

Internationalization of the Bachelor's Degree in Physics and Mathematics: connections between curriculum and global knowledge in initial teacher education

Suiane Costa Alves

Universidade do Vale do Rio dos Sinos
Fortaleza, CE — Brasil

✉ suiane.alves@prof.ce.gov.br

 0000-0001-9103-617X

Maria Julieta Abba

Universidade do Vale do Rio dos Sinos
Caxias do Sul, RS — Brasil

✉ mjulietaabba@gmail.com

 0000-0003-1248-6805



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Abstract: The internationalization of physics and mathematics curricula has permeated academia with the aim of preparing students to face local and global challenges. In line with this proposal, the Federal Institute of Education, Science, and Technology of Ceará (IFCE) adopts a pedagogical approach based on interdisciplinarity and contextualization, supported by the internationalization process. Methodologically, this research is characterized as a case study, with a quantitative-qualitative approach, which seeks to investigate how the internationalization of the curriculum has been implemented on an IFCE campus, with an emphasis on the Bachelor's Degree Courses in Physics and Mathematics. The results reveal that undergraduate students demonstrate a certain level of familiarity with the internationalization of higher education and the curriculum. Although few are deeply familiar with the topic, it was observed that students consider internationalization relevant to their education, highlighting the academic, professional, and personal benefits of a more internationalized and globally connected curriculum.

Keywords: Internationalization of the Curriculum. Teaching of Physics and Mathematics. Federal Institute of Education, Science, and Technology of Ceará. Initial Teacher Education.

Internacionalização da Licenciatura em Física e Matemática: conexões entre currículo e saberes globais na formação inicial de professores

Resumo: A Internacionalização do Currículo de Física e Matemática tem permeado o meio acadêmico com o objetivo de preparar os estudantes para enfrentar os desafios locais e globais. Alinhado a essa proposta, o Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE) adota uma abordagem pedagógica pautada na interdisciplinaridade e na contextualização, sustentada pelo processo de internacionalização. Metodologicamente, esta pesquisa caracteriza-se como um estudo de caso, com abordagem quanti-qualitativa, que busca investigar como a Internacionalização do Currículo vem sendo implementada em um campus do IFCE, com ênfase nos Cursos de Licenciatura em Física e Matemática. Os resultados revelam que os graduandos demonstram certo nível de familiaridade com a Internacionalização da Educação Superior e do Currículo. Embora poucos conheçam o tema em profundidade, observou-se que os alunos consideram a internacionalização relevante para sua formação, destacando os benefícios acadêmicos, profissionais e pessoais de um currículo mais internacionalizado e globalmente conectado.

Palavras-chave: Internacionalização do Currículo. Ensino de Física e Matemática. Instituto

Federal de Educação, Ciência e Tecnologia do Ceará. Formação Inicial de Professores.

Internacionalización del Currículo de la Licenciatura en Física y Matemática: conexiones entre el currículo y los saberes globales en la formación inicial del profesorado

Resumen: La Internacionalización del Currículo de Física y Matemáticas ha permeado el ámbito académico con el objetivo de preparar a los estudiantes para enfrentar los desafíos locales y globales. Alineado con esta propuesta, el Instituto Federal de Educación, Ciencia y Tecnología de Ceará (IFCE) adopta un enfoque pedagógico basado en la interdisciplinariedad y la contextualización, sustentado por el proceso de internacionalización. Metodológicamente, esta investigación se caracteriza como un estudio de caso, con un enfoque cuanti-cualitativo, y busca investigar cómo se está implementando la Internacionalización del Currículo en un campus de IFCE, con énfasis en los Cursos de Licenciatura en Física y Matemáticas. Los resultados revelan que los estudiantes demuestran cierto nivel de familiaridad con la Internacionalización de la Educación Superior y del Currículo. Aunque pocos conocen el tema en profundidad, se observó que los alumnos consideran la internacionalización relevante para su formación, destacando los beneficios académicos, profesionales y personales de un currículo más internacionalizado y conectado globalmente.

Palabras clave: Internacionalización del Currículo. Enseñanza de Física y Matemática. Instituto Federal de Educación, Ciencia y Tecnología de Ceará. Formación Inicial del Profesorado.

1 Introduction¹

The teaching of physics and mathematics still faces challenges due to the difficulties presented in learning these subjects, which are fundamentally based on mathematical calculations and equations. In this regard, Bachelor's Degree Courses in Physics and Mathematics are important mechanisms for a new perspective on teaching based on global citizenship, interculturality, scientific initiation, and project development.

Given the importance of education physics and mathematics teachers in Brazil, reflecting on the curriculum and its internationalization process has become central to discussions proposed by academic centers and education departments. In this dialogue, the Federal Institute of Education, Science, and Technology of Ceará (IFCE) has the mission of offering quality technical and higher education based on interdisciplinary and contextualized work (Federal Institute of Education, Science, and Technology of Ceará [IFCE], 2024a).

According to Goodson (2007), the curriculum is essential in promoting learning and, in this context, aligning reflections on the curriculum with the internationalization process leads to a vision of teaching and learning that focuses on the formation of global citizens. In this regard, Leask (2015) emphasizes that the process of curriculum internationalization has been expanding over the last 25 years, mobilizing reflections on themes such as global citizenship, interculturality, and academic mobility.

Concerns about the quality of initial teacher education have been the focus of discussions in recent decades. In this regard, studies in the field of teacher education have shown the need for more reflective pedagogical action in undergraduate courses. This

¹ This study is an offshoot of research conducted as part of the Diploma in Management of Latin American University Internationalization, promoted by the National University of Comahue in partnership with the Network of Researchers and Managers in Internationalization of Higher Education in Latin America.

movement contrasts with the education model based on the transmission of knowledge, the fragmentation of knowledge, and the separation between specific and pedagogical disciplines.

Even in the face of kaleidoscopic views on the curriculum, based on different epistemological perspectives, we identify intersections between them that we highlight as fundamental to the debate about the identity of undergraduate courses [...] (Farias & Neto, 2022, p. 927).

In this sense, “Regulatory frameworks and debates have moved toward changes in initial and continuing education that are expressed in their curricula [...]” (Farias & Neto, 2022, p. 932). In fact, working on the internationalization of the curriculum in undergraduate courses has become a necessity and, in this context, Knight (2020) states that learning is the result of the particularities inherent in the international and intercultural attributes of knowledge, enabling an inclusive dimension whose possibilities focus on scientific literacy.

In Brazil, the internationalization of higher education occurs in a heterogeneous manner, with a greater concentration of work produced in the southeast and south of the country compared to the northeast and north. Because of this, there is a need for greater academic production in these regions in relation to the aforementioned theme, “[...] the analyses produced in this regard require an understanding of extremely varied realities, given that HEIs have varied missions, orientations, profiles, spatial distribution, and academic organization” (Sousa & Sousa Filho, 2024, p. 4).

Thus, the questions that permeate this research can be expressed as follows: (1) How is the internationalization of the curriculum being implemented at IFCE in the Bachelor's Degree courses in Physics and Mathematics?; (2) How do students perceive this process?; (3) What are the contributions of internationalization to the academic and civic education of undergraduate students?; (4) How does internationalization relate to pedagogical practices such as interdisciplinarity, research, and academic mobility?

In this context, this research is justified by the need to strengthen and disseminate academic production related to internationalization in Higher Education Institutions in the North and Northeast regions of Brasil, territories historically marked by socioeconomic inequalities and where a large part of the population sees quality public education as an essential path to social mobility and the transformation of their realities.

In this dialogue, Leask (2015) argues that making use of Curriculum Internationalization in Higher Education Institutions leads students to greater intercultural understanding, the development of global skills, and critical engagement with diverse knowledge, thus promoting a more inclusive academic education, connected to contemporary challenges and sensitive to local specificities.

This approach is particularly relevant because it enhances the role of students and teachers in the international academic scene, while valuing knowledge produced in historically invisible contexts (Alves, 2024).

Methodologically, this research is characterized as a case study, presenting a quantitative-qualitative approach. The research subjects are undergraduate students in the Physics and Mathematics Degree Courses at an IFCE campus², located in northeastern

² Small fragments of this text, in terms of theoretical basis, have already been cited in another publication by us (Alves, S. C. & Abba, M. J. (2023). Environmental Citizenship and Curriculum Internationalization Strategies. *Revista Eletrônica Científica Ensino Interdisciplinar*, 9(30), 374-383. <https://doi.org/10.21920/recei72023930374383>).

Brazil. The research technique used was the application of a questionnaire, made available via *Google Forms*. As a result, we have the presentation of the undergraduate students' perception of university internationalization.

In terms of the organization of this work, in addition to the Introduction, the text is outlined as follows: section 2 presents the theoretical framework that underpins the research. Section 3 discusses the methodological procedure adopted in the development of the study. Section 4 presents the results achieved and the discussion held. Finally, section 5 presents the final considerations on the research.

2 Theoretical Framework³

This section presents the theoretical framework that underpins the core discussions of this study, providing the conceptual support necessary for analyzing the education practices developed in the Physics and Mathematics Teacher Education courses. It is considered that significant challenges remain in consolidating teacher education that provides answers to the contemporary demands of science education, especially with regard to the need for more contextualized, integrated curricula that are aligned with international perspectives.

In this sense, the historical, epistemological, and pedagogical understanding of these areas is a basic requirement for interpreting the transformations that Brazilian education has undergone in recent decades, as well as for addressing the limitations still observed in education processes. Thus, the reflections made in this research establish the theoretical foundation that guides the interpretation of the data and supports the construction of the analyses developed throughout this work.

2.1 Physics and Mathematics Education and Knowledge Production

Reflections on the teaching of physics and mathematics in Brasil have been motivated by the needs of society. According to Araújo and Vianna (2010), the Physics Degree Course in Brasil was created by Decree No. 1190 of 1939. For Nascimento (2010, p. 7), “Physics participates in scientific and technological development with important specific contributions, whose consequences have economic, social, and political reach [...]”.

Also according to Nascimento (2010, p. 8), “There is a strong emphasis on mathematical models and memorization of formulas, forgetting that this science brings students closer to their reality [...]”. In fact, interaction with physical knowledge promotes different types of knowledge that affect life in society.

According to Heineck (1999, p. 228), “The utilitarian value of physics as a school subject is associated with the reasons that make it an instrument for life, work, and other sciences, manifested through different real situations observed and through the construction of models [...]”. This action manifests itself in the interpretation of the results found, which are the product of individual and collective action.

In fact, physical knowledge involves the measurement of natural phenomena, culminating in technological production and the promotion of natural resource sustainability, preparing students for a better quality of life through the exercise of global citizenship. Through the teaching of physics, students construct and develop coherent models, involving simple and complex methodological processes, which ensure the deepening of the curricular in a dynamic and gradual manner.

³ The identity of the campus was kept confidential to ensure anonymity.

According to Frota Pessoa (1984) cited by Heineck (1999, p. 229), "[...] it is common to confuse two aspects related to the student's mental work in learning: on the one hand, thinking, analyzing, and constructing reasoning; on the other, applying models and formulas to solve problems." Still in relation to the teaching of physics, Heineck (1999, p. 229) argues that

The teaching situation itself is, above all, educational, so it should be a situation of encounter, of dialogue, in which teacher and student place themselves as human beings. This relationship, then, is neither neutral nor impersonal, but characterized by intersubjectivity, because it is open. Therefore, how to teach science stems from the relationships that the teacher can make between their knowledge about the student's cognition and their social practice.

In this regard, it should be noted that discussions on the teaching of physics began in the 1970s with the publication of works in the field of study in question, discussing the need to develop national projects to improve teaching. This should be based on the student's everyday reality, structured in such a way as to enable continuous learning, given the complexity in the detail and observation of the issues that arise in society in order to reflect on possible solutions. Thus, the physics teacher

"[...] is preferably dedicated to the formation and dissemination of scientific knowledge in different social instances, whether through formal school teaching or through new forms of scientific education, such as videos, software, or other means of communication (Brasil, 2001a, p. 3, emphasis added).

In fact, Physics Degree Courses play a major role in the development of university extension curricula in order to meet the educational needs of the 21st century. With the objective of scientific education and the dissemination of knowledge, they seek to train teachers through the development of skills and abilities for working in basic education and/or higher education.

According to the National Curriculum Guidelines for Physics Degree Programs (Brasil, 2001a, p.1), "There is practically a consensus that physics education in contemporary society should be characterized by a flexible curriculum in order to offer alternatives to graduates. [...]" and, in this regard, incorporating the internationalization of the curriculum into the curricular dynamics fosters solid and up-to-date knowledge in physics capable of transcending the limits of national education.

In relation to the teaching of mathematics, from a didactic point of view,

it takes as its starting point the logical acts of teaching. It seeks to understand mathematics, taken as a science, or even as a field of inquiry, analyzing the logic underlying this science in order to put this knowledge at the service of teaching. Teaching is characterized by the task of mediating the knowledge produced, the forms of its production, and the knowledge under construction by the student (Bicudo, 1999, p. 6).

According to Evangelista (2014), during the 210 years that the Jesuits remained in Brazilian territory, the sciences, and mathematics in particular, were not considered important content for the education of their students. The imperial period was marked by the teaching of arithmetic in the early years of the educational process, followed by the teaching of geometry

and algebra. In later years, trigonometry and mechanics were taught.

In the 20th century, the international scene pointed to issues in mathematics education focused on the reflections of the German Felix Klein, signaling the existence of a first international movement for the modernization of the teaching and learning process of mathematics.

In traditional teaching, in which mathematics was conceived as a mental discipline, the practice of memorization ended up having an impact on the development of more intuitive textbooks, which led to a decline in teaching (Passos & Nacarato, 2018). The editions of the National Congress on Mathematics Education focused on reflections on this process and, in particular, on the need for teacher education. In this context, it should be noted that the first Bachelor's Degree Courses in Mathematics were created in the 1930s.

“[...] In the late 1970s and early 1980s, the discussion about the failure of modern mathematics in Brazilian education and the end of the military dictatorship were part of a context of renewal of educational ideals” (Evangelista, 2014, p. 26). Thus, the history of mathematics was included in the curriculum starting in the 1980s.

The approach to higher education subjects, specifically the mathematics teacher education course, based on empirical research (mainly through interviews with teachers, but also using teaching materials, syllabi, and programs) seemed to fit perfectly with a reading from the studies of theorists (Valente, 2014, p. 182).

According to Brasil (2001b, p. 1), “[...] Mathematics has a long history of exchange with Physics and Engineering and, more recently, with Economics, Biology, Humanities, and Social Sciences.” In this regard, the inclusion of Curriculum Internationalization, from an interdisciplinary and contextualized perspective, deliberates on teaching performance in the context of promoting skills and abilities from a critical-reflective stance, developing students' problem-solving abilities.

Mathematical activity focuses mainly on ‘doing mathematics’, the mathematical activities that teachers carry out in their classes and that they want students to learn. This component includes the following aspects: teachers’ mathematical noticing, teachers’ mathematical reasoning, and teachers’ mathematical creation (Silva & Pazuch, 2025, p. 4, emphasis added).

According to Marín, Spinillo, and Lauter (2023, p. 2), "Research into the relationships between comprehension and problem solving requires establishing a broader association between mathematics and reading comprehension."

“Concerns surrounding the teaching and learning of mathematics have long been a point of interest, debate, and proposals, especially in research, studies, and investigations related to the field of mathematics education [...]” (Xavier, 2024, p. 112). In this context, there is an incentive for laboratory practices in mathematics as a space for problematization, organization, simulation, systematization, elaboration of proposals, reflections, and pedagogical practices in mathematics education.

Among the definitions used to characterize the Mathematics Teaching Laboratory, we defend “[...] the one that conceives it as a powerful space for structuring, organizing,

planning, and making mathematical thinking happen” (Lorenzato, 2012⁴, *apud* Xavier, 2024, p. 112).

These spaces have been the subject of studies in recent decades by authors such as Lorenzato (2012) and Passos (2012). These scholars have highlighted what is expected of this type of environment: to provide mathematical investigation and the socialization of ideas, encouraging curiosity about the unknown. According to them, it is a place to look at the certainties brought by those who use the environment, validate or refute them, and discover that different types of mathematics can coexist, as well as different ways of learning and teaching. In more concrete terms, it is a place that can provide playfulness and empirical experiments with different teaching materials (Godoi & Klöpsch, 2024, p. 22).

Thinking about mathematics education from the perspective of interdisciplinary laboratory practices promotes intellectual autonomy, creativity, and critical reflection, culminating in the formation of global citizens and constituting a fundamental element of a liberating education based on horizontal educational relationships (Freire, 2001⁵, *apud* Godoi & Klöpsch, 2024).

With the Law of Guidelines and Bases 9.394 of 1996, the National Curriculum Parameters of 1999, and the National Common Curriculum Base of 2017, there has been an educational strengthening that has fostered the improvement of Physics and Mathematics teaching, providing opportunities for better teacher education and making degree courses in the field of study in question an effective mechanism for meeting the needs of society.

In this context, it is important to note that the renewal of science education (biology, physics, mathematics, and chemistry) has been discussed by authors such as Antônio Cachapuz, Daniel Gil-Perez, Amparo Vilches, Attico Chassot, among other teachers and researchers in education who are faced with the need for curricular renewal in the sciences based on interdisciplinarity and contextualization.

2.2 The need for curriculum renewal

According to Cachapuz *et al.* (2005), the renewal of science education is linked to the epistemological renewal of teaching through initial teacher education based on research from the triad of teaching, research, and extension, whose spectrum focuses on the development of projects and research that enable experimentation.

In this perspective, Chassot (2003) states that scientific literacy represents an emerging aspect of science teaching, incorporating everyday scientific practice into the classroom and promoting mastery of scientific language, an essential tool for education citizens to exercise their citizenship in a global context. Thus, reflecting on the physics and mathematics curricula from a diverse syllabus that incorporates elements of curriculum internationalization under an intercultural and interdisciplinary approach favors the contextualization of content and broadens its meaning for students.

Chassot (2003) highlights scientific literacy as an innovative approach in science teaching, focused on the critical understanding of scientific knowledge in everyday life. Complementarily, Leask (2021) proposes global literacy as a model that integrates international and intercultural dimensions, enabling students to act consciously and engage in

⁴LORENZATO, S. A. The Mathematics Teaching Laboratory in Teacher Education. 3rd ed. Campinas, SP: Autores Associados, 2012.

⁵ FREIRE, Paulo. Letter from Paulo Freire to teachers. *Advanced Studies*, vol. 15, no. 42, 2001, pp. 259-268.

diverse social and professional contexts.

In this scenario, it can be observed that scientific literacy and global literacy, by broadening students' critical understanding and insertion into broader contexts, converge with contemporary discussions on the internationalization of the curriculum, which now plays a structuring role in academic policies and teacher education practices.

2.3 Internationalization of the Physics and Mathematics Degree Curriculum and the Role of Academic Institutions and Policies

Abba (2018) points out that internationalization, especially in the fields of university teaching and research, has driven the attraction of financial resources for the promotion of interinstitutional projects. Analyzing its impacts on the teaching-learning process allows us to recognize the multiple layers and challenges involved in this phenomenon. Thus, over the last 50 years, internationalization has played a central role in the reconfiguration of higher education on a global scale.

In this scenario of transformation and growing demands, the role of Brazilian public institutions in strengthening educational quality and international integration stands out. With a mission to offer quality education, the Federal Institute of Education, Science, and Technology of Ceará (IFCE), for the purposes of the legal provisions that regulate the evaluation and supervision of the institution and higher education courses, has the legal support of the Federal Government and is equivalent to federal universities (IFCE, 2024a).

The IFCE's International Relations Office (ARINTER) plays a strategic role in promoting international cooperation and is responsible for formulating and coordinating policies aimed at scientific, technological, artistic, and philosophical exchange with partner institutions. Through agreements and partnerships, ARINTER enables the development of interinstitutional projects aligned with the areas of teaching, research, and extension (IFCE, 2024b).

Among ARINTER's responsibilities are

- 1) Representing IFCE before other organizations in Brasil and abroad, with regard to the institution's international relations;
- 2) Assisting faculty, students, and technical-administrative staff in seeking academic and professional development opportunities abroad;
- 3) Interacting with other IFCE departments in the conduct and execution of various international programs, monitoring their development and disseminating the results obtained [...] (IFCE, 2024b).

Fulfilling its social role, IFCE works to train teachers and professionals for education networks, developing teaching, research, extension, and internationalization activities focused on social transformation. When analyzed in its various dimensions, the internationalization of higher education places the internationalization of the curriculum as a crucial aspect, resulting from the learning generated through cooperation and academic exchange activities. These practices have directly impacted university curricula, promoting the transformation of teaching approaches and strengthening collaboration between Higher Education Institutions (Knight, 2020).

Specifically, the internationalization of the curriculum in physics and mathematics courses facilitates the incorporation of global knowledge, encouraging theoretical deepening and the development of skills that enable students to act effectively in contemporary reality. In this context, internationalization becomes a strategic element for improving academic learning

(Leask, 2015).

This process involves an articulation between interdisciplinarity and contextualization, fundamental principles of Curriculum Internationalization, which translate into innovative pedagogical practices. Cooperation and solidarity between different areas of knowledge, combined with a global vision, are decisive for the creation of a more dynamic and integrated curriculum (Alves & Abba, 2023). Thus, when reflecting on the Internationalization of the Curriculum in Physics and Mathematics Degree Courses, the aim is to align specific knowledge in the areas of study with an education that integrates the concepts of global citizenship and interculturality, promoting a more accessible and transformative science education for all.

3 Methodological Design

This research is configured as a case study, as defined by Triviños (1987), which is a methodology that allows for in-depth study of a specific topic. The empirical field of this research is a campus of the Federal Institute of Education, Science, and Technology (IFCE), located in the state of Ceará, in the Northeast region of Brasil.

The research technique used was a questionnaire, made available via *Google Forms*, featuring open and closed questions with the generation of graphs that are available in the presentation of the results. According to Gil (1987), the questionnaire is an investigative technique for obtaining data from the empirical field, used in the presentation of results in social research and, in this context, may have one or more questions, with the aim of understanding different opinions and situations experienced by the research participants.

The research adopts a mixed approach, that is, quantitative-qualitative. As Triviños (1987) explains, the quantitative approach refers to the analysis of data in terms of quantification, which can be expressed in absolute numbers or percentages. In this case, the quantitative data were obtained through closed questions, resulting in the generation of the graphs available in the presentation of the results.

On the other hand, the qualitative approach, according to Minayo (2013), seeks to understand the subjective aspects of social reality. Qualitative data were extracted from the open-ended questions in the questionnaire, allowing participants to express their perceptions on the topic. The use of the quantitative-qualitative approach is justified by the need to analyze the data comprehensively, combining numerical precision with the nuances of individual experiences.

The participants in this research are undergraduate students in the Physics and Mathematics Degree Courses at IFCE, totaling 212 students. The choice of this group is based on the fact that the students have a complete academic experience in the course, having contact with all disciplines and, thus, a comprehensive view of the Degree, IFCE, and the process of university internationalization.

The importance of looking at internationalization from the students' perspective is reiterated, as they are the main subjects of this academic transformation. Direct involvement with the curriculum, academic activities, and internationalization actions allows undergraduate students to offer a unique view of the real impacts of these initiatives on their personal and professional development. Furthermore, by considering the students' perspective, it is possible to identify which aspects of internationalization are most valued, which ones still present challenges, and how the process can be improved to better meet their educational and education needs for the globalized job market.

This perspective is also essential for adjusting internationalization policies to students' expectations and reality, promoting greater adherence and engagement in the actions proposed by the institution. Among the questions presented to students, the following stand out:

- (a) Dear Participant, have you heard of the Internationalization of Higher Education and the Internationalization of the Curriculum? (Open Question);
- (b) Dear Participant, does IFCE have foreign teachers? (Closed Question) (Alternatives: () yes / () no);
- (c) Dear Participant, in your opinion, what actions does the Internationalization of Higher Education refer to? (Closed question) (Alternatives: (a) Dynamic and multidimensional process involving actions such as partnerships between universities; (b) Result of international and intercultural learning; (c) The reformulation of the higher education system is driven by revisions; (d) Process involving interculturality and global citizenship);
- (d) Dear Participant, in your opinion, what actions does the internationalization of the curriculum refer to? (Closed question) (Alternatives: (a) Guaranteeing academic mobility; (b) Promoting exchanges with other institutions; (c) Offering courses on topics related to the internationalization of the curriculum);
- (e) Dear Participant, when do you identify the internationalization of the physics and mathematics curriculum? (Closed question) (Alternatives: (a) The university promotes scientific literacy among students; (b) The university encourages scientific initiation programs and scholarships; (c) The university discusses concepts and central elements of curriculum internationalization; (d) The university guarantees actions such as international mobility);
- (f) Dear Participant, do you consider the internationalization of higher education and the internationalization of the curriculum to be relevant to your professional career? (Closed question) (Alternatives: () yes / () no);
- (g) Dear Participant, does IFCE have students in Academic Mobility? (Closed question) (Alternatives: () yes / () no);
- (h) Dear Participant, comment on how the internationalization of the physics and mathematics curriculum can help students in their intellectual, emotional, and professional development (Open-ended question).

The questions above were organized to capture different dimensions of students' perceptions of the internationalization of higher education and, in particular, the internationalization of the curriculum in the context of IFCE's Physics and Mathematics degree programs. The first question (a), which is open-ended, seeks to identify participants' prior knowledge of key concepts. The following questions (b, c, and d) deepen the investigation, addressing institutional and practical aspects of internationalization. Question (e) directs students' attention to the concrete identification of internationalization experiences in their own course, while question (f) assesses the perception of the relevance of these actions for professional education. Question (g) complements the institutional overview, verifying students' knowledge of academic mobility at IFCE, and finally, the open question (h) allows for a more qualitative analysis of how students perceive the impacts of curriculum internationalization on their intellectual, emotional, and professional development. Thus, the proposed questions strategically combine open and closed questions to capture both the level of knowledge and the perceptions and experiences of the participants, allowing for a broad and integrated understanding of the phenomenon under investigation.

After data collection, the analysis stage aimed to organize the data in order to enable

the construction of coherent answers to the research problem, allowing for an understanding of the phenomena investigated (Gil, 1987). In this study, the analysis focuses on the perceptions of undergraduate students in the Physics and Mathematics Degree Courses regarding the process of Curriculum Internationalization, seeking to identify how this theme is understood and experienced in the context of IFCE.

To this end, the content analysis method was adopted, as proposed by Bardin (1977), which considers the word as the fundamental unit of investigation, allowing a systematic, objective, and qualitative approach to the information collected. This method enables the decomposition of messages into thematic categories, facilitating the interpretation of the meanings attributed by participants to their experiences and opinions.

Content analysis is especially useful in research involving data from questionnaires, as it offers a theoretical and methodological tool capable of revealing recurring patterns, implicit meanings, and latent structures in the subjects' narratives. In the context of this study, this technique was applied to the students' responses to the questionnaire questions, with the aim of achieving a richer and deeper understanding of the representations and perceptions related to the Internationalization of the Curriculum.

Through this analytical process, it was possible to identify not only relevant themes but also nuances in the students' ways of thinking and feeling about the topic, contributing to a more sensitive and informed interpretation of the information obtained. The main results extracted from this analysis are presented below, highlighting relevant aspects of the undergraduate students' engagement with the topic, their understanding, and the challenges perceived in the educational process.

4 Results and Discussion

This section aims to present the results obtained in the research. As mentioned earlier, the participants in this study are students from the IFCE's Physics and Mathematics Degree Courses. Initially, undergraduate students were asked if they had ever heard of the Internationalization of Higher Education. Twenty percent of the students answered affirmatively, indicating that the topic has been discussed, albeit to a limited extent, on the campus investigated, suggesting a certain level of knowledge on the subject.

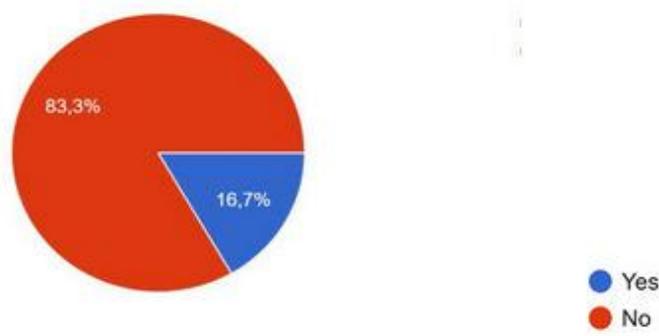
According to Knight (2020), the internationalization of higher education has had a significant impact on the construction of university curricula, especially as globalization and information technologies advance. This process fosters sociability and the communicability of knowledge, expanding the possibilities for research and collaborative projects and, in addition, contributing to the promotion of a curriculum with an international vision.

During the survey, students were asked if they had ever heard of Curriculum Internationalization. In this case, 16.7% of participants stated that they were aware of the topic (Graph 1). This result indicates that the debate on Curriculum Internationalization is still in its infancy among students, highlighting the need for greater dissemination and in-depth study of the topic in undergraduate courses and, more specifically, in the subjects offered, which may also be indicative of the gradual integration of the topic into teaching practices.

Leask (2015) argues that Curriculum Internationalization is an essential strategy for universities, with the aim of enriching learning and preparing students for the demands of a globalized society. By developing curricula aligned with contemporary needs, higher education institutions have the opportunity to promote actions that favor the insertion of students into the international scene, especially in areas such as Physics and Mathematics,

which have a strong global component in the development of scientific knowledge.

Graph 1: Dear participant, have you heard of Curriculum Internationalization?

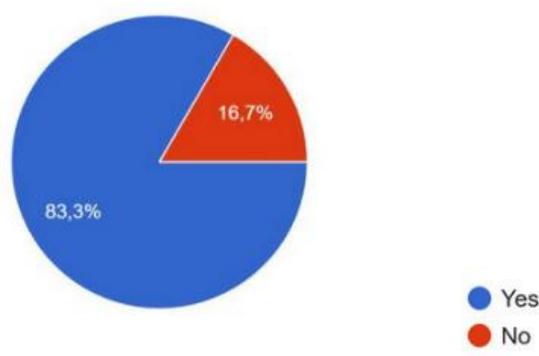


Source: Prepared by the authors (2024)

Next, undergraduate students were asked if IFCE has foreign professors, and 83.3% of students answered positively (Graph 2). This data highlights the inclusion of international practices in the institution, albeit on an ad hoc basis, contributing to the construction of a more diverse academic environment aligned with the principles of Curriculum Internationalization.

Based on the response obtained, we can observe the importance of the work carried out by the International Relations Advisory (ARINTER), the body responsible at IFCE for developing and coordinating international cooperation policies. ARINTER plays an essential role in promoting scientific and technological exchanges with other institutions, enabling the creation of interinstitutional projects and the establishment of partnerships and agreements, with an emphasis on the pillars of teaching, research, extension, and internationalization (IFCE, 2024b).

Graph 2: Dear participant, does IFCE have foreign teachers?

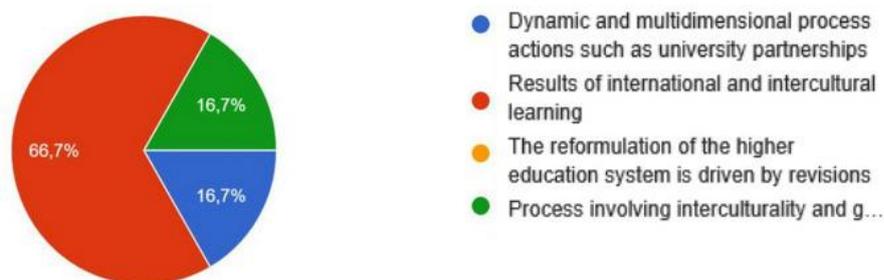


Source: Prepared by the authors (2024)

Continuing with the questions, undergraduate students were asked to share their opinion on the actions they consider to be related to the internationalization of higher education. When asked about this topic, 66.7% of participants stated that internationalization is directly linked to the results of international and intercultural learning, emphasizing the importance of these experiences in academic education. In addition, 16.7% of participants believe that the internationalization of higher education mainly involves the promotion of global citizenship and interculturality, which are fundamental aspects in preparing students for

an increasingly connected world. Finally, 16.7% of participants also consider internationalization to be a dynamic and multidimensional process, whose objective is to promote strategic partnerships between universities, enriching academic education and favoring the exchange of knowledge and experiences (Graph 3).

Graph 3: Dear participant, in your opinion, what actions does the internationalization of higher education refer to?



Source: Prepared by the authors (2024)

The survey presented above reveals a relatively broad, albeit still diverse, understanding among undergraduate students of the concept of the internationalization of higher education. The majority (66.7%) of participants associate internationalization with the results of international and intercultural learning, which indicates a perception focused on the concrete benefits that these experiences bring to academic education, such as the acquisition of linguistic, cultural, and scientific skills in global contexts. This data suggests that students value international experiences as tools for personal and professional improvement, recognizing their role in building more competitive and adaptable academic profiles.

On the other hand, a smaller portion (16.7%) highlights the promotion of global citizenship and interculturality, aspects that go beyond technical or academic biases and demonstrate a more critical and humanistic understanding of internationalization. This view is in line with contemporary educational guidelines that seek to train individuals who are aware of their role in an interdependent and culturally diverse world. Finally, another 16.7% understand internationalization as a dynamic and multidimensional process aimed at building strategic partnerships between institutions. This perspective demonstrates an institutional and structural view of internationalization, recognizing its importance as a policy for academic, scientific, and cultural development supported by international collaboration networks.

Taken together, the data reveal that, although most still associate internationalization with individual learning experiences, there is a significant presence of more complex and comprehensive understandings among students. This may reflect both the impacts of institutional actions already implemented and the need to broaden the debates and pedagogical practices that involve internationalization in its multiple dimensions.

In this sense, Knight (2020) states that the internationalization of higher education is, in fact, a complex and multifaceted process that fosters cooperation between universities. When analyzing the expansion of this process in Higher Education Institutions around the world, its profound academic repercussions can be observed, which have led to the creation of innovative curricula, adapted to the demands of contemporary society. In this context, the Teaching of Physics and Mathematics emerges as a strategic didactic practice, focused on the common good.

Continuing with the questions, students were asked what actions could be considered related to the internationalization of the curriculum. All undergraduate students, i.e., 100% of the participants, responded that it is associated with promoting exchanges with other academic institutions (Graph 4).

Graph 4: Dear participant, in your opinion, what actions does the internationalization of the curriculum refer to?



Source: Prepared by the authors (2024)

The results show that the undergraduate students who participated in the survey associate Curriculum Internationalization with the promotion of exchanges with other academic institutions. This conclusion is quite significant, as it reveals a limited and predominantly traditional understanding of the concept of internationalization. Although academic exchange programs are indeed an important strategy within the internationalization process, they represent only one of several possible ways to implement this educational policy.

Curriculum internationalization goes beyond the physical mobility of students and teachers, as it includes, for example, the inclusion of international and intercultural content in teaching plans, the adoption of international online collaborative methodologies, the promotion of bilingual or multilingual activities, as well as the encouragement of virtual academic cooperation.

This understanding corroborates Knight's (2020) view, which highlights academic mobility, the inclusion of international content, the adoption of collaborative methodologies, among other topics, as mechanisms for internationalization. In this sense, internationalization in the teaching of physics and mathematics facilitates the exchange of teachers, students, policies, programs, projects, and services between institutions in different countries, expanding the dissemination of knowledge.

Reflecting on the internationalization of the curriculum for physics and mathematics courses, it is clear that this approach not only promotes deeper learning through interinstitutional projects and research, but also favors the integration of international and intercultural knowledge. In this context, the laboratory environment emerges as a crucial space for the development of innovative pedagogical practices.

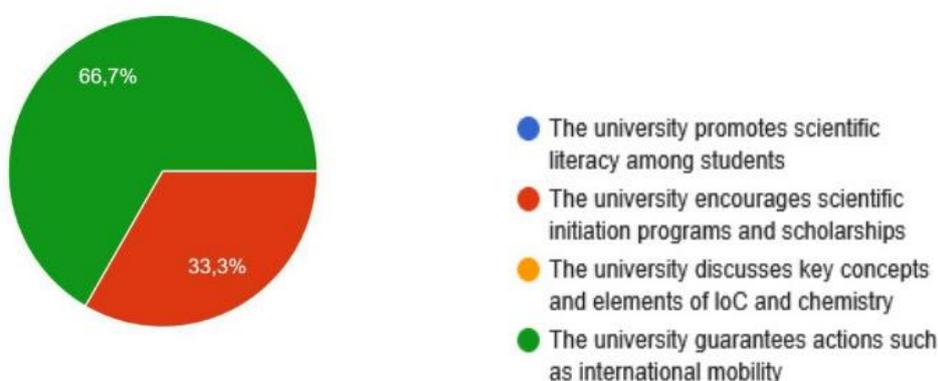
According to Xavier (2024), laboratories are characterized as places for problematization, organization, simulation, and reflection, which are fundamental for the construction of knowledge and the realization of pedagogical proposals. This process also contributes to the global literacy of undergraduate students, who are challenged to incorporate international knowledge into their field of study.

In line with this perspective, Morosini (2018) argues that curriculum components should be developed in such a way as to integrate international themes that drive knowledge

production. Therefore, when reflecting on the physics and mathematics curriculum from an intercultural and interdisciplinary perspective, it is possible to contextualize the content to the students' reality, promoting learning that is more aligned with the needs and challenges of the contemporary world. According to Lima and Alves (2022), interdisciplinarity and contextualization are key elements for the didactic transposition of knowledge, ensuring that learning becomes meaningful and transformative.

Next, students were asked how they perceive the internationalization of the curriculum in Physics and Mathematics courses. The results revealed that 66.7% of students associate internationalization with the implementation of actions such as international mobility. On the other hand, 33.3% of students identify internationalization as a process that involves encouraging research through scientific initiation scholarships (Graph 5).

Graph 5: Dear participant, when do you identify the internationalization of the Physics and Mathematics Curriculum?



Source: Prepared by the authors (2024)

In line with the previous responses, students again highlight the need to ensure international mobility, as well as the incentive for scientific initiation scholarships, highlighting the crucial role of the laboratory environment in the development of research and interinstitutional projects in Physics and Mathematics Education.

In dialogue with the responses of undergraduate students in the Physics and Mathematics Degree Courses at IFCE, Beneitone (2019) emphasizes that higher education institutions should promote curricula that favor international knowledge, preparing students to work in both national and international contexts.

Regarding the expansion of the internationalization of the Physics and Mathematics Curriculum, Heineck (1999) states that Physics Education should be understood as an essential tool for academic, professional, and scientific development. Xavier (2024) complements this view, pointing out that mathematics education should be approached as a discipline capable of provoking reflections on mathematical thinking in global contexts, connecting it with social and scientific realities.

Subsequently, undergraduate students were asked whether they consider the internationalization of higher education and the internationalization of the curriculum to be relevant to their future professional careers. All participants, 100%, answered affirmatively (Graph 6). The result shows that students recognize the importance of international and intercultural education as a differential in the job market, in addition to highlighting a growing awareness of the need to develop global skills to work in increasingly interconnected

professional contexts.

This not only promotes education that is more aligned with the demands of the contemporary world, but also contributes to the development of a Physics and Mathematics curriculum that integrates concepts of global citizenship and interculturality, covering both internationalization at home and across borders.

Graph 6: Dear participant, do you consider the internationalization of higher education and the internationalization of the curriculum to be relevant to your professional career?



Source: Prepared by the authors (2024)

Following on from the previous question, undergraduate students were asked whether IFCE offers academic mobility programs. Thirty-four percent of participants answered yes, showing that the institution has been committed to providing academic exchanges for undergraduate and graduate students. In this regard, there is a need for greater dissemination and accessibility of academic mobility programs.

It is important to note that ARINTER, the department responsible for managing internationalization at IFCE, coordinates programs such as IFCE International, the Emerging Leaders in the Americas Program (ELAP), the Milton Santos Program for Access to Higher Education (Promisaes), and the Merit Scholarship Program, in partnership with the Ministry of Foreign Affairs (IFCE, 2024b). These programs are fundamental for promoting exchanges and expanding academic mobility opportunities, contributing to the internationalization of IFCE and the education of its students in a global context.

Finally, students were asked to reflect on how the internationalization of the physics and mathematics curriculum could contribute to their intellectual, emotional, and professional development. Most undergraduate students highlighted that internationalization provides an enriching experience, allowing for more comprehensive learning and preparing them for global challenges through an internationalized curriculum.

“Through contact with internationalization, one can diversify the curriculum and acquire new knowledge of other cultures while also taking a little of our culture to other *places*” (Report by Student GMA, Undergraduate Physics Course, March 2024).

Below is another student's report:

The internationalization of the physics and mathematics curriculum offers significant benefits to students. By exposing students to global perspectives, it promotes intellectual development by broadening their understanding of complex concepts and stimulating creative problem solving. Emotionally, the diversity of cultural approaches contributes to cognitive flexibility and emotional adaptability,

valuable skills in life and career. In addition, interaction with students from different cultural backgrounds strengthens empathy and interpersonal understanding. In a professional context, the internationalization of the curriculum provides a competitive advantage, preparing students for globalized work environments (Report by Student VMM, Undergraduate Mathematics Program, March 2024).

Based on the reports of graduates from the Physics and Mathematics Degree courses, enriching perceptions are revealed that are aligned with the contemporary principles of Curriculum Internationalization. Although different in depth and focus, both testimonials offer valuable contributions to understanding the impact of this practice on students' academic and personal development, recognizing the formative and transformative value of Curriculum Internationalization.

These insights reinforce the importance of promoting continuous and reflective dialogue on internationalization in the academic environment, as well as expanding pedagogical strategies that allow students to experience in a concrete way the benefits that they themselves recognize as essential to their education.

According to Brasil (2001a, 2001b), the articulation between the teaching of physics and mathematics and the principles of interdisciplinarity and contextualization has been decisive in promoting skills and abilities essential to professional performance. When aligned with the logic of internationalization, this approach strengthens the communication of scientific knowledge and helps students understand and apply knowledge in diverse social, cultural, and educational contexts, expanding the scope and relevance of the academic curriculum.

The data obtained reinforce that the campus investigated has specific internationalization initiatives, such as the presence of foreign professors and the offer of academic mobility programs. However, students' perceptions indicate that these actions are still little known or insufficiently publicized, with only 34% stating that they are aware of mobility programs, and only 20% and 16.7% reporting familiarity with the concepts of Internationalization of Higher Education and Curriculum, respectively.

Despite this, the reports and responses demonstrate that there is a growing understanding of the importance of internationalization for academic, intellectual, and professional education, especially in the context of degrees in Physics and Mathematics, areas marked by strong global connections in scientific and educational development.

These findings reveal that, although there is institutional potential and student interest, Curriculum Internationalization still needs to be expanded, systematized, and incorporated more effectively into pedagogical practices and institutional policies. ARINTER's work is strategic, but it requires greater coordination with undergraduate courses and with teaching and learning activities that integrate international and intercultural content into the formal curriculum.

In addition, it is essential to promote awareness-raising and teacher education actions that enable academic mobility to become just one component of a broader policy of internationalization at home. In this way, the campus will be able to consolidate a more inclusive, globalized educational environment committed to the civic and professional education of its students, in line with the contemporary demands of higher education, as guided by international organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) (2016).

5 Final Considerations

Throughout this research, it became clear that the topics of the internationalization of higher education and the internationalization of the curriculum are still little known among students in the Physics and Mathematics Degree Courses at the IFCE campus investigated. Despite this, the data point to a growing awareness of the importance of internationalization as an academic and professional differential. Although only a minority of participants demonstrated familiarity with the concepts investigated, the majority recognize their formative and transformative value, especially in the context of a globalized and interconnected society.

The perceptions gathered reveal that, for students, internationalization is mainly associated with academic mobility, indicating a traditional understanding of the concept. However, the literature points to the need to broaden this understanding, incorporating actions such as the inclusion of international content in teaching plans, the use of collaborative methodologies, and the encouragement of interinstitutional research. This conceptual expansion is essential to make Curriculum Internationalization more accessible and effective, especially for those students who are unable to participate in physical mobility.

It is also noteworthy that the laboratory environment and scientific initiation are seen as privileged spaces for the development of international practices, especially in the areas of Physics and Mathematics, which have a strong connection with global scientific production. Encouraging collaborative research projects, participation in international networks, and building partnerships with foreign institutions can significantly expand opportunities for intercultural and interdisciplinary learning for undergraduate students.

ARINTER's work is a highlight within the IFCE's institutional structure, being responsible for important initiatives such as mobility programs and international partnerships. However, the data show the need to increase awareness of these actions among students, as well as to integrate the proposals of the international relations advisory department more directly into the curricula and teaching practices of the courses. This includes the need for continuous teacher education focused on internationalization at home, allowing teachers to act as mediators of this process in their daily classes.

Student reports show that internationalization is perceived not only as a mechanism for improving academic education, but also as an opportunity for personal, emotional, and cultural growth. By experiencing global experiences, even if locally, students develop skills such as empathy, adaptability, critical thinking, and collaboration, which are essential for working in an increasingly pluralistic world. Thus, the internationalization of the curriculum contributes to a more humane, critical, and engaged education.

Finally, it is concluded that the campus investigated has the potential to expand its internationalization policy, especially in Physics and Mathematics courses. To this end, it is necessary to strengthen the articulation between institutional actions and pedagogical practices, promote greater dissemination of existing opportunities, and invest in teacher education. Only with a systematic, continuous, and integrated approach will it be possible to consolidate a truly internationalized curriculum that prepares students for the scientific, social, and cultural challenges of the 21st century.

Like all scientific research, this study has limitations that need to be recognized for a proper understanding of its results. Although empirical data were collected through questionnaires administered to students, the research did not consider other sources of evidence, such as interviews, analysis of teaching plans, or systematic observations of

teaching practices. This methodological choice limited the possibility of further exploration of how curriculum internationalization and formative practices are implemented in the work of teachers in undergraduate physics and mathematics courses.

Another limitation refers to the institutional sample adopted, which may restrict the generalization of the findings. The understandings and perceptions identified reflect a specific context and may not fully represent the reality of other Brazilian institutions. The organizational structure, local educational policies, and different levels of consolidation of internationalization can directly influence curriculum implementation, requiring caution in extrapolating the results.

Given these limitations, it is recommended that future studies: (1) expand data collection strategies, incorporating interviews, detailed document analysis, focus groups, or participant observation, allowing for an understanding of the dynamics between the prescribed curriculum, the curriculum in action, and the pedagogical experiences of teachers; (2) compare different higher education institutions in Brasil and other countries, allowing for the identification of convergences, divergences, and structural challenges of internationalization in physics and mathematics degree programs; (3) investigate teachers' perspectives, exploring their preparation, conceptions, and difficulties in implementing practices integrated with internationalization and the development of global competencies; (4) analyze longitudinally the impacts of curriculum internationalization on students' academic education and professional trajectories, contributing to a more consistent assessment of its formative relevance.

In this way, future research will be able to deepen the understanding of the transformation of educational practices in higher education, contributing to the strengthening of more inclusive, critical, global curricula that are aligned with the contemporary demands of society.

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