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Massive Open Online Courses as a Digital Learning Strategy of Education for Sustainable Development

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ABSTRACT

This article aims to present the results of a case study of the use of Massive Open Online Courses as a digital learning strategy to promote education for sustainable development. The research focuses on the results of four Massive Open Online Courses offered to more than 17,000 participants, a case study research method was carried out to identify the didactic activities recommended to integrate on the Massive Open Online Courses of education for sustainable development. Among the results, it was found that challenge-based learning didactic activities develop participants' skills that can be transferred to real-world scenarios and allow learning to become more profound and durable. The results also show that a better understanding of the network dynamics to explore how to develop a robust peer-learning environment is necessary. Future works are recommended to explore the potentials of big data to anticipate the needs of the participants' digital skills.

KEYWORDS

Education for sustainable development, Energy sustainability, Digital learning strategy, Connectivism, Massive open online courses.

INTRODUCTION

In an interconnected world, characterized by exponential economic growth, globalization, and rising inequalities, sustainable development poses a unique set of challenges. Education systems need to develop innovative approaches to contend with these global issues, from government policies to classroom teaching methods at all levels. It is also required to improve the learning resources with a technology capable of empowering people with the knowledge required to adapt to their changing environments [1].

The Internet is precisely that type of technology: it has not only brought significant social changes, but it has also generated cultural revolutions. Also, it has entered directly into life's processes, as well as multiplied them, generating infinite possibilities of interaction. The Internet of everyday life is the struggle for permanent connectivity, for being present in the world, for apprehending what happens in reality and building reality, becoming the vehicle that stores key information for social life, builds environments and, links objects and people. In fact, for many, daily life is not conceived without the

Internet. Its existence has become part of everyday life activities that promote the individual and collective knowledge construction [2].

Using the Internet on learning environments, the Massive Open Online Courses (MOOC) have framed the openness to share resources, ideas and experiences, communication and the creation of new information in an interconnected world. These strategies contrast with the traditional educational models of closed lectures, private texts, and closed classroom discussions, openness and participation in networks offers a refreshing change of perspective and is essential as a principle of connective learning [3].

Internet is a unique platform for innovation, creativity, economic opportunity and social inclusion, which can make a significant contribution to achieving these core objectives. Also, online education has contributed to new pedagogies and technologies as MOOCs that substitute face to face traditional class [4]. However, it is also concerned with the MOOCs capacity not being sufficiently studied. Better data-gathering and analysis are essential for evidence-based policymaking. More reliable data are required concerning the relationship between the Internet and sustainable development. Additional attention must be paid to study the relationship to ensure potential gains. Without these studies, crucial opportunities to achieve sustainable development goals may be missed [5].

It is also important to consider that with connectivism, the underlying conditions to support learning processes have been altered so significantly that a traditional skill assessment is also no longer feasible [6]). According to Tschofen and Mackness [7], the use of MOOCs as a digital learning resource requires understanding the way knowledge through connected networks is acquired. With this new reality, a completely new research approach may also be needed [8].

Indeed, MOOCs have allowed the design of new training schemes carried out outside the classroom spaces. However, when analyzed in detail, their educational quality is often questioned, since they generally do not integrate standards that allow the evaluation of the results of their teaching-learning processes [9]. In this regard, the Technological Prospective Institute reports that the quality criteria of MOOCs are not very transparent and warns that, for the moment, most models have not proven to be sustainable.

For Sangrà and Wheeler [10], the massification of the courses, which is now sold as something positive, has never been a characteristic of successful training, they believe that in MOOCs, informal learning has found a perfect ally in ICT in general, and in online learning, in particular. Therefore, MOOCs should still be investigated in depth to establish whether they represent real opportunities for learning in informal settings, or if they are attempting to formalize the informal.

According to Downes [11], no standardized measure has yet been established to assess the result or success that can be obtained concerning its design or user expectations. At the moment, the only alternative for MOOC evaluation is to identify what a successful massive course is expected to produce, and emphasizes that these results are a logical consequence of its conception. It is important to understand that without measuring the results, the success of a MOOC cannot be assessed, so improvement efforts cannot be focused [12]. Nor can processes be planned for change, without defining what they want to achieve as a result [13].

This article aims to present the results of a case study of the use of MOOCs as a digital learning strategy to promote education for sustainable development. It will focus the research on the results of the four MOOCs offered to more than 17,000 participants:

- Energy: past, present, and future;
- Mexico's energy reform and opportunities;
- Conventional, clean energy and its technology;
- The new electricity industry in Mexico.

The research activities apply a case study research method to generate relevant information to answer the question: what didactic activities are recommended to integrate on education for sustainable development MOOCs?

SUSTAINABLE DEVELOPMENT AND DIGITAL TECHNOLOGIES

The development, defined as a widely participatory process of social change in a society is intended to bring about both social and material advancement, including greater equality, freedom, and other valued qualities, for the majority of people through their gaining greater control over the environment [14]. Under this perspective, the foundational concept of "sustainable development" has been described as the process that meets the needs of the present without compromising the ability of future generations to meet their own needs [15]. It is a process of progress in the current system that seeks to improve the wellbeing of the people and society [16].

When applied to education, sustainable development cannot be prescriptive, that is, defined by "planetary boundaries" or "social thresholds" as in political resolutions. Education for Sustainable Development (ESD) seeks to enable self-determined participation in the transformation of unsustainable paradigms, policies, and practices. It emphasizes the democratic participation of individuals and local, national, and global citizens in making the changes needed to move towards a sustainable society.

UNESCO also included those emerging sustainable development trends in its four education principles:

- Education as a fundamental human right;
- Education as a public good;
- Education as foundation for the human fulfillment, peace and sustainable development, economic growth, decent work, gender equality, and responsible global citizenship;
- Education as a contributor to reducing inequality and poverty.

For this reason, ESD has remained a continuous challenge to interpret and apply these principles to relevant pedagogy issues at all society levels and has been a focus of international public policy since the Earth Summit in 1992, where three core objectives for human development were identified: economic growth, social inclusion and environmental sustainability [17]. In September 2015, a new approach was settled when the United Nations adopted the Development Agenda based on Sustainable Development Goals. This agenda increased the capabilities and reach of Internet networks. Its impact was felt in all development sectors, through education and innovation programs to secure and preserve the social development and the environment [17].

Digital technologies have the potential to facilitate a long-desired shift from learning as an individualized, passive content acquisition to learning as participation in active knowledge co-creation and communities of practice. The use of digital technology on education processes can provide new opportunities for access to information and the potential of communication networks has substantially transformed the acquisition, storage, and dissemination of knowledge [18]. Those principles, applied to the digital pedagogy, offer orientation in the learning process and fosters sustainability as a "frame of mind", as a basic attitude and awareness of a global interconnectedness [17].

Use of Massive Open Online Courses as a digital learning strategy to promote education for sustainable development

MOOCs have generated important expectations and revolutionized some educational practices by offering educational resources open for consultation, use, and adaptation [19]. In the specialized literature on MOOCs, it can be observed that this phenomenon has received more attention in recent years [20]. Its recent interest is manifested both in

the evolution registered by its conceptual referents, theoretical foundations and characteristics, as in the various definitions coined to describe them.

The emergence of new technology has always been of great interest to researchers, not only because it represents the culmination of years of work, but because it represents the triumph of reason and the practical application of science over material reality. Each technology brings interesting changes in social life. Some technologies have been responsible for major revolutions or have been introduced directly to households transforming family dynamics. Applying technology in existing learning theories raises many relevant questions. That is why the natural vocation of the theorists will push to continue revising them, to develop them as conditions of change [2].

Studies carried out by Siemens [21] explain that connectivism is a theory characterized by considering learning as an extension of knowledge and understanding through a network. According to Zapata-Ros [22], MOOCs establish their epistemological bases in the connectivism and combine open content and teaching compatible with mass participation. That is achieved through the adoption of pedagogy and connectivism. This transformation is now possible, and not just for the advances of educational technology, but by the development of theorists.

Trna and Tronova [23] agree that connectivism is a "theory of learning" that emerges in the digital age as a new pedagogical theory that joins those existing in the Sciences of Education. The field of evidence for this theory has been the MOOC and as its numbers increase at the pace of scalability in communications [24], the interest in knowing how people interact and develop as individual students in these complex, diverse and distributed environments, is growing. The most important contribution lies in the potential of these resources to change the relationship between students and teachers, and between academia and community through the possibility of providing an extensive and diverse virtual environment, a meeting place for ideas.

Likewise, the ESD is not an extension of environmental education and has gained a place as a framework that addresses the required changes in behaviours and values in order to have a sustainable future. Regarding digital technology and sustainability, sustainability, technology, demographics, and globalization should be considered and understood as a whole because they influence each other and study their impact individually will relay an incomplete approach. A comprehensive teaching and learning arrangement should involve content and pedagogical methodology.

In 2015, the UN launched the 17 Sustainable Development Goals (SDGs). Adopted by 193 member states, the goals represent an important international step in setting humanity on a trajectory towards sustainable development. To promote the SDGs, some Universities offers MOOCs to provide a historical overview of how sustainability has been understood, as well as a thorough introduction to the SDGs – what they are, how progress can be measured, and how the SDGs are relevant for the management of the global systems supporting humanity. The courses examine how various societal actors are responding to and implementing the SDGs. However, there are still a few MOOCs offered as a digital learning strategy to promote ESD.

METHOD

Although the MOOCs are an expression of the knowledge society, its development and research, around its possibilities of use to strengthen the quality and equity of education, is a field scarcely explored. Cross [25] reports that MOOC research generates major methodological and interpretative challenges. It warns about the difficulty of properly encoding and analyzing a large amount of information from disparate sources to determine how and in what terms the success of a course is valued. This type of analysis can be complicated in a MOOC context, because the public is massive, and the heterogeneous articulations of the technologies with the pedagogy. For Siemens and

Long [26], MOOCs bring together a surprising variety of quantitative data in the teaching-learning processes, which have been little used.

Furthermore, sustainable development is a multi-dimensional and multimodal concept and proposes economic and social growth within environment respect. It is based on an economic development that promotes financially viable initiatives, efficient in the use of natural resources, improving the quality of life of society, and contributing to diminishing the environmental impacts of productive activities, such as the generation of electric power. ESD learning strategies produces tangible benefits supported by indicators that generate a vast amount of information to encourage the development of productive chains, particularly in the clean energy industry. In a world that generates large amounts of data, the mathematics applied in its analysis can replace some traditional research instruments.

In educational research, the quantitative approach provides an explicit guidance framework for applying metrics for the evaluation of teaching-learning processes [27]. Based on the research question, it was decided to adopt a quantitative approach through a case study. Although there is a debate about the application of the quantitative approach in a case study, Yin [28] argues that case studies can be based entirely on quantitative evidence and do not need to include direct and detailed observations as sources of evidence. Bryman [29] corroborates that not all case studies can be adequately analyzed with qualitative information so that sometimes quantitative research methods are required.

Recognized international organizations state that sustainable development is not only achieved with technological solutions, political measures, and economic resources and that all people must change the way of thinking and acting. It is also necessary to promote ESD at all levels and social contexts. Following this recommendation, the MOOCs of this case study were developed by the Binational Laboratory for the Intelligent Management of Energy Sustainability and Technological Training, an initiative of the Secretariat of Energy, the National Council of Science and Technology, in collaboration between several higher education institutions.

Created in this laboratory, the Openenergy research network promotes the development of thinking skills in sustainable energies through the analysis of problems and the production of collective knowledge, for the solution of energy problems from different areas. It consists of a platform for the generation of technology and knowledge about the energy that seeks to place Mexico at the level of the most advanced countries in the sector by providing training, research, and infrastructure. The Openenergy MOOCs are online courses aimed at a large number of participants through the Internet, according to the principle of open and mass education.

These MOOCs are available on the Mexico X platform and open to the population in general so that anyone interested in energy sustainability issues can benefit from them, with a special interest for the conversion of engineers to the energy sector and the massive development of technical profile specialists. An added value is the use, under the inspiration of new educational trends, of avant-garde technological resources suitable for training in energy sustainability with innovative elements of gamification, virtual and augmented reality, and biometrics.

RESULTS AND DISCUSSION

In Mexico, the wide geographic distribution of renewable energy sources, specifically biomass, hydroelectricity, solar and wind energy, offers new socioeconomic opportunities to geographically isolated communities with high levels of marginalization. To promote the use of these energies, the National Development Plan (PND) raised the need to strengthen the development of science and technology, the transfer and social appropriation of best practices for the use of renewable energies, to supply energy with competitive prices, quality and efficiency throughout the productive chain.

One of the significant problems posed to the scientific community by the PND, questions its ability to reduce, through the renewable energy sources, the levels of inequality and poverty that Mexico faces. This problem constitutes a political and moral challenge for a nation that bases its foundations on social justice since it highlights a contradiction with the level of development achieved. In Mexico, 46.2% of its population lives in conditions of poverty and 10.4% live in extreme poverty, which represents the more than 50% of Mexicans who, day after day, subsist in vicious circles of precarious development where opportunities for progress are scarce.

Although Mexico has demonstrated its commitment to the international environmental agenda and participates in more than 90 agreements and protocols, being a leader in climate change and biodiversity, its socioeconomic development is closely linked to energies that generate solid waste, composed of greenhouse effect, pollutants to the atmosphere, untreated wastewater, and loss of forests. During decades, the exploitation of hydrocarbons in this country has not allowed reducing its levels of inequality and poverty. More than half of the electricity is still generated from natural gas, due to its lower price, but with serious environmental consequences.

Despite the potential and rapid growth in the use of renewable energy, its contribution to the national energy supply is only 2% of the total. Within this context, technologies that use renewable sources will have to face the challenges posed by the PND concerning energy diversification, the primary energy balance, and the sustainable use of natural resources. By this reason, the Ministry of Public Education (SEP) and the Federal Electricity Commission (CFE) analyze projects that promote the use of renewable energy sources.

In recent years, sustainable energy development has been sought to include the environment as one of the elements of competition that contribute to the economic and social development of the population. Hence, there is a clear commitment derived from the Energy Reform: to foresee the gradual increase of the participation of Renewable Energies in the Electricity Industry, to comply with the established goals in terms of clean energy generation and emission reduction. Today these goals are strengthened by the new laws that encourage better planning of the expansion of electricity generation considering the accelerated incorporation of clean energies in the National Electric System, as is the case of the Transition Law Energetic.

Participation profile

The call for mass participation on the four MOOCs was disseminated via Mexico X platform, institutional electronic media and social networks for six weeks. All the MOOCs generated interest, and a total of 17,210 participants enrolled. The majority of participants, 95%, were from Mexico and the 5% remaining were from 37 different countries, most of them from Latin America. Of Mexico's participants, 25% were located in Mexico City and Mexico State, and the remaining 75% were from urban and rural cities located in the other 30 states that integrate the Mexican Republic.

Regarding the participants' profile characteristics, 39.1% were female, and 59.9% male with an average age of 30. The range of age was from 14 years old to 83 years old, and the highest frequency was from 21 to 25 years old. The prerequisites defined to participate were having an undergraduate degree in progress or finished, and basic computer skills. The results' analysis shows that 40% of the participants were in high school, 37.7% undergraduate, 10% master, 8% technician, 4.3% secondary school, 1% Ph.D., and 1% other educational levels. Most of the participants were professionals, teachers, technicians, and students (Figure 1).

The MOOCs were totally free access and open to all public via a computer with an updated browser and an internet connection. All MOOCs were offered in six weeks and 30 study hours were estimated in total, distributed into five weeks that included the

activities for the review of the general information pages, academic instructions and specifications to obtain the certificate. The required academic materials were provided, and additional resources were recommended to be consulted by open links. During the period of the course, all the modules were available 24 hours a day, including virtual reality videos, augmented reality videos, gamification activities, and remote laboratories.

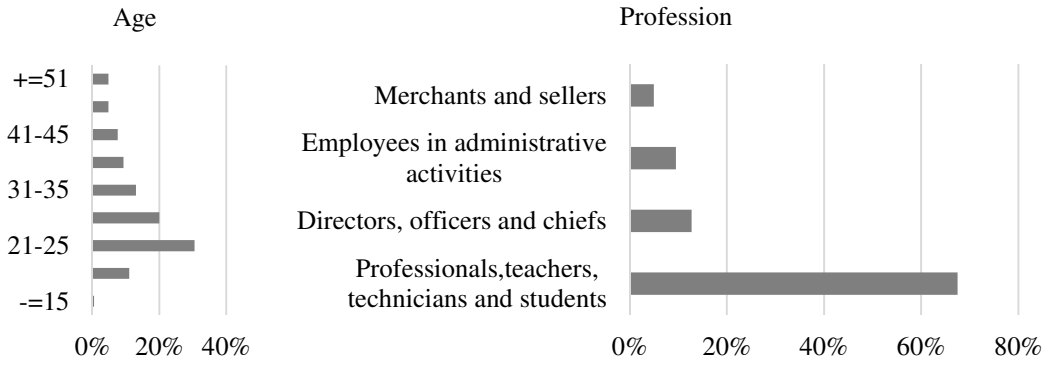

Figure 1. Participation profile

The Massive Open Online Courses instructional design scheme

An instructional design scheme was applied on all the MOOCs, and the offer on energy issues was classified into three types of courses according to the objective pursued:

- Dissemination, general knowledge, to provide general information on energy issues;
- Basic theoretical, to expose basic concepts related to energy issues;
- Basic experimental theory, to approach principles of electrical energy and explore processes for its application.

The content was developed by a team of energy experts of the research group on energy and climate change, professors from the school of engineering and sciences, business school, and expert guests. Professors that integrate the research group at the school of humanities and education innovation graduate students carried out the instructional design of the didactic activities and digital pedagogic resources. The teaching and learning process was performed by a MOOC professor leader of the teaching tutors and the e-learning team.

The specific topics of the MOOCs were defined in conjunction with the Federal Electricity Commission to ensure that they support the capacities required by the electricity sector:

- Conventional & Clean Energies and their Technology (ECLE): describes how energy is produced, transformed, used, and stored, identifying challenges and benefits;
- Energy Past, Present & Future (EPPE): presents a historical and prospective overview of how energy is a factor of change in the development of society;
- The Mexican Energy Reform and its Opportunities (LREE): explains the main changes and opportunities for a new business that facilitate the energy reform in Mexico;
- The New Electricity Industry in Mexico (LNIE): describes the reform to the electricity sector and the new business in generation and commercialization of inputs, electricity, and associated products.

The MOOC with the highest number of enrolled participants was the “Conventional & clean energy and its technology” with 35% of the participants, and the lowest number of enrolled participants was “The new electric industry in México” with the 16%, however, both MOOCs had a completion rate of 17% (Table 1). The average terminal efficiency rate of 16% for all MOOCs was superior to the average reported in studies by the University of Pennsylvania Graduate School of Education [30].

Table 1. MOOCs participation

MOOC	Enrolled	Certificates	Completions
ECLE	6,022	1,031	17%
EPPE	4,224	646	15%
LREE	4,201	648	15%
LNIE	2,763	474	17%
	17,210	2,799	16%

Didactic activities result

Tree types of modules integrated the MOOCs learning path:

- Introductory;
- Six specific topics;
- Conclusion.

Each module offered different digital pedagogic resources and didactic activities integrated by an initial survey, self-diagnostic, exercises, practices, challenges, and exams. The exams were designed to evaluate the knowledge acquired by the participant through the content offered by the digital pedagogic resources. The exercises and practice aimed to evaluate the skills developed to resolve problems through critical inquiry. The challenge activities were designed to improve learning and behaviour around authentic learning experiences that encouraged the participants to leverage the clean energies and technology in their daily lives.

With the 16% completion rate, the "Enrolled" graphic of the learning results (Figure 2a) shows that the average of the 17,210 participants was calculated from 2/100 up to 27/100 points. The learning results of the 2,799 participants "Certificated" that completed all activities were calculated from 15/100 up to 100/100 points (Figure 2b). The analysis of both "Enrolled" and "Certificated" learning results shows that most of the exams activities got similar results. The "T6 Challenge" activity got the highest grades. The challenge-based learning provides the satisfaction that comes from figuring out both the issue to be undertaken and the solution to it, even though it requires more time commitment than more traditional learning activities.

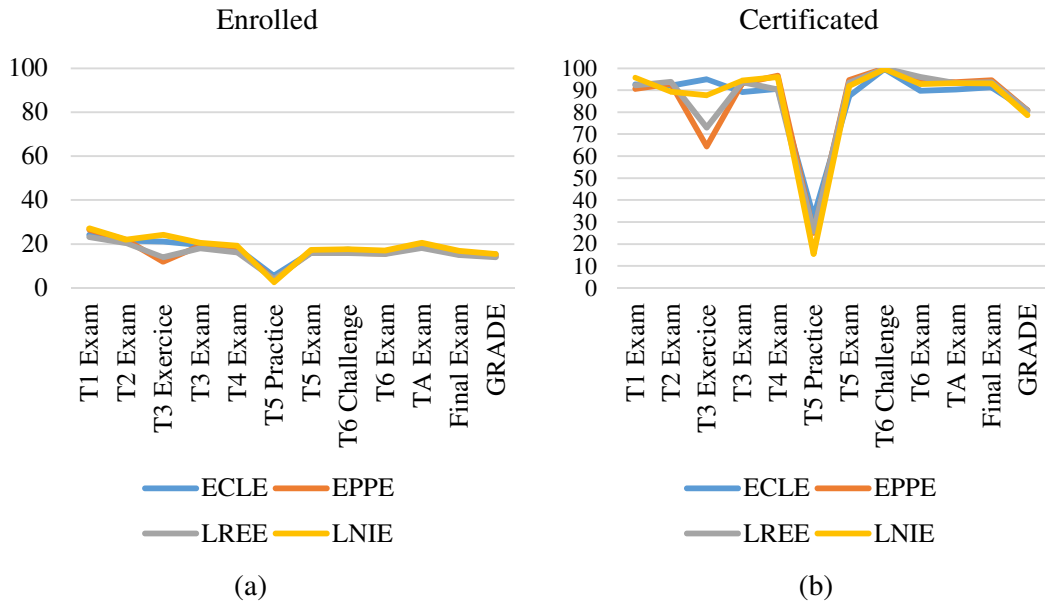

Figure 2. Didactic activities result

The analysis of "Enrolled" and "Certificated" shows the atypical results of the peer grade activity "T5 Practice". In MOOCs, peer grading serves as a critical tool for scaling

the grading of complex, open-ended assignments to courses with tens or hundreds of thousands of students. Despite promising initial trials, it does not always deliver accurate results compared to human experts. Thus, a critical challenge lies in how to obtain accurate grades from peers reliably. In particular, the analysis shows that there is much to be gained by maintaining estimates of grader specific quantities such as bias and reliability.

Forums learning evidence

The discussion forum is a digital resource that facilitates interactions and communications among the participants and instructors, and it also helps to build a learning community. The four MOOCs offered the participants several forums to exchange post about the topics studied to promote sustainable development (Table 2). A total of 7,814 posts were registered by the participants that represent the 34% of the "Enrolled" but the 199% of the "Certificates" for ECLE, 65% of the "Enrolled" but the 427% of the "Certificates" for EPPE, 44% of the "Enrolled" but the 286% of the "Certificates" for LREE and 42% of the "Enrolled" but the 244% of the "Certificates" for LNIE.

Table 2. Post examples in discussion boards

MOOC	Post examples
ECLE	"To measure the capacity of energy production of a power plant, it is not enough just the knowledge of the energy value of the raw materials that are being used, but also, it is necessary to know the performance of the equipment."
	"I agree with you, and I would add if it is profitable or not because if you spend more than what is produced is not sustainable, another point is whether the premium is a single item or several. Regards."
EPPE	"The solution is responsible for consumption and reducing the production of garbage. I work in the collection of solid waste and the amount of garbage that is produced by the consumption of things that are not indispensable to us is incredible."
	"I agree with you and I think that if we wish that in the long or medium term we can take advantage of the waste to generate energy, first we must generate an awareness of the correct separation of waste in the different sectors of the population, thus achieving an optimization of landfills and a risk reduction of emitting toxic gases."
LREE	"The energy reform is a very interesting and delicate issue. We live in an age where electricity consumers require clean energy (there are more renewable energies without counting wind and solar) where international investment from the private sector is also required for innovation and development since our nation does not, you know, and that impulse is required for its demand."
	"I agree, but a lot of national technological investment is missing. However, this issue must be addressed from its root, that is, from universities and companies. For this, there is an initiative that supports the energy industry. It would be worth knowing if this initiative is yielding the expected results."
LNIE	"Mexico has the necessary solar radiation to provide all the energy that our country requires, you should only invest in taking advantage of such a natural resource."
	"Yes, it is possible to supply only with solar energy, but in Mexico, there is not enough infrastructure and economy to manufacturing this type of installation. That is why we take advantage of renewable and clean energy."

Reciprocal interaction is considered as a vitally important part of sharing the cognitive processes at a social level. The posts registered on the four MOOCs forum are also evidence of the learning results that required a critical thinking development about the conventional and clean energy and its technology, the past, present and future of the energy, the Mexican Energy Reform and its opportunities and the new electric industry in México.

CONCLUSIONS

In all nations, universal access to quality education is essential for the building of peace and the sustainable development of societies. However, the debate on the social impact of education for sustainable development has not ended, on the contrary, it is only just the beginning. Its effects are evident in the general aspects of daily life, generating new forms of social contact and, therefore, the social construction of reality into consideration the historical context in which everyday life is structured.

Major digital transformations such as artificial intelligence, machine learning, internet of things, and big data analytics generate a change in skills requirements and, in turn, impact capacity building and skills development for the 21st century digital economy. As the use of technology advances in educational processes, an understanding of the elements and principles of connectivism will be put to the test, and educational research works will provide evidence on the capacity of networks. By providing relevant information, it will be possible to evaluate the learning potential they possess to strengthen didactic activities. Undertaking this goal requires methods for making large scale grading systems more dependable, accurate, and efficient.

Within this context, the MOOCs have created a gap in the curricular rigidity, because they question the ability of traditional didactics to respond to training needs in changing scenarios, to observe that a formative path is massively selected, in which the didactic is so different from that used in what is now considered a traditional face-to-face class. It promotes a critical reflection on how the learners perceive these resources. This strategy also leads to a paradigm shift by educational agents in teaching processes.

The case study analysis of the Openenergy MOOCs offers relevant information about the activities that are recommended to integrate into the MOOCs of education for sustainable development. While providing access to learning for large numbers of learners, MOOCs have become instrumental in the transformation to more technologically enhanced learning. Among the results, the challenge-based learning didactic activities develop participants' skills that can be transferred to real-world scenarios and allow learning to become more profound and durable.

This case study provides evidence that MOOCs are becoming important factors in achieving the Sustainable Development Goal 4: Quality Education (SDG4). However, quality and financial viability are key considerations for making online learning programs successful and sustainable. The results also show that a better understanding of the network dynamics to explore how to develop a robust peer-learning environment is necessary [31]. The future of MOOCs as a digital learning strategy represents a significant opportunity for meeting the Education of Sustainable Development goal. However, they also present serious digital pedagogy and instructional design challenges.

Future work

It is a reality for the educational community that MOOCs imply a change in the instructive schemes, both in their pedagogical design and with the learning expectations of the students. If initially the structure of MOOCs was presented in a minimalist way, in order to allow participants to design their learning process, new models are currently appearing in this type of massive learning recourses.

Future works are recommended to explore the potentials of the big data to anticipate the needs for digital skills that the participants need to fully integrate the experimental theory, analyze participants based on some economic index, explain the reasons of the completion rate, information about the knowledge transfer and flow in the network. These will improve the pedagogic quality of the MOOCs that will be developed to promote the Education of Sustainable Development.

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