



## Article

# Incorporating bioeconomics as a course of an undergraduate program in Economic Science

**Rosana Zau Mafra<sup>1</sup>, Andreia Brasil Santos<sup>2</sup>**  
Federal University of Amazonas (UFAM), Manaus-AM, Brazil

## Abstract

This study advocates the importance of including a course of bioeconomics in an undergraduate program in Economic Sciences of a Higher Education Institution in the State of Amazonas, considering the institution's location in a region of enormous environmental value. A course of bioeconomics contributes to promote sustainable use of the region's biodiversity and meet most elements advocated by the Bioeconomy Agenda for 2030. The strengthening of the techno-scientific basis for this area of knowledge has been supported in reports from international and national entities such as the Organization for Economic Cooperation and Development (OECD) and the National Confederation of Industry (CNI). A literature review was carried out. Resolutions that include program outlines and sectoral reports defending the proposal were consulted. Empirical data revealed that the word bioeconomics appears only as an element of the syllabus in a few undergraduate programs in Brazil. Some graduate programs, on the other hand, offer a module on bioeconomics. The proposal to add bioeconomics as a course offered in undergraduate programs is discussed in this article, considering the particularities of the Federal University of Amazonas. It is a daring proposal and demands a paradigm change. Among the findings, it is worth stressing the advantages of partnerships between academia and the private sector to stimulate the development of the studies in bioeconomics in undergraduate programs, following examples observed in other countries such as Germany.

**Keywords:** Bioeconomics, Economic Sciences, Pedagogical Project, Syllabus.

## Introduction

The Brazilian National Council of Education (CNE) issued Opinion 776 in 1997, advising undergraduate programs to abandon program outlines based on characteristics that reduce them to instruments for the transmission of knowledge and information (BRASIL, 1997). The CNE suggests that these programs offer basic qualifications that prepare undergraduate students to face the challenges of the rapid changes in society and the labor market.

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<sup>1</sup> Adjunct Professor of the Department of Economics and Analysis of the Federal University of Amazonas. Ph.D. in Biotechnology. ORCID id: <https://orcid.org/0000-0002-7133-9824>. E-mail: [rosanazau@ufam.edu.br](mailto:rosanazau@ufam.edu.br)

<sup>2</sup> Associate Professor of the Department of Economics and Analysis of the Federal University of Amazonas. Ph.D. in Production Engineering. ORCID id: <https://orcid.org/0000-0002-6691-744X>. E-mail: [brasiland@ufam.edu.br](mailto:brasiland@ufam.edu.br)

The National Curriculum Guidelines for the undergraduate programs in economic sciences were established by Resolution 4, enacted on July 13, 2007 (BRASIL, 2007). The guidelines instruct that the program outline (PO) for undergraduate programs in economic sciences should offer the objective conditions to guarantee adequate education and maintain the program's vocation while respecting particularities and ensuring the operationalization and the structural elements of the same guidelines. The discussion in this article is developed in the context of the Federal University of Amazonas (UFAM). The institution's purpose is to encourage knowledge of current world problems, particularly Brazilian problems and those of the Amazon region (UFAM, 1998; 2016). Thus, the current PO of the UFAM undergraduate program in economics details that graduated students must be citizens identified with the problems of the Amazonian reality (UFAM, 2008).

Article 5 of Resolution 4 states that POs must include content that deals with the interrelationships with national and international reality, according to a historical and contextualized perspective of the different phenomena related to the economy, using innovative technologies. The challenge posed by the Organization for Economic Cooperation and Development (OECD) for 2030 refers to the global ecosystem that shelters human society and which will be unsustainable and overexploited to meet the demand for forest, agricultural, aquaculture, and health products (OECD, 2009). In this perspective of following the international mainstream, it is timely to introduce Bioeconomics<sup>3</sup> to undergraduate programs, even if it is an elective course, as provided for in Opinion CNE/CES 95/2007 (BRASIL, 2007).

Bioeconomics is the result of a revolution of applied innovations in the field of biological sciences. It is directly related to the innovation of biological products and processes in the areas of human health, agricultural and livestock productivity, and biotechnology (CNI, 2013). As it is located in a region of enormous environmental value, it is natural for a higher education institution (HEI) such as UFAM to start inserting courses of this nature in the PO, bringing the theoretical aspects closer to regional particularities and respecting the minimum workload of each program.

Therefore, this article proposes to offer subsidies to argue for the inclusion of a course on bioeconomics in the PO of the undergraduate program in economic sciences at UFAM (Manaus – Brazil), bringing to the discussion necessary paradigm changes for the acquisition of skills. This article is structured as follows: the next section presents a brief theoretical context for a better understanding of the object of study, followed by the methodology, and subsequently the experiences of institutions in the conception and implementation of courses on bioeconomics in undergraduate and graduate programs.

### **Update of the program outline (PO)**

The objective of the program outline (PO) is to develop the professional skills that are required of the student in the labor market, in addition to contributing to innovation, creation, and transformation of their work environment, collaborating with the development of essential skills (CHING et

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<sup>3</sup> When it comes to discipline, this term will be capitalized.

al., 2014). Among the main areas of activity of graduates of economic sciences are the elaboration of projects' economic viability, business economics, financial orientation, consulting and advisory, agroindustrial/agribusiness advisory projects, development of infrastructure projects, preparation of market studies, budgeting, expert examination, various economic advisory services, study and guidance of economic feasibility for new businesses, and creation of fundraising projects (UFAM, 2008).

The National Curriculum Guidelines represent an important milestone in the training of professionals in the field of economics and an invitation to dialogue in an attempt to mobilize efforts that do not allow a program to accommodate situations of perpetuity and conformity (CHING et al., 2014). According to the authors, there is no way to implement a new PO proposal without the faculty's support and participation that will teach the course. In addition:

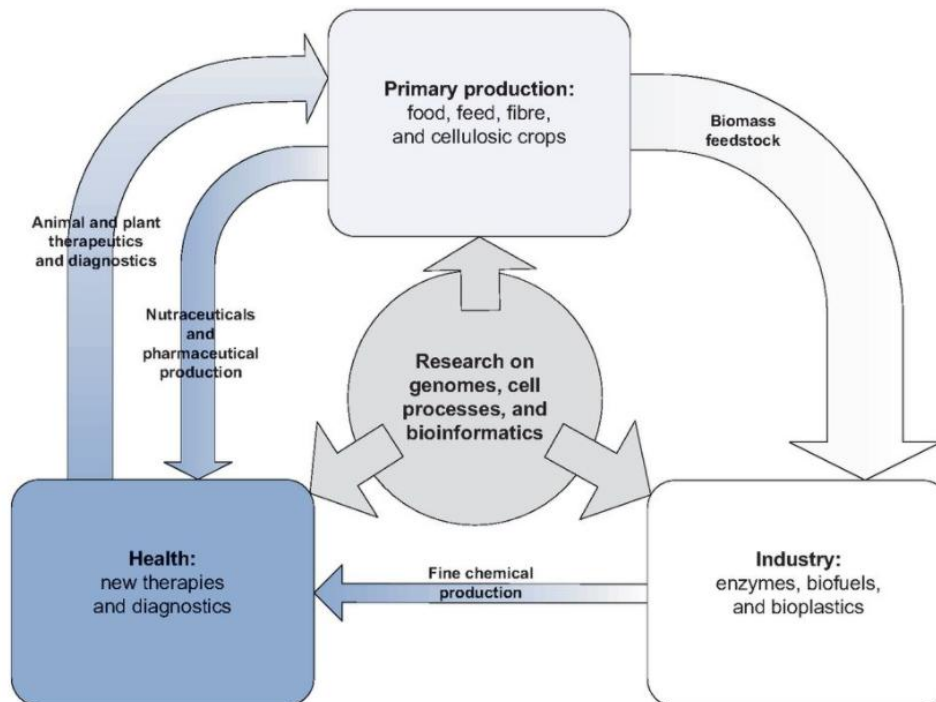
Any implementation of a program outline proposal requires a change in the mentality and paradigm of the program coordinator, faculty, students, as well as reorganization of educational institutions that are committed to training their students (CHING et al., 2014, our translation).

The undergraduate program in economic sciences at UFAM has ten professors who are members of the Structuring Teaching Nucleus (NDE, an acronym for *Núcleo Docente Estruturante*) that meet to develop a new PO proposal. Since April 2018, there have been about twelve meetings in a participatory process that has adjusted the PO. The nucleus activity is an opportunity for including bioeconomics as a subject of a course in the undergraduate program's PO.

## **Bioeconomy**

Bioeconomy does not have a single concept. In an article by Santi (2012) for *Revista O Papel*, the author reports the understanding of the prime-minister of Finland, Jyrki Katainen, on bioeconomy. According to Katainen, bioeconomy is understood in the US as "an ally of society; it can be considered as a new social and economic practice that challenges the current market practice." (Santi, 2012, p. 37, our translation). For the European Commission (EC), bioeconomy is understood as the "production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy" (EUROPEAN COMMISSION, 2012, p. 9).

The Organization for Economic Co-operation and Development (OECD, 2009, p. 22) developed the bioeconomy agenda for 2030. The institution considers bioeconomy as "a world where biotechnology contributes to a significant share of economic output." According to this agenda, bioeconomy involves three elements: biotechnological knowledge, renewable biomass, and integration between applications. Figure 1 shows this integration.

**Figure 1:** Current and expected integration across biotechnology applicationsSource: OECD (2009)<sup>4</sup>

The first element refers to using the knowledge necessary to produce a range of products, including biopharmaceuticals, recombinant vaccines, new plant varieties, and industrial enzymes. The second element refers to the use of biomass and efficient bioprocesses to achieve sustainable production. Renewable biomass can be obtained from the cultivation of food, grasses, trees, and seaweed, household, agricultural and industrial waste, among other sources. The third element has to do with integrating knowledge and application, based on general knowledge and the value-added chain that crosses applications and comprises three axes<sup>5</sup>: primary production, health, and industry (OECD, 2009).

For IPEA (2017), bioeconomy can be defined as an economy in which the basic pillars of production, i.e., materials, chemicals, and energy, are obtained from renewable biological resources.

In this “new” economy, biomass transformation plays a central role in the production of food, pharmaceuticals, fibers, industrial products, and energy. The difference between past and current bioeconomy is that it is now based on the intensive use of new scientific and technological knowledge, such as that produced by biotechnology, genomics, synthetic biology, bioinformatics, and genetic engineering, which contribute to the development of biological-based processes for the transformation of natural resources into goods and services (IPEA, 2017, p. 220).

<sup>4</sup> Arrow width represents the relative importance of the integration.

<sup>5</sup> Some literature consider 4 axes, including the environmental application. The OECD’s agenda includes environment in the primary production (OECD, 2009).

Therefore, bioeconomy appears as an alternative for sustainable development, and the determining factor involves the possibilities brought by the biological sciences to solve complex and often overlooked problems.

### **Bioeconomy worldwide and in Brazil**

It is estimated that in 2016 bioeconomy contributed USD 50 billion to the gross domestic product (GDP) of the American economy and generated 250 thousand jobs (IPEA, 2017). The IPEA (2017) also states that, in Europe, bioeconomy businesses produced about EUR 2.1 trillion in 2013, 50% of which in the food, animal feed, and beverage sectors. The sector generated 18.5 million jobs in Europe, 58% in agriculture, forestry, and fishing (FARIA; CALDEIRA-PIRES, 2018).

In Brazil, the importance of bioeconomy is demonstrated by the sugarcane production chain. This business includes bioenergy, producing BRL 113.26 billion in 2015, BRL 34.19 billion in the primary production sector, and BRL 49.33 billion in the industry segment, the rest generated by input and services (IPEA, 2017). In 2014, more than 900 thousand formal jobs were created in the productive sector alone. These examples illustrate the importance of bioeconomy for economic development.

### **Reasons to include bioeconomics as a course in undergraduate programs**

The National Confederation of Industry (CNI, 2014), in its publication, *Agenda para o desenvolvimento da bioeconomia no Brasil* (Agenda for the development of bioeconomy in Brazil), recognizes that the development of innovative solutions in the bioeconomy industry is connected to knowledge. Therefore, it is necessary to prepare human resources and laboratory infrastructure to pursue advanced research lines related mainly to synthetic, genomics, proteomics, and biomaterials biology.

For Brazil to meet the three dimensions of bioeconomy (Figure 1) – industrial biotechnology, primary sector, and human health – the state must prioritize specific actions for each area that, combined, can generate important scientific, technological, and business results, translated into social, economic and environmental benefits for the country (CNI, 2014). Among the actions considered critical by the CNI's agenda is the consolidation of the technological scientific base.

The study also considers that bioeconomy requires researcher-entrepreneur-innovator individuals and multidisciplinary scientific groups capable of relating to the business world. Knowledge about strategies for the protection, commercialization, and management of intellectual property assets, emphasizing patents, needs to be expanded (CNI, 2014).

Proposals for program outlines with a strategic syllabus for the current and future needs of the country, based on interaction with the business sector, are infrequent. The result is a gap between the supply of qualified researchers in academic areas versus the demand for qualified researchers in strategic areas with high added-value in the market (CNI, 2014, p. 40).

The expansion of undergraduate and graduate programs of excellence, emphasizing bioeconomy's three sectors, is one of the proposals to strengthen the scientific-technological basis. This comes from the need to generate a critical mass of qualified researchers so that new talents and scientific-technological leaders can emerge in Brazil (CNI, 2014). This characteristic of management is offered by social science programs, particularly in economics, when the undergraduate student can learn to analyze bio-business or bio-entrepreneurship, according to the areas of professional activity. So far, these three sections briefly dealt with concepts, examples, and human resource needs regarding bioeconomy. The empirical approach to inserting bioeconomics in the curriculum is proposed below.

## **Methodology**

This study comprises a literature review of national and international studies. According to Vosgerau and Romanowski (2014), a literature review has the characteristic of not using explicit and systematic criteria for the search and critical analysis of the selected material. The selected works reflect the recent debates on bioeconomics and its insertion in undergraduate and graduate programs. For Rother (2007), a literature review uses a bibliography to explore other authors' findings, seeking to discuss relevant issues.

The material collected in this research consisted of scientific studies such as articles published in scientific journals and other works designed to disseminate ideas and news, such as sector reports, magazines, and websites. This selection contributed to contextualize the consolidation of the scientific and technological base of bioeconomics in countries like Germany.

## **Empirical approach to the implementation of a course on Bioeconomics**

When considering the need to consolidate the technological and scientific base to strengthen bioeconomy's three sectors in Brazil, as proposed by the CNI Agenda (2013), we sought to identify experiences of implementing courses on bioeconomics in the curriculum of higher education institutions in Brazil. The scenario we found is far from what the CNI and other studies recommend. It is also underdeveloped in comparison to international initiatives, as observed below.

### *Bioeconomics in undergraduate programs*

This study did not find courses on Bioeconomics in any undergraduate program in Brazil. However, the theme of bioeconomy is included as a topic to be discussed over the programs (Table 1). Most of the programs that mention bioeconomics are related to life sciences, agriculture, and fishing.

Table 1 – Undergraduate programs which include the theme of bioeconomy

PROGRAM	COURSE	MODALITY	UNIT/HEI
Bachelor in Ecological Economics	<ul style="list-style-type: none"> <li>Contemporary Ecological Economic Thought</li> <li>Economy and Entropy</li> </ul>	Compulsory Compulsory	Center of Agricultural Sciences (CCA) – Federal University of Ceará (UFC)
Bachelor in Biological Sciences	Conservation and management of wild animals	Compulsory	Tiradentes University (UNIT) – Aracajú (SE)
Bachelor in Biotechnology	<ul style="list-style-type: none"> <li>Biorefineries</li> <li>Innovation in Biotechnology</li> </ul>	No information available	Science and Technology Institute (ICT) – Federal University of São Paulo – São José dos Campos (SP)
Bachelor in Environmental Science	Environmental Biotechnology	Elective	Sea Sciences Institute – Federal University of Ceará (UFC)
Bachelor in Economics	Fisheries economy	Elective	Campus Serra Talhada – Rural Federal University of Pernambuco (UFRP)

Source: Elaborated by the authors based on data collected from the HEI websites

Some programs mentioned the term bioeconomy among the topics to be addressed during undergraduate education. However, bioeconomics is not included in these program outlines as one of the courses, different from what is seen in graduate programs in Brazil and other countries.

### *Bioeconomics in graduate programs*

Unlike undergraduate courses, the study of bioeconomics was identified in graduate programs in Brazil, most of them in HEIs in the southeastern and southern regions. In Europe, bioeconomics is taught in specific courses or programs such as in Germany and Slovakia (Table 2). Most of these courses aim to identify contemporary and future societal challenges that are somehow related to agribusiness and present the conceptual and theoretical bases of bioeconomy and its association or contrast with other theoretical approaches to economics and other areas of knowledge.

Table 2 – Graduate programs which include Bioeconomy – Brazil and internationally

PROGRAM	COURSE	MODALITY	UNIT/S	COUNTRY
Graduate Program in Agribusiness	Bioeconomics	Elective	Agribusiness Research Center – CEPAN – Federal University of Rio Grande do Sul – UFRGS (RS)	Brazil
Master in Biotechnology	Bioeconomics	Compulsory	Univeristy of Vale do Taquari – UNIVATES - (RS)	Brazil
Specialization in Bioeconomics with emphasis on Agribusiness	Various	No information available	Mario Quintana Faculty (FAMAQUI) – (RS)	Brazil
Graduate Program in Regional Economics and Public Policy	Introduction to Bioeconomics	Elective	Federal University of Acre (AC)	Brazil

PROGRAM	COURSE	MODALITY	UNIT/S	COUNTRY
Graduate Program in Expert Examination, Auditing, and Environmental Management	Bioeconomics and Sustainability	Compulsory	University Center of the North (UNINORTE) – Manaus (AM)	Brazil
Graduate Program in Communication and Semiotics	Media Processes and Knowledge Production	No information available	Pontifical Catholic University of São Paulo (SP)	Brazil
Bioeconomics	Various	No information available	Institute of Economics of the Federal University of Rio de Janeiro – UFRJ (RJ)	Brazil
Ph.D. Program in Biodiversity and Biotechnology	Special Topics in Biotechnology: Introduction to Bioeconomics	Elective	Biodiversity and Biotechnology Network of Legal Amazonia - BIONORTE	Brazil
Master in Business Economics	Bioeconomics	No information available	Faculty of Economics and Management – University of Agriculture of Nitra	Slovakia
Interdisciplinary Master in Bioeconomics	Various	Compulsory or bridge module	Faculties of Agricultural Sciences, Natural Sciences, and Business, Economics, and Social Sciences – University of Hohenheim	Germany

Source: Elaborated by the authors based on data collected from the HEI websites

In addition to these courses, a study group in Bioeconomy was identified at the School of Chemistry of the Federal University of Rio de Janeiro (UFRJ). This group includes chemical engineers and economists with a Ph.D. in economics, innovation management, and process technology. Two cases offering graduate programs with a focus on bioeconomics are described below.

#### *Implementation of the Graduate Program in Bioeconomics at the University of Hohenheim (Germany)*

At the University of Hohenheim, the Faculties of Agricultural Sciences, Natural Sciences, and Business, Economics, and Social Sciences gathered their knowledge in bioeconomics and established the Interdisciplinary Master's program in Bioeconomics. The program offers a comprehensive and systematic perspective of all aspects of producing (new) bio-based products and services (LEWANDOWSKI, DENNELER, 2015).

According to the authors, during the program, students examine the use of renewable resources in a systematic analysis of the bio-based value chain, with a focus on a) sustainable resource production; b) the properties and means of conversion and processing; and c) the sale and consumption of bio-based goods and services. Students acquire the necessary knowledge to consider these issues from the perspective of resource producers, manufacturers of bio-based products, and consumers.



According to the program outline (Figure 2), during the program's first year, students acquire i) fundamental knowledge of all aspects of bioeconomy, ii) bioeconomy interconnections and interdependencies, and iii) the skills needed for a systematic analysis of bio-based economies. Three bridge modules are offered in the first semester, which introduce the basic concepts of agricultural, natural, or economic sciences. This allows students with various backgrounds to acquire the qualifications necessary to successfully complete the program (LEWANDOWSKI; DENNELER, 2015).

In the program's second year, students can guide their own training by choosing from various courses. In a systematic examination of the entire bio-based value chain in the module entitled Projects in Bioeconomic Research, students test their skills by tracking a specific product, from its beginning to market launch, in close cooperation with industry representatives. A research-intensive master's thesis completes the program.

**Figure 2** – Program structure – Master's program in Bioeconomy of the University of Hohenheim

	1st semester	2nd semester	3rd semester	4th semester
6 credits	Inter- and Transdisciplinary Approaches in Bioeconomics	Sustainable Industrial Processes	Elective modules (30 credits)	Master's Thesis
6 credits	Properties of Biobased Resources and Products	Internal and External Costs and Benefits of Biobased Products		
6 credits	Agricultural Production of Biobased Resources	Markets, Innovation and Social Acceptance of Biobased Products		
6 credits	Economics and Management			
6 credits	Natural Science Concepts	Projects in Bioeconomic Research		

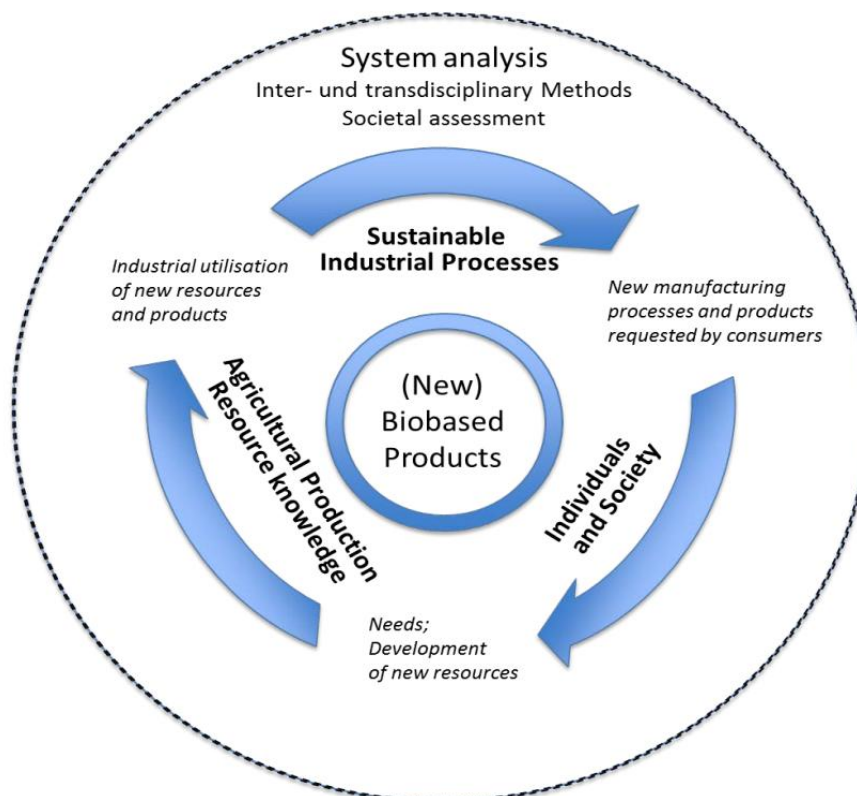
■ Compulsory modules  
■ Bridge modules

Source: Lewandowski and Denneler (2015)

For the authors, the first step was obtaining a concept of bioeconomy that reflected the comprehension and practice in the three faculties of the University of Hohenheim. Figure 3 represents the common research approach among the three faculties.

Bioeconomics is grounded on (new) biologically, economically, socially, and environmentally sustainable products and services. All activities necessary to create, produce, and distribute such products and services are fundamentally interconnected and interdependent. Consequently, the graduate program's approach to bioeconomic production is inter and transdisciplinary, as it requires attention to the entire value chain.

**Figure 3** – Research approach of the Master’s program in Bioeconomy of the University of Hohenheim



Source: Lewandowski and Denneler (2015)

In close cooperation with industrial partners, the graduate program’s creators brought this concept to the skills needed to pilot and productively engage bioeconomic production. At the beginning of the program, a three-day seminar introduces methods and strategies for engaging productively in the various courses and cultural boundaries. These skills are developed during a one-year project conducted in small groups. The goal is for students to acquire skills to work across the bio-based value chain with multiple teams and globally.

#### *Implementation of the Graduate Program in Bioeconomics at the University of Heidelberg (Germany)*

The BBW ForWerts Graduate Program is part of the Bioeconomy Research Program Baden-Württemberg, which aims to establish a research strategy across the value chains, integrating the different research groups in bioeconomics in an active network in the state of Baden-Württemberg. The program operates with funds from the Baden-Württemberg Ministry of Science, Research, and Arts (MWK-BW) and started operating in July 2014 (PETERSEN et al., 2015).

According to the authors, to date, more than 40 graduate students have been admitted to BBW ForWerts and are conducting research at one of the nine participating research institutions in Baden-Württemberg. The program also attracted 13 international students (mostly Chinese), strengthening international collaboration on bioeconomic issues.

The BBW ForWerts Program aims to train young academics who will take on the task of connecting the natural sciences to current economic demands to solve global problems. The program offers a three-year curriculum, during which students have the opportunity to participate in a structured educational program to gain an in-depth view of their own research fields and an overview of other bioeconomy research areas. This interdisciplinary approach allows students to acquire extensive knowledge of a variety of bioeconomic issues.

According to Petersen et al. (2015), the biggest challenge when implementing the program was the distribution of students among the various partner institutions, which makes supervision and monitoring difficult. However, the high level of support from both project coordinators and students helped to overcome this challenge. Networking with colleagues, industrial partners, and research institutions is a crucial part of the BBW ForWerts Program combined with the professional training that young researchers receive (PETERSEN et al., 2015). In general, efficient communication and participants' strong support have been fundamental for a graduate program with students distributed in several locations.

### **Final Considerations**

This article offered a brief contextualization of bioeconomy and the need to develop skills to work in this area, suggesting that Bioeconomics courses can be incorporated into undergraduate programs in economic sciences, even if it is an elective course. The panorama outlined in this study illustrates the current importance of bioeconomy in Brazil and in the world. It makes clear the need for the insertion of a course on the topic in undergraduate and graduate programs.

In the State of Amazonas, the Manaus Free Trade Zone Superintendence (SUFRAMA) runs the Bioeconomy Priority Program, which consists of developing solutions for the Amazon biodiversity's sustainable economic exploitation. The Committee for Research and Development Activities in the Amazon (CAPDA), a body linked to SUFRAMA and responsible for allocating research grants, presented in 2019 the projects supported. At that time, the applications had to meet the criteria of the Bioeconomy Priority Program, which includes 1) discovery of active ingredients and new materials from Amazonian biodiversity; 2) synthetic biology, metabolic engineering, nanobiotechnology, biomimetics, and bioinformatics; 3) processes, products, and services for the different sectors of bioeconomy; 4) technologies to support environmentally healthy regional production systems; 5) technologies for bioremediation, treatment, and reuse of waste; 6) business with a social and environmental impact; and 7) the establishment or improvement of incubators and bioindustry parks (BRASIL, 2018; SUFRAMA, 2019). Requirements 3, 6, and 7 can be met by qualifying undergraduate students of economic sciences and preparing them to work on these projects.

While building the case for the inclusion of courses on Bioeconomics in an undergraduate program in economic sciences of the UFAM, we identified the absence of specific courses addressing the theme in undergraduate programs in Brazil. Therefore, we collected data from HEIs that included bioeconomics as a topic to be discussed throughout the programs, even though not as a course.

We also collected experiences of graduate programs offering specific modules on bioeconomics. After analyzing the data, we argue that the existence of experiences in graduate programs that may be used as a reference and the absence of such courses in undergraduate programs may be an opportunity for UFAM to innovate.

Regarding the insertion of Bioeconomy in graduate programs, it is observed that the theme is already more familiar at this level of education than at the undergraduate level. It was not possible to identify in Brazil cases similar to the German experiences that revealed the importance of the partnership between academia and the private sector.

The proposal to insert bioeconomy in undergraduate programs in economic sciences is bold, both because it demands a change in paradigms and because there are no experiences in programs in economics in Brazil. However, the case of Hohenheim University suggests that understanding bioeconomics as a theme that is already taught – even though in a specific course – was the first step to implementing the program.

A proposal for the insertion of Bioeconomy in the PO of an undergraduate program in economic sciences of the UFAM was underway by the time this study was under development. When submitted to the Program Collegiate, by the end of the second semester of 2019, it was decided that Bioeconomy would be one of the topics professors could choose to offer in the Special Topics course. Future studies could follow up the debates for a definitive adoption of the discipline with the academic community and other sectors to verify the need for these new competencies.

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#### **Authors' contributions**

Author 1: conception of the article's proposal, preparation of the bibliographic review, analysis, and interpretation of the data, final review.

Author 2: participation in the discussion of results and support in the final review.

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