº 11.982/2008 where basic education, with high school integrated to a technical course, and the teaching degrees must correspond to 50% and 20% of the total vacancies, respectively. The rest of the vacancies are filled by bachelor's courses, technicians concomitant with high school, postgraduate courses and by the National Program for the Integration of Professional Education with Basic Education, in the Youth and Adult Modality (PROEJA).

Brazil has a total of 2,537 HEIs, divided into 199 Universities, 230 University Centers, 2,068 Colleges and 40 Federal Institutes. Universities are subdivided into 107 public and 92 private institutions. Among the public universities, the federal ones correspond to 63, representing 2.3% of the HEIs. In relation to the number of FIs, there is a value of 40 FIs, which correspond to 1.6% of the HEIs.

In relation to the total of 5,528 baccalaureate courses existing in public HEIs, 3,169 are present in FUs and 500 in FIs, representing, respectively, 57.3% and 9% of baccalaureate courses in public HEIs. Within the category of bachelor's degree courses at HEIs, there are 58 mechanical engineering courses in the UFs and 36 in the IFs, representing, in relation to the total number of courses in the engineering, production and construction category (5,870 courses), 0.99% and 0.61%, respectively.

As for the assessment instruments for undergraduate courses in Brazil, there is the National Student Performance Examination (ENADE), an examination that is periodically applied to undergraduate students, during the first (starting) and last (final) year of the course, which aims to monitor the learning process and academic performance of students in relation to the syllabus provided for in the curricular guidelines of the respective undergraduate courses.

Entrants and graduates of the areas/courses/qualifications defined by MEC/INEP must be registered to participate in the exam, and only graduating students answer the student questionnaire and take the test. For newcomers, the results of the National High School Exam (ENEM) are used.

ENADE results produce data by higher education institution, administrative category, academic organization, municipality, state, geographic region and Brazil. In this way, it is possible to build references that allow the definition of actions aimed at improving the quality of undergraduate courses by teachers, technicians, directors and educational authorities.

Regarding the mechanical engineering course, the three highest scores in ENADE 2017 (BRASIL, 2018) were achieved by the Military Institute of Engineering (IME) (4.843), with a mechanical engineering course focused on weapons, followed by the Federal Technological University of Paraná (UTFPR) (4,799) and the third highest score was achieved by IME (4,776) with a mechanical engineering course focused on automobiles.

Another evaluation mechanism for undergraduate courses in Brazil refers to the Preliminary Course Concept (PCC). Its calculation and publication take place in the year following the completion of the ENADE. Comprising the assessment of student performance, the value added by the training process and inputs relating to the faculty, infrastructure and didactic-pedagogical resources. It is classified in levels ranging from 1 to 5. Levels 1 and 2 represent unsatisfactory courses, track 3 represents courses that meet the minimum quality criteria, track 4 represents courses that fully meet the quality criteria to function and level 5 refers to courses of excellence.

The HEIs that obtained the three highest PCC values for mechanical engineering courses in 2017 were IME (4.35), followed by UTFPR (4.11) and the Federal Institute of Pernambuco (IFPE) (3.69) respectively. It is noteworthy that no FU or FI obtained the PCC 5 concept, which is interdependent with ENADE, with the institution's infrastructure, faculty and pedagogical methodology.

In the present study, 35 mechanical engineering courses in FIs and another 21 in FUs were analyzed (Table 3), distributed in the selected institutions, noting that some institutions had more than one campus (unit) where the aforementioned course was offered. The 56 curricula of mechanical engineering courses selected in the research showed divergences between the workloads of the courses available on the institutions' websites with those presented on the Nilo Peçanha platform and in the Registry of Institutions and Higher Courses. Thus, the data from the institutions' websites related to the workload were discarded, opting for data from the Nilo Peçanha platform and the Registry of Institutions and Higher Courses due to greater reliability.

Table 3. List of educational institutions by state of the federation

State	FIs	FUs
AM	IFAM	UFAM
BA	IFBA	UFBA
PB	IFPB	UFPB
CE	IFCE	UFCE
ES	IFES	UFES
GO	IFGO	UFGO
MA	IFMA	UFMA
MG	IFMG	UFMG
PE	IFPE	UFPE
PI	IFPI	UFPI
RS	IFRS	UFRGS
SC	IFSC	UFSC
SP	IFSP	UFSCAR
RJ	IFRJ	UFRJ
PR	-	UTFPR

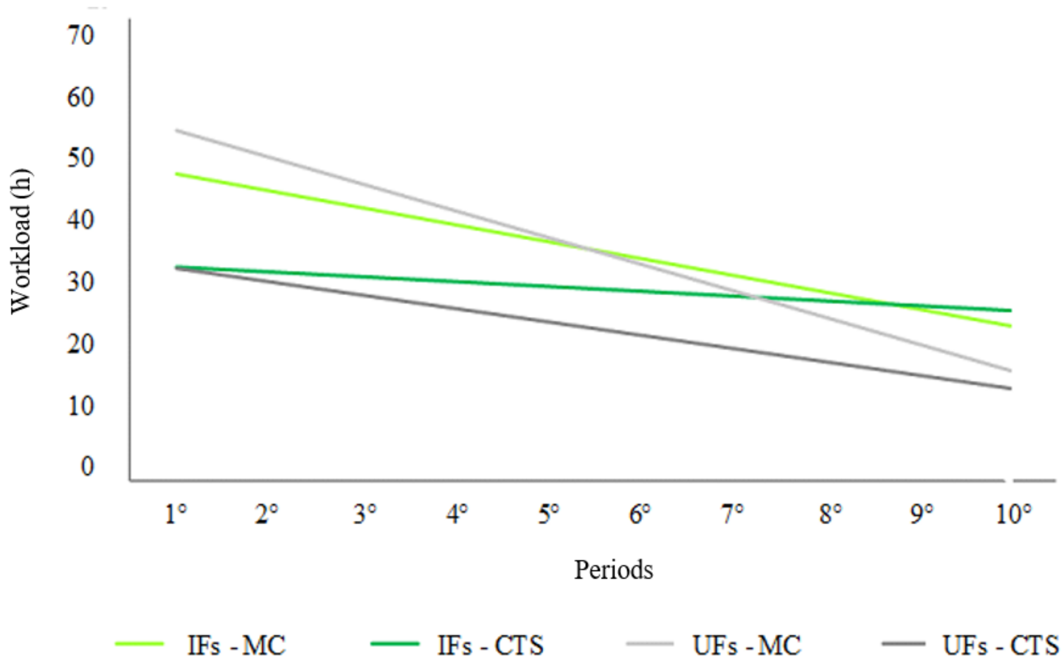
Source: [The authors, 2020]

According to the mechanical engineering course reference presented by BRASIL (2010), the courses must have a minimum workload of 3,600 hours, through the analysis of the workloads of the mechanical engineering courses of the educational institutions studied, it was found that all courses had a workload higher than that established by the MEC, the largest of which was found at the Federal Institute of Goiás (FIG) with a workload corresponding to 4,644 hours and the average workload of the courses was 3,955 hours, a value also above the minimum established by the MEC.

Analysis of computer modeling classes and with an STS focus in relation to workloads

In order to analyze the STS approach and the use of CM during the training of the mechanical engineer, the workload of these themes per period of the courses was studied in the course menus, in order to verify how these concepts are approached throughout the University course (Graph 1).

Graph 1. Trend lines of the distribution of the average workloads of the disciplines with a focus on STS and CM by period of graduation in mechanical engineering in Federal Institutes (FIs) and Federal Universities (FUs)

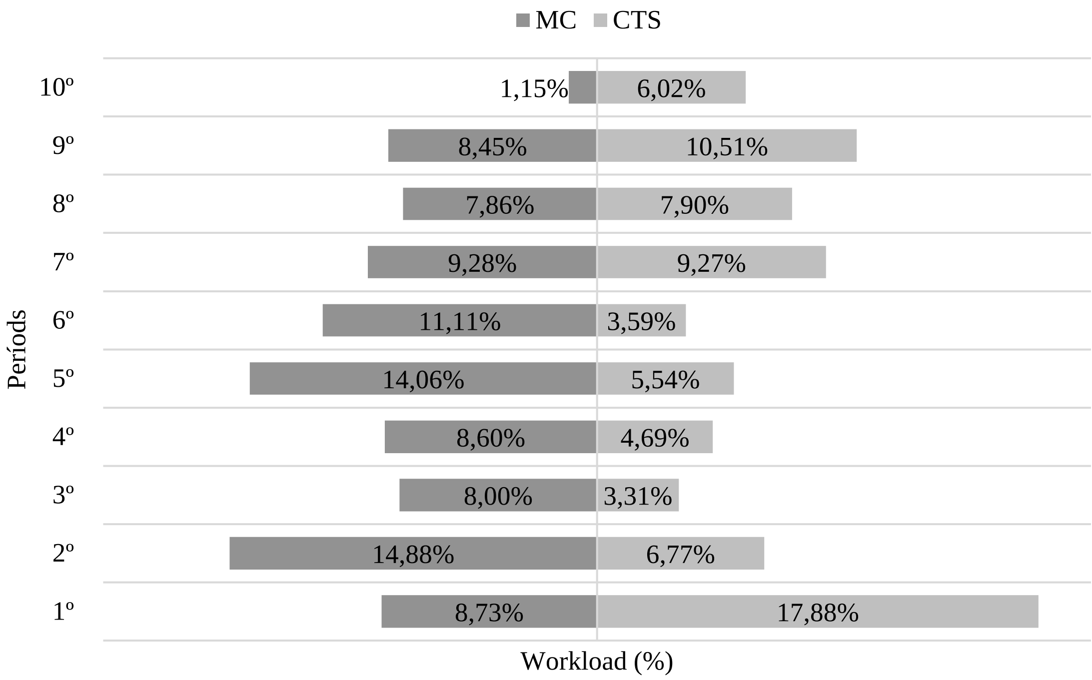


Source: [The authors, 2020]

Through the trend lines of Graph 1, it is observed that in the FIs the concepts related to CM and the STS approach showed a lower rate of variation over the periods compared to the FUs. However, it appears that for all educational institutions analyzed there is a tendency for these concepts to fall during graduation.

Analyzing the average hourly distribution of subjects in mechanical engineering courses in FIs involving STS and CM by periods (Graph 2), it was found that for subjects with a STS focus, between the third and seventh period the FIs had a lower workload average and higher average workload in the first period. The distribution of disciplines related to CM occurred differently, where the maximum values of 14.06% and 14.88% occurred in the fifth and second periods, respectively, and the lowest value of 1.15% was found in the tenth period. Also noteworthy is the non-uniformity in the distribution of these concepts during the ten undergraduate periods.

Graph 2. Average hourly distribution of subjects in mechanical engineering courses involving STS and CM by semester in FIs

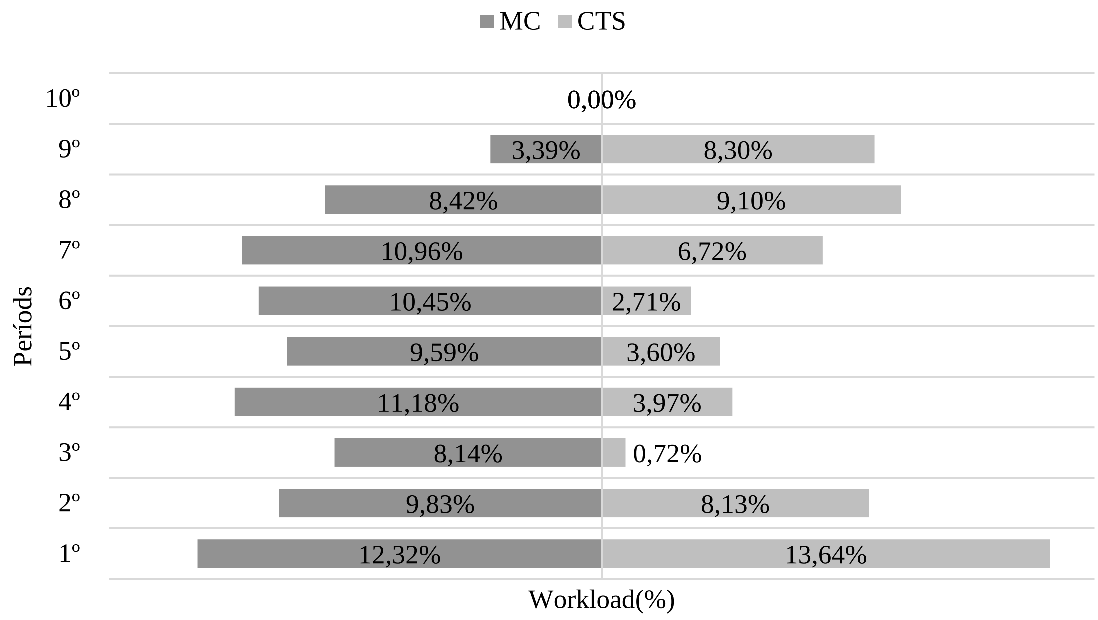


Source: [Adapted from PNP and BRASIL, 2018]

As for the distribution of the percentage of the average workloads of the STS and CM concepts in the FUs per semester (Graph 3), a greater intensity was observed in relation to the STS approach in the first, eighth and ninth semesters with a decrease in the approach included in the intervals between the third and seventh period. On the other hand, the distribution of the percentage of the average working hours of the concepts related to CM is more uniform in the first eight semesters, with a reduction in the ninth semester.

Only in the tenth semester the concepts related to CM and the STS approach were not worked, this can be justified because it is the year of completion of the course, being an indication of the need to update the curricula, aiming at completion works that can consider these approaches in situations that are close to the reality of the professional future, thus allowing the concepts worked in previous years to be assimilated in an organic way.

Graph 3. Average hourly distribution of subjects in mechanical engineering courses involving STS and CM for semester in FUs.



Source: [Adapted from PNP and BRASIL, 2018]

Through a more detailed analysis, by campus (unit), it is possible to observe how the topics presented in Table 2 are approached during graduation (Table 4). Among the 35 FIs studied, only 12 had workloads (WL) above 10% for CM, 20 had WL in the range between 5% and 10% and only 3 had WL less than 5%. On the other hand, in relation to the STS theme of the same FIs, 7 reached a workload of more than 10%, 21 were in the range between 5% and 10% and 7 with WL below 5% for the STS approach. The FIs that presented the highest workload in relation to the STS approach were the Federal Institute of Bahia (IFBA) on the Salvador campus (14.5%) and the Federal Institute of Rio Grande do Sul (IFRS) on the Rio Grande campus (13.4%). As for CM, the IFBA campus Jequié (19.15%) and the IFRS campus Ibirubá stood out. (15,75%).

Table 4. Hourly percentage involving the CM and STS focus in FIs

CM	Workload W.L. (%)	STS
IFBA-Jequié IFBA-Salvador IFCE IFG IFMG-Congonhas IFPE-Recife IFPI IFRS-Ibirubá IFSP-Araraquara IFSP-Itapetininga IFSP-Piracicaba IFSP-São José dos Campos	C.H ≥10%	IFBA-Simões filho IFBA-Salvador IFMG-Arcos IFRS-Rio Grande IFC- Luzema IFSP-Piracicaba IFSP- São Paulo
IFAM IFBA-Simões filho IFPB-João Pessoa IFES-Aracruz IFES-Cachoeira de itapemirim IFES-São Mateus IFES-Vitória IFMG-Arcos IFMG-Betim IFPE- Caruaru IFPE- Ipojuca IFRS-Rio Grande IFRS-Farroupilha IFSC-Joinvile IFSC-Lages IFSC-Xanxerê IFC- Luzema IFSP- São Paulo IFSP-Sertãozinho IFRJ- Paracambi	5% ≤ C.H ≤ 10%	IFBA-Jequié IFES-Aracruz IFES-Cachoeira de itapemirim IFES-São Mateus IFES-Vitória IFMA IFMG-Betim IFPE- Caruaru IFPE- Ipojuca IFPI IFRS-Farroupilha IFRS-Ibirubá IFSUL-Sapucaia do sul IFSC-Joinvile IFSC-Lages IFSC-Xanxerê IFSP-Araraquara IFSP-Itapetininga IFSP-São José dos Campos IFSP-Sertãozinho IFRJ- Paracambi
IFMA IFSUL-Sapucaia do sul IFRS-Erechim	C.H < 5%	IFAM IFPB-João Pessoa IFCE IFG IFMG-Congonhas IFPE-Recife IFRS-Erechim
Average STS FU's = 9,3%		**Average C.M. FU's = 7,8%**

Source: [Adapted from PNP and BRASIL, 2018]

Regarding the 21 FUs analyzed, 4 presented WL above 10% in relation to CM, 15 with WL between 5% and 10% and 2 with WL below 5% (Table 5). As for the STS theme of the same, 2 presented WL above 10%, 8 concentrated in the range between 5% and 10% and 11 with WL below 5% of the total WL (Table 5). The FUs that presented the highest WL in relation to the STS concept were the Federal Technological University of Paraná (UTFPR) Curitiba campus (15.5%) and the Federal University of Amazonas (UFAM) Rio Grande campus (10.6%). As for CM, UFAM (17.11%) and the Federal University of São Carlos stood out (UFSCar) (13,64%).

Table 5. Hourly percentage involving the CM and STS focus in FUs

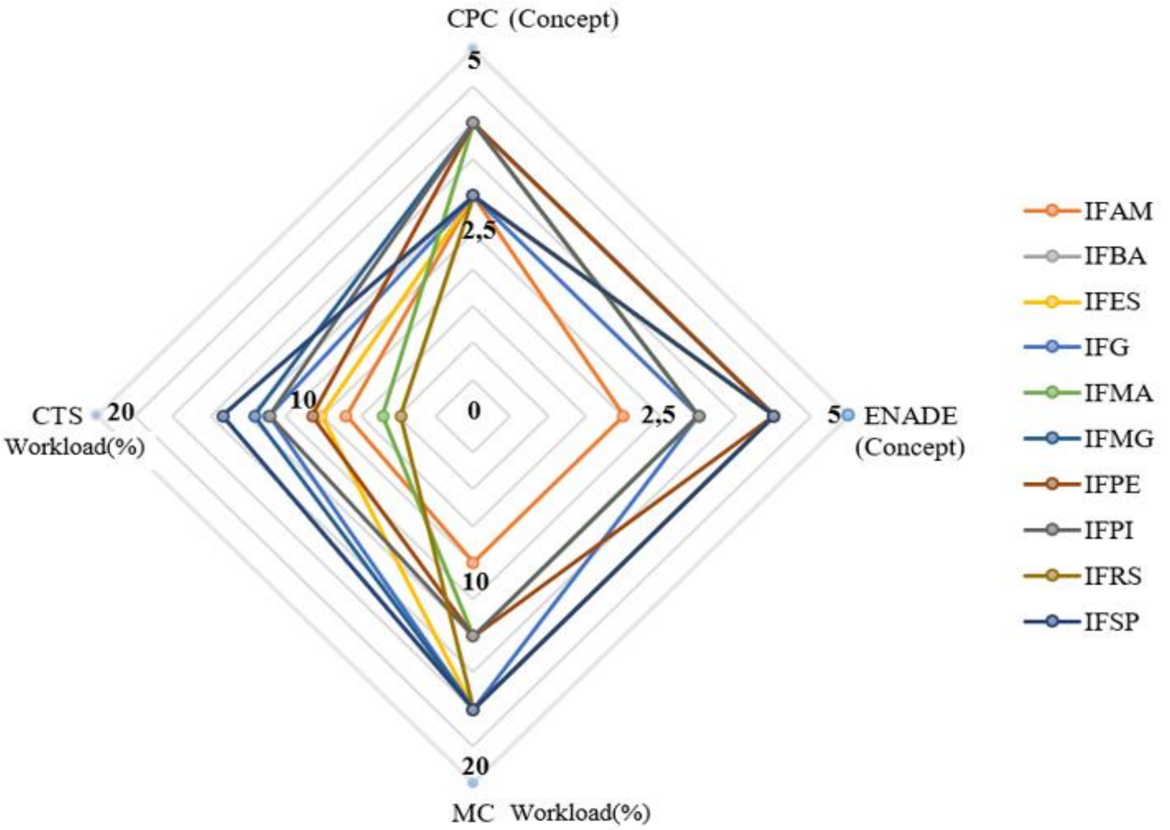
CM	Workload W.L(%)	STS
UFAM UFBA UFMA UFSCar	C.H ≥10%	UFAM UTFPR-Curitiba
UFSC UFPB UFCE UFG UFES UFMG UFPE UFPI UFRGS UFRJ-Macaé UFRJ-Rio de Janeiro UTFPR-Cornélio Procópio UTFPR-Guarapuava UTFPR-Londrina UTFPR- Ponta Grossa	5% ≤ C.H ≤ 10%	UFBA UFSC UFSCar UTFPR-Cornélio Procópio UTFPR-Guarapuava UTFPR-Londrina UTFPR-Curitiba UTFPR-Pato Branco
UTFPR-Curitiba UTFPR-Pato Branco	C.H < 5%	UFPB UFCE UFES UFG UFMA UFMG UFPE UFPI UFRGS UFRJ-Macaé UFRJ-Rio de Janeiro
C.H. Média UF's = 8,2%		**C.H. Média UF's = 5,5%**

Source: [Adapted from PNP and BRASIL, 2018]

Another analysis carried out was the relationship between the CPC and ENADE concepts with the distribution of hours of CM content and the STS perspective of the FIs (Graph 4). The results presented by the FIs showed that high grades are not always directly related to high workloads, the Federal Institute of Pernambuco (IFPE), for example, obtained grade 4 in the CPC and ENADE with less than 10% of its workload allocated to concepts related to the STS theme and close to 12% of their workload reserved for content related to CM.

On the other hand, IFAM obtained grades in the CPC and ENADE in the amount of 2.5 with workloads close to 7% and 6% for STS and CM respectively. Another finding related to the FIs was that they obtained a homogeneous distribution when analyzing the concepts of CM and the STS approach.

Graph 4. Relationship between the CPC and ENADE concepts with the distribution of hours of CM content and the STS focus of the FIs

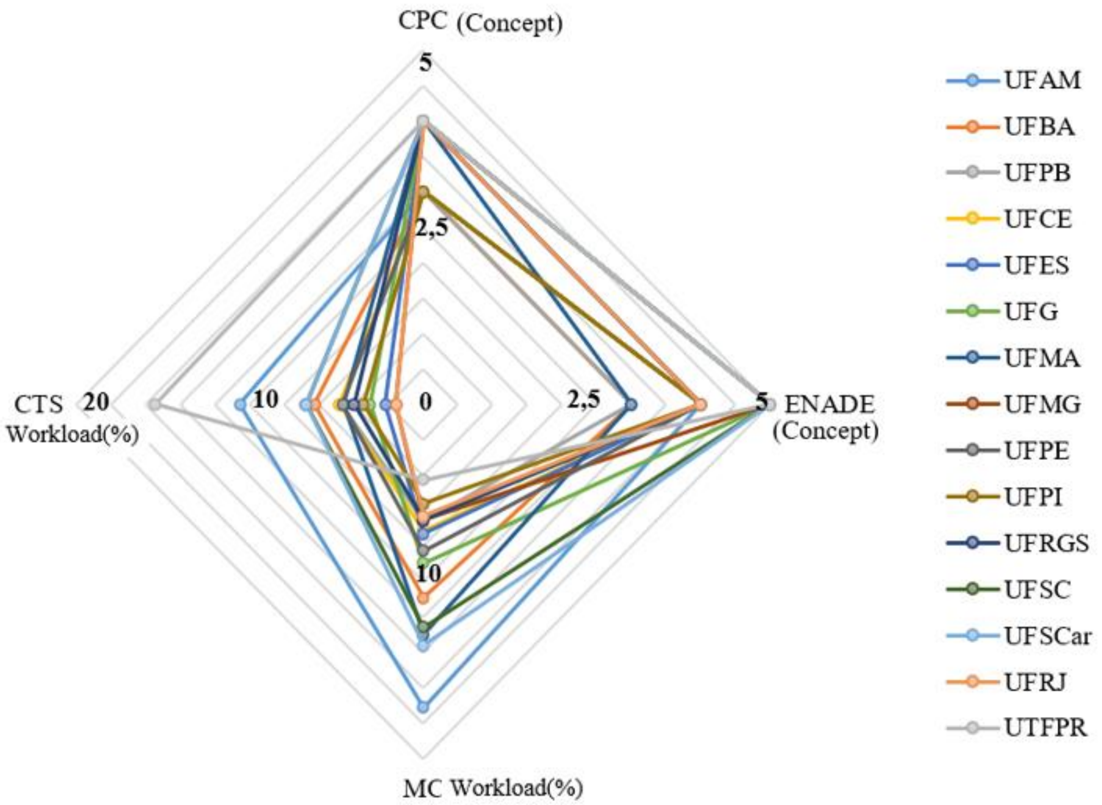


Source: [The authors, 2020]

Comparing the performance of the FUs in ENADE and CPC when confronted with the hourly distribution of the STS and CM approach in the respective related curricula (Graph 5), it was found that high concepts also did not reflect in high workloads, for example, the UTFPR - Curitiba campus reached maximum grade in ENADE even with high workloads in the STS theme and low in relation to CM.

As another example, UFG, with less than 12% of workload related to CM and less than 4% related to the STS approach, obtained maximum grade in ENADE and grade 4 in CPC. On the other hand, UFBA presented grade 4 in ENADE and CPC with reduced workloads related to STS and CM. UFAM, on the other hand, obtained grade 3 and 4 in the CPC and ENADE, respectively, presenting workloads above 15% in MC and above 10% in the STS theme.

Graph 5. Relationship between the CPC and ENADE grades with the distribution of workloads of CM content and the STS perspective of the FUs



Source: [The authors, 2020]

The studied FUs did not obtain grades lower than 3 in the course evaluations in both ENADE and CPC, and there was also no correlation between low grades and low workloads in relation to the CM approach and the STS approach, but the distribution of workloads related to CM was higher than those available for the STS theme.

Although there was no connection between the concepts of CM and the STS approach in mechanical engineering curricula with the performance of the educational institutions studied in the evaluations of existing courses, one should consider how the evaluation processes used in Brazil are carried out.

Final Considerations

It was found that in the current scenario the mechanical engineer must be able to propose solutions that are not only technically correct, but also have the ambition to consider the problems in their entirety and in their insertion in a chain of causes and effects of multiple dimensions. Thus, the professional must be able to apply science and technology, that is, adapt scientific and technological knowledge to human needs. Educational institutions must provide new students with the possibility to encounter and manipulate the main technologies in close conditions, simulated in the real world, consistent with the inherent challenges of the professional market.

For this, the search for the contextualization of teaching activities in mechanical engineering, which can also be carried out by CM, make the contents addressed not isolated and with a real meaning. The use of this technology enables the construction of multiple representations of the same situation. Mastering this technology makes the future mechanical engineer able to visualize different scenarios and choose the best solution.

Alternatively, the application of CM in conjunction with the STS approach can provide future mechanical engineers with the ability to visualize wider ranges of scenarios and solutions, and increase the critical sense necessary to choose alternatives that impact society as little as possible.

The set of information, collected through the applied methodology, allowed the comparison between the FUs and FIs and the mapping of the mechanical engineering courses offered by these institutions. It was found that, despite the courses offered by the FIs being newer, the evaluation rates of existing courses are very similar to the already consolidated courses of FUs.

Another verification observed refers to how CM concepts and the STS approach are approached during the course. In the FIs, the concepts related to the CM and the STS approach showed a lower rate of variation over the periods compared to the FUs. However, it was found that for all educational institutions analyzed there is a tendency for these concepts to fall during the course.

Through the research, it was noticed in general that the concepts related to the STS and CM approach are not worked in a connected way in the mechanical engineering courses in the analyzed educational institutions. This problem can be identified by the non-uniform distribution of these subjects over the periods. These disconnections directly influence the quality of training of professionals who are being trained in these institutions, either because these professionals do not manipulate new technologies that allow the simulation of real situations or processes, or due to the lack of training that awakens the critical thinking provided by the STS theme.

Although no correlation was found between the concepts of CM and the STS approach in mechanical engineering curricula with the performance of the educational institutions studied in the evaluations of existing courses, possible weaknesses in these evaluation processes used in Brazil should be considered.

In this way, the research points to the need to reformulate and adapt the curricula of mechanical engineering courses, seeking training in which the concepts of CM and the STS approach are worked more adequately in order to meet the desires of new students and the current market demands, and also the need to implement new course assessment tools.

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