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Review

A Review of the Current Practices of Bioeconomy Education and Training in the EU

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Abstract: This study conducts a review of the current practices of bioeconomy education and training in the EU; as well as the associated methodologies; techniques and approaches. In recent years; considerable efforts have been made towards developing appropriate bioeconomy education and training programs in order to support a transition towards a circular bioeconomy. This review separates bioeconomy education approaches along: higher education and academic approaches, vocational education and training (VET) and practical approaches, short-term training and education approaches, and other approaches. A range of training methodologies and techniques and pedagogical approaches are identified. The main commonalities found amongst these approaches are that they are generally problem based and interdisciplinary, and combine academic and experiential. Higher education approaches are generally based on traditional lecture/campus-based formats with some experiential approaches integrated. In contrast, VET approaches often combine academic and practical learning methods while focusing on developing practical skills. A range of short-term courses and other approaches to bioeconomy education are also reviewed.

Keywords: bioeconomy; bioeconomy education; bioeconomy learning; higher education; vocational education and training

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1. Introduction

In recent years the Bioeconomy has become a central topic in EU policymaking, especially in the context of the Green Deal which was approved by the European Commission in 2020 and includes a set of policy-related initiatives supporting the transition to carbon neutrality by 2050, and is expected to continue to receive increased national and EU-wide policy support in the coming years [1]. In this context, the bioeconomy is expected to underpin the transition from a linear economic model that is based on non-renewable resources, to a circular, low-carbon economy that relies heavily on the production and consumption of renewable, organic-based resources. Such a transition requires both a mentality change of the population and a practical transformation of its skillset; as the standards and the needs change, new job types arise across entire value chains. In order to effectively support such a transition, a comprehensive bioeconomy education and training system needs to

be developed, one that will take into account the special needs and the interdisciplinary approach that the bioeconomy entails. Such a system requires a transformation of existing education methods and training approaches, as well as the development of new ones [2–5].

Considerable gaps exist in our understanding of the existing practices around bioeconomy-related training and education. This can partly be explained due to the relevant newness of the bioeconomy as a concept [6], but also because multiple educational practices and approaches, that are clearly located within the bioeconomy conceptually, are not explicitly labelled as such. A range of previous projects and studies have investigated bioeconomy education programs and approaches [7–10], however a comprehensive review of training methods and approaches across higher education (HE) and vocational education and training (VET) is lacking. This is especially relevant as previous studies have highlighted that education, training and knowledge development in bioeconomy sectors vary widely across Europe. According to the European Commission, there is a particular lack of training on bioeconomy for small enterprises and at low levels [2,6,11,12]. In addition, there is a concern that the labour force is not trained adequately for this transition to a bioeconomy, especially as it requires expertise that originates in different disciplines and combines a variety of skills across and along value chains.

This paper aims to fill this gap by conducting a review of the current practices of bioeconomy education and training in the EU, as well as the associated methodologies, techniques and approaches. This will contribute to our understanding of how bioeconomy education and training is conducted, evaluate the different approaches, and provide the background for the development of additional and necessary bioeconomy curricula. Furthermore, this study aims to conduct a review of current practices of bioeconomy education and training in the EU as well as the associated methodologies, techniques and approaches. By doing so this study provides an overview on and relevant categorisations of existing bioeconomy approaches and also highlights where developments in bioeconomy education and curriculum have been occurring and where they have been lacking in recent years. In addition, this study facilitates a discussion on the main commonalities and differences between the various educational approaches currently used in the bioeconomy and identifies various areas for future areas of research.

The paper is structured as follows: the rest of this section provides an overview of previous studies on bioeconomy training and education; Section 2 discusses the methodology used in this review; Section 3 presents the results of this study; Section 4 provides a discussion and macro analysis of trends in bioeconomy training and education in the context of previous studies; and Section 5 provides concluding remarks.

2. Literature Review

There isa range of bioeconomy policies and strategies developed at the EU level and country level that support related bioeconomy training and education processes. At EU level, the 2012 European Bioeconomy Strategy, which was updated in 2018 with the addition of a Bioeconomy Action Plan, which calls for the new education processes and the testing of new HE and vocational training curricula [13]. Beyond this, the bioeconomy is supported by other major EU policies and strategies, including the Green Deal, the Circular Economy Action Plan and the Farm to Fork Strategy [14,15]. There are also a few EU Member States with a national bioeconomy strategy, including Finland, Germany, Latvia, France, Spain, Italy, Ireland, Austria and the Netherlands, while Norway and the UK also feature their own strategies. Estonia, Hungary and Lithuania are in the process of developing national strategies [16]. Similarly, all these policies tend to include and promote relevant bioeconomy education and training in their strategies. In September 2022 the EU released the report on 'Promoting education, training and skills across the bioeconomy,' which assesses expert insights on current bioeconomy education practices and the future needs for bioeconomy related education until 2050 [17].

Various recent publications exist that investigate bioeconomy-related education and programmes. Pubule et al. (2020) analyse 10 Master programmes in bioeconomy and high-

light the interdisciplinary nature of the approaches used [6], while Kalnbalkite et al. (2021) look more widely at education for the bioeconomy [1]. Ruxandra et al. (2018) investigate the role of the University in developing human capital for a sustainable bioeconomy [18], and Masiero et al. (2020) look into bioeconomy-related perceptions among 1400 students in 29 Universities [19]. Less recently, Watkinson et al. (2012) conducted a review of advanced bioenergy education and training in Europe [11], and Ray et al. (2016) highlighted the importance of linking bioeconomy development with education in developing countries, emphasising the potential of e-learning courses [20].

A common theme among relevant journal publications is the importance of interdisciplinarity in any method or approach with the bioeconomy education [21]. Sacchi et al. (2021), investigate the educational processes required for a bio-based economy, and highlight that the main challenge for education related to the bio-based economy is the development of an effective framework that bridges the life sciences and the social sciences [22]. Onpraphai et al. (2021) argue for the importance of creating new education approaches that are able to support the shift to a sustainable bioeconomy [23]. It is documented that education for the bioeconomy is conceptually related to the attainment of the Sustainable Development Goals (SDGs) and education for sustainable development (ESD). Urmetzer et al. (2020) highlight that pedagogical approaches based on ESD that are interdisciplinary can support transformational bioeconomy education processes [3].

Lask et al. (2017), in looking at academic approaches to education for the bioeconomy, find that most HE programs, in particular at university level, are designed with I-shaped profiles whereby students specialise in one discipline and research field. However, bioeconomy programs are inherently interdisciplinary and aim to create a T-shaped profile, i.e., where integrative professionals are ideally also disciplinary experts, educated to incorporate and connect different disciplinary knowledge domains and methods. Therefore, the paper makes the case for a bioeconomy education that is multi- and transdisciplinary as well as practice-oriented in order to create bioeconomy professionals who, although specialised in one specific field, have an understanding of other related disciplines and are able to manipulate scientific jargon [24].

Moreover, a range of European and national projects are focused on supporting education and training in the bioeconomy. Examples of such projects include the European Bioeconomy Library [10], BIOEAST, The BRANCHES PROJECT [7], BE-Rural [8], MPowerBio [9]. Many of these projects include knowledge exchange and capacity building programmes for the bioeconomy. The ERASMUS+ project VET4BioECONOMY, which was completed in 2021, focused on VET programmes on forest bioeconomy, while the ERASMUS+ project FIELDS has a database on VET related programmes in the bioeconomy [25]. Extending the horizon beyond the EU landscape, the ERASMUS+ Capacity Building project BBChina established a 120 ECTS equivalent Master Program on Bioeconomy in three Chinese Universities through a cross-collaboration between European and Chinese Higher Education Institutions [26].

In recent years, a host of platforms have already proliferated that support education processes often by hosting and sharing relevant bioeconomy knowledge, including the Rural Bioeconomy Portal, the European Bioeconomy Network, the European Bioeconomy Library, the Bio-based Industry Consortium's (BIC) bioeconomy platform, the European Bioeconomy University, the European Bioeconomy Alliance, and the Circular Bioeconomy Alliance. These platforms, at times overlapping, generally support bioeconomy knowledge and information sharing and development, stakeholder collaboration, policy development and provide tools and support for relevant stakeholders.

These publications provide relevant insight into bioeconomy education but none of them conducts a comprehensive review of the entire bioeconomy education theme. Additionally, as the bioeconomy is such a wide concept, there are many educational programmes that are not labelled as 'bioeconomy' but clearly belong in this theme. For instance, a range of studies investigate training and education within the bioeconomy themes–the farming and agricultural sectors, water-based bioeconomy, forestry, bioindustry,

bioenergy. However, these studies do not include courses in the bioeconomy per se–there are few curricula that are focused on the bioeconomy but there are many more that are related to the bioeconomy. This is an important finding, especially given the established significance for interdisciplinarity within bioeconomy-related courses, potentially entailing that bioeconomy education is inherently inter- and trans-disciplinary.

A common point between the relevant policies and strategies, the papers and the projects is that existing education and training approaches need to be transformed and new ones need to be developed to effectively train individuals for a sustainable bioeconomy–the bioeconomists. Relevantly, a recent report by the Global Bioeconomy Summit 2020 investigates how to shape education for a sustainable bioeconomy and identifies the relevant needs; "The expertise required in the [sustainable circular bioeconomy] SCB workforce in the industry by 2030+ was identified as: Knowledge transfer from lab to industry; critical thinking and problem-solving abilities, knowledge in business models and project management; knowledge about the principles of sustainable development and the circular economy; knowledge in bio-based markets and techno-economic expertise." This conclusion convincingly demonstrates the need for bridging theory with practice, life with social sciences, and cognitive with technical skills [27].

3. Methodology: Materials and Methods

3.1. Conceptual Approach

3.1.1. The Bioeconomy

There are a variety of definitions and approaches to 'bioeconomy' ranging from a broader, inclusive definition that focuses on biological resources and processes in general to narrower and more specific definitions that focus on particular sectors. The European Commission defines the bioeconomy as "using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy [28]." A more in-depth definition provided in the EU Bioeconomy Strategy is that the bioeconomy includes all systems that are dependent on biological resources (biomass, animals, plants, organisms), their functions and principles. This includes land and marine ecosystems; primary production sectors (agriculture, forestry, fisheries and aquaculture) and; all economic and industrial sectors using biological resources to produce food, feed, biobased products, energy and services [13].

Considering this definition, the bioeconomy can be conceptually categorised along 5 themes, and in line with the EU bioeconomy strategy. These are:

- Food/agriculture systems, which encompass the value chains related to farming, the production of food and biological feedstocks within the 10.5 million farms in the EU [29].
- Forestry/natural habitats systems, which are a source of environmental public goods, raw materials and services, and refer to processes of managing and utilising the EU's 182 million ha of forests [30].
- Water systems, which refer to all aquatic systems and respective economic activities (such as fisheries, aquaculture, aquatic biomass production, etc.).
- Bioenergy, which refers to all energy derived from organic sources, being the largest RES in the EU (12% of total energy demand).
- Biomaterials/bio-based products, which are derived from renewable biological feedstocks and are processed creating conventional products (e.g., timber and textiles) and advanced products (bio-plastics and pharmaceuticals).

It is well documented that the bioeconomy is interdisciplinary [12] and both transcends and interlinks between the themes (food/agriculture, forestry/natural habitats and aquatic/water system bioenergy and biomaterials), sectors (primary, secondary, tertiary) and the wider economy. The bioeconomy is inherently an inclusive concept as it is a response to the unsustainability of current economic processes that are often based on unsustainable production models and contribute to environmental degradation and societal fragmentation [3].

3.1.2. Educational Approaches and Methodologies

Bioeconomy education is generally distinguished by a number of characteristics. The previously cited studies indicate that the bioeconomy needs to adopt interdisciplinary learning and teaching approaches that are often focused on bringing together and integrating the STEM disciplines with the SSH (social sciences and humanities) disciplines.

This paper investigates training methodologies, techniques and approaches that are prevalent within bioeconomy education within the EU. A range of labelling of methodologies exists by different projects and studies. For this study, we prefer a relatively simple conceptual categorisation of educational approaches and methodologies, combining the insights and expertise from the RELIEF consortium as well as the research outputs of the Erasmus+ FIELDS project [31].

Training and education approaches are wide concepts that aim to broadly describe the pedagogical approaches to teaching. Based on a variety of sources, and in the framework of the RELIEF project, we categorise our research and findings along four main approaches: (i) the higher education and academic approaches, (ii) the VET and practical approaches, (iii) short-term approaches, and (iv) other approaches. Academic approaches are mainly based on cognitive approaches to education and learning knowledge and theory. These are knowledge-based approaches where the goal is to learn, integrate and apply knowledge in academic disciplines. This approach is often central to higher education institutions, such as universities, and teaching and learning generally occur over a number of years. Practical approaches are mainly centred around 'learning by doing' methods and are focused on supporting the development of an individual's skills, abilities and knowledge around practical, real-life (as opposed to theoretical, hypothetical) issues. These are competence-based approaches that are focused on supporting students in mastering specific skills and competencies. This approach is often used in VET institutions and learning duration ranges from a number of months to multiple years. This generally includes training in skills and knowledge for a trade or occupation and may be part of secondary or tertiary education programs or training for specific employment. Short-term approaches are time-bound, ranging from less than a day to a couple of months. These approaches are generally intensive, compressing large amounts of knowledge and learning in short time periods and may adopt a academic, practical or hybrid approach. Other approaches refer to other learning methodologies encountered in the literature, including do-it-yourself (DIY) learning, lifelong learning and informal education.

These are conceptual categorisations and considerable overlap between approaches exists, while each individual approach often adopts learning practices that are favoured by another approach. The categorisation has been determined based on the 'focus' of the given approach. For instance, in practice an academic bioeconomy University program may have a focus on theoretical concepts but generally also includes parts that are centred around problem or project or challenge based learning and also include practical learning and training. In addition, education and training for a sustainable and circular bioeconomy is closely related to education for sustainable development (ESD). ESD refers to incorporating key sustainable development factors into education programs including topics focused on climatic change, sustainable production and consumption and biodiversity. Similarly, it is recognized that ESD is interdisciplinary and requires participatory teaching and learning approaches [3].

Each approach adopts and favours a range of training methodologies and techniques. Training methodologies and techniques refer to those used in designing and implementing education and training, i.e., the pedagogical tools used to impart knowledge and skills in the context of each educational setting. These methodologies and techniques are explored as a sub-category of the four main training and education approaches identified. The training methodologies and techniques that were identified and referred to in the existing literature include: lecture and classroom-based formats, e-courses, virtual learning tutorials, on-the-job training, work placements/traineeships, practical workshops, in-person class, focus groups, panel discussions, mentoring, peer learning, participatory learning, on-site

demonstration, gamification [31]. (See Figure 1). These methodologies and techniques are not mutually exclusive, meaning that more than one can be used in one education setting and overlap within one approach, while they are also not assigned specifically to any of the main approaches. For instance, a lecture/classroom-based University course may make use of participatory learning techniques, as can a VET course.

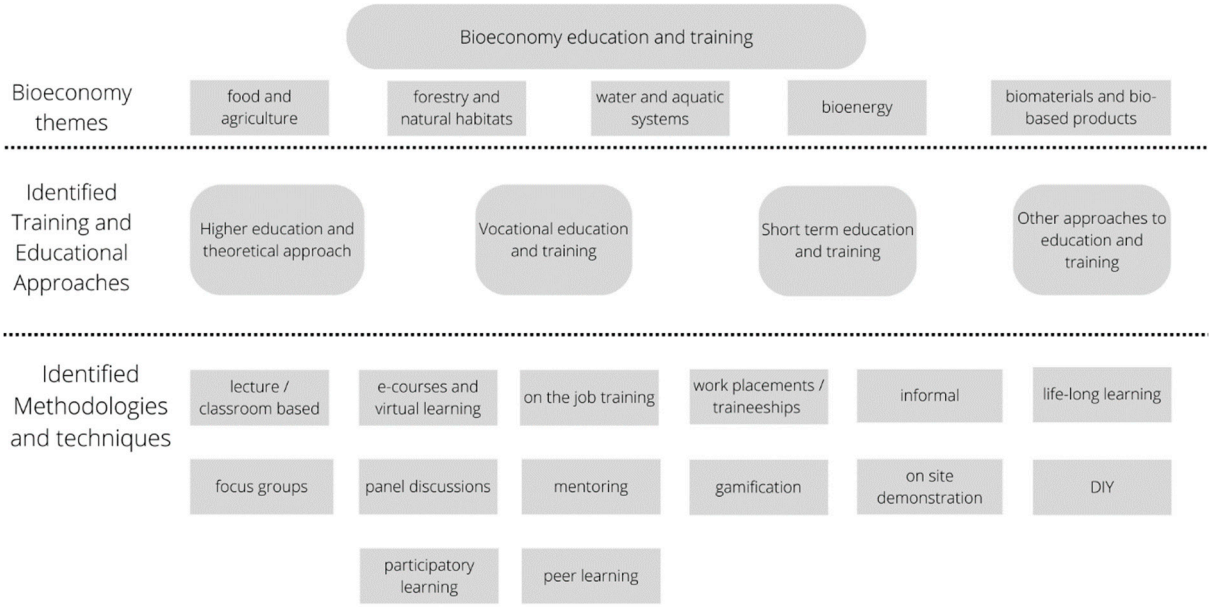

Figure 1. Conceptual Educational Approach.

3.2. Data Sources, Selection Criteria, Search Strategy and Data Collection

This study conducts a review of the current practices of bioeconomy education and training. Data was collected from a range of sources including peer-reviewed publications, reports, results from previous projects, national policies. Our search strategy followed a number of key steps: on the one hand, all partners of the RELIEF consortium were asked to participate in the data collection process by providing relevant information and data on educational approaches in their respective countries as well as the EU. On the other hand, relevant studies were identified through key word searches through google scholar and SCOPUS and desk-based research. Keywords used in these searches included 'bioeconomy education', 'bioeconomy training', and 'bioeconomy learning', these searches identified a total of 259 publications (175 in Scopus). The publications identified show considerable increase in recent years until October 2022 (Figure 2).

The studies included here, and in particular journal articles, were screened for relevance and applicability, the reports and projects used came from respected publication sources, while the journal articles had to be published in well respected and peer-reviewed journals. 72 studies were found relevant and selected for further analysis. These studies were chosen as they contained a clear thematic focus on the bioeconomy and education and training approaches in the EU. Information and data were extracted, compiled and categorised along a number of categories for each bioeconomy theme. Due to the descriptive nature of the data and the goal of this study, data was analysed in a qualitative manner whereby different educational approaches were compared and contrasted.

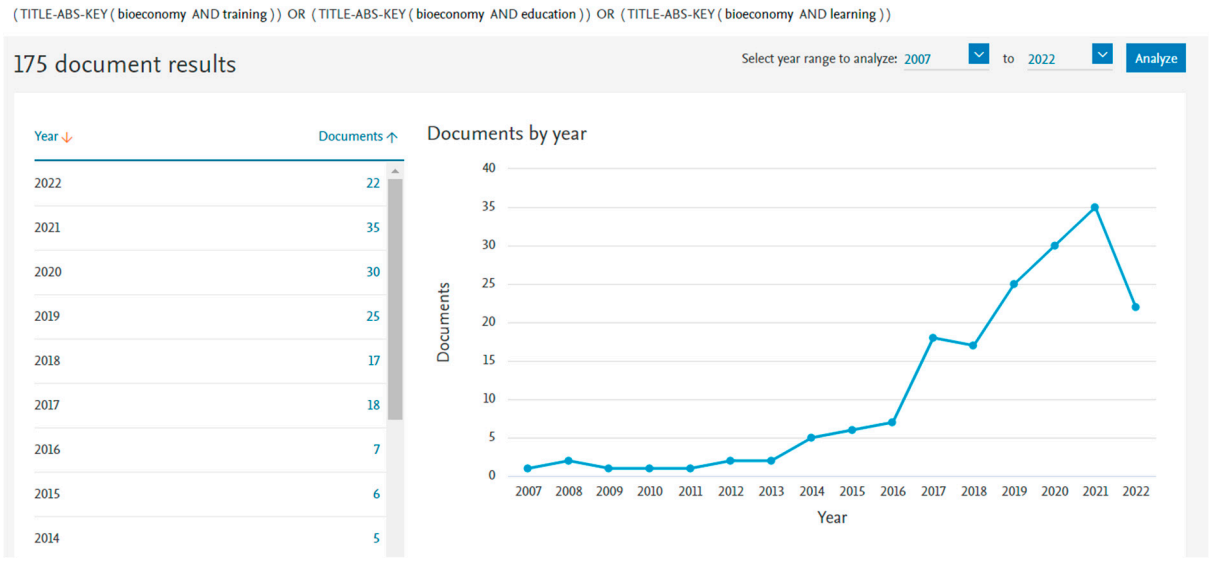

Figure 2. Number of bioeconomy education publications in Scopus by year.

3.3. Bias Risk and Limitations

There are a number of key limitations to the present study. Bioeconomy is a general concept with varying interpretations. In this sense, there is a risk of losing specific answers/results when discussing the bioeconomy [4] as they might be found under different terms. In addition, and due to these variations, authors and studies mean different things when they refer to 'bioeconomy education'. Moreover, as the bioeconomy is a relatively new concept there are relatively few studies and approaches that focus solely on the bioeconomy or use the term 'bioeconomy'. This is a limitation as some educational approaches adopt lenses other than the bioeconomy. Due to this newness, there is relatively little research available on existing bioeconomy education approaches and techniques and there are considerable data gaps. Future research is needed on more specific aspects of each education approach in the bioeconomy. There are also a number of bias risks when conducting a review. As the study is based on data and knowledge that has been shared with the authors and on keyword searches in google scholar and Scopus, the inclusion of knowledge and data is at risk of bias.

4. Results

4.1. Higher Education and Academic Approaches

In recent years, many higher education programs centred around the bioeconomy and its components have been developed throughout the EU. These exist at a range of higher education levels, including at bachelor, master/post graduate and PhD level as categorised in Table 1. Common characteristics amongst these programs include: (i) interdisciplinary design, often bridging STEM and SSH disciplines, (ii) focus on the bioeconomy as a whole and/or on one or more bioeconomy-related themes, (iii) priority is given on academic approach, and (iv) teaching and learning approaches are predominantly classroom/lecture-based formats. These programs tend to be geared around supporting the development of a knowledge economy and have a strong sustainability-related dimension. This sustainability dimension appears in many forms throughout the available courses, for example there could be a focus on the study of the circular economy, the design of eco/efficient bio-products or on sustainable practices in general [32].

Further, there is a variety of designs and focus attached to these programs and they can generally be categorised along three main lines: (i) programs focused on a scientific discipline that emphasise on specific bioeconomy themes (e.g., Bio-technology) [33–36] (ii) general Bioeconomy programs that provide a general overview of the Bioeconomy and all its components [32,37], and (iii) programs that give equal emphasis in two disciplines,

usually combining a STEM and a SSH discipline [38], and that focus on the relevant aspects of the bioeconomy (e.g., a course combining Bio-technology with Economics or with Ethics). In recent years, there has been a rapid increase in all of these programs, and specifically the interdisciplinary design, and this trend is likely to continue [24]. Such study designs are increasingly accepted within academia and higher education programs, while inclusive and interdisciplinary approaches are favoured as being paramount to the creation of a circular and sustainable bioeconomy, which is inherently interdisciplinary. Such courses approach the subject with a holistic and critical understanding in order to accommodate the multidisciplinary character of the bio-economy which, as explained above, requires a re-designing of the traditional educational methodologies which are fragmental.

Regarding bachelor level programs, several were identified in several countries and can broadly be split into either general bioeconomy programs or specific theme-based programs. The design of these general bioeconomy programs has a focus on learning and education across the entire bioeconomy value chain, while some of them may include an additional focus on particular aspects of the bioeconomy. These programs generally adopt an academic approach; although the teaching approach somewhat varies, they appear to use traditional approaches to higher education centred around an on-campus lecture format combined with problem-based learning with some or limited access to field-work and laboratory programs [32,37,39].

Regarding the bachelor programs that are focused on specific bioeconomy themes, this study located several bachelors of science, such as biotechnology, biomaterials, bioenergy, agricultural sciences and agricultural engineering, forestry and bioeconomy. These programs are likely to incorporate more of a hands-on approach than the general programs discussed above, with access and use of laboratory facilities and research infrastructure. In many instances, these programs also have close links with industry and can provide relevant work placements for the students. Course descriptions often mention approaches centred around problem-based or challenge-based learning or experiential learning, as well as hands-on learning through lab experiments, field trips, and a capstone project [33,34,36,40].

Regarding Masters programs, these tend to have a closer focus on specific themes of the bioeconomy and generally adopt a mixed education approach that combines academic and practical methodologies [11]. The course descriptions of such post-graduate programs often appear to include a more general, foundational module focused on the bioeconomy/bio-circular economy as a whole, followed by more focused modules on, for instance, biobased industries, management of biobased feedstocks, etc. Often, in addition to the course modules which are generally lecture-based and emphasise on theory, there is a more practical component as part of the program. This practical component may include carrying out experiments, either in lab or real-life conditions, or a work placement, or some independent research [6]. Similarly, to bachelor programs course descriptions are also often centred around problem-based or challenge-based learning [38,41–46].

Despite these commonalities bioeconomy Masters programs and their development generally follow country specific developments. For instance, in Italy, Master degrees are intended as in-depth thematic studies offered independently by universities. The first example of a Master program related to the Bioeconomy was the "IMES Master in Bioenergy and Environment", set up in 2004 with the support of the "EU/US Programme for Cooperation in Higher Education and Vocational Education and Training" [47]. The 60 ECTS equivalent course run in three US Universities and in two EU Universities and was mainly focussed on the Biomass to energy chain. It was held in ten editions until 2019 at the University of Florence, while at the Universidade Nova de Lisboa, it was transformed into a Master Degree at the end of the 2010's. In this Master, the multidisciplinary approach was developed all along five different axes: Biomass Production (Agriculture, Forestry, and Energy crops), Energy conversion (Renewable Energies and Bioenergy Generation), Biofuels (Conventional and Advanced) and Biorefineries, Environmental Impact (modelling and LCA), and Legislation & Economy. Another important example, started in 2016 and presently running, is the 2nd level Master "Bioeconomy in the Circular Economy

BIOCIRCE". It is an interdisciplinary program jointly offered by four Italian Universities (University of Bologna, University of Milano-Bicocca, University of Naples Federico II, and University of Turin), by 4 non-academic partners (Intesa Sanpaolo, Novamont SpA, GFBiochemicals SpA, and PTP Science Park di Lodi), and 2 Italian Technological Cluster (Cluster SPRING and Cluster CLAN agrifood) providing skills and expertise necessary to deal with the full range of issues in the complex bioeconomy field [45].

Regarding PhD and further higher education programs, these are not prescribed and they are variable depending on the topic, however, the general trend shows that there are an increasing number of PhD programs around the bioeconomy [48]. Such programs can be practical, academic or hybrid, including a mix of educational approaches. They are research-focused with the goal of advancing bioeconomy-related research and development, and they often go in-depth on one more specific topic within the sectors of the bioeconomy [48–50].

Table 1. Current higher education practices for the bioeconomy.

Type of Program	Description	Typical Learning Method	Time Period (Years)	Geographical Locations	Prevalence	Qualifications
General Bioeconomy Bachelor	Theory-based learning with some practical elements.	lecture/classroom based, e-courses and virtual learning, participatory learning, some practical elements/on site demonstration	3–4	Germany [37], Finland [51], Norway [32], Poland [39]	Several	Undergraduate degrees
Bachelor on specific bioeconomy themes	Mixed learning approach	lecture/classroom based, e-courses and virtual learning, participatory learning, many practical elements/on site demonstrations	3–4	Germany [33,34], Spain [40], Finland [36], UK [35]	Several	Undergraduate degrees
Masters	Mixed learning approach	lecture/classroom based, e-courses and virtual learning, participatory learning, many practical elements/on site demonstrations	1–2	Greece [38,41], UK [42], Austria, Ireland, France [31], Germany [43], Netherlands [44], Italy [45], Sweden [46]	Many	Postgraduate certificates and degrees
PhD, Post-doc	Research oriented	Self-learning, some lecture/classroom based	2+	Ireland [49], Switzerland, Spain, Italy, Sweden, Netherlands, Germany, Austria, Belgium [48], France [50]	Several	Degree

4.2. VET and Practical Approaches

The EC defines VET as "the training in skills and teaching of knowledge related to a specific trade, occupation or vocation in which the student or employee wishes to participate. Vocational education may be undertaken at an educational institution, as part of secondary or tertiary education, or may be part of initial training during employment, for example as an apprentice, or as a combination of formal education and workplace learning" [52].

VET programs that are focused on specific themes of the bioeconomy are prevalent across the EU. This study has located a multitude of agricultural courses, forestry courses, energy/electrician courses. Relevantly, the EU ERASMUS + project FIELDS has created a database on VET related programs in the bioeconomy [31]. VET programs are generally not standardised across the EU in terms of education and training methodologies and there is a wide range of approaches and learning methods used. In practice, different countries have different approaches to VET education and the training is linked differently with secondary

and tertiary education systems. For instance, it is common for VET education to be centred around education institutions but in some countries VET education and certification can also be achieved through apprenticeships, which is the case in France.

VET courses are predominantly focused on training and teaching of skills and knowledge for employment. In this sense, in VET courses on the several bioeconomy themes, the typical learning approach is centred around the teaching of practical skills, achieved through experiential learning and hands-on practice [53]. A common VET course description is likely to include a short theoretical overview of the relevant topic/bioeconomy theme, followed by a range of practical training directed towards the specific topic and the practical skills attached to it. There is a large variation in the types of practical training offered, which can come in the form of lab work, traineeship, apprenticeship, etc.

Common thematic focuses for the courses located (Table 2) are agricultural technicians, digital/technological expertise combined with a bioeconomy theme and forest management expertise. A commonality amongst all VET courses located is that they all involve some level of practical training, usually done through on site/farm demonstration and learning activities and students receive a certificate at the end of their studies. This may also be combined with a work placement, generally towards the end of the program. Amongst the VET courses located there are considerable differences in terms of the time period of all courses ranging from a couple of weeks and/or hundreds of hours to 2+ years and/or 2000 h [53–59]. Clearly rural extension services are also important methods for providing training and education for rural stakeholders on the bioeconomy, however, during this review no extension programs with a focus on the bioeconomy were located. The development and integration of these is an important area of future research.

Table 2. Approaches and Methodologies in VET Education and Training for the Bioeconomy.

Course Title	Description	Typical Learning Methods	Time Period	Location	Qualifications
Smart Farming and Bioeconomy Technician [53]	Training to become a smart farming technician following a range of courses, field learning and cv related training	Lecture/classroom and on-farm demonstration activities	800 h (400 on site, 400 classroom)	Italy	Certificate
Professional Higher Technician in Agrotechnology [60]	Agrotechnology technician training for the management of a small-medium agricultural enterprise	Lecture/classroom and on-farm demonstration activities	2 years	Portugal	Certificate
Technicians in rural areas [54]	Focused on creating entrepreneur with thematic focuses on innovation in agriculture, the viability of farms, irrigation	Lecture/classroom and on-farm demonstration activities	1 year	Spain	Certificate
Data-Driven Agri-Food Business [61]		Online learning	10 weeks	Netherlands	Certificate
Agrogardening [56]	Vocational training with job placements	On-farm demonstration activities and job Placements	2000 h	Spain	Certificate
Forest Harvesting [55]	Training on forestry use and management with associated job placements	Lecture/classroom, on-site demonstration activities and job placements	2 years	Spain	Certificate

Table 2. *Cont.*

Course Title	Description	Typical Learning Methods	Time Period	Location	Qualifications
Environmental Technician [57]	Technical training as an environmental technician through training and job placements	On-site demonstration activities and job placements	2 years	Belgium	Certificate
Technician in agricultural production [62]	Technical training on producing agricultural products	Lecture/classroom and on-farm demonstration activities	2000 h	Spain	Certificate
Technician in Forest Management and the natural environment [63]	Technical studies for forestry and environmental work in mountainous areas and nurseries	Lecture/classroom and on-farm demonstration activities		Spain	Certificate
Entrepreneur Biodynamic agriculture [59]	Training for sustainable agricultural production technician integrated with high school	Lecture/classroom and on-farm demonstration activities		Netherlands	Certificate
Agricultural Technician [58]	Technical training as an agricultural technician through training and job placements	Classroom/lecture and participatory learning	Up to 6 years	Belgium	Certificate
Agricultural Production Technician [64]	Training for Agricultural Production Technician Integrated with high school	Lecture/classroom and on-farm demonstration activities	1 year	Portugal	Certificate

Table 3. Short term education and training approaches for the bioeconomy.

Category	Typical Learning Approach	Methods	Description	Example Courses
Workshops	Mainly academic, possible some practical	Panel Discussions Focus groups Lecture based	Short events ranging from a few hours to a few days. Focused on specific themes around the bioeconomy or general bioeconomy. Condensed knowledge transfer. Often are organised in the context of EU and/or national bioeconomy related projects	Unlocking Regional bioeconomy transitions. State of the art and ways forward [65] Sustainable Production of Biobased Products in the Bioeconomy Era [66]
Short Courses	Mix between academic and practical	Lecture based Tutorials Practical teaching E-learning courses	Range from a few days to Some assessment. Students with bioeconomy background or not. Generally, a mix of lectures, lab and field visits. Online courses	Training course for farmers: non-food crops (NFC) for bioeconomy in Italy [67] Summer School: Towards a Biobased Economy [68] Bioeconomy school [69] ELLS Summer School on Bioeconomy [70]
SME Training	-	Mentoring	Generally centred around capacity building and supporting SME developments in the bioeconomy	Bioeconomy Ventures [71] MPowerBio [72] DigiCirc [73]

With regards to connections between these more practical VET courses and the academic higher education courses described above, there seems to be a considerable overlap between the two; the VET courses usually include a theoretical aspect, albeit smaller than the practical part of the course, often in the introductory modules, while in the higher education courses there often is a module that requires more practical skills, possibly in the form of lab experimentation or work placement.

4.3. Short-Term Training and Education Approaches

Several short-term education and training approaches for the bioeconomy have been located and are summarised in Table 3. They have been categorised according to workshops, short courses and SME training. These categories generally adopt varying and mixed learning approaches and methods, depending on the goal and the scope of the training, they last for a short period of time and are generally knowledge-intensive. These courses are run by several bodies and are supported through various funding modes, including national and EU projects, universities, research institutes, NGOs and for-profit enterprises. Most of these courses either focus on general knowledge sharing on the bioeconomy or the development of specific skills for specific topics within the subject.

4.4. Other Approaches

A range of other bioeconomy education approaches is also mentioned by various actors. These approaches are often informal and/or are not attached to educational institutes and are centred around individual and lifelong learning schemes, though are often dependent on open-source data published by educational institutes. These approaches are generally characterised as self-motivated and voluntary, for personal and professional reasons, and can be practiced by a range of methods, including both academic and practical, depending on the relevant scope and goals [24,27,74]. A range of education techniques are practiced but are generally based around on the job training and participatory learning techniques, mentoring and self-learning through audio-visual material but can also include learning appropriated through informal means such as through discussions with other relevant stakeholders. Multiple authors argue that these self-motivated processes are crucial for supporting a society wide transition towards a circular bioeconomy and need to be supported by educational material and scientific research that is available to the general public [20,27].

5. Discussion

The findings presented in this report illustrate that education approaches attached to the subject of the bioeconomy vary considerably across the EU, with a range of academic, practical, hybrid, short term and other approaches. There are some important commonalities in the methodologies used within these approaches; the education offered is generally problem-based, interdisciplinary and combines academic and experiential learning. Furthermore, the teaching methods vary, traditional lecture based and lab based formats are popular while in recent years online-learning has also become popular [31] replacing and/or adding to the more traditional lecture formats.

Courses focused around academic and higher education have proliferated, especially in recent years. These have also been centred around creating increased collaborations between existing institutions, for instance, In 2022 the European Bioeconomy University was launched as a collaboration between 6 European universities to promote bioeconomy education [75]. The main learning approaches used in these educational systems are based around traditional, campus-based lectures and tutorials, sometimes with slight variations in the format [24]. There is some focus on problem-based and experiential learning within relevant courses. More specifically, there is a relatively high selection of masters' courses that combine bioeconomy with a thematic focus. Pubule et al. (2020) highlight that bioeconomy master programs are designed around thematic focuses that aim to facilitate long-term employment in the bioeconomy sector. They also highlight that most of these

programs are currently concentrated in Western Europe though they predict a likely spread to other areas around the world as the bioeconomy becomes more and more prevalent [6].

Regarding VET programs, in the research process of this study, it was relatively easy to locate higher education courses but harder to locate practical VET courses. This is in line with the study by Ciriminna et al. (2022) who highlight that in recent years university courses on the bioeconomy have proliferated but that there is a need for more practical courses [12]. However, the distinction between the various education approaches is not always clear when it comes to VET programs, while the categorisations between VET and HE programs appear increasingly blurred. On the one hand, this is likely to be due to the newness of the bioeconomy as a concept but also due to the inherent interdisciplinary nature of bioeconomy education that generally requires and includes a mix of academic and practical approaches to education. The lack of data around specific design of VET courses is a major data limitation this study, and as more practical courses become available, our understanding of the approaches used and their effectiveness will become clearer. A key recommendation coming out of various studies is that there is a need for considerably more practical bioeconomy education approaches, especially vocational ones, that support the development of relevant skills across a variety of economic sectors [76].

Given that a thriving bioeconomy is the foundation for the transformation towards a circular economy, there is a need for more bioeconomy programs [3]. It is clear, that on a policy level, the importance of bioeconomy education is now widely recognised [12], however our understanding of what transformative bioeconomy training approaches are and how they fit into supporting the transition towards a circular economy remains limited. There is a need for bioeconomy experts across the economy, within research, the public sector and private sector [12]. Considerable attention is now being put towards mapping and creating new approaches to training for the bioeconomy and these can build on the research presented in this paper. Such programs, courses and modules are necessary to support knowledge-wise this transition and the training approaches and methodologies need to also be transformative and need to combine higher education, VET and industry in each of the themes of the bioeconomy, in order to approach the concept in an interdisciplinary manner that supports an understanding of the complexities of a sustainable bioeconomy. Indeed, various studies [3,11,27,77,78] argue that bioeconomy educational programs need to be designed to create a knowledge-based economy and to provide the new skills needed for the new and upcoming bioeconomy [17]. To fulfil this, relevant programs need to be innovative, interdisciplinary, holistic and open to advancements.

This review indicates multiple areas for future research on bioeconomy training and education. Overall, it is clear that, considering the size of the EU and the bioeconomy, bioeconomy education programs remain relatively limited. As the development and transformation to a sustainable bioeconomy is depended on new and relevant skills and competences a unified EU bioeconomy training and education program is needed that is both multidisciplinary and dedicated to the development of a sustainable bioeconomy. For this to happen further research is needed on what skills are required for such a transition. Such research can be strengthened by EU wide initiatives that monitor and analyse new bioeconomy learning approaches and identify and disseminate best practices. A standardised methodology that carries this out could focus on first 'identifying emerging skills needs', then 'updating existing content and teaching methods' and then 'adopting a modular approach' that allows for the development of tailor made education programs [79].

This review also suggests that there is a lack of current VET programs focused on the bioeconomy, further research on how to develop and integrate them into existing structures would facilitate their development. There are various ways to support this including research on what long term skills and competences for the bioeconomy are needed and how to better embed educational approaches in career guidance, this could be then be followed by a process that integrates relevant educational recommendations in relevant national and EU strategies. In addition, Kuckertz 2020 recommends integrating and facilitating entrepreneurship, research on how entrepreneurship can aid bioeconomy

training programs could be valuable [80]. This review also suggests that a focus on how to integrate extension and advisory services would be beneficial for bioeconomy stakeholders. Extensive research is needed on how bioeconomy extension services can be integrated in existing extension services. This is particularly important as the remit of the bioeconomy is considerably larger than existing services.

A considerable drawback of current bioeconomy related research is that there is no concrete accepted definition of what bioeconomy education entails. A recent study found that some programs still have a tendency to be discipline oriented and that this can hinder the capacity of students to dealt with complex issues [81]. In the design of educational programs and pedagogical practices ways need to be found to overcome learning boundaries [81] whilst ensuring an interdisciplinary approach to bioeconomy education [82]. Moreover, drawing upon D'Adamo's et al. [83] remarks, it is important the education aspects in bioeconomy to be investigated in relation with the EU Next Generation Fund (as VET and skills consist major priorities) and its funding initiatives and outcomes.

6. Conclusions

This paper has conducted a review of the current practices of bioeconomy education and training in the EU, as well as the associated methodologies, techniques and approaches. It has provided an overview of education approaches for the bioeconomy, including higher education and academic approaches, VET and practical approaches, short term training and education approaches, and other approaches. The main commonalities amongst these approaches are that they are generally problem based and interdisciplinary, and combine academic and experiential. Higher education approaches are generally based around traditional lecture/campus-based formats together with some integrated experiential approaches. In contrast, VET approaches often combine academic and practical learning methods while focusing on developing practical skills. Various areas for future research are identified in this study. In recent years, considerable efforts have been made towards developing appropriate bioeconomy education and training programs. However, due to the scale and complexity required for the bioeconomy transition it is clear that considerably more bioeconomy education programs are required, especially focused on specific bioeconomy themes.

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References

1. Kalnbalkite, A.; Pubule, J.; Blumberga, D. Education for Advancing the Implementation of the Green Deal Goals for Bioeconomy. *Environ. Clim. Technol.* **2022**, *26*, 75–83. [CrossRef]
2. Hakovirta, M.; Lucia, L. Informal STEM education will accelerate the bioeconomy. *Nat. Biotechnol.* **2019**, *37*, 103–104. [CrossRef] [PubMed]
3. Urmetzer, S.; Lask, J.; Vargas-Carpintero, R.; Pyka, A. Learning to change: Transformative knowledge for building a sustainable bioeconomy. *Ecol. Econ.* **2020**, *167*, 106435. [CrossRef]
4. Takala, T.; Tikkanen, J.; Haapala, A.; Pitkänen, S.; Torssonen, P.; Valkeavirta, R.; Pöykkö, T. Shaping the concept of bioeconomy in participatory projects—An example from the post-graduate education in Finland. *J. Clean. Prod.* **2019**, *221*, 176–188. [CrossRef]
5. Pascoli, D.U.; Aui, A.; Frank, J.; Therasme, O.; Dixon, K.; Gustafson, R.; Kelly, B.; Volk, T.A.; Wright, M.M. The US bioeconomy at the intersection of technology, policy, and education. *Biofuels Bioprod. Biorefining* **2022**, *16*, 9–26. [CrossRef]
6. Pubule, J.; Blumberga, A.; Rozakis, S.; Vecina, A.; Kalnbalkite, A.; Blumberga, D. Education for advancing the implementation of the bioeconomy goals: An analysis of MASTER study programmes in bioeconomy. *Environ. Clim. Technol.* **2020**, *24*, 149–159. [CrossRef]
7. BRANCHES. Boosting Rural Bioeconomy Networks BRANCHES. Available online: https://www.branchesproject.eu/ (accessed on 4 August 2022).
8. BE-Rural Home. BE-Rural. Available online: https://be-rural.eu/ (accessed on 4 August 2022).
9. MPowerBIO. MPowerBIO. Available online: https://mpowerbio.eu/ (accessed on 4 August 2022).
10. EBL European Bioeconomy Library—The Bioeconomy Knowledge Base Meeting Point! Available online: https://www.bioeconomy-library.eu/ (accessed on 4 August 2022).
11. Watkinson, I.I.; Bridgwater, A.V.; Luxmore, C. Advanced education and training in bioenergy in Europe. *Biomass Bioenergy* **2012**, *38*, 128–143. [CrossRef]
12. Ciriminna, R.; Albanese, L.; Meneguzzo, F.; Pagliaro, M. Educating the managers of the bioeconomy. *J. Clean. Prod.* **2022**, *366*, 132851. [CrossRef]
13. European Commission. *A sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment*; European Commission: Brussels, Belgium, 2018; ISBN 9789279941450.
14. European Commission. *Farm to Fork Strategy*; European Commission: Brussels, Belgium, 2020.
15. European Commission. *Circular Economy Action Plan*; European Commission: Brussels, Belgium, 2020.
16. European Commission. Knowledge Centre for Bioeconomy. Available online: https://knowledge4policy.ec.europa.eu/bioeconomy_en (accessed on 4 August 2022).
17. Deloitte; Empirica; FGB. *Promoting Education, Training and Skills Across the Bioeconomy—Final Report*; European Commission: Brussels, Belgium, 2022.
18. Bejinaru, R.; Hapenciuc, C.V.; Condratov, I.; Stanciu, P. The university role in developing the human capital for a sustainable bioeconomy. *Amfiteatru Econ. J.* **2018**, *20*, 583–598. [CrossRef]
19. Masiero, M.; Secco, L.; Pettenella, D.; Da Re, R.; Bernö, H.; Carreira, A.; Dobrovolsky, A.; Giertlieova, B.; Giurca, A.; Holmgren, S.; et al. Bioeconomy perception by future stakeholders: Hearing from European forestry students. *Ambio* **2020**, *49*, 1925–1942. [CrossRef]
20. Ray, S.; Srivastava, S.; Diwakar, S.; Nair, B.; özdemir, V. Delivering on the promise of bioeconomy in the developing world: Link it with social innovation and education. *Biomark. Discov. Dev. World Dissecting Pipeline Meet. Challenges* **2016**, 73–81. [CrossRef]
21. Baptista, F.; Lourenço, P.; Fitas da Cruz, V.; Silva, L.L.; Silva, J.R.; Correia, M.; Picuno, P.; Dimitriou, E.; Papadakis, G. Which are the best practices for MSc programmes in sustainable agriculture? *J. Clean. Prod.* **2021**, *303*, 126914. [CrossRef]
22. Sacchi, S.; Lotti, M.; Branduardi, P. Education for a biobased economy: Integrating life and social sciences in flexible short courses accessible from different backgrounds. *N. Biotechnol.* **2021**, *60*, 72–75. [CrossRef] [PubMed]
23. Onpraphai, T.; Jintrawet, A.; Keoboualapha, B.; Khuenjai, S.; Guo, R.; Wang, J.; Fan, J. Sustaining Biomaterials in Bioeconomy: Roles of Education and Learning in Mekong River Basin. *Forests* **2021**, *12*, 1670. [CrossRef]
24. Lask, J.; Maier, J.; Tchouga, B.; Vargas-Carpintero, R. The bioeconomist. *Bioeconomy Shap. Transit. A Sustain. Biobased Econ.* **2017**, 341–354. [CrossRef]
25. VET4BioECONOMY. VET4BioECONOMY. Available online: https://vet4bioeconomy.sumins.hr/ (accessed on 4 August 2022).
26. Nibbi, L.; Chiaramonti, D.; Palchetti, E. Project BBChina: A new master program in three Chinese universities on bio-based circular economy; from fields to bioenergy, biofuel and bioproducts. *Energy Procedia* **2019**, *158*, 1261–1266. [CrossRef]
27. Global Bioeconomy Summit. How to shape education for a sustainable circular bioeconomy? In Proceedings of the Conclusions from the GB2020 Workshop on Education, training and capacity building, Berlin, Germany, 16–20 November 2020.
28. European Commission. Bioeconomy. Available online: https://ec.europa.eu/info/research-and-innovation/research-area/environment/bioeconomy_en (accessed on 27 July 2022).
29. Eurostat Farms and Farmland in the European Union-statistics-Statistics Explained. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics#The_evolution_of_farms_and_farmland_from_2005_to_2016 (accessed on 11 April 2022).
30. Eurostat Forests, Forestry and Logging—Statistics. Explained. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Forests,_forestry_and_logging#Forests_in_the_EU (accessed on 13 September 2021).

31. FIELDS Database-Erasmus Fields. Available online: https://www.erasmus-fields.eu/database/ (accessed on 4 August 2022).
32. NORD University. Study Plan Bachelor in Circular Bioeconomy. 2022. Available online: https://www.nord.no/en/Student/study-plans/basirk (accessed on 1 September 2022).
33. Rhine-Waal University of Applied Sciences Biomaterials Science, B.Sc. Available online: https://www.hochschule-rhein-waal.de/en/faculties/technology-and-bionics/degree-programmes/biomaterials-science-bsc (accessed on 20 October 2022).
34. University of Hohenheim Biobased Products and Bioenergy (Bachelor's). Available online: https://www.uni-hohenheim.de/en/biobased-products-and-bioenergy-bachelors (accessed on 19 October 2022).
35. Imperial College London BSc Biotechnology. Available online: https://www.imperial.ac.uk/study/ug/courses/life-sciences-department/biotechnology-bsc/ (accessed on 20 October 2022).
36. HAMK Information and Communication Technology, Bioeconomy-Häme University of Applied Sciences. Available online: https://www.hamk.fi/dp-bachelor/bioeconomy-engineering/?lang=en (accessed on 19 October 2022).
37. University of Hohenheim Sustainability & Change Bachelor. Available online: https://www.uni-hohenheim.de/en/sustainability-and-change-bachelors-studies (accessed on 19 October 2022).
38. International Hellenic University MSc in Bioeconomy: Biotechnology and Law—University Center of International Programmes of Studies. Available online: https://www.ihu.gr/ucips/postgraduate-programmes/bioeconomy (accessed on 19 October 2022).
39. Politechnika Łódzka Bioeconomy-I Stopnia-Faculty of Biotechnology and Food Sciences. Available online: https://rekrutacja.p.lodz.pl/en/biogospodarka-first-cycle-faculty-biotechnology-and-food-sciences (accessed on 19 October 2022).
40. ETSIAAB BSc Degree in Agricultural Sciences and Bioeconomy. Available online: https://www.etsiaab.upm.es/Internacional/Studies?fmt=detail&prefmt=articulo&id=fa45d4183f117610VgnVCM10000009c7648a____ (accessed on 19 October 2022).
41. University of Piraeus Bioeconomy, Circular Economy and Sustainable Development. Available online: https://www.unipi.gr/unipi/en/oik-spoudes-en/metapt-spoudes-en/bioeconomy-and-sustainable-development.html (accessed on 12 October 2022).
42. FindAMasters Masters Degrees (Bioeconomy). Available online: https://www.findamasters.com/masters-degrees/?Keywords=bioeconomy (accessed on 19 October 2022).
43. TUM Bioeconomy-Master of Science (M.Sc.)-TUM. Available online: https://www.tum.de/studium/studienangebot/detail/bioeconomy-master-of-science-msc (accessed on 19 October 2022).
44. Wageningen University Master's Biobased Sciences-WUR. Available online: https://www.wur.nl/en/education-programmes/master/msc-programmes/msc-biobased-sciences.htm (accessed on 19 October 2022).
45. BIOCIRCE Master BioCIRCE. Available online: https://masterbiocirce.com/ (accessed on 19 October 2022).
46. University of Borås Master Programme in Resource Recovery-Biotechnology and Bioeconomy. Available online: https://www.hb.se/en/international-student/program/programmes/master-programme-in-resource-recovery---biotechnology-and-bioeconomy/ (accessed on 19 October 2022).
47. University of Florence IMES Master in Bioenergy and Environment. Available online: https://docplayer.net/15146972-The-master-is-managed-by-the-crear-research-centre-on-renewable-energies-of-the-university-of-florence.html (accessed on 5 November 2022).
48. EURAXESS 11 PhD Positions Available in Bioeconomy. Available online: https://euraxess.ec.europa.eu/worldwide/australia-nz/11-phd-positions-available-bioeconomy (accessed on 18 October 2022).
49. University College Dublin PhD in Planning and the Bio-economy. Available online: https://www.findaphd.com/phds/project/phd-in-planning-and-the-bio-economy/?p145296 (accessed on 19 October 2022).
50. ESP Postdoctoral Position in Sustainable Bioeconomy Strategies. Available online: https://www.es-partnership.org/postdoctoral-position-in-sustainable-bioeconomy-strategies/ (accessed on 20 October 2022).
51. EUNICAS BSc Bioeconomy Enginering | Hame University of Applied Sciences (HAMK) | Search Programmes | European Universities Information. Available online: https://www.eunicas.ie/index.php/eunicas/course/bsc-bioeconomy-enginering-1442.html (accessed on 19 October 2022).
52. Eurostat Glossary: Vocational Education and Training (VET)-Statistics Explained. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Vocational_education_and_training_(VET) (accessed on 4 August 2022).
53. CEFAP Smart Farming & Bioeconomy Technician. Available online: https://www.cefap.fvg.it/it/31220/tecnico-smart-farming-bioeconomy (accessed on 19 October 2022).
54. MAPA Plan de Formación Continua Para Técnicos del Medio Rural. Available online: https://www.mapa.gob.es/es/desarrollo-rural/formacion/cursos/ (accessed on 19 October 2022).
55. EFA Casagrande Aprovechamientos Forestales. Available online: https://www.efacasagrande.org/programas-formativos/fp-basico/ (accessed on 19 October 2022).
56. EFA Centro AGROJARDINERÍA-Formación Profesional Dual en EFAS. Available online: https://efa-centro.org/fp-basica-agrojardineria/ (accessed on 19 October 2022).
57. EPASC Qualification en Environnement. Available online: https://www.epasc-ciney.be/epasc/enseignement/technique-de-qualification/environnement/ (accessed on 19 October 2022).
58. EPASC Qualification en Agriculture. Available online: https://www.epasc-ciney.be/epasc/enseignement/technique-de-qualification/agriculture/ (accessed on 19 October 2022).
59. Warmonderhof Voltijd Biologisch-Dynamische Landbouw. Available online: https://aereswarmonderhof.nl/studeren/voltijd-leren-wonen-werken (accessed on 19 October 2022).

60. Politécnico de Coimbra Técnico Superior Profissional em Agrotecnologia. Available online: https://www.ipc.pt/pt/estudar/cursos/18197 (accessed on 19 October 2022).
61. Wageningen University Course Data-Driven Agri-Food Business-WUR. Available online: https://www.wur.nl/en/education-programmes/wageningen-academy/what-we-offer-you/courses/show/online-course-data-driven-agri-food-business.htm (accessed on 19 October 2022).
62. CIFP CICLO FORMATIVO DE GRADO MEDIO: Producción Agroecológica. Available online: http://www.cifpaguasnuevas.es/2012-10-08-14-46-23/actividades-agrarias/59-ciclo-formativo-de-grado-medio-produccion-agroecologica-tecnico-en-produccion-agroecologica (accessed on 19 October 2022).
63. CIPF CICLO FORMATIVO DE GRADO SUPERIOR: Gestión Forestal y del Medio Natural. Available online: http://www.cifpaguasnuevas.es/2012-10-08-14-46-23/actividades-agrarias/61-ciclo-formativo-de-grado-superior-gestion-forestal-y-del-medio-natural (accessed on 19 October 2022).
64. EPADRC Técnico/a de Produção Agropecuária | Profissionais | EPADRC-Escola Profissional de Agricultura e Desenvolvimento Rural de Cister. Available online: https://www.epadrc.pt/pt/profissionais/tecnicoa-de-producao-agropecuaria (accessed on 19 October 2022).
65. European Forest Institute Bioregions Workshop: Unlocking Regional Bioeconomy Transitions. Available online: https://efi.int/events/bioregions-workshop-unlocking-regional-bioeconomy-transitions-2022-06-28 (accessed on 20 October 2022).
66. Agricultural University of Athens Online Workshop Entitled "Sustainable Production of Biobased Products in the Bioeconomy Era". Available online: https://www2.aua.gr/en/news-events/ekdiloseis/online-workshop-entitled-sustainable-production-biobased-products-bioeconomy (accessed on 20 October 2022).
67. Panacea Training Course for Farmers: Non-Food Crops (NFC) for Bioeconomy in Italy. Available online: http://www.panacea-h2020.eu/2020/10/01/training-course-for-farmers-non-food-crops-nfc-for-bioeconomy-in-italy/ (accessed on 20 October 2022).
68. BICOCCA TOWARDS A BIO-BASED ECONOMY: Science, Innovation, Economics, Education. Available online: https://www.summerschoolbicocca.com/017-10-bio-based-economy-course.php (accessed on 20 October 2022).
69. Lake Como School of Advanced Studies Bioeconomy School: From Basic Science to a New Economy. Available online: https://bsne.lakecomoschool.org/ (accessed on 20 October 2022).
70. Euroleague for Life Sciences ELLS Summer School on Bioeconomy 2021. Available online: https://www.euroleague-study.org/en/bioeconomy-2021 (accessed on 20 October 2022).
71. Bioeconomy Ventures Home-BioeconomyVentures. Available online: https://www.bioeconomyventures.eu/ (accessed on 20 October 2022).
72. CTA MPowerBIO Project is Calling Bioeconomy SMEs to Participate in a Business Support Programme. Available online: https://www.corporaciontecnologica.com/en/sala-de-prensa/noticias/MPowerBIO-project-is-calling-bioeconomy-SMEs-to-participate-in-a-business-support-programme/ (accessed on 20 October 2022).
73. DigiCirc DigiCirc–Accelerator for Circular Economy. Available online: https://digicirc.eu/ (accessed on 20 October 2022).
74. Mustalahti, I. The responsive bioeconomy: The need for inclusion of citizens and environmental capability in the forest based bioeconomy. *J. Clean. Prod.* **2018**, *172*, 3781–3790. [CrossRef]
75. EBU European Bioeconomy University: Six Universities Form International Alliance with Focus on Bioeconomy—European Bioeconomy University. Available online: https://european-bioeconomy-university.eu/european-bioeconomy-university-six-universities-form-international-alliance-with-focus-on-bioeconomy-21-11-18/ (accessed on 19 September 2022).
76. Sakellaris, G. Bioeconomy Education. *Bio#Futures* **2021**, 489–506. [CrossRef]
77. Stegmann, P.; Londo, M.; Junginger, M. The circular bioeconomy: Its elements and role in European bioeconomy clusters. *Resour. Conserv. Recycl. X* **2020**, *6*, 100029. [CrossRef]
78. *Bio-Based Industries Consortium Report about the Analysis of Educational Gaps Identified in the Different Regional Contexts and Action Fields*; Bio-Based Industries Consortium: Madrid, Spain, 2020.
79. European Commission. *Promoting Education, Training and Skills across the Bioeconomy-Policy Brief*; European Commission: Brussels, Belgium, 2022.
80. Kuckertz, A. Bioeconomy Transformation Strategies Worldwide Require Stronger Focus on Entrepreneurship. *Sustainability* **2020**, *12*, 2911. [CrossRef]
81. Vuojärvi, H.; Vartiainen, H.; Eriksson, M.; Ratinen, I.; Saramäki, K.; Torssonen, P.; Vanninen, P.; Pöllänen, S. Boundaries and boundary crossing in a multidisciplinary online higher education course on forest bioeconomy. *Teach. High. Educ.* **2022**. [CrossRef]
82. Výbošťok, J.; Navrátilová, L.; Dobšinská, Z.; Dúbravská, B.; Giertliová, B.; Aláč, P.; Suja, M.; Šálka, J. Bioeconomy perception by students of different study programs-study from Slovakia. *Cent. Eur. For. J.* **2022**, *68*, 91–100. [CrossRef]
83. D'Adamo, I.; Gastaldi, M.; Morone, P.; Rosa, P.; Sassanelli, C.; Settembre-Blundo, D.; Shen, Y. Bioeconomy of Sustainability: Drivers, Opportunities and Policy Implications. *Sustainability* **2022**, *14*, 200. [CrossRef]