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Article

Sustainability Education in Massive Open Online Courses: A Content Analysis Approach

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Abstract: The purpose of this study was to investigate the current status of sustainability education in Massive Open Online Courses (MOOCs). Sample MOOCs were searched for from seven popular platforms and three search engines. After screening, 51 courses were identified as the final sample. Course description, content outlines, reading materials, recommended textbooks and discussion threads were coded to obtain insights into sustainability education learning contents, pedagogical methods, and interaction situations. Results indicated that: (1) Edx and Coursera are platforms that incorporated the most sustainability-related courses, and most instructors were senior academics with the title of professor. American and European countries outperformed other English speaking countries as early birds in sustainability education using MOOCs. The average course length of our MOOC samples is 7.6 weeks, which is much shorter than a typical face-to-face college course; (2) Current MOOCs provided mainly introductory-level courses without prerequisites. Fourteen sustainability-related hot topics and five most popular textbooks were identified; (3) The pedagogical means used most frequently were discussion forums and lecture videos, while pedagogies such as team-based learning were not used to a large extent; (4) Learner interaction flourished in MOOCs, and sub-forums regarding Lecture Reflection, Welcome and Introduction were posted with most threads, replies, and votes. Our findings suggest that the MOOC is an innovative method in sustainability education and research. A variety of information and strategies could be used when preparing sustainability-related MOOCs.

Keywords: sustainability education; MOOC; open educational resource; open courseware; content analysis; learning content; pedagogical methods; interaction pattern

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1. Introduction

Since the 1980s, there have been a series of major changes in the social, economic, cultural and technological arenas. Global issues such as population overgrowth, environmental degradation and resource depletion have made significant impacts on our daily lives. Some experts have promoted the concept of sustainability and are trying to make people aware of these rapidly-deteriorating worldwide issues. Sustainability involves the integration of social and environmental factors with economic considerations [1]. The key message is that a win for the environment is not necessarily a loss for the bottom line, such as profit [2]. The concept of "sustainability education" emerged from the Brundtland Report by the World Commission on Environment and Development in 1987 and Agenda 21 from the Earth Summit of the United Nations Conference on Environment and Development in 1992 [3–6]. The central theme has been "to what extent is the use of natural resources and the environment possible, if our economy is to exist on at least the present level in the very long run" [7] (p. 908). Sustainability education encompasses three major dimensions: economic, social, and environmental [6,8]. Nowadays, there is continuing pressure for curriculum changes involving broad-scale and cross-disciplinary re-organization to facilitate education on sustainability [9]. This is especially true in engineering and environment-related subjects, in which the degree accreditation criteria within the UK [10], New Zealand [11], and the US [12] all include statements regarding sustainability, and require students to equip themselves with a range of relevant knowledge, attitudes, and skills.

However, the question about how to teach sustainability-related courses remains under discussion by experts from various fields. This is likely due to the following reasons: First, sustainability is a broad concept and is difficult to define, thus there are extended discussions on what should be included in sustainability education courses and the management of the content structure. Second, before the rise of the concept of sustainability, colleges and universities already had established curriculums. To embed the principles of learning for sustainability would require major curriculum changes that would cost time and effort [13,14]. Third, the sustainability issue is a global one and related to everyone, thus it should be a kind of general education. How to make it widely available to more people in order to promote environmental ethical awareness and sustainability and to safeguard our precious natural and cultural resources is another issue to which many educators and scholars are paying closer attention [15].

The emergence of Massive Open Online Courses (MOOCs) has allowed many sustainability educators to glimpse the light. The first university to offer a MOOC was widely recognized as the University of Manitoba in Canada, with George Siemens and Stephen Dawnes's Connectivism & Connective Knowledge in 2008 [16]. The MOOC is a new form of online course in the field of open education, with the characteristics of being open, having a great number of students, and increasing the scale of social interaction. Its world-wide spread and development have been attracting plenty of attention all over the world [17], just like a strong wind blowing against and possibly turning our traditional education on its head [18]. MOOCs emerged from an era in which open education was popularized and the idea of life-long learning became widely accepted. Nowadays, online education has gradually become the norm and the development of MOOCs would be beneficial to social learning networks, knowledge building and sharing, as well as the development of a learning society [19].

There are three important concepts that are closely related to the topic of open education—*i.e.*, OER, OCW, and MOOC—thus it is necessary to define them at this early stage. The Open Educational Resource (OER) was first proposed at UNESCO's 2002 Forum on Open Courseware and is designated as "Teaching, learning and research materials in any medium, digital or otherwise, that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions" [20]. Finni (2009) pointed out that the MOOC may be considered to be a special type of OER [21]. According to these definitions, in this paper, the OER is regarded as a general concept for educational materials that is freely available to the public, including Open Courseware (OCW) and Massive Open Online Courses (MOOC). Open Courseware (OCW) means online learning materials that are open to the public without offering any learning support or instructional services. It is basically lesson plans that are available freely on the internet through university portals, intended for educators to use in their own courses rather than for learners' self-study. The Massive Open Online Course (MOOC) is defined as a course that provides free learning materials as well as learning support and instructional services for mass learners within a specific period of time.

The MOOC aims to provide free learning opportunities to more people, and therefore obtains widespread support from government and society. It has also caught the eye of sustainability educators and scholars. As early as 2001, when MIT started a vigorous global OCW Movement that gave world-wide learners and instructors free access to its undergraduate and graduate course materials through the Internet [22], several sustainability-related courses became available online. However, at that time, the OCW Movement was just at the stage of course material presentation [23], only presented related course resources to the public online, without providing subsequent learning support services [24]. Accordingly, many learners found it hard to communicate with course instructors and discuss learning issues with fellow learners. This largely led to the inadequate application of open resources [25]. Since 2012, when MOOC sites such as Edx, Coursera, and Udacity have been set up one after another, sustainability-related courses have also appeared one after the other, on MOOC platforms. They not only offer learning resources and opportunities for people to cultivate their awareness of global environmental protection and a sense of sustainability, but also provide a window for us to learn about the ways in which world-class universities teach sustainability-related knowledge in an open online environment.

This research attempts to determine the current status of sustainability education in MOOCs and help readers to know more about how sustainability education is being taught in various well-known universities and organizations. To sum up, we have dual aims in this research paper: to understand the contents to teach in sustainability education and to discover specific methods of teaching sustainability in MOOCs. Based on the above research objectives, we attempt to address the following research questions:

(1) Current status: What is the current status of sustainability education in MOOCs across different massive open online learning platforms?
(2) Learning content: What kinds of sustainability-related topics and learning contents are most frequently taught in MOOCs? What are the most frequently used reading materials and textbooks in the field?
(3) Pedagogical methods: What are the most popular pedagogical methods when teaching sustainability-related open online courses? How do sustainability educators get the most out of MOOCs? And how do they overcome the shortfalls?
(4) Interaction and discussion: How do instructors facilitate learner interaction and communication in MOOCs?

2. Literature Review

In recent decades, the language of sustainability education has been constantly shifting [26], and the terms "Sustainability Education", "Education for Sustainability" and "Education for Sustainable Development" may be used interchangeably [27]. In curriculum terms, sustainability education invites a systemic, holistic and trans-disciplinary approach to addressing knowledge, skills, and attitudinal development [28,29], which requires a new framework operating under the organizing principle of head, hands, and heart [30]. Based on the dual aims of this research, literature was reviewed on sustainability-related learning contents and pedagogical methods, respectively. Learning contents refer to "what" should we teach students when providing education in sustainability. Pedagogical methods refer to "how" we should teach students in sustainability-related courses, especially in an open distance learning environment.

2.1. Learning Contents in Sustainability Education: What to Teach

To start a sustainability-related course, one of the key considerations is the learning contents for teaching purposes. What kinds of topics should be put into the instructional packages and demonstrated to students? As sustainability education has a universal learning goal, including coverage of sustainable technologies, sustainable development and consideration of the social and environmental effects, there are potentially a lot of relevant specific learning content in the field. Some research has been done on specifying sustainability-related learning contents according to the targeted outcomes for students' knowledge of sustainability. For example, by adopting the framework in the cognitive domain of Bloom's taxonomy [31], the American Society of Civil Engineers [32] defined critical sustainability-related learning contents (e.g., key aspects of sustainability relative to engineering phenomena, society at large, and its dependence on natural resources; and relative to the ethical obligation of the professional engineer). The American Academy of Environmental Engineers [33] also proposed two objectives of knowledge acquisition: (1) recognize life-cycle principles in the context of environmental engineering design; and (2) identify components in an engineered system that are not sustainable. In addition, the Joint Board of Moderators (JBM) and the Engineering Council in the UK (ECUK) established 19 different statements of knowledge, abilities, and skills related to sustainability that students should possess. The majority of these relate to "awareness" or the lowest level of Bloom's cognitive taxonomy, including climate change and carbon emissions, ethics, environmental impact assessment, energy, and resource scarcity [34,35].

Other than identifying learning contents from targeted outcomes, some other researchers have tried to define sustainability learning contents by analyzing the definition of "sustainability" or "sustainable development" [36,37]. The term "sustainability" has been defined in various ways in different contexts. In the ecology context, sustainability is defined as how biological systems remain diverse and productive, such as promoting long-living and healthy wetlands and forests. In the building industry context, sustainability is about how to design and build green constructions or create energy-efficient products. In the environmental context, sustainability is the way of reducing negative human impact, such as applying environmentally-friendly chemical engineering, environmental resources management and environmental protection. In the social context, sustainability entails international and national law, urban planning and transport, local and individual lifestyles and ethical consumerism. Ways of living more sustainably can take many forms, from reorganizing living conditions (e.g., eco-villages, eco-municipalities and sustainable cities), reappraising economic sectors (permaculture, green building, sustainable agriculture), or work practices (sustainable architecture), and using science to develop new technologies (green technologies, renewable energy and sustainable fission and fusion power), to adjustments in individual lifestyles that conserve natural resources [36]. In a more general context, sustainability is the endurance of systems and processes, which includes three interconnected domains: environmental, economic, and social. Some experts have pointed out that ecological, political and cultural perspectives should also be included [37].

Some authors did not focus on the learning outcome or the definition of sustainability, but discussed the common labels used in sustainability education, finding that Business Ethics (35%), Corporate Social Responsibility (11%) and Ecological/Environmental Management (9%) were the top three labels in Western Europe. The other learning contents included: Accounting 7%; Globalization, Transnational, Geopolitics 7%, Sustainable Development 5%; Business and Society 4%; Corporate Governance 4%; Leadership 4%, Management/Business; Human Resources Management; Corporate Citizenship; Culture; Finance; Diversity Management; Philosophy; Strategy (all 2%); The Economics of Corruption; Sociology; Marketing (all 1%) [38]. In addition, Wu *et al.* [2] (2010) analyzed the observed sustainability-related courses from 642 business schools in terms of frequency of terms used, and their findings were consistent with those of Matten and Moon (2004) [38]. They found that the top 10 labels associated with sustainability were "Ethics," "Sustainability," "CSR", "Sustainable Development", "Natural Resources", "Energy", "Cultural Diversity and Intercultural Understanding", "Climate Change", "Peace and Human Security", and "Ecology". It is interesting to note that business schools from North America placed more emphasis on "Ethics" as a sub-topic.

To sum up, with the further development of either the concept of sustainability or the expected learning outcome from sustainability education, considerable discussion has been aroused on what kind of learning contents should be included when providing sustainability education. Most researchers have tried to answer this question only by critical thinking, or by analyzing the connotations and denotations on the definition of sustainability. However, we are still not clear about the learning contents that are currently most frequently discussed and taught from a global perspective in the open online platforms. Thus, this is one of our research purposes and has been listed as our second research question; we will search the MOOCs for answers.

2.2. Pedagogical Methods in Sustainability Education: How to Teach

Pedagogical methods refer to the instructional means adopted by instructors when providing sustainability education. With a wide array of teaching tools available to instructors, it is crucial to examine the pedagogical methods that have been used to address and deliver sustainability-related issues in classes. Some research pointed out that inviting business and NGO speakers into classrooms for talks or simply to apply case studies were the most common methods utilized by university instructors in Western Europe [38]. Relevant findings indicate that case studies and discussions were the most commonly practiced teaching methods across all accredited business schools, and university instructors welcomed the arrival of a diverse variety of sustainability-related case studies [2]. Besides, project-based learning was demonstrated to be an effective approach to develop graduate attributes, and that the concept map is a useful tool to evaluate innovations in teaching sustainable engineering [39]. A recent study summarized the teaching formats of three fundamental approaches to sustainability education: project-based learning and service learning are usually used in case study-oriented teaching; simulation games, exercises and research case studies are commonly used in method-oriented teaching; and lectures and seminars are used in theory-oriented teaching [40]. Also, a survey conducted in a case study found that a wide range of pedagogical methods were utilized and experienced in face-to-face higher education: fieldwork and use of outdoor environment (100%), questions and discussions (100%), lectures (94%), presentations (94%), group work/activities (88%), various audio-visual aids (82%), arts and crafts-related activities (76%), handouts and printed matter (76%), simulations/role play/games (76%), individual investigations (59%), and drama and bodywork (59%) [41]. Moreover, according to the pedagogical methods that have been adopted to educate college engineering students about sustainability, researchers found that lectures, in-class active learning, readings, and appropriately targeted homework assignments can achieve basic sustainability knowledge and comprehension by requiring students to define, identify, and explain aspects of sustainability. Case studies and the application of software tools are good methods of achieving application and analysis competencies. Project-based learning (PBL) and project-based service-learning (PBSL) design projects can help to reach the synthesis level and develop affective outcomes related to sustainability [42].

Most of these previous studies have focused on pedagogical methods that have been used in a face-to-face traditional classroom environment. However, in MOOCs, students are learning in an online environment, without much face-to-face interaction. There are many differences between face-to-face and online learning because of the physical environmental difference and learners' psychological mechanism [43]. Are the above pedagogical methods frequently used in the face-to-face environment still suitable for MOOC users, who are normally learning in an open and online environment? How do we make good use of MOOCs and foster student-centered activities in sustainability education? These are the issues addressed by this study, and they are listed as our third research question.

As Barth and Burandt (2013) point out, providing sustainability education through an open online environment can be characterized by three key principles: self-directed learning, collaborative learning, and problem-oriented learning. Linking e-learning with the specific learning objective of sustainability education brings about a number of potential benefits such as intercultural dialogue, interdisciplinary communication and knowledge generation, and process and project management [44]. The online environment is a good place for forming an online learning community [45]. How to design a suitable community setup in order to promote learning discussions and interactions is also an issue worth discussing, and is listed as our fourth research question.

3. Method

The primary objective of this paper is to provide a holistic picture of the current usage of MOOCs for sustainability education, based on an exploratory empirical content analysis of sustainability-related MOOCs from major universities through general platforms such as EdX, Coursera, and FutureLearn. In order to obtain appropriate data for analysis, we searched for and identified sustainability-related courses from the world's major MOOC platforms, and then collected and analyzed information about the curriculum design (including course goals, objectives, syllabi, content outlines, *etc.*), reading materials (including textbooks, reading lists, *etc.*), and learner interaction (including discussions, social media, listserv, *etc.*) of the MOOCs identified in the first step.

3.1. Data Collection

We chose sustainability-related online courses from three well-known MOOC search engines: AllTheMOOCs [46], Class-central [47], and GuoKr [48] as well as popular MOOC platforms like Edx [49], Coursera [50], Udacity [51], FutureLearn [52], Chinese MOOC [53], NetEase Cloud Classroom [54], and XueTangX [55]. These major MOOC platforms were identified according to previous studies [16–19,56].

The data collection process started on 13 September and ended on 6 November 6 2014. A total of 312 MOOCs were located from MOOC platforms by using "sustainability" or "sustainable" in English and Chinese as keywords, and we clustered them by instructors and course titles. If some of the MOOCs ran more than once, they were merged into one. We then deleted those that were less relevant to the theme of sustainability, as well as those that were not regarded as MOOCs according to our definition, and finally identified 51 MOOCs as sustainability-related courses for the next-step content analysis. We determined "sustainability-related MOOCs" mainly from the general definition of sustainability [1–8], thus only those that focus on the three major dimensions (economic, social, and environmental) would be taken as our sample. Figure 1 demonstrates the flow diagram of our data collection process. From this search, we can say that sustainability education is still new in MOOCs.

With regard to the sample selection, we attempted to use all these selected MOOCs (from 2012 to 2014) so that we could obtain a full picture of the current status of sustainability education in MOOCs.

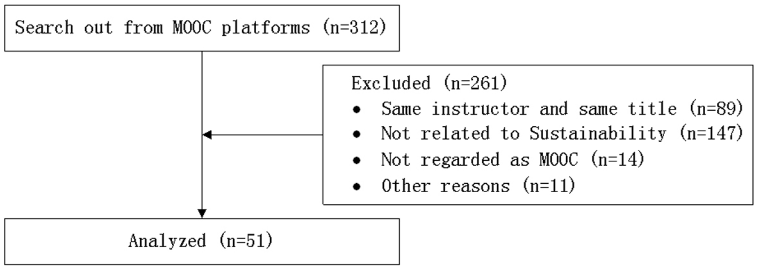

Figure 1. Data collection flow diagram.

Through hyperlinks, we were able to access the webpage of every selected MOOC. From the course descriptions, we collected information such as course goals, syllabi, content outlines, textbooks, reading materials, learning resource elements, pedagogical methods, projects, prerequisites, grading, course length, hours per week, language, subtitle, course level, number of instructors, instructor titles, instructor gender, institute, and country. Some of this information could be used to answer Research Question 1 about the current status of sustainability education in MOOCs. To answer the last three research questions, we needed to access the learning resources and online activities. Thus, we registered for each MOOC and collected information on course outlines, lecture notes, textbooks, readings, multimedia courseware, learning activities, online discussion posts, and so on to determine the hot topics, popular pedagogical methods, and knowledge sharing patterns in sustainability education (Research Questions 2–4). Out of our total sample, there were only 21 MOOCs in which we could participate and obtain the interaction data, thus they were demonstrated and analyzed to answer the last research question. Besides, during this data collection process, three MOOCs were treated as invalid samples because they were in French or Spanish, which did not meet our language requirements (Sample MOOCs need to be provided in English or Chinese, because of the coders' language proficiency). We therefore could not perform any further analysis on them.

Also, from the MOOC search engines, we collected some learner assessment information, such as the number of people who pay attention to this MOOC, the number of people who have learned this MOOC, the number of people who have finally got certificates, the customer grading of knowledge contents, instructor participation, interestingness (how interesting is the course), course design, difficulty (how difficult are the course contents), number of learner reviewers, and evaluation scores from MOOC platforms that present reviews from former learners. This supplementary information helped us to judge the quality of these courses and link them to learners' responses.

3.2. Coding Scheme

With regard to coding mechanics, we based our procedures on previous studies, such as those of Miles and Huberman (1994) [57], Wu (2007) [58], Aerts, Cormier and Magnan (2008) [59] and Wu *et al.* (2010) [2]. We divided our coders into two teams, each consisting of two to three people, in order to ensure inter-rater reliability. Our coders consisted of faculty and graduate students from multiple backgrounds, such as educational technology, economics and management, building and real estate, tourism management, and knowledge management. Coders who were selected for data collection were required to be proficient in English. A coding manual detailing coding instructions and standardized coding worksheets was prepared and distributed to every coder. Each coder then applied the following coding steps and finished all the coding tasks:

(1) Course Status coding: A list of selected MOOCs with basic information such as course title, URL, platform, instructor, learning fees (if applicable), number of students, class available period, country, course length in weeks, hours needed per week, number of instructors, gender of instructors, title of instructors, institute, language used.
(2) Reading Materials coding: We want to find out the most popular textbooks and learning materials in sustainability education. Thus, coders collected all the textbooks and reading references in a file, and then counted the appearance of each reference by frequency.
(3) Content Outline coding: We wanted to know about the hot topics that are taught most frequently in MOOCs about sustainability. Thus, coders would code the course content outlines and syllabus text and extract the topics that appeared. We then finalized the results based on the sustainability-related terms proposed in previous research by Wu *et al.* (2010) [2].
(4) Pedagogical Method coding: We wanted to know what kind of teaching methods instructors used most frequently in MOOCs. Thus, coders identified the pedagogical methods that had been applied in each course, and coded them by means.
(5) Interaction Coding: We want to find out the interaction status of current sustainability-related MOOCs, thus we coded the title of the sub-forums and threads, calculated the number of threads within one sub-forum, and further calculated each thread's number of posts, votes, and views.

3.3. Coding Reliability

Before the actual coding process, we performed training sessions, discussing the coding instructions and including an online demonstration by one of the authors. With these subjective tasks, such as text coding, each coder usually has personal preferences or biases, thus it is essential to perform a code-check procedure across coders in the early stages [57]. In this case, we believe inconsistencies between coders mostly occurred during the first five courses processed. To improve consistency, we held a code-check meeting after the first five courses to enable coders to exchange ideas and resolve issues. The actual coding process commenced after the second discussion, when every coder was clear on the requirements.

To ensure quality, we kept in close communication with the coders, so that whenever a question arose, the solution could be passed on to every member of the coding team. Once coding had been completed, coders were asked to exchange their results with each other to perform a pair inter-rater reliability check. The inter-rater reliability in terms of agreement percent for the first research question was 90.6% with a Kappa of 0.851, the second research question was 80.4% with a Kappa of 0.714, the third research question was 86.3% with a Kappa of 0.803, and the last research question was 88.6% with a Kappa of 0.819, indicating satisfactory agreement.

4. Results

4.1. Current Status of Sustainability Education in MOOCs

4.1.1. Open Course Platforms

There were 51 sustainability-related MOOCs in our sample, of which 19 were from Edx.org (37.3%) and 16 from Coursera (31.4%). These two platforms are the most popular platforms that include sustainability education. In addition, there are five MOOCs in FutureLearn.com (9.8%), five in Canvas.net (9.8%), and 1 MOOC in Acumen, CourseSites, Desire2Learn.com, leuphana.com, NovoEd, and OpenSAP, respectively. We can see from Table 1 that sustainability-related courses are distributed across a wide variety of open platforms.

Table 1. Platform Distribution of Sustainability-Related Open Courses.

Platform	Frequency	Percent
Edx	19	37.3%
Coursera	16	31.4%
Canvas.net	5	9.8%
FutureLearn	5	9.8%
+Acumen	1	2.0%
CourseSites by Blackboad	1	2.0%
Desire2learn.com	1	2.0%
Digital.leuphana.com	1	2.0%
NovoEd	1	2.0%
OpenSAP	1	2.0%

4.1.2. Participating Countries

Table 2 demonstrates that MOOCs related to sustainability were mainly provided by American and European countries. Universities and organizations in the US were the biggest providers of MOOCs related to sustainability education, accounting for 56.9% of our sample. The other sample in this study covered the UK (13.7%), the Netherlands (11.8%), Canada (7.8%), Switzerland (3.9%), Germany (2.0%), Sweden (2.0%), and Denmark (2.0%).

Table 2. Countries Participating in Sustainability-Related Open Courses.

Countries	Frequency	Percent
US	29	56.9%
UK	7	13.7%
Netherland	6	11.8%
Canada	4	7.8%
Switzerland	2	3.9%
Germany	1	2.0%
Sweden	1	2.0%
Denmark	1	2.0%

4.1.3. Participating Universities

As can been seen in Table 3, Delft University of Technology set up five MOOCs related to sustainability-related issues, making it the most MOOC-active of all the institutes in our sample. The University of Florida ranked second, setting up four MOOCs. The other universities included Clemson University, Columbia University, Harvard University, Queen's University in Belfast, Rice University, the University of British Columbia, and the University of Pennsylvania, all of which had set up two courses each. MIT, as the first university to provide OCWs to the public in 2001, has now also set up one sustainability-related MOOC on the Edx platform, demonstrating that MOOCs that combine OCW with learning support and instructional services (e.g., learning guidance, expert communication, instructor feedback, *etc.*) might be the possible trend of the future and an attractive method for sustainability educators to try.

Table 3. Universities Participating in Sustainability-Related Open Courses.

Universities	Frequency	Percent	Universities	Frequency	Percent
Delft University of Technology	5	9.8%	SAP open platform	1	2.0%
University of Florida	4	7.8%	School of Nursing Duke University	1	2.0%
Clemson University	2	3.9%	Stanford University	1	2.0%
Columbia University	2	3.9%	The Cloud Institute for Sustainability Education	1	2.0%
Harvard University	2	3.9%	The University of Illinois	1	2.0%
Queen's University in Belfast	2	3.9%	The University of Nottingham	1	2.0%
Rice University	2	3.9%	The University of Sheffield	1	2.0%
UBCx	2	3.9%	University of Alabama	1	2.0%
University of Pennsylvania	2	3.9%	University of Bath	1	2.0%
International Monetary Fund (IMF)	1	2.0%	University of Central Florida	1	2.0%
Copenhagen Business School	1	2.0%	University of Geneva	1	2.0%
Cornell University	1	2.0%	University of Illinois	1	2.0%
DartmouthX	1	2.0%	University of Manchester	1	2.0%
ETHx	1	2.0%	University of Minnesota	1	2.0%
Fanshawe College	1	2.0%	University of Reading	1	2.0%
Harvard University	1	2.0%	University of Toronto	1	2.0%
Leuphana University Lüneburg	1	2.0%	UTArlingtonX	1	2.0%
Lund University	1	2.0%	WageningenX	1	2.0%
MITx	1	2.0%			

4.1.4. Instructors

A total of 116 instructors were involved in these 51 MOOCs. Among them, three instructors were in charge of more than one MOOC. Almost all of the MOOCs were taught by experienced academics. For example, 49% of the courses were taught by professors, and 74.5% of the MOOC instructors held a PhD degree.

Most of the MOOCs were conducted under the name of one instructor (56.9%), and the other 19.6% MOOCs were conducted by more than four instructors. Interestingly, there are far more male instructors on MOOC courses than females, and 49% of MOOCs were conducted by male-only instructor groups. Only 15.7% of MOOCs were conducted by female-only instructor groups. 35.3% of MOOCs were conducted by mixed-gender instructor groups.

The Open Educational Resource provided by MIT on the OpenCourseWare platform was offered from 2004 to 2011, which was a period in which the general public was not so involved in MOOCs. In 2012, MIT began to provide open online courses on the Edx platform and offer instructional services.

4.1.5. Recommended Time Spent on Learning

Table 4 presents the course length and learning hours in the sample MOOCs. With respect to course length, the largest proportion of open online courses lasted around six weeks (31.4%). The average course length was 7.6 weeks, with a standard deviation of 2.9, which is much shorter than a typical college course (normally about 12–14 weeks). Actually, MOOCs usually have the flexibility to schedule shorter courses, because there are none of the limitations in MOOCs that exist within universities as to when courses can be scheduled.

With respect to weekly learning hours, most of the open online courses encouraged students to spend three to five hours per week on the course. The average expected hours that students were supposed to spend on the course was 5.0 h, and the standard deviation was 1.9. We can see from here that compared to typical college courses, MOOCs required more learning hours per week. This fits the regulations regarding open online learning, and helps to minimize the online learner drop-out rate.

Table 4. Course Length and Learning Hours in MOOCs.

Variables	Units	Mean	Std. Deviation	Minimum	Maximum
Course length	weeks	7.6	2.9	4	15
Standardized learning hours per week	hours	5.0	1.9	2	9

4.1.6. Course Prerequisites

Very few of the MOOCs had prerequisites for students. Only three courses required basic information and a relevant background, such as: (1) basic knowledge of physical and life sciences; (2) basic financial literacy; and (3) basic understanding of business and administration processes, industry value chains and information technology (IT). From this information, we can see that MOOCs really are open to the public, thus in this early stage of developing sustainability education in MOOCs, courses appear to be at preliminary levels so that more people can learn and benefit from them.

4.2. Learning Contents

4.2.1. Hot Topics

The concept of sustainability covers a wide variety of topics and is subject to various interpretations. Wu *et al.* (2010) [2] embarked on a review of key sustainability-related topics from various reports and academic papers [3,8,38,60–62], centering on the core understanding of a balance between economic growth, environmental carrying capacity and sociocultural concerns. They finally decided upon 39 terms as their selection criteria for curriculum content analysis. Our study used these sustainability-related terms as they were developed through a robust process. If the coders encountered a course outline that is related to one of these terms, they entered code "1" after the term. If the coder encountered a course outline that could not be linked to any of these terms, they would list the topics in the table and try to code them in categories.

Table 5 shows the frequency and percentage of sustainability course contents that appeared more than five times in our sample. As we can see, the hottest topic is related to environmental issues such as the energy crisis, climate change, and natural resources management; economic issues such as a sustainable economy, a sustainable supply chain, and sustainable consumption; and social issues such as ethics, population, disaster prevention, and job creation. The energy issue was discussed in 14 open courses, indicating that it is a topic of public focus. In addition, 9.8% of the courses integrated discussions about the concept and definition of sustainability; most of these were introductory courses and gave a broad picture of this field.

Table 5. Most Frequently Discussed Topics in Sustainability-Related MOOCs.

Topics	Frequency	Percentage
energy	14	27.4%
sustainable development	12	23.5%
natural resources	10	19.6%
ethics	9	17.6%
sustainable economy	8	15.7%
ecology	6	11.8%
climate change	6	11.8%
natural resource management-water & land management	6	11.8%
green engineer	6	11.8%
population	6	11.8%
agriculture	6	11.8%
disaster prevention and mitigation	5	9.8%
What is sustainability?	5	9.8%
sustainability and innovation	5	9.8%

4.2.2. Reading Materials and Textbook Selection

By listing all the recommended textbooks and reading references from the 51 courses in our sample, we extracted textbooks that had appeared more than once in our sample course and counted the number of times that they appeared. Finally, we found that the following books were most frequently used by MOOC instructors.

(1) Stavins, Robert N. *Economics of the Environment: Selected Readings* [63]. This textbook appeared in our sample courses five times. This book has established itself as the standard student reader for environmental economics courses, and provides a balanced selection of classic and contemporary readings to firmly ground students' understanding in this field as primary literature. This book grabs readers' attention and serves to combine environmental fervor with economic reality. It is a good introductory text on environmental policy and its shortcomings.

(2) Tainter, Joseph A. *The Collapse of Complex Societies* [64]. This textbook appeared in our sample courses four times. It is an interesting textbook that modifies some of our views about early states and their collapse mainly by using data. It shows how archaeology in alliance with social sciences and provides a framework for organizing and evaluating the evidence of collapse.

(3) Sachs, Jeffrey. *The Age of Sustainable Development* [65]. This textbook appeared in our sample courses twice. It is a new textbook and the author presents a compelling and practical framework for how global citizens can address the seemingly intractable worldwide problems of persistent extreme poverty, environmental degradation, and political-economic injustice. It offers readers the tools, metrics, and practical pathways they need to achieve sustainable development goals.

(4) Allenby, Braden R. (1998). *Industrial Ecology: Policy Framework and Implementation* [66]. This textbook appeared in our sample courses twice. It takes a multidisciplinary approach and provides the first integrated view of industrial ecology and sustainability policy issues through actual case studies that incorporate real-world multidisciplinary examples.

(5) Meadows, Donella H. *The Global Citizen* [67]. This textbook appeared in our sample courses twice. It views the world as an interconnected system for which we are all responsible, and discusses complex issues such as population, poverty and development, and solid waste disposal in a clear, concise and engaging way for a wide audience.

The textbook is one of the essential elements of a course, and it might also affect the development of an academic discipline [68–70] .The textbooks listed here reveal the current status of the most popular textbooks in sustainability MOOCs, and it is not inferred to be the best or the most exhaustive list. From the results, we can find that the textbooks for sustainability education on MOOCs are kind of dispersed, with not much overlap. With this textbook information, sustainability educators are able to choose suitable ones for their own courses according to their foci. From the coverage and content of these textbooks, we also find that economics issues, environmental changes, knowledge economy, industrial ecology policy, international law, resource scarcity, and global citizens' responsibility are actively discussed. In addition, previous studies have usually used interviews to obtain the textbook information for a particular field [68,70]. Here, we have presented a novel way of collecting textbook information directly from course documents based on MOOCs, which we believe is a more objective method.

4.3. Pedagogical Methods

Table 6 demonstrates the pedagogical methods that have been adopted in MOOCs. We divided these methods into two categories indicating the Pedagogies and Means.

As can be seen in the Pedagogy section, most MOOCs are offered in a direct instruction manner, without adopting specific pedagogies. About one third of the sample MOOCs have adopted project-based learning, which is the pedagogy used most in the current stage, especially in application-oriented courses. Research-based learning is another approach that is fit for use in sustainability education, especially for theory-oriented courses. Team-based learning has also been reported to be used in a small portion of MOOCs (9.8%). In the MOOC environment, teamwork is more difficult than in face-to-face courses, because it requires additional organization and is sometimes not easy to control in a massive user context. However, some MOOC instructors have also used these means to achieve their goals. For example, to implement team-based learning, MOOC instructors divide students according to their individual interests, knowledge background, and location as reported in their initial online activities. Subsequently, each group selects a suitable task and accomplishes it through collaboration. The outcomes of the group work can be research reports or recorded videos through remote presentations to peer classmates, which helps to enhance social presence among learners.

Table 6. Pedagogical Methods for Sustainability Curriculum in MOOCs.

	Pedagogical Method	Frequency	Percentage
Pedagogies	Project-based learning	14	27.4%
	Research-based learning	9	17.6%
	Team-based learning	5	9.8%
Means	Discussions	51	100.0%
	Lecture videos	51	100.0%
	Assignments	28	54.9%
	Quiz	26	51.0%
	Reading materials	20	39.2%
	Peer evaluation	15	29.4%
	Social media	14	27.4%
	Final exam	12	23.5%
	Case studies	11	21.6%
	Expert communication	10	19.6%
	Survey	6	11.8%
	Self-assessment and reflection	4	7.8%
	Slides	3	5.9%
	Video presentation	2	3.9%
	Location mapping	2	3.9%
	Poster	1	2.0%
	Offline get-togethers	1	2.0%

With regard to pedagogical means, the online discussion forum and lecture video are both popular means that have been adopted in all of the sample MOOCs. Discussion forums are used to provide timely online interaction between instructors and learners. In order to ensure the quality and quantity of discussions, the number and quality of the threads from students are part of the criteria of assessment for their final course grades. Lecture videos are used to provide vivid and interactive learning contents to course participants. Both of them can be treated as important elements in sustainability-related MOOCs.

Traditional pedagogical methods such as assignments, final examinations, reading lists, lecture slides, case study materials, field expert communication, presentations, poster activities, self-assessment and reflection are also adopted in MOOCs. They are all frequent and effective means of strengthening students' learning in both traditional face-to-face and online environments. For example, expert communication can be provided to students by inviting experts to give face-to-face lectures, while in

MOOCs, experts are invited to talk to students via video conference or to assist in answering questions on online forums.

Other pedagogical means are deemed to be suitable for use in MOOCs, even though they are not often adopted at this stage. For example, quizzes are useful tools in MOOCs. Some quizzes are even embedded in videos to avoid duplicity and enhance comprehension. In MOOC platforms, students can gain access to a video whenever they need it, and replay it over time. In Coursera, Edx, and many other major MOOC platforms, the play speed of lecture videos can be adjusted by learners. About 41.5% of the courses had subtitles for videos, but only 4.6% had translations, such as into Chinese. MOOCs also provide some unique pedagogical means such as peer evaluation, social media, surveys, mapping locations, Google Video Chatting and offline get-togethers, in order to promote course quality in the massive open online environment. Peer evaluation opens up the opportunity for students to evaluate their classmates' assignments. Surveys open up the opportunity for instructors to understand students' levels and needs. Social media (e.g., Facebook, Twitter, *etc.*) provides an opportunity for learners to share knowledge and exchange ideas in their own social networks. Location mapping and offline get-togethers are both special features that are only suited to open education. The former activity shows students' locations on the map and helps them to get acquainted with each other. The latter tries to gather students from the same place to meet with each other and build up deeper relationships.

Note 1: Here are selected definitions of the pedagogical methods listed in Table 6. Project-based learning: Students are assigned to projects either individually or with a team, so that they can learn together when doing the project. Research-based learning: Students pick a research topic and learn related subjects accordingly. The outcome of this pedagogy is usually research reports. Team-based learning: Students are divided into teams and learn collaboratively. Social media: Course participants use social media such as Facebook, Twitter, micro-blog, Google hangouts, *etc.* to communicate. Expert communication: Field experts rather than course instructors come to talk to students or interact with them through media. Location mapping: An interactive digital map is provided for students to indicate their locations, which might be helpful when they want to arrange an offline get-together, or to find out the learning companions who are close to them. Offline get-togethers: MOOC students can organize face-to-face get-togethers to meet with their classmates, so as to increase social presence and also build up their social network through MOOCs.

Note 2: The pedagogical methods presented in Table 6 are not totally independent. We code this information according to the statement reported by every MOOC, thus some of the pedagogical methods overlap. The coders coded the pedagogical methods with relevant information supporting their judgments. Our purpose for doing this was to objectively present the pedagogical methods that have been adopted in MOOCs.

4.4. Interaction in Discussion Boards

Our data collection revealed 21 MOOCs in which we could register and participate in their discussions and gain access to their interaction data. Ten were in progress, and the other 11 had already ended. Among these 21 MOOCs, seven were collected from Coursera, 11 from Edx, and the other three from FutureLearn, thus the data covers three major platforms in our sample courses. There are some differences in the sub-forum settings in different MOOC platforms, thus we analyzed the data separately. For example, MOOCs on the FutureLearn platform would cost us more time because they only have discussion threads and no sub-forums. Thus, we would need to divide all the threads into the six sub-forum categories (as can be seen in Table 7) according to their contents before analyzing them.

Table 7. Means and standard deviation of threads, views, replies and votes in online discussions.

Sub-Forum Categories	Threads M (SD)	Replies M (SD)	Votes M (SD)	Views M (SD)	Votes/ Thread	Views/ Thread
Welcome and introduction	208.4 (331.4)	1046.5 (1651.8)	188.8 (278.3)	12,647.5 (17,076.26)	0.9	60.7
Weekly assignment	182.0 (304.8)	831.8 (1225.6)	104.8 (174.0)	4032.2 (3619.8)	0.6	22.2
Lecture reflection	555.9 (1388.9)	2326.1 (4657.3)	420.8 (812.5)	12,734.4 (24,633.9)	0.8	22.9
Technical issue	39.4 (29.6)	167.0 (140.0)	11.2 (10.3)	1533.0 (1208.2)	0.3	38.9
General discussion	80.5 (70.5)	507.2 (551.4)	56.7 (57.7)	3996.9 (4590.4)	0.7	49.7
Course feedback	24.5 (16.1)	157.9 (147.8)	34.3 (41.0)	1139.6 (905.0)	1.4	46.5

Table 7 demonstrates the means and standard deviation of the threads, views, replies, and votes in online discussions of Edx, Coursera, and FutureLearn. Edx mainly sets sub-forums according to the course contents learned each week, including quizzes, exams, assignments, lectures, topic discussion, and question discussion. Sub-forums were also set up for general discussion, like introductions, enquiries about technical issues, application for certificates, lecture time, *etc.* Coursera has its own logic by setting up sub-forums in a more established way, including those for general discussions, assignments, lectures, technical issues, course materials errors, study groups and weekly discussions. FutureLearn had no sub-forums, so we summarized the threads and categorized them into sub-forums with justification.

By integrating all the threads from these three MOOC platforms, we classified all the sub-forums into six common categories. First, a “Welcome and Introduction” was often set up in the early stages of a course, to allow students to warm up and get to know more about the course and the instructors, and to enable them to introduce themselves to their classmates, which is essential preparation for forming teams later in course activities. This sub-forum was very active but did not contain much information related to the course contents. Second, a “Weekly Assignment” was set up for discussion on assignments that students had to complete each week. It also included assignment solutions, submitting forms, deadlines, course-related content enquiries, and so on. Teaching staff gave regular feedback and responses. Usually, hot posts attract instructors’ attention easily and problems get solved more quickly. Third, “Lecture Reflection” was usually set up as an independent sub-forum so that instructors could provide relevant topics enabling students to reflect on lecture contents, learn more deeply, and obtain extended knowledge through in-depth peer discussions. Fourth, “Technical Issues” were discussed in most of the platforms, since MOOCs take place in an online environment using computers or mobile phones. Technical issues are hard to avoid in such an environment, and sometimes they can be a problem that causes a lot of trouble. This sub-forum helped students to find solutions from their classmates or frequently asked questions in the discussion histories. Fifth, “General Discussion” was related to issues about course time, student assessment, how to obtain an achievement certificate, pre-course enquiries, and so on, which were educational administration issues and also a common sub-forum across platforms. Sixth, “Course Feedback” is a sub-forum whereby some MOOCs used the public to bring their courses to a higher standard and include more accurate learning materials. Students' feedback gave instructors the opportunity to learn more about students' feelings and responses to their lectures. For example, instructors might want to know what the students thought of the lecture for this week; if there any topics that were not explained adequately; and if any of the reading materials challenging for the students. Within this sub-forum was a special section called "Errata and Course Material Feedback", where students could correct errors in course materials. Since about 41.5% of the courses had subtitles for videos, 46.1% of the courses provided self-assessment, and 4.6% of the courses had translation, these materials might contain errors. The inclusion of this sub-forum helps to improve the quality of open educational resources through public effort.

5. Discussions

5.1. Current Status of Sustainability Education on MOOCs

Based on the open educational resources movement started by MIT, many universities are now trying to set up sustainability education curricula on MOOC platforms. Nowadays, Edx and Coursera, are the platforms that host most open sustainability-related courses. Universities from North American and European countries are the early birds in English-speaking countries in current adoption of these platforms and courses. These results are consistent with those of the study conducted by Liyanagunawardena *et al.* (2014) [56], which found that the Coursera platform offered most MOOCs on health and medicine, and that most of the courses were offered by developed countries.

Most of the MOOC instructors are senior experts in the field, with a PhD degree and professorship, and most of the MOOCs are focused on introductory-level course contents without prerequisites. This means that institutes and organizations encourage excellent faculty to provide generalized open online courses, as MOOCs are a good place to invest resources and enroll good students from all over the world. They are also a good means of advertising—to promote the reputation of the faculty and the university, and to spread ideas and concepts quickly.

By comparing the course length and recommended learning hours, we found that the course length of the MOOC (about 7.56 weeks) is much shorter than those of a typical college course (about 12–14 weeks). However, the recommended hours per week to be spent on a MOOC (about 5 h) are much more than those of resource typical college course (about 3 h). This may be because online learners participating in MOOCs drop out more frequently than those in traditional education. Thus, instructors keep the course length shorter by encouraging students to spend more time on it every week. When comparing our results with those obtained by Liyanagunawardena *et al.* (2014) [56], who reported an average MOOC length of 6.7 weeks and expected participants to work on course material for 4.2 h per week in the field of health and medicine, we are confident in reporting this conclusion.

5.2. Learning Contents

According to the course outline, the following topics could be recognized as popular course contents in the field of sustainability: energy, sustainable development, natural resources, ethics, sustainable economics, ecology, climate change, natural resource management (water and land management), green engineering, population, agriculture, disaster prevention and mitigation, defining sustainability, and sustainability and innovation. Most of the topics can be easily linked to the three basic domains of sustainability: environmental, economic, and social, except the concept of sustainability, which might be in the center of the circle. From the percentage of learning content indicated in Table 5, we can see that topics related to energy and resources, ethics, ecology, and management were the predominant vehicles in sustainability learning contents. This finding is consistent with those of previous studies conducted by Matten and Moon [38] (2004) and Wu *et al.* (2010) [2], which also found the Ethics topic to be one of the most important contents in sustainability education; most of the sustainability-related hot topics (e.g., energy, climate change, ecology, natural resources, management, *etc.*) overlapped in these three studies.

According to the textbooks used in the MOOCs, the following textbooks can be identified as popular textbooks in the field of sustainability: *Economics of the Environment: Selected Readings; The Collapse of Complex Society; Industrial Ecology: Policy Framework and Implementation; The Age of Sustainable Development; and The Global Citizen*. These textbooks cover environmental change, economics, social science, ecology issues, policy issues, legal issues, resource issues, and the responsibility of citizens. The textbook information also gave us some indication as to the connotation and denotation of the concept of sustainability, which should be considered when providing open education on this subject.

By integrating the results of hot topics and textbook orientations, we tried to gain insight into the question, "What kind of contents should be taught in sustainability education?" As Warburton (2003) has pointed out, interest can be stimulated by placing more emphasis on contextual interpretation [71]. If sustainability education is to successfully blend with complementary and essential themes of ecological sustainability and social justice [72], students must be able to explore the complex interactions between social, economic and environmental factors and critically examine assumptions underlying related policy and management issues [73–75].

5.3. Pedagogical Methods

According to the coding results, discussion forums and lecture videos are the most frequently used pedagogical methods in sustainability education in MOOCs; they are widely offered by all the MOOCs in our sample. Social media like Facebook, Twitter, micro-blog, *etc.* are popular means in MOOCs, although they have seldom been used before in traditional university courses. It is believed that social media should integrate well into MOOCs because they both have the characteristics of opening up social communication and interaction in online environments. Learners have enthusiasm for sharing what they have learned from MOOCs with their own social networks, and this interaction with their friends could help to enhance learning and reduce drop-out rates. Besides, as seen in Table 6, the pedagogical methods provided by MOOCs have covered almost all the traditional pedagogical methods mentioned in previous studies [2,38–42], though adjustments have been made to fit into the MOOC environment. For example, lectures were provided as videos with sub-titles and embedded quizzes in MOOCs. Reading materials, slides, previous examination papers were provided as online resources. Discussion, case study, and expert communication were usually carried out on the discussion forum.

Team-based learning, project-based learning, and presentations are pedagogical methods that have not been used sufficiently in the current status of MOOCs, because these methods require a higher level of social presence and more frequent interaction among learners. In addition, team-based learning requires more organized work from teaching staff, such as grouping students who are not familiar with one another, and checking to make sure that all the groups are of a suitable size and the group combinations are reasonable. Some instructors encourage students to enroll in their courses in groups, which might not only be beneficial to students who can learn collaboratively, but also help to reduce instructors' work load. In addition, some MOOC instructors encourage students who live or study in the same city to meet-up offline regularly, which can help to enhance learners' interaction and social presence. Presentations are not easy to organize in the MOOC environment due to synchronicity. One of the possible solutions is for students to record videos and upload them for others to watch online; another is to use video conferencing software for presentations. The former means allows more students to participate, because it does not set limits on time or the number of participants, but the presenters cannot feel the atmosphere and obtain real-time feedback. The latter can create a higher level of social presence, which is usually needed to limit the number of participants because of restrictive technical conditions. Better solutions for all these issues are expected in the near future.

5.4. Interaction

The most significant improvement from OCWs to MOOCs is that MOOCs place more emphasis on instructional service and learner interaction, rather than only providing free educational resources online. Thus, interaction is an important perspective that should be carefully examined. From the coding results, we found that: (1) from platform level, MOOCs in Coursera are found to be the most interactive, with more posts and replies than MOOCs in Edx and FutureLearn. Also, Coursera opens up more options to demonstrate students' online interaction information, such as positive votes, negative votes, number of views per post, and so on, while in Edx and FutureLearn, learners can only give positive votes, and information regarding number of views per post is not shown; (2) At the course level, we found the course "Global Sustainable Energy: Past, Present and Future", taught by Professor Wendell A. Porter from the University of Florida, to be a special node when coding. This is possibly because the instructor sets up strict requirements to link students' achievement certificate with their interaction and contribution to the course. For example, for the Statement of Accomplishment, students have to (a) make a minimum of 20 posts in the Module Discussions and Global View Discussions; (b) achieve seven or more on at least nine quizzes; (c) achieve 25 or more on at least one peer-assessment and complete the required four reviews of others. For the Statement of Accomplishment with Distinction, students need to (a) make a minimum of 33 total posts in the Module Discussions and Global View Discussions; (b) achieve seven or more on at least nine quizzes; (c) achieve 25 or more on all three peer-assessments and complete the required four reviews of others on each one (for a total of 12 peer reviews). With these accomplishment levels, the posts and replies on this course are much higher than on the others; (3) At the sub-forum level, we classified related sub-forums from different platforms and found that the sub-forums of "lecture reflection" and "welcome and introduction" were the most popular sub-forums with the most average threads and replies; the sub-forum of "Technical issues" and "Course Feedback" had the fewest threads and replies. This general conclusion is of high consistency across all different platforms; (4) from the time sequence dimension, we found that with the progress of each course, the number of threads declined significantly with time. This may be because students are most excited and interested in participating in course activities when they initially enrol in courses, however, their enthusiasm for these courses tends to decrease with time. This may explain why most MOOCs were designed to be completed within shorter course periods and required more hours per week, as mentioned in Table 3.

6. Limitations

There are some limitations in this study that we would like readers to bear in mind, especially for researchers who want to conduct further related research. First, this research can only rely on the analysis of available data. Some data (such as individual students' information) might be valuable to deepen our conclusion. However, because of privacy protection issues in MOOCs, these kinds of data are not available to us. Second is the language limitation. In our study, we only took MOOCs which were provided in English and Chinese for review, because our coders were only familiar with these two languages. Thus, we might have missed out some MOOCs provided in other languages such as Spanish, French, German, and so on. The third limitation is about searching keywords. In this study, we used "sustainability" or "sustainable" in English and Chinese as keywords for searching. Sample courses would be flagged if they contained any one of these keywords in their title, course description, or course syllabus. However, there might still have been a small number of sustainability courses that we might have omitted if these keywords were not used at all. The fourth limitation relates to multiple instances of the same MOOC. In our study, we encountered some MOOCs that had been run more than once: in such cases, we only took into consideration the one that was on-going. This merge might not affect our conclusion to a large extent based on our comparison, because we are only interested in the learning content, pedagogical methods, and learner interactions. However, for future reseach that is interested in the development process of sustainability-related MOOCs, it is better to take all instances into account.

7. Implications and Future Research

Higher education serves a specific function: to educate influential citizens who value the environment and appreciate that they have a responsibility to help to sustain it [13]. Since the last decade, higher education institutions from around the world have been involved in promoting sustainability in various ways [76–79]. The appearance and development of MOOCs provides both opportunities and challenges for sustainability education. The current paper has made contributions from the following perspectives: (1) We analyzed and demonstrated the current status of sustainability education in open online courses across different platforms, countries, and universities. This is thefirst paper to be conducted that has analyzed sustainability education in MOOCs; (2) Hot sustainability-related topics were discussed through coding all content outlines, and popular textbooks were sorted by calculating the frequency with which they appeared. Both of these hot topics and textbook orientation could provide inspiration for what should be taught in sustainability education, and more emphasis should be placed on contextual interpretation by creating an active and transformative process of learning that allows values to be lived out and spread; (3) Pedogogical methods and learner interaction were coded to get more insights into the question of how we should provide sustainability education in MOOCs.

According to our findings, there are several implications and suggestions that could be referred to by those who want to design and run sustainability-related MOOCs in the future. First, according to the current status of sustainability-related MOOCs, it might be more beneficial to create a new MOOC in a more popular platform such as Edx and coursera, as open learners will find it easier to locate related courses and get familiarized with the course platforms. Second, subtitles, transcription, and translation of MOOC documents are in great need, especially for learners from non-English speaking countries and developing countries. Third, the suitable length for a sustainability-related MOOC could be six to eight weeks, and the suitable learning hours required for learners to spend on course materials could be around five hours per week. In this way, MOOC learners can complete the course in a shorter period of time and then bring down the drop-out rate. Fourth, when providing introductory sustainability education, some frequently-discussed topics (as listed in Table 5) and popular textbooks (as listed in Section 4.2.2) could be considered and covered in the course. Fifth, pedagogies such as project-based learning, research-based learning, and team-based learning could be effective ways for engaging learners to actively participate in MOOCs, however, the team-based learning might require extra effort to divide new learners into groups. One feasible strategy might be to encourage learners to enroll the course in groups initially. Sixth, a serials of pegagogical means (as listed in Table 6) could be considered to use in sustainability-related MOOCs. Among these, social media platforms (such as Facebook, Twitter, *etc.*) should be helpful tools that could go well with MOOCs to arouse public participation on sustainability. Seventh, discussion forum settings and assessment criteria could both affect learner interaction to a large extent. The more we enable participants to know about their interaction information (e.g., number of positive or negative votes for their posts, number of views per post, *etc.*), the more they will be motivated. In the same vein, the more learners rely on their interaction data, the more they would actively participate in the discussion. Therefore, in order to promote learner interaction, it is important to provide more options for learners to review their interaction status, and consider using suitable assessments to link learner performance with individual contribution to the course. These promoted instructional strategies should be helpful for educators or trainers when establishing sustainability-related MOOCs.

Besides, future research could be considered in the following two directions: (1) Longitudinal studies could be conducted to track the developing routine of sustainability-related MOOCs and analyze the instructional design models for sustainability education. Since the MOOC is a new educational initiative that started to be known to the world only in 2008, and the first MOOC in sustainability education was started in 2012, it is beneficial to track and understand its development at this early stage; (2) A content analysis approach could be employed specifically on the cultural issue of different sustainability-related MOOCs, and to try to find cultural differences between Eastern and Western countries on the concept of sustainability. In the current study, not many Eastern countries were found to provide sustainability education via MOOCs, thus our sample did not allow us to make such a comparison. However, with the current speed of development in this arena, MOOCs would be a helpful supporter for cross-cultural studies; we look forward to seeing them emerge.

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Author Contributions

Zehui Zhan, Patrick SW Fong, and Hu Mei conceived and designed the study; Zehui Zhan, Hu Mei, Ting Liang, Zicheng Ma, and Xuhua Chang conduct the content analysis; Zehui Zhan and Hu Mei wrote the paper; Patrick SW Fong contributed to literature review and edited manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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