

THE  
GREAT  
WORLD  
OF

# NANOTECHNOLOGY

**Marcos Augusto de Lima Nobre**  
(Organizador)



**EDITORA  
ARTEMIS**  
2020

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OF  
**NANOTECHNOLOGY**

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 **EDITORA  
ARTEMIS**  
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## APRESENTAÇÃO

O mundo em escala dos nanômetros tem-se mostrado cada vez mais presente no cotidiano. Em qualquer área encaixamos o nano, e muitas palavras têm sido criadas com o prefixo nano. Algo que exiba uma de suas dimensões na escala de um bilionésimo de metro pertence a este universo, que de forma gradual tem alcançado a ciência e a tecnologia. A nanociência e nanotecnologia têm modificado tintas, tecidos, metais, cerâmicas, polímeros a compreensão dos minérios e minerais, por fim criando a necessidade de cursos para otimizar a compreensão de seus conceitos aplicados a engenharia, a medicina e áreas correlatas. O mundo dos “nano” tem alcançado as ligas metálicas, os argilominerais, o ensino aplicado, a mecânicas dos fluidos e pós cerâmicos funcionais com partículas com tão baixa densidade que podem ser consideradas apenas casca. Cada um destes tópicos está sendo desenvolvido neste exato momento para ganharmos durabilidade, novos materiais mais fortes, mas com menos peso, novas técnicas de ensino para conceitos novos e inovadores, transporte mais eficiente de combustíveis e biocombustíveis em linhas e dutos cada vez menores e pós nanométricos funcionais capazes de acelerar reações químicas. Este livro traz um conjunto de textos abordando diversos aspectos dos conceitos materiais em escala dos nanômetros.

Desejo a todos uma excelente leitura!!

Marcos Augusto de Lima Nobre

## SUMÁRIO

<b>CAPÍTULO 1</b> .....	<b>1</b>
PRODUÇÃO E CARACTERIZAÇÃO DO COMPOSTO INTERMETÁLICO TERMOELÉTRICO TINISN	
Ernest Pedroza Araujo Silva	
Daniela Menegon Triches	
<b>DOI 10.37572/EdArt_1702510201</b>	
<b>CAPÍTULO 2</b> .....	<b>11</b>
MICROSTRUCTURAL AND RHEOLOGICAL CHARACTERIZATIONS OF A CLAY MINERAL FROM THE SOUTHWEST REGION OF THE BRAZILIAN STATE OF SÃO PAULO FOR APPLICATION IN NANOCOMPOSITES	
Delia do Carmo Vieira	
Felipe Ferreira Lopes	
Rebeca Abreu Nascimento	
Alessandra Stevanato	
Elisângela Corradini	
Janksyn Bertozzi	
<b>DOI 10.37572/EdArt_1702510202</b>	
<b>CAPÍTULO 3</b> .....	<b>28</b>
ANALYSIS OF THE EFFECTIVENESS OF DISTANCED LEARNING STRATEGIES FOR NANOSCIENCE AND NANOTECHNOLOGY SUBJECTS APPLIED TO HEALTH SCIENCES	
Jackeline Neres Bellucci	
Felipe Silva Bellucci	
Gilberto Lacerda Santos	
<b>DOI 10.37572/EdArt_1702510203</b>	
<b>CAPÍTULO 4</b> .....	<b>40</b>
SÍNTESE DE NANOPARTÍCULAS NANOESTRUTURADAS OCAS	
Marcos Augusto Lima Nobre	
Felipe Silva Bellucci	
Silvania Lanfredi	
<b>DOI 10.37572/EdArt_1702510204</b>	
<b>CAPÍTULO 5</b> .....	<b>48</b>
EFEITOS DE NANOESTRUTURAS DE GRAFITE SOBRE A VISCOSIDADE DE BLENDDAS DIESEL-S10 E BIODIESEL	
Túlio Begena Araújo	
Marcos Augusto Lima Nobre	
<b>DOI 10.37572/EdArt_1702510205</b>	

<b>CAPÍTULO 6</b> .....	<b>59</b>
FENÔMENO DE CONTORNO DE NANOGRÃO EM MICROESTRUTURAS NANOMÉTRICAS CERÂMICAS	
Marcos Augusto Lima Nobre Silvania Lanfredi	
<b>DOI 10.37572/EdArt_1702510206</b>	
<b>CAPÍTULO 7</b> .....	<b>71</b>
SÍNTESE DE NANOCOMPÓSITO CERÂMICO DE ZIRCÔNIA-HIDROXIAPATITA	
Carolina Cury Lopes Fabiana Barbara Piveta Flores Fabíola Stahlke Prado Ana Júlia Machado Merino Alejandra Hortencia Miranda González	
<b>DOI 10.37572/EdArt_1702510207</b>	
<b>SOBRE O ORGANIZADOR</b> .....	<b>80</b>
<b>ÍNDICE REMISSIVO</b> .....	<b>81</b>

## ANALYSIS OF THE EFFECTIVENESS OF DISTANCED LEARNING STRATEGIES FOR NANOSCIENCE AND NANOTECHNOLOGY SUBJECTS APPLIED TO HEALTH SCIENCES

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**ABSTRACT:** The formation and training of society have been strongly impacted by digital technologies of information, communication and expression (TICE), a fact that has been emphasized in moments of health crises, such as that of COVID-19. Nevertheless, the development of more effective distance education (EaD) methodologies, capable of addressing highly complex issues such as nanoscience and

nanotechnology (N&N), and fields that need a more experimental approach, such as engineering and health sciences, remains challenging. This work presents the results of the application of a fully EaD course, which addressed topics of Nanoscience and Nanotechnology applied to Health Sciences, using three methodological variations and comparing their results in order to suggest the most efficient strategy. The course was structured in six thematic modules, provided to more than 300 students, from different levels and backgrounds. From the standpoint of provenance and predominance, as expected, the highest percentage of interested parties in the topic came from the field of health sciences. The main assessment was the Success Index, whose results suggest that the use of a methodological variation associated with the use of more traditional resources, such as informative texts and articles, was the most successful. The results of the study suggest that it is possible to approach complex themes such as N&N applied to Health Sciences, using fully distant education strategies, as well as indicating that there are more effective methodological variations in this subject.

**KEYWORDS:** Nanoscience and Nanotechnology; Distance Education; Health Sciences; and Methodological Strategies.



## ANÁLISE DA EFICÁCIA DE ESTRATÉGIAS DE ENSINO TOTALMENTE A DISTÂNCIA PARA TÓPICOS DE NANOCIÊNCIA E NANOTECNOLOGIA APLICADOS ÀS CIÊNCIAS DA SAÚDE

**RESUMO:** A formação e capacitação da sociedade têm sido fortemente impactada pelas tecnologias digitais de informação, comunicação e expressão (TICE), fato que ficou evidenciado em momentos de crise sanitária, como a do Covid-19. No entanto, segue desafiador o desenvolvimento de metodologias de Educação a Distância (EaD) mais eficazes, capazes de abordar temas complexos, como a Nanociência e a Nanotecnologia (N&N), e as áreas que precisam de maior abordagem experimental, como as engenharias e as ciências da saúde. Este trabalho apresenta os resultados da aplicação de um curso totalmente EaD, que abordou tópicos de Nanociência e Nanotecnologia aplicadas as Ciências da Saúde, utilizando três variações metodológicas e comparando seus resultados para sugerir a estratégia mais eficiente. O curso foi estruturado em seis módulos temáticos e ofertado a mais de 300 estudantes, de diferentes níveis e procedências. Do ponto de vista da procedência e predominância, como esperado, o maior percentual de interessados no tema foi proveniente da área de ciências da saúde. O principal avaliado foi o Índice de Sucesso, cujos resultados sugerem que a utilização de uma variação metodológica associada a utilização de recursos mais tradicionais, como textos informativos e artigos, foi a mais exitosa. Os resultados do estudo sugerem que é possível abordar temas complexos como a N&N aplicada as Ciências da Saúde utilizando estratégias educacionais totalmente a distância, bem como indicam que há variações metodológicas mais eficazes para a temática.

**PALAVRAS-CHAVE:** Nanociência e Nanotecnologia; Educação a Distância; Ciências da Saúde; e Estratégias Metodológicas.

## ANÁLISIS DE LA EFECTIVIDAD DE ESTRATEGIAS DE EDUCACIÓN A DISTANCIA PARA LOS TEMAS DE NANOCIENCIA Y NANOTECNOLOGÍA APLICADOS A LAS CIENCIAS DE LA SALUD

**RESUMEN:** La formación y calificación de la sociedad ha sido fuertemente impactada por las tecnologías digitales de información, comunicación y expresión (TICE), un hecho que se evidenció en momentos de crisis de salud, como el de Covid-19. Sin embargo, el desarrollo de metodologías de educación a distancia (DE) más efectivas, capaces de trabajar con temas complejos, como la nanociencia y la nanotecnología (N&N), y áreas que necesitan un mayor enfoque experimental, como la ingeniería y las ciencias de la salud. Este trabajo presenta los resultados de la aplicación de un curso de educación totalmente a distancia, que abarcó temas de Nanociencia y Nanotecnología aplicados a las ciencias de la salud, utilizando tres variaciones metodológicas y comparando

sus resultados para sugerir la estrategia más efectiva. El curso se estructuró en seis módulos temáticos y fue presentado a más de 300 estudiantes, de diferentes niveles y formaciones. Desde el punto de vista del origen y formación, como esperado, el mayor porcentaje de personas interesadas en el tema provino del área de las ciencias de la salud. El principal parámetro evaluado fue el Índice de éxito, cuyos resultados sugieren que la utilización de una variación metodológica asociada con el uso de recursos más tradicionales, como textos y artículos informativos, fue el más exitoso. Los resultados del estudio sugieren que es posible abordar temas complejos como las N&N aplicadas a las Ciencias de la Salud, utilizando estrategias educativas a distancia, así como sugieren que existen variaciones metodológicas más efectivas para el tema.

**PALABRAS CLAVE:** Nanociencia y Nanotecnología; Educación a Distancia; Ciencias de la Salud; y Estrategias Metodológicas.

## 1 . INTRODUCTION

For author Kenski (2012), distance education is not only an exclusive self-learning process, but mainly a method of education that allows individual management of space and time, so that students access the content and have the opportunity to seek learning in an individualized way, respecting their pace and limitations. In Brazil, there is an aging population, an increase in the middle class and a greater interest in schooling, therefore EaD appears as a great option for mass reach, reduced costs, as well as encountering a fertile environment in the Z generation individuals, digital natives born since 2000, and in the process of massification of Internet access in Brazil (IPEA, 2015).

Among the key advantages of this sort of education is the flexibility of time and place of learning, elimination of commuting time to traditional education venues, and an increase in the number of students per class. In distance education, the learning process is mainly built by the student himself; in other words, he becomes the main actor of knowledge, relying on the teacher as a mediator of this process, contributing to the learning to be highly effective (LACERDA SANTOS, 2014). Nevertheless, major challenges are still being overcome – including the improvement of teaching methodologies, the assessment of the teaching-learning process – and, more importantly, the wide-ranging extension of this sort of education to subjects of greater complexity and abstraction, such as: Health Sciences, Nanoscience and Nanotechnology and their interfaces (MCNEW *et al.*, 2016).

Nanoscience and Nanotechnology (N&N) are emerging, cross-sectional and interdisciplinary fields for the study and application of materials with a dimensional scale of the order of nanometers ( $1 \times 10^{-9}$  m) (MULVANEY, 2015). Specifically, Nanoscience studies the phenomena and their influence on the properties

of materials at the nanoscale, whereas Nanotechnology delves into the knowledge resulting from Nanoscience to create structures, devices, and systems that exhibit new properties and functions due to the dimensional scale used (BELLUCCI, F., 2008). N&N studies are currently fostering major scientific breakthroughs and new ways to understand and create materials, devices, and systems. New generations of materials are under development and improvement, such as nanoparticles, thin films, and nanocomposites, with applications in the fields of electronics, telecommunications, computing, and biotechnology (MCNEW *et al.*, 2016).

Technological and innovative applications related to N&N in sciences are mainly centered on the diagnosis of differentiated diseases and cells, more precise therapy, prevention of extraordinarily complex diseases, understanding of biological mechanisms, and development of cosmetic and cosmeceutical products. Therefore, health professionals must become familiar with drug-delivery concepts, hyperthermia treatments, nanobiosensors, among others, thus being able to provide their patients with new treatment options and provide better health actions (FECYT, 2009). However, analyses and discussions on the use of fully distant education actions of the subject “Nanoscience and Nanotechnology Applied to Health Sciences” are still scarce in scientific literature.

The main objective of this multidisciplinary study was to suggest the possibility and potentiality of using the modality of distance education for complex and multidisciplinary themes, specifically Nanoscience and Nanotechnology applied to health sciences, specially developing a teaching action in this subject using 03 different educational strategies based on EaD and comparing their results in order to suggest the most efficient strategy. It must be mentioned that this work is part of the studies carried out by the first author during her master’s degree, and the other results of the study can be found at (BELLUCCI, J., 2016).

## 2 . METHODOLOGICAL APPROACH

**Research Method:** With the intent to gather information and conduct the construction of the stages of this work, a comparative study was adopted. The comparative method is concerned with the search for systemic patterns, convergences, and divergences of phenomena between two or more sample groups. It scrutinizes similarities and differences between different types of groups, not necessarily of the same nature, contributing to a better understanding of the relationship and temporal evolution of the groups. In this method, the researcher attempts to ascertain the cause or reason that justifies the existence of differences in the behavior or condition of groups of individuals or sample spaces (LAKATOS; MARCONI, 2007).

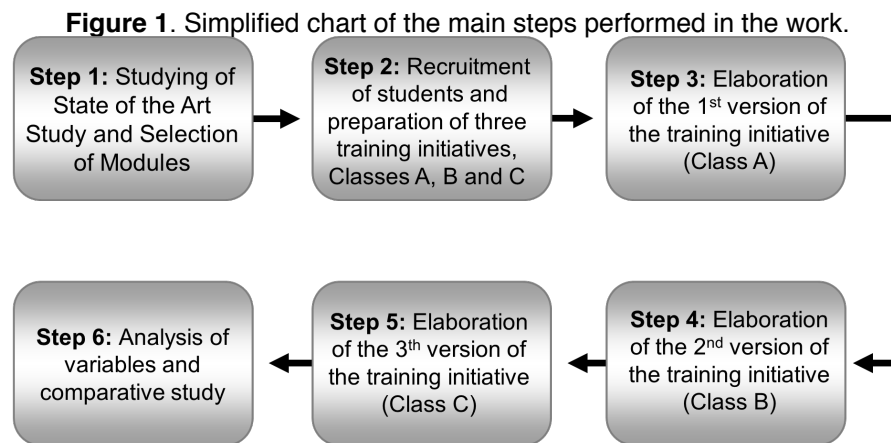
**Ethical Procedure:** Before starting the project, the research plan was submitted and obtained approval from the Research Ethics Committee of the Faculty of Health, University of Brasilia (CEP-FS / UnB), according to the National Health Council resolution (CNS) nº 466/2012, under Number: 010355/2015 and the project identifier CAAE nº 41860815.0.0000.0030.

**Teaching Action:** With the intent to select a statistically significant sample of students/cursors for the study, 311 students were enrolled for free in the course entitled “Topics of Nanoscience and Nanotechnology Applied to Health Sciences”. The students were then divided into 03 classes (A, B, and C) the same content was worked on by all classes, albeit with different methodologies. In class A, the methodology was based exclusively on articles and informative texts. In class B, the methodology was centered on technical videos. In class C, the methodology was based on video lectures recorded specifically for the course. It should be emphasized that the 03 versions of the course were conducted fully EaD, in the Learning Platform of the UnB MOODLE environment.

**Course Composition:** The teaching action integrated six finalist modules of the course and one evaluation module. Module 1 – General Aspects of Nanoscience and Nanotechnology; Module 2 – Consolidated Applications in Nanoscience and Nanotechnology; Module 3 – Nanomaterials Designed for Drug-Delivery Type Systems; Module 4 – Nanoscience Applied to Cancer Technology, Oncology, and Radiology; Module 5 – Nanomaterials Applied as Biomaterials and Nanobiosensors; Module 6 – Perspectives on the Use of Nanobiomachines and Nanobatteries in Health Sciences; and Module 7 – Final Evaluation.

**Mention System of the University of Brasília:** The following is registered: (i) SS – Superior (9.0 to 10.0); (ii) MS – Upper middle (7.0 to 8.9); (iii) MM – Middle (5.0 to 6.9); (iv) MI - Lower middle (3.0 to 4.9); (v) II – Lower (0.1 to 2.9); (vi) SR - No performance (zero). The mentions for approval are SS, MS and MM, whereas the mentions MI and II refer to those not approved and, finally, the mention SR is attributed to failure due to absences, when the student did not attend at least 75% of the classes.

**Variables Analyzed in the Comparative Study:** At the end of the three teaching actions, it was conducted a comparison of parameters, their characteristic values and the influence of their variation on the students’ teaching-learning process. The parameters analyzed were: (i) Target Audience Reached by the Actions and (ii) Parameter Success Index. The other variables assessed in the complete study are mentioned and discussed in (BELLUCCI, J., 2016). Figure 1 reveals an organization chart of the main steps developed in the work from the State-of-the-Art multidisciplinary study to the analysis of the results.



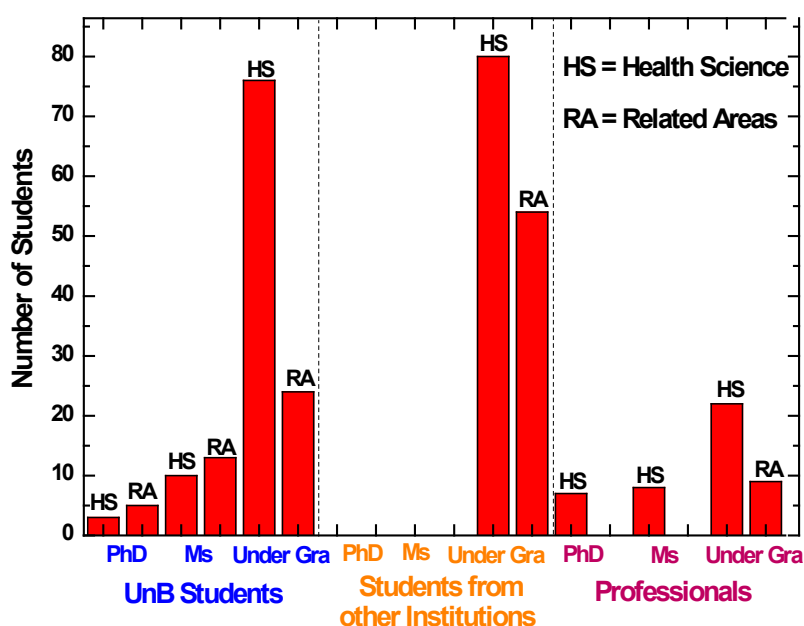
Source: Own Author.

### 3 . RESULTS AND DISCUSSIONS

#### 3.1 Analysis of the Target Audience Reached by the Actions

Understanding the students’ origin, educational background, and field of interest simplifies the process of delivery and adding value, while also facilitating the understanding of the results obtained. Therefore, Figure 2 reveals the distribution of students enrolled in the course “Topics of Nanoscience and Nanotechnology Applied to Health Sciences” by origin, level of education, and area of operation, while Table 1 enlists the percentage related to the distribution. As expected, the columns connected to graduation stand out from the others in both complex and contemporary themes, such as N&N and its interfaces with Health Sciences.

**Figure 2.** Distribution of students enrolled in the course by origin, education background, and field. As expected, the columns related to the level of education stand out.



Source: Own Author.

**Table 1.** List of the absolute number and percentage of students enrolled in the educational action by origin, education background and main area.

Origin	Education Background	Main Area	# of Students	Percentage (%)
UnB Students	PhD	Health Science	3	1.0%
		Related Areas	5	1.6%
	Master	Health Science	10	3.2%
		Related Areas	13	4.2%
	Under graduation	Health Science	76	24.4%
		Related Areas	24	7.7%
Students from other institution	PhD	Health Science	0	0
		Related Areas	0	0
	Master	Health Science	0	0
		Related Areas	0	0
	Under graduation	Health Science	80	25.7%
		Related Areas	54	17.4%
Professionals	PhD	Health Science	7	2.3%
		Related Areas	0	0
	Master	Health Science	8	2.6%
		Related Areas	0	0
	Under graduation	Health Science	22	7.1%
		Related Areas	9	2.9%
<b>Number of Students</b>			<b>311</b>	<b>100%</b>

Source: Own Author.

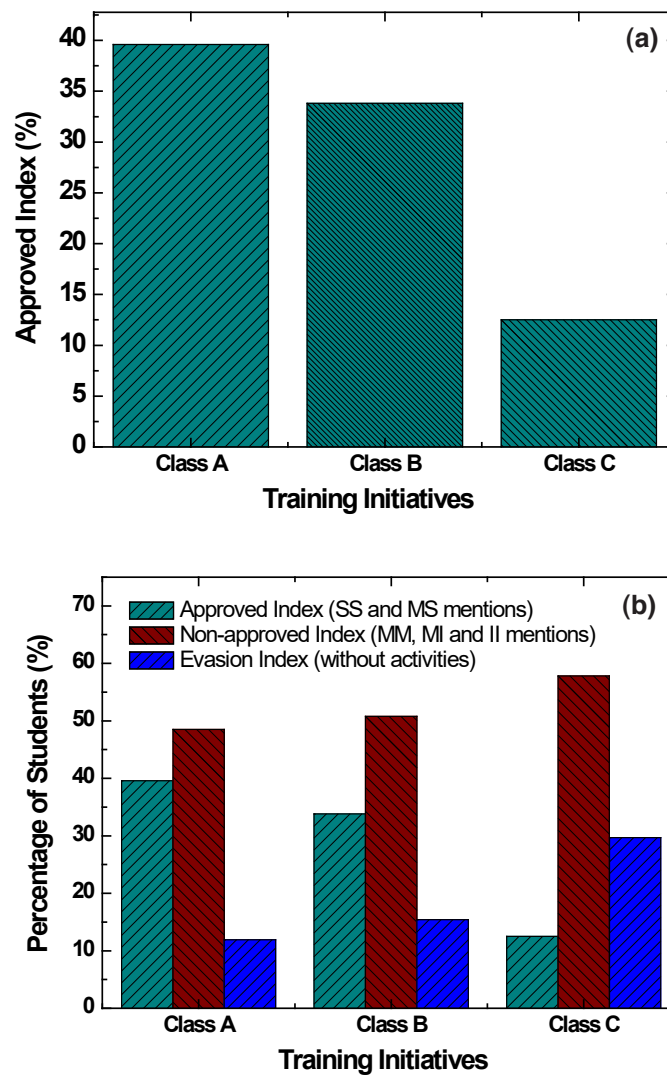
Multidisciplinary research initiatives in N&N have substantially increased in recent years. Nevertheless, the reflective actions on the teaching-learning process in the subject continue to be scarcely debated. In this regard, Figure 2 and Table 1 disclose the quantitative results referring to the number of students enrolled in N&N teaching actions, distributed according to the institutional origin, level of education, and field. The most significant target audience was undergraduate students from outside the UnB in the field of health sciences (25.7%). As expected, given the specificity of the topics addressed in the course, most of the interested parties have originated from the field of health sciences and related areas. Reports forwarded by the students revealed that the subject is regarded as having the potential to revolutionize the theme in health-related treatments. Nevertheless, due to the timeliness and cross-sectional nature of the N&N theme, there was a considerable number of interested people from other fields of knowledge.

### 3.2 Analysis of the Parameters Success, Failure and Evasion Indexes

Generally speaking, the main indexes assessed by managers and teachers of a given education field in face-to-face or remote education are the success, failure, and evasion indexes. These are associated, among many factors, to the application's effectiveness and the quality of the course and socio-cultural factors. Figure 3 (a)

presents the percentage values calculated for the Success or Approved Index (SS and MS Mentions), whereas (b) shows the comparison between the percentage values calculated for the Success or Approved, Failure or Non-approved Index (MM, MI and II Mentions) and the Evasion Index (SR Mention - Dropouts without Activities) for the three education actions in the fully EaD modality applied to classes A, B and C. Table 2 shows the absolute and percentage values for the aforementioned Indexes, referencing the mentions and equivalences in grades attained by the students/students.

**Figure 3.** (a) Percentage of success or approved index (SS and MS mentions) and (b) comparison between success or approved, failure or non-approved indexes (MM, MI and II mentions) and evasion (without activities) for teaching actions applied to classes A, B and C.



Source: Own Author.

**Table 2.** List of absolute values (frequency) and percentages associated with success, failure, and evasion indexes of education actions in the fully EaD modality, applied to classes A, B, and C.

Training Initiatives	Approved Index (SS and MS mentions)		Non-approved Indexes (MM, MI and II mentions)		Evasion Index (without activities)	
	f	(%)	f	(%)	f	(%)
<b>Class A</b>	40	39.6	49	48.5	12	11.9
<b>Class B</b>	22	33.8	33	50.8	10	15.4
<b>Class C</b>	8	12.5	37	57.8	19	29.7

Source: Own Author.

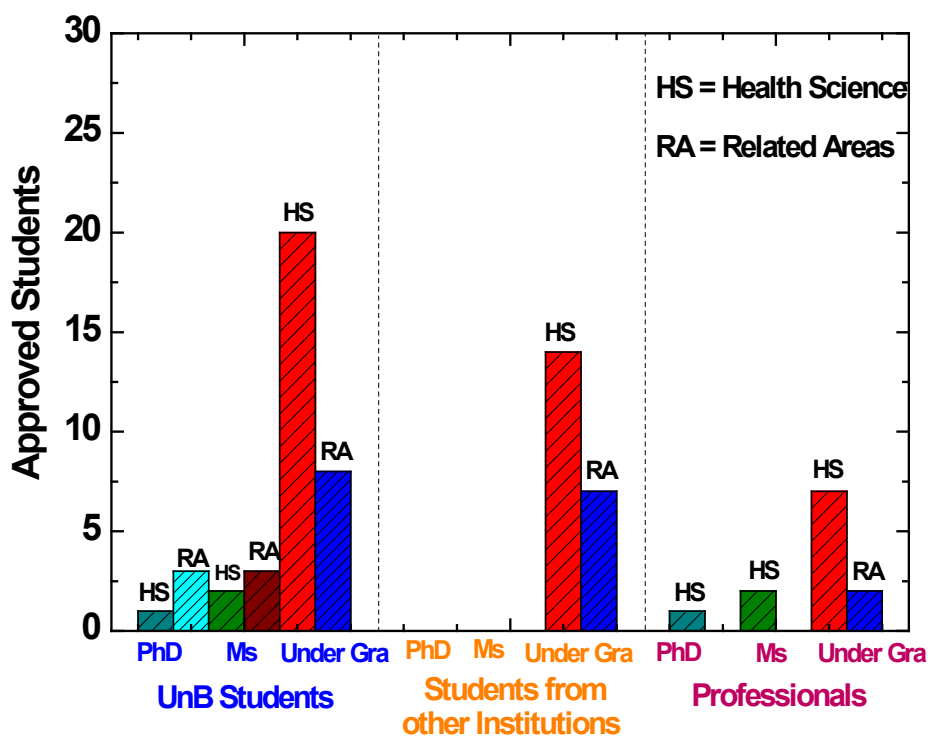
According to Figure 3 (a) and Table 2, the highest value obtained for the parameter success index was equal to 39.6% (Class A), whereas the lowest value was equal to 12.5% (Class C). The difference between the highest and lowest value is approximately 27.1%. It should also be mentioned that the values obtained for this parameter decrease with the type of action performed. In Figure 3 (b), it is seen that the highest value obtained for the parameter failure index was equal to 57.8% (Class C), whereas the lowest value was equal to 48.5% (Class A). For the evasion index parameter, it should be emphasized that Class C obtained the highest value (29.7%) in this index, while Class A had the lowest value (11.9%). For the teaching activities conducted in this study, it is important to point out that the average success index obtained was higher than 28%. Based on the scientific literature, the success index in actions regarding the EaD modality, in the most diverse subjects, is found to be in the range between 10 and 25% (ABED, 2015). Therefore, the average success index obtained is consistent with the values reported in the literature. Based on the success index parameters, success stratification index, the methodology that proved to be most effective was the one based fundamentally on written content (Class A), which was technically based on less interactive and more conceptual activities. The main factors associated with these results are discussed in (BELLUCCI, J. 2016).

### 3.3 Correlation of Indexes with the Origin of the Students

When attempting to find a correspondence between the parameters success, failure, and evasion indexes, and the origin of the course participants by origin (UnB students, external UnB students, and professionals), level of education (Ph.D., master's degree and undergraduate) and field (health sciences and related areas), may point to factors and indications that acted decisively to verify the values observed. Figure 4 presents the percentage values calculated for the Success Index or Approved Index by the origin of the course participants, for the three fully EaD teaching actions applied to classes A, B, and C. Table 3 lists the absolute values associated to the Success, Failure and Evasion Indexes, by origin, level of education and field, of the teaching activities.



**Figure 4:** The percentage values calculated from the Success or Approved by the origin of the students for the three teaching actions fully encompassed in the EaD modality, applied to classes A, B, and C. Source: Own Author.



**Table 3.** It presents the absolute values associated with the Success Index by origin, level of education, and field, of the three teaching actions fully encompassed in the EaD modality.

Origin	Education Background	Main Area	Approved Index	Percentage (%)
UnB Students	PhD	Health Science	1	33%
		Related Areas	3	60%
	Master	Health Science	2	20%
		Related Areas	3	23%
	Under graduation	Health Science	20	26%
		Related Areas	8	33%
Students from other institution	PhD	Health Science	0	0%
		Related Areas	0	0%
	Master	Health Science	0	0%
		Related Areas	0	0%
	Under graduation	Health Science	14	18%
		Related Areas	7	13%
Professionals	PhD	Health Science	1	14%
		Related Areas	0	0%
	Master	Health Science	2	25%
		Related Areas	0	0%
	Under graduation	Health Science	7	32%
		Related Areas	2	22%
<b>Number of Students</b>			<b>70</b>	<b>23%</b>

Source: Own Author.

According to Figure 4 (a) and Table 3, the highest number of approved course participants reveals a graduation level in the field of health sciences. This pattern was repeated for the three classes of origin, UnB students (20), UnB external students (14), and professionals (07). The lower quantitative value of approved students reveals the Ph.D. level in the field of health sciences from UnB (01) and professionals (01). There were no approved UnB external students in the course. Of the students approved by UnB, most (29%) are graduated in health sciences. This value has a justification, since the largest number of students enrolled had this profile – undergraduate students – and, in general, with greater availability to invest in complementary courses, while also having more interest in training based on current topics. Regarding the non-approved students (failure) in the three teaching actions (total of 119), about 90% are students in different levels and only 11% are professionals. Of the non-approved internal and external students, the majority (80%) are graduates. This figure may have a justification, given that the largest number of students enrolled had this profile and, in general, they are more prone to not managing their time properly and struggle more with multidisciplinary and complex subjects. Key factors for the student enrollment have been studied by several authors, such as Law *et al.* (2019).

#### 4 . CONCLUSIONS

In recent years, the popularization and propagation of digital technology have vastly transformed society, while bringing changes in individuals' personal and professional lives. Due to its strengths, such as time flexibility, low cost *per capita*, absence of geographical boundaries, the possibility of providing a large number of vacancies, among others, EaD has been expanding its insertion in society and complementing the learning methods and access to knowledge. As we speak, multidisciplinary and complex subjects, such as N&N, have begun to be disseminated through these teaching actions. The effect of different methodologies fully encompassed in EaD in the students' performance was tested, through the development and application of a technological extension course, with 40 hours, addressing Topics of Nanoscience and Nanotechnology Applied to Health Sciences. Three methodological approaches for the same course were developed and applied in 03 classes (A, B, and C). Among the main results attained in the work, the following should be underlined: (i) the most expressive target audience was undergraduate students from UnB in the field of health sciences (25.7%); (ii) the parameter "Success or Approved Index" had a higher evaluation for Class A (39.6%), while Class C exhibited the lowest value (12.5%) and, therefore, Class A presented the lowest value of "Failure or Non-Approved Index"; and (iv) for the correlation of the "Success, Failure and Evasion" Indexes, regarding the students' origin, the undergraduate students in the field of health sciences were the ones with the best performance overall.. With the results, the use of distant learning methodologies is effective for the teaching of complex subjects, such as N&N applied to health sciences, and that the predominant

methodology in the teaching possesses a strategic role in the learning process of individuals and the most effective methodology studied (A, B and C) was based exclusively on articles and informative texts.

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## ÍNDICE REMISSIVO

### B

Biodiesel 41, 42, 47, 48, 49, 51, 52, 54, 55, 56, 57, 58, 80

Blendas 48, 54, 55, 56, 57, 80

Blends 48, 49, 58

### C

Cerâmica de  $\text{KSr}_2\text{Nb}_5\text{O}_{15}$  59, 60, 65, 67

Ciências da Saúde 29

Clay 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27

Clay minerals 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 23, 24, 25, 26, 27

### D

Diesel 41, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58

Distance Education 28, 30, 31, 39

### E

Educação a Distância 29, 39

Estratégias Metodológicas 29

### G

Graphite nanostructures 49

### H

Half-Heusler 1, 10

Health Sciences 28, 30, 31, 32, 33, 34, 36, 38, 39

High energy ball milling 1, 2, 3

Hollow nanoparticles 40

### I

Intermetálico 1

Intermetallic 1, 2

### K

$\text{KSr}_2\text{Nb}_5\text{O}_{15}$  ceramic 59

### M

Mechanical alloying 1, 4, 9, 10

Methodological Strategies 28

Moagem de alta energia 1  
Montmorillonite - nontronite species 12, 82

## N

Nanociência e Nanotecnologia 29  
Nanoestruturas 40, 48, 56, 57, 59  
Nanoestruturas de grafite 48  
Nanograins 59  
Nanogrão 59, 66  
Nanopartículas nanoestruturadas 40  
Nanopartículas ocas 40  
Nanoscience and Nanotechnology 28, 30, 31, 32, 33, 38, 39  
Nanostructured nanoparticles 40  
Nanostructures 10, 40, 47, 48, 49, 59  
Nanotechnology 27, 28, 30, 31, 32, 33, 38, 39, 40, 48, 59, 72  
Nanotecnologia 29, 40, 46, 48, 49, 59, 71, 73, 80

## S

SEM images 11, 12, 23, 24

## T

TErmoelétrico 1  
Thermal analysis 11, 12, 14, 19, 20  
Thermoelectric 1, 2, 5, 10  
Thixotropic behavior 12, 23

## V

Viscosidade 48, 49, 52, 53, 54, 55, 56, 57, 74  
Viscosity 21, 22, 26, 48, 49, 57, 58