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Learning Design Decisions in Massive Open Online Courses (MOOC) Applied to Higher Education in Civil-Engineering Topics

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Received: 31 July 2020; Accepted: 6 October 2020; Published: 13 October 2020

Abstract: Sustainable Development Goals (SDGs) reflect the relationship among social, economic, and environmental aspects of society. Massive online open courses (MOOCs) represent an opportunity to promote lifelong learning (SDG 4), complementing university education or providing knowledge to society free and openly. The objective of this work is to analyze experiences in one MOOC about wastewater treatment applied to higher education in civil engineering (SDG 6). The proposed educational methodology and the achieved participation results are studied. The MOOC had three editions and was hosted on the Miríadax platform. Data about sociodemographic characteristics, initial motivation, and satisfaction level were collected from questionnaires. The results highlighted the importance of design decisions to obtain a high completion rate: defining a target audience, without prejudice to the course's open character, where the prior knowledge of students is crucial. The teaching methodology is based on autonomous and progressive learning, with short and direct master classes, social support, with the motivation of students to continue their training with opening complementary topics in the forums, following up on their doubts, and their combination with social networks.

Keywords: experiences of open education; massive open courses; eLearning; civil-engineering education

1. Introduction

Sustainable Development Goals (SDGs) are the result of a new definition of sustainable development where economic, social, and environmental pillars are combined as a nested concept [1]. One of the environmental challenges that must be faced is urban water-resource management [2]. SDG 6 [3] reflects society's global demand for the sustainable use of water for long-term protection. In answering this key question, continuous learning is essential, especially in civil engineering. Such continuing education should not only be in dimensioning infrastructures but should also consider their relationship with the environment and the societies they serve.

SDG 4 is related to education and promotes lifelong learning opportunities for all [4]. The term "lifelong learning" refers to training that is carried out alongside and after academic degrees. Lifelong learning includes all learning activities in the educational path of a person to increase their knowledge and improve their personal, civic, social, and employability skills. The main difference from traditional education is that this type of learning is entirely voluntary and elective. The student chooses specific skills to develop [5].

Massive online open courses (MOOCs) are an innovation in learning in modern education [6], distinguished by being accessible to anyone interested in taking them, free, and without participant limit [7]. This new educational modality facilitates lifelong education in massive, diverse, and open quality learning [8].

However, there are still some problems with MOOCs that affect their expected performance, with completion rate being the leading cause. For most courses, it is below 13%, typically ranging from 2% to 10% [9]. A possible reason for this is the simple organization of MOOC courses in a static mode, teaching all learners in the same way, with a consequent lack of consideration of their different needs and characteristics [9].

Aldowah et al. [10] recently identified 12 factors organized into four categories—personal, circumstantial, relative to the course, and academic factors—on the basis of the literature. The results of their study highlighted six central factors that directly influenced MOOC student dropouts. These were (1) academic skills and abilities, (2) previous experience, (3) course design, (4) feedback, (5) social presence, and (6) social support. Instead, factors related to the difficulty of the course or family/work circumstances play a secondary role concerning the dropout of students in MOOCs.

Regarding the profile of the student enrolled in a MOOC (Factors (1) and (2)), Ruiz-Palmero et al. [11] studied several MOOCs at the University of Málaga (Málaga, Spain) and students' opinions of them. Results revelated that participants were occupied with university studies and that previous experience in MOOCs is relevant to achieving the established targets at the beginning of the MOOC. The students showed a high level of satisfaction with them, which was indicated by the high percentage (99.4%) of those who would enroll in another MOOC, or that 97.9% would recommend it [11].

Concerning the didactic methodologies defined in course design (3), discussion forums and conference videos are the most used pedagogical methods in education for sustainability in MOOCs [12]. Guo et al. [13] studied how video production in MOOCs affects student engagement. Among principal findings were that shorter videos, and videos with the instructor interposed with slides where the teacher speaks with enthusiasm, inviting student participation in forums of discussion make an MOOC more attractive.

Social support (6), feedback (4), and presence in social networks (5) are essential in the successful development of an MOOC [10]. Park et al. [14] reported that a lack of social support, indicated as not encouraging and motivating students to complete the course, and a lack of instructor–student or student–student communication, could cause a high dropout rate of students. Social networks as a learning tool must be well-integrated into MOOCs to open up social communication and interaction in online environments [15]. Jiang et al. [16] indicated that social media could help improve learning and reduce dropout rates in online courses if there is real interaction beyond just promoting the course.

Once the critical factors for the success of an MOOC are defined and analyzed, the main aim of this work is to assess the proposed educational methodology of an MOOC on the basis of these crucial factors. The subject of the studied MOOC is wastewater treatment at a higher-education level in civil engineering and related engineering. The provided training was from integral technical, social, and environmental points of view. In other words, the objective of this study is to evaluate the implementation of an MOOC for the dissemination of knowledge of a technical topic, the proposed educational methodology, and the achieved participation results.

2. MOOC Learning Design

The University of Extremadura considered the implementation of several MOOCs as an ideal tool to complement the training of students and as social-responsibility action that gives back to society part of the knowledge generated within it in a free and open way for personal and career development.

To this end, in 2016, the public call for proposals for the selection and implementation of various MOOCs was published: Pilot Project I for Massive Open Online Courses (MOOC) [17], providing the human and material resources necessary for its realization. Miríadax hosted a total of eleven MOOCs, among which was the MOOC object of this study: "Water management—introduction to the treatment of urban sewage" [18]. The Miríadax platform made available to the participants enrolled in the MOOC all necessary resources, so that students could acquire the key skills of the course at their own pace and

from any location. Through the forums, students could generate debate and share doubts, experiences, and ideas with other participants.

2.1. Objective and Didactic Methodology

The objective of this MOOC was to offer quality up-to-date training with regard to urban wastewater treatment. The provided education was comprehensive, both in infrastructure type and dimensions, and in their relationship with the environment and with the society that the infrastructure serves.

MOOC design is based on three pillars: student autonomy, short and direct methodology, and social support. These aspects are shown in Figure 1, and the more interesting references regarding the literature review appear in Table 1.

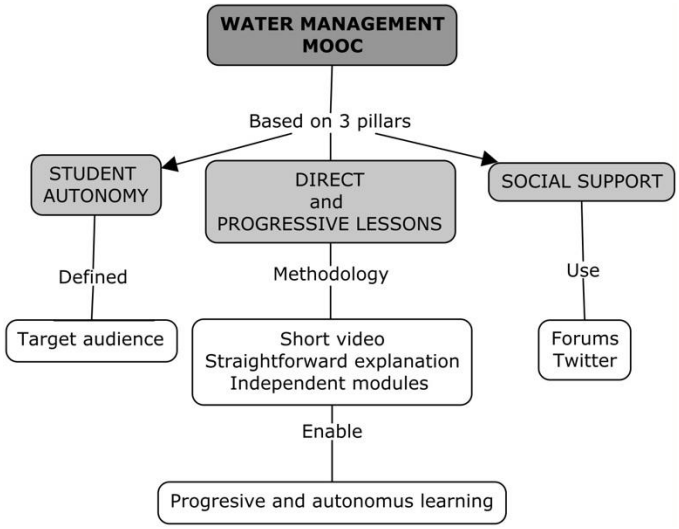


Figure 1. Main pillars of massive online open course (MOOC) design of "Water management—introduction to the treatment of urban sewage".

Table 1. Defined MOOC pillars, related factors, and references.

MOOC Pillars	Factors	Reference
Student autonomy	Academic skills Previous experience	Ruiz-Palomero et al. [11] Kennedy et al. [19] Lee et al. [20]
Direct and progressive lessons	Course design	Guo et al. [13] Callejo et al. [21]
Social support	Feedback Social presence Social support	Park et al. [14] Panigrahi and Srvastava [15] Jiang at al. [16]

1. Student Autonomy: The students' learning is based on prior knowledge and autonomy, where defining the target audience is particularly highlighted. The MOOC was preferentially developed for students or graduates in civil engineering, environmental engineering, or related careers to urban water-cycle management to facilitate its correct understanding in an autonomous manner.
2. Direct and Progressive Lessons: The master class must be short, simple, and straightforward. The structure of the MOOC, consisting of short videos and independent modules, enables autonomous and step-by-step learning in such a way that the acquisition of knowledge is progressive, from the global to the more technical aspects.
3. Social Support: Social support and communication (instructor–student and student–student) were promoted in forums of the online training platform. The forums were a support to add

complementary information, to open topics for discussion, and to share appreciation or resolve issues about MOOC matters.

A key to MOOC success is their dissemination to reach the population to which they are directed. In this case, different routes were adopted to reach as many potential students as possible. First, the Miríadax platform actively disseminated information by announcing courses with a start date close to the date of the website visit. On the part of the university, through the Vice-Rector's Office for Quality, dissemination was carried out both on the website and through majority-use social networks such as Twitter.

The decision to create and manage a Twitter profile related to the course, @MoocUexDepura, propitiated the possibility of pursuing objectives of the massive and open nature of this type of education. Through the course's profile on Twitter, complementary information was disseminated and organizations related to the topic were suggested. There was a weekly reminder to monitor the MOOC with the objective that students would be encouraged to continue with the training and in response to possible technical incidents.

2.2. Sequencing, Resources, and Teaching Materials

The MOOC was organized into five modules; each module was independently structured to make them easy to understand and follow. This MOOC involved 5 hours of work per week by the student and the MOOC duration was 5 weeks. The modules are described below:

- Module I: Introduction to urban water-cycle management. Water Framework Directive. Social and legislative contextualization of urban water-cycle management.
- Module II. Urban wastewater treatment. Description and parameters. Presentation of a conventional wastewater-treatment plant (WWTP).
- Module III. Wastewater-treatment plants. Water lines. Study of water lines, global schemes, and treatments of a WWTP.
- Module IV. Wastewater-treatment plants. Sludge lines. Study of sludge lines, global schemes, and treatments of a WWTP.
- Module V. Nonconventional debugging techniques. Development of unconventional debugging techniques and methods. Advantages and disadvantages.

This structure enables progressive learning from global, environmental, and social aspects in Module I; chemical and technical aspects related to conventional WWTP design (Modules II, II, and IV); and Module V introduced unconventional treatments on the basis of environmental friendliness, such as lagooning or wetland systems. This MOOC highlights sustainability and social responsibility associated with wastewater treatment. Module I introduces and relates wastewater treatment to the SDGs (mainly SDG 6) and the green and circular economy. In this way, the student is provided with sufficient information to understand a WWTP beyond the technical aspects and to develop environmental and social awareness linked to this civil-engineering infrastructure.

Each of the five training modules included a series of learning resources, such as audiovisual materials of their own production, complementary materials (external links to websites, case studies, and a list of bibliographical material and recommended reading), and an evaluation questionnaire.

The duration of the videos was variable, 4–5 minutes on average. Each module was made up of five or six videos, depending on the distribution of the teaching material to be shown.

Evaluation was carried out through test questionnaires published at the end of each of the course modules (the rest of the activities were optional), designed for proper completion. It was essential to have obtained 50% out of 100% in the corresponding module test to pass it. Evaluation was carried out by using automated-type tests made up of questions with a single, numerical-value, or true–false answer. By considering a self-assessment model, the student knows the results at the end of each module.

To obtain the "certificate of participation" in the course, the user must have passed 75% of the modules. To receive the "certificate of achievement", the student must have passed 100% of the compulsory activities and would also have to request their diploma according to the procedure described in Miríadax.

3. Materials and Methods

3.1. Sociodemographic Characteristics of Respondent Participants

The MOOC was published in Miríadax with two initial editions (Table 2) The third edition was the result of a collaboration between Miríadax and the University of Extremadura to offer the possibility of opening the latest editions of the MOOCs. Consequently, it was possible to provide the best academic offer given the circumstances from the COVID-19 pandemic and the mobility restrictions that were generated.

Table 2. MOOC editions, start dates, enrolled students, and completion rate.

Data	First Edition	Second Edition	Third Edition [1]
Start dates	16 October 2017	21 May 2018	22 April 2020
Enrolled students	1508	2331	555
Starting rate	63.66%	39.36%	74.59%
Completion rate	23.93%	36.80%	45.41%
Questionnaires	1520	843	323

[1] third edition during COVID-19 pandemic.

As shown in Table 2, the second edition was the most popular, with 2331 students enrolled, where 39.36% started the MOOC, and 36.80% of the students who had started the course finished it. These rates are higher than those of several indicated studies [9,10] in which the completion rates varied between 2% and 23%. The third edition had fewer students enrolled due to the circumstances from the COVID-19 pandemic, and this edition had scarce resources, especially in terms of dissemination on social networks. The value of the questionnaire is attached to the number of participants that filled out the final questionnaire about the content, teachers, and platform.

Figure 2 shows the percentage of total students by age distribution. Most of the participants were adults, similar to in other studies [10,22,23]. The majority age group was from 25 to 35 years old in the three editions (37.5%, 29.9%, and 38.7%, respectively), which reflects the goal attainment for the previously defined targeted audience in the course design, without prejudice to the original open and massive nature of an MOOC.

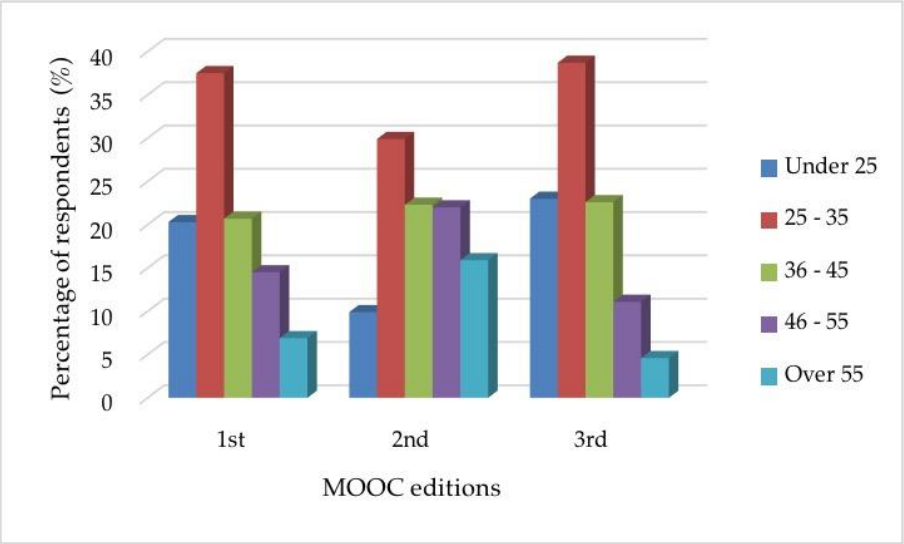


Figure 2. Age distribution in three MOOC editions.

The percentage of men and women was practically identical in the last three editions (Figure 3). As can be seen in Figure 3, the number of men was slightly higher than that of women, with an average rate of 62.2% for men and 37% for women.

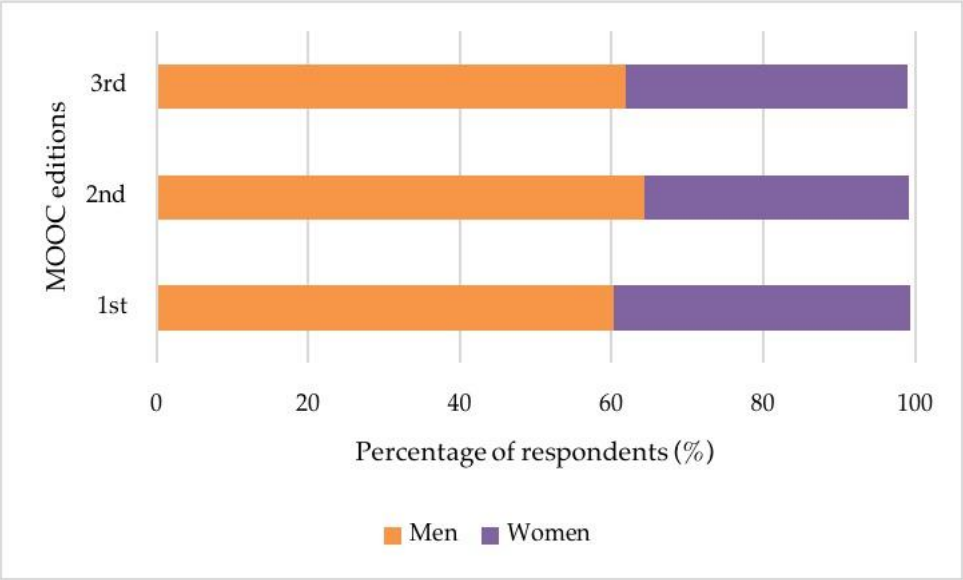


Figure 3. Gender distribution in three MOOC editions.

Regarding the distribution and location of the students, Figure 4 shows that most of the participants came from Spanish-speaking countries; approximately half of the participants came from Spain, with almost 20% of them located in Mexico and Colombia. The remaining 30% were distributed evenly across all Latin American countries. Training is taught entirely in Spanish, which confirmed that language is a key factor [23]. However, there were students from Russia, which indicated that the dissemination of MOOCs can spread knowledge to environments in which students are a priori not expected to train in the Spanish language.

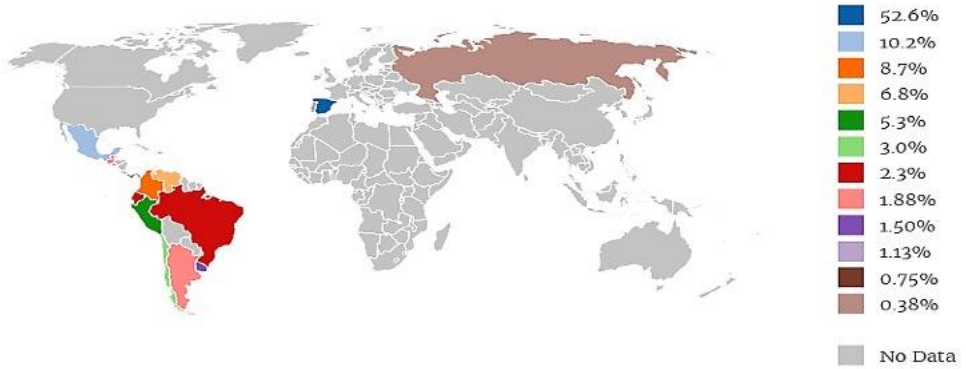


Figure 4. Countries of origin of integrated-water-management MOOC students expressed in student percentage.

3.2. Instruments

Data were collected through two questionnaires by the Miríadax team. One poll was during the beginning of the course, defined as Module 0. This survey asked about sociodemographic characteristics (age, gender, residence country, and study level) and the initial motivation to enroll in the course. The second questionnaire was available at the end of the MOOC, and survey questions were about satisfaction level with the design course and platform, and the possibility of recommending the course to prospective students. Both questionnaires were entirely voluntary. The number of respondents to both polls per edition was equal to 1520, 843, and 323, respectively.

The Miríadax team carried out and controlled the design and management of the qualitative questionnaires for the courses hosted on the platform. The questions were similar to those proposed in similar studies [6–8].

Focusing on social media, the approach adopted in this study was analyzing the descriptive statistics of the MOOC Twitter account and examining the feedback during each MOOC edition. Descriptive statistics are facilitated by the Twitter team and show interactions and impressions of account activity on the social network [24].

4. Results and Discussion

4.1. Previous Interests

Academic skills, abilities, and previous experience are critical factors in the completion rate of a MOOC [9,18]. These crucial aspects are reflected in Table 3, where the highest percentage of students enrolled were graduates in the three editions (i.e., 45.3% in the third edition), following university students (between 20% to 27% in the three editions), similar to percentages obtained by [21]. Regarding the target public, MOOCs were preferential to a student or graduate in careers related to urban water-cycle management.

Table 3. Level of education.

Education Level	First Edition	Second Edition	Third Edition
Secondary education	7.72%	6.67%	8.0%
Undergraduates	23.02%	27.0%	20.4%
Graduates	44.67%	59.4%	45.3%
Postgraduates	24.18%	6.77%	25.0%
Any studies	0.41%	-	1.3%

The influence of previous knowledge about the topic is shown in students having reported prior knowledge about the subject in the course—72.7% on average in the three editions. However, just over half of the participants (57.4%) had done online training before (Table 4).

Table 4. Average percentage concerning total survey respondents in three editions about previous knowledge and online training.

Questions	Yes	No
Have you ever done online training before?	42.6%	57.4%
Do you have previous knowledge on the subject of the course?	72.7%	22.3%

The results in Figure 5 indicate the diversity of reasons or desired uses of MOOCs beyond certification [23]. Close to 30% of surveyed students reported their studies or professional goals as reasons or desired uses for enrolling in this MOOC, similar to the reasons indicated by [25]. However, only 0.95% of participants showed interest in a certificate, in contrast to [21] and [25]. This contradiction can be explained by the seemingly unofficial nature of the certificates issued in most MOOCs [11].

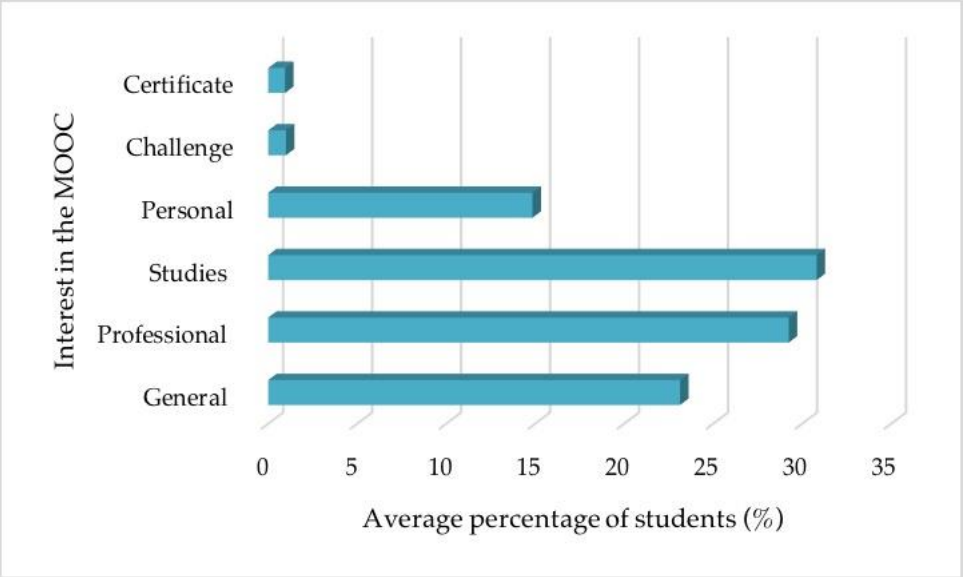
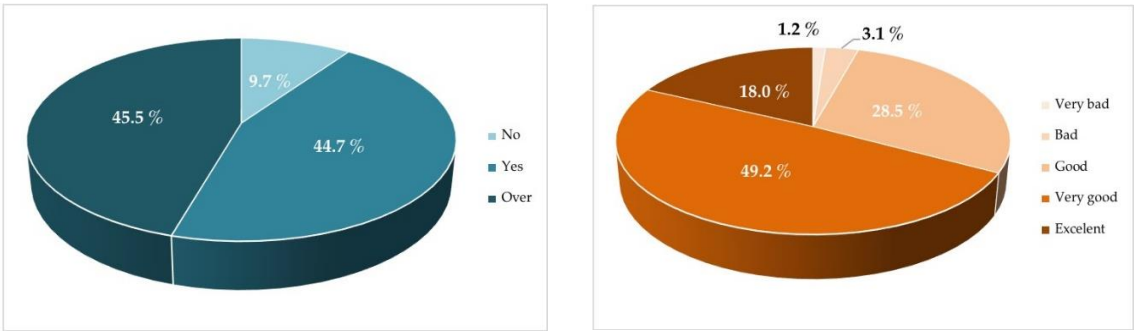


Figure 5. Average percentage concerning total survey respondents in three editions about their reasons for or interest in their enrollment.

4.2. Satisfaction Rates

Focusing on the evaluation of the MOOC, a satisfaction questionnaire was realized at the end of the first edition. In this section, we review the interest and achievements accomplished by the MOOC after its completion and among the students who passed the course.

The surveyed students indicated that their expectations were exceeded (44.7%) and their expectations in the early stages of the course were highly surpassed (45.5%) (Figure 6a). The MOOC's general evaluation was very optimistic when classifying the course within the platform for 67.2% of the students, who assessed it as "very good" or "excellent" (Figure 6b).



(**a**) (**b**)

Figure 6. Percentage concerning total survey respondents in first edition: (**a**) MOOC met student expectations (yes, no, or above expectations); (**b**) general assessment of MOOC on a scale of "very bad", "bad", "good", "very good", or "excellent".

The course design was evaluated, and results are shown in Figure 7.The methodology and resources, referenced in audiovisual and complementary materials, and evaluation mode, were classified by most surveyed students as "very good". However, participation in the forums was predominately defined as "good". This lower valuation could be due to higher demands from the students in the involvement and feedback of the teaching team, in line with results obtained by [11], where students demanded more teaching support.

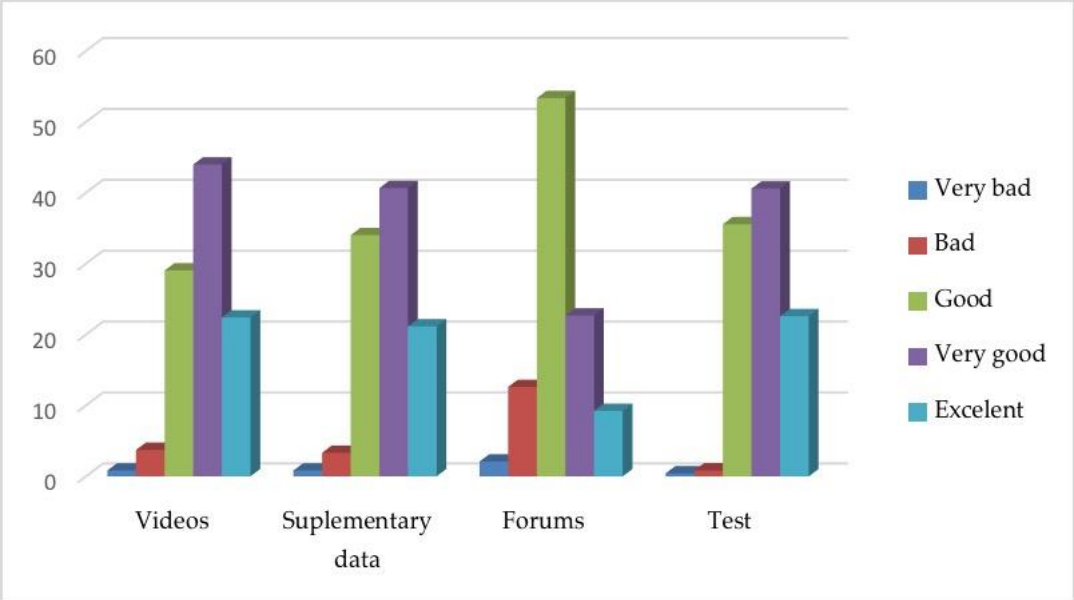


Figure 7. Material and resource assessment by students, expressed in percentage concerning total survey respondents in first edition.

4.3. Social-Media Interactions

As several studies [9,10,18] indicated, and Figure 7 reflects, social factors such as student–teacher relationships, communication, and social support are crucial for the success of an MOOC. In addition to forums on the platform or email notifications, teaching staff of the integrated-water-management MOOC created a Twitter account to publicize the MOOC on social networks and to promote social contact with the students more informally.

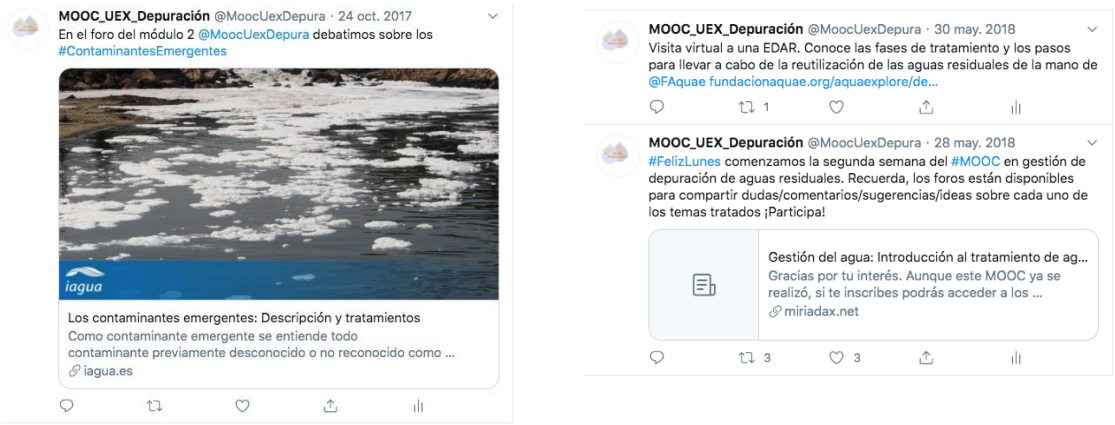
Table 5 shows the statistical results provided by Twitter analytics during the first and second editions of the MOOC, respectively. Impressions were defined as the times that people were sent a

tweet in their timeline or found it in search results; engagements are the total number of times that someone interacted with a tweet (clicks, retweets, replies, etc.). Engagement rate was similar to the number of engagements divided by the number of impressions.

Table 5. Twitter analytics.

Twitter Analytics		First Edition	Second Edition
Total impressions.		9500	8200
Impressions per day.		272	245
Engagement rate.		1.6%	1.5%
Types of tweets.	Promotional.	8	4
	Motivational.	6	6
	Complementary information.	7	9
	Incidents.	-	1

Through the course's profile on Twitter, besides MOOC promotion, 7 own tweets in the first edition and 9 in the second edition suggest that complementary information and topics discussed in the forums were shared. A weekly reminder to motivate students to continue with the training was published in both editions. A series of tweet examples is shown in Figure 8. Figure 8a shows a Module II supplementary-information tweet in the first edition to motivate participation in a forum, and Figure 8b shows motivational tweets from the second edition.



(**a**) (**b**)

Figure 8. Examples of @MooUexDepura tweets: (**a**) supplementary information in first edition and (**b**) motivational tweets in second edition.

In this Twitter profile, the period with the most reliable impressions and engagements rate coincided with the first edition (Table 5), although the second edition had more participants (Table 2). This may be due to the most active period being during the beginning weeks of October, similar to the conclusions of the study by Shen C. [26]. As Jiang and Kotzias indicated in their study [16], merely using Twitter does not necessarily lead to an increase in student–student interactions and that communication by the instructor or MOOC-promoting platforms is dominant. The success of the second edition is justified because the number of participants that had completed the second edition was 857 against the 360 of the first one (Table 2). As the content was similar in two editions, the only difference was information given in social networks to assist students in their training efforts by suggesting complementary information. Consequently, this study showed the incorporation of social networks as a learning strategy that can help reduce the dropout rate, as was highlighted in [27].

5. Conclusions

The nature of MOOC courses represents an inspiring opportunity to promote lifelong learning beyond the established contents of most university degrees. This extension and amplification of education that is free and for everyone who has an Internet connection helps to achieve the purposes of Sustainable Development Goal 4 (quality education) [28]. Opening massive, public, free, and online education is not incompatible with multidisciplinary and technical topics such as a civil-engineering education. Moreover, their symbiosis brings together a new type of student who is interested in the latest advances and developments.

This study illustrates a successful educational experience in the MOOC about wastewater treatment at the higher-education level, with completion rates equal to 23.93%, 36.80%, and 45.41% for the three latest editions, respectively, which were higher than those of several other indicated studies [9,10]. The course topic helps to promote the sustainability of water uses and the social-responsibility perception of the wastewater-purifying process. The reasons for its high acceptance and completion rates were evaluated. The principal obtained conclusions from the work presented in this paper are:

(1) The importance of the establishment of a target audience to whom the course is directed. As other studies indicated [19,20], prior knowledge is crucial to completing a specific MOOC. Without prejudice to its open character, graduate and university students who want professional improvement are the target group.
(2) Students value a course design that promotes autonomous learning combined with social support.
(3) The use of social networks as a learning tool is necessary for this type of education. Total impressions and engagements per day (Table 5) support the relevance of social media in MOOC courses [27].

MOOCs allow for the high-quality dissemination and transmission of knowledge and the overcoming of barriers such as the available time or physical location of their students. The limitations of this study are that the surveys were voluntary (266, 126, and 200 respondents for each edition) and managed by the platform (Miríadax); thus, only those who had completed the study filled them out and there is no information on those who did not answer them. Moreover, in the case of the third edition of this course, circumstances derived from the COVID-19 pandemic could have influenced analysis. Despite these limitations, this study improves the understanding of these types of courses and their application in higher education with technical topics.

Author Contributions: Conceptualization, P.D.-B. and E.G.-L.; methodology, E.G.-L.; formal analysis, E.G.-L.; investigation, E.G.-L.; resources, P.D.-B. and E.G.-L.; data curation, E.G.-L.; writing—original draft preparation, E.G.-L.; writing—review and editing, P.D.-B.; visualization, P.D.-B.; supervision, P.D.-B.; funding acquisition, P.D.-B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors would like to express their acknowledgements to the Vice-Rector's Office for Quality from the University of Extremadura for promoting and supporting Pilot Project I for Massive Open Online Courses (MOOC), and for providing the database; and to the person responsible for this pilot project, Beatriz Rodriguez-Caldera, for her invaluable support in developing and conducting this MOOC project. We would also like to thank the Miríadax platform for hosting and managing the MOOC.

Conflicts of Interest: The authors declare no conflict of interest.

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