

Incidence of digital competences in the completion rates of e-Learning training. Case study on Energy Sustainability MOOCs

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Abstract—Contribution: This article analyzes the correlation between users' digital competencies and their tendencies to successfully complete energy sustainability MOOCs (massive online open courses). In addition to reviewing whether digital competencies are a predictor of the effective completion of the course, this article analyzes whether participants acquire higher levels of digital competence through interaction in the course.

Background: Completion rates of MOOCs typically range between 5% and 8%, with respect to registered participants. According to the literature, low rates may be due to factors such as students' lack of motivation or digital competence limitations.

Research Questions: RQ1: Is there a correlation between the level of digital competence declared by the participants and their tendency to successfully complete the MOOC? RQ2: Does participation in a MOOC improve participants' digital competencies?

Methodology: Two surveys, one pre-test and one post-test (before and after the MOOCs), were applied to assess the digital competence levels of the participants. The total population of participants in the 12 MOOCs was 123,124 unique users, from which 9,075 participants (pre-test)—7.37% of the universe—and 6,029 (post-test)—35.70% of the universe—were extracted as a sample. To determine its internal consistency, exploratory factorial analysis was performed on both instruments, and a Cronbach's alpha greater than 0.8 was obtained in all its dimensions.

Findings: A significant level of moderate to high correlation between the declared levels of digital competence and the trend toward successful completion of the MOOCs under study was observed. However, a significant increase was not demonstrated in the levels of digital competence acquired in the interaction with MOOCs.

Conclusions: The level of digital competence of a participant in a MOOC was a valid predictor of their tendency to finish it. Although no increase in the levels of digital competence acquired through MOOCs was demonstrated, this may be because the subject matter of the MOOCs was alien to the indicators and dimensions of digital competence. Further research could analyze the effectiveness of MOOCs in terms of digital competition at the acquired levels of competition.

Index Terms—e-Learning, MOOC, completion rates, online education, digital competences, sustainability, technology-enhanced learning.

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I. INTRODUCTION

MOOCs (massive online open courses) have been a critical revulsive in the educational field and democratized access to knowledge and training content because of their characteristics of gratuity, ubiquity, and heterogeneity. MOOCs also demonstrate wide possibilities for innovations in instructional models, architectures of knowledge management, and MOOCs' life-long learning approach, which leads to understanding them as a new pedagogical paradigm [1] [2].

In a broad sense, MOOCs are organized with a pedagogical logic—by subjects, modules, or subject—offered to the public through specialized web platforms (i.e., Udacity, Edx, Coursera, Khan Academy) or proprietary interfaces. The main characteristics of MOOCs are free access to the content—although some MOOCs charge a fee for certificates—its ubiquity of access, the heterogeneity of its contents and income profiles, and its life-long learning approach [2] [3]; thus, MOOCs should be analyzed as a learning tool that improves or amplifies knowledge on a subject and not as a substitute for formal education [4].

MOOCs have been criticized by the scientific-academic community, especially because of their low completion rates. On average, the range of the completion rates of MOOCs is between 5% and 8% with respect to registered participants [5], which has served as a basis for various researchers to assume a failure of this educational model, given the low level of commitment of the students analyzed through dropout [6] [7] [8]. However, as aforementioned, MOOCs should not be analyzed with the same parameters as formal education because these are more heterogeneous learning tools—in target audience and content—that attempt to improve or broaden knowledge on a topic.

Notably, scientific literature agreed to a greater extent on the primary reasons for desertion of MOOCs, namely, courses are monotonous and boring because they preserve the traditional paradigm of a teacher-student-class dynamic at a different level than expected, interest was in only part of the course, demotivation, or limitations of digital competence [9] [10]. Regarding the first causes, literature recommended the use of

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innovative teaching strategies that promote interaction, commitment, and, in summary, engagement [1] [2] [11] [12] [13] [30]. Notably, MOOCs, by nature, address multiple target audiences and ergo an enormous variety of needs; thus, prior intentionality and expectation of value must be considered. Second, dropout rates can reflect a “zapping” behavior, in which students only select content that interests them most or about which they are most curious [14].

In relation to the incidence of digital competences in the completion rates of MOOCs, researchers determined that the level of digital competence is a predictor of enrollment in MOOCs, especially in relation to interaction skills rather than informational skills [1] [15]. However, no evidence in the literature on the impact of these competencies on the individual trend toward successful completion of MOOCs—and ultimately on completion rates—was observed. In this sense, this study attempted to analyze whether there is a correlation between digital competencies and the completion rate of 12 MOOCs in energy sustainability taught by the Tecnológico de Monterrey (Mexico) to more than 123,000 participating students.

II. DIGITAL COMPETENCES

Digital competences range from the capacities or abilities of users to process, relate, search, and express information to those of thinking in a more fragmented, visual, interactive, and fast manner [16]. In this sense, this multidimensional vision conjugates the consciousness and attitudes of individuals to use tools and digital sources (ICT) to recognize, access, manage, evaluate, analyze, and synthesize digital resources for the construction of knowledge, the creation of contents, communication with others, and critical capacity in virtual contexts, succeeding in establishing collective social actions [17] [18] [19].

However, unlike other educational competencies (e.g., literacy, logic-mathematics, music), the need for digital competencies advance at a much faster pace than formal educational efforts. The vertiginous changes in the digital ecosystem, which in less than two decades transformed from simple access to static websites and non-interactive multimedia content (Web 1.0) to the most current interactive social networks, blogs, videoblogs, and online courses (Web 2.0) and immersion in virtual and augmented reality, MOOCs, and wearables (Web 3.0) [20], have meant to a certain extent that subjects (users) learn about these new platforms in a self-taught manner, which means on the one hand a natural adaptation to human-computer behavior and, in some manner, to self-efficacy in uses and gratifications but on the other hand to deploy inequities in the development of this type of skill, which has been called the digital divide [21].

Although the concept of the digital divide was initially more focused on the impossibility of access to digital media infrastructures, such as computers and the internet [22], with the expansion of mobile signal coverage (i.e., GSM, 2G, 3G, 4G, and 5G) and the gradual reduction in prices of devices such as smartphones, tablets, phablets, and laptops, the concept evolved beyond its initial idea. Today, while it is no less true that digital infrastructures do not reach everyone equally, especially in certain regions of third-world countries because of

fundamentally economic gaps, the digital divide remains present in terms of society, age, and knowledge gaps [23] [24] [25]. Moreover, it must be understood that digital competition is not static, because as ICT changes develop, so do the skills required to interact with them. In this sense, whoever exhibited digital competencies at the turn of the century does not necessarily exhibit the same level of digital competence today.

According to the Digital Competence Framework 2.0 of the European Commission (2019) [26], digital competences can be summarized in five specific areas:

- Information and data literacy: To articulate information needs, to locate and retrieve digital data, information, and content. To judge the relevance of the source and its content. To store, manage, and organize digital data, information, and content.
- Communication and collaboration: To interact, communicate, and collaborate through digital technologies while being aware of cultural and generational diversity. To participate in society through public and private digital services and participatory citizenship. To manage one’s digital identity and reputation.
- Digital content creation: To create and edit digital content to improve and integrate information and content into a body of knowledge while understanding how copyrights and licenses are to be applied. To know how to provide understandable instructions for a computer system.
- Safety: To protect devices, content, personal data, and privacy in digital environments. To protect physical and psychological health and to be aware of digital technologies for social well-being and social inclusion. To be aware of the environmental impact of digital technologies and their use.
- Problem-solving: To identify needs and problems and to resolve conceptual problems and problem situations in digital environments. To use digital tools to innovate processes and products. To keep up-to-date with the digital evolution.

Based on this integrative effort, an understanding exists that digital competencies go beyond the ability to access, interact, communicate, create, and solve problems related to digital content to include individual attitudes and aptitudes toward that content.

In this sense, for this study, the five areas of Digital Competence Framework 2.0 of the European Commission (2019) [26] was used as an epistemological framework to assess the level of digital competence of the participants in MOOCs. However and notably, as a result of an *ex post facto* expert judgment, the “Safety” competition did not achieve a sufficient level of agreement to be incorporated (Cohen’s kappa [k] ≤ 0.5) in the questionnaires reviewed in subsection IV-b.

III. APPLICATION CONTEXT: ENERGY SUSTAINABILITY MOOCs

Tecnológico de Monterrey, together with the National Commission for Science and Technology of Mexico (CONACYT) and the Ministry of Energy (SENER), created in 2015, a strategic initiative to develop proposals for sustainable

energy development in a national market that depended primarily on hydrocarbons and coal. The project “Binational Laboratory for the Intelligent Management of Energy Sustainability and Technological Training” (<https://energiatlab.tec.mx/>) was created within the framework of this initiative, in which several sectors of society participate, from academia, government, companies, and communities.

One of the sections of this project was related to training in energy sustainability, through MOOCs, with content that ranged in scope from the most general information on energy conservation to more complex topics such as smart grids. These 12 MOOCs were offered to all Spanish-speaking stakeholders, from January 16, 2017, to September 21, 2018, through the MexicoX platform (<http://www.mexicox.gob.mx/>) and MOOCs edX platform (<https://www.edx.org/school/tecnologico-de-monterrey>).

In total, 123,124 participants enrolled in these 12 MOOCs, of which 16,887 successfully completed the courses, an overall completion rate of 13.715% (Table I), well above the 5%–8% average explained by Osuna-Acedo, Marta-Lazo, and Frau-Meigs [5].

These courses followed the traditional instructional design of the xMOOCs; for example, the content was predesigned in a structured form (table of contents), start and end dates were set for each module, and evaluations were based on multiple selection tests and coevaluation exercises [2] [27] [28].

TABLE I
ENERGY MOOCs SUBJECT OF STUDY

MOOC	<i>n</i> (e)	<i>n</i> (f)	<i>C_R</i>
Energy conservation	12929	2019	15.616%
Distribution of electrical energy	5549	639	11.515%
Smart Grid: Electrical networks of the future	6608	821	12.424%
Smart Grid: Technical fundamentals	5498	743	13.514%
Electric power transmission	5961	1074	18.017%
Conventional, clean energy and its technology	18693	2770	14.818%
Electric power: Concepts and principles	15978	1807	11.309%
Energy: Past, present, and future	13224	2106	15.925%
Carbon markets	6710	910	13.561%
Energy markets	10255	846	8.249%
The new electricity industry in Mexico	8975	1224	13.637%
Energy reform and its opportunities	12744	1928	15.128%
TOTAL	123124	16887	13.715%

n (e) = Number of enrollments / *n* (f) = Number of finished / *C_R* = Completion Rates.

Notably, although the courses were open to Spanish-speaking participants from a country, 94.5% of the universe of participants were from Mexico. In this sense, according to data from the National Survey on the Availability and Use of Information Technologies in Households (ENDUTIH), conducted by the National Institute of Statistics and Geography of Mexico (INEGI), in that North American country, there are 71.3 million internet users representing 63.9% of the population over six years of age. Of these, 50.8% were women, and 49.2% were men.

According to the results of the same survey, the group with the highest proportion of internet users was men aged between 18 and 34 years, with 85% use, and the group with the lowest

use was women aged over 55 years. Likewise, the main activities of Mexican users on the internet were search for information (96.9%), entertainment (91.4%), communication and messaging (90.0%), access to audiovisual content (78.1%) and access to social networks (76.6%).

Mexico demonstrates a digital and knowledge gap. Research on the digital skills of the Mexican population have been scarce [29].

IV. RESEARCH METHODOLOGY

The aim of this study was to analyze whether there was a correlation between levels of digital competencies and the individual trend of successful completion of 12 MOOCs on energy sustainability delivered by Tecnológico de Monterrey (Mexico) (Table I) on the MexicoX and edX platforms. For this purpose, a method with an exploratory–correlational scope and quantitative design was used that considered a pre-test (administered to the participants before the MOOC) and a post-test, administered only to participants who completed the course. However, these tests were neither binding nor obligatory because of data protection and privacy regulations and were completed by 9,075 participants (pre-test)—7.37% of the universe—and 6,029 (post-test)—35.70% of the universe. These data allowed a confidence value equal to 95% and a margin of error of +/- 5% for the analysis of the data, understanding that the execution sample (*M_E*) participated randomly. Regarding gender, 5,814 participants were men, and 2,923 were women.

A. Quantitative Research and Sample

Exploratory factorial analysis (EFA) was first carried out to generate the theoretical constructs. These constructs measure, from 1 to 4 (4 being the maximum), the degree of agreement with a series of statements. The dimensions of the first survey (pre-test) were conclusive, and the items yielded significant loads on one of the four proposed variables. The data from EFA were explained variance = 66.83%, KMO = 0.930, and Bartlett's sphericity test: [$X^2(190) = 63854.763, p < 0.001$]. Cronbach's alphas were all good, above 0.84 (Table II).

TABLE II
RESULTS OF PRE-TEST EXPLORATORY FACTORIAL ANALYSIS

	<i>M&EV</i>	<i>DC</i>	<i>PK</i>	<i>II</i>
Eigen Value	2.048	8.164	1.677	1.477
% Explained Variance	10.24%	40.82%	8.38%	7.39%
Cronbach's Alpha	0.861	0.890	0.847	0.872

M&EV = Motivations and Expectancy Value / *DC* = Digital Competence / *PK* = Previous Knowledge / *II* = Intention of Interaction

EFA of the post-test survey dimensions was more problematic, but given the intention to compare constructs equivalent to those used in the first survey, and given that Cronbach's alpha also yielded high values, four constructs were created: course evaluation (Cronbach's alpha: 0.842); acquired digital competencies (Cronbach's alpha: 0.847); acquired knowledge (Cronbach's alpha: 0.882); and peer interaction (Cronbach's alpha: 0.871).

Based on the definitions of the variables, the research questions are as follows: RQ1: Is there a correlation between

the level of digital competence declared by the participants and their tendency to successfully complete the MOOC? RQ2: Does participation in a MOOC improve participants' digital competencies? Based on this context, the following hypotheses are proposed:

Null hypothesis-1 (H0): There is no correlation between the level of digital competence of MOOC participants and their tendency to successfully complete the MOOC.

Alternate hypothesis-1 (HA): There is a correlation between the level of digital competence of MOOC participants and their tendency to successfully complete the MOOC.

Null hypothesis-1 (H0): Participation in MOOCs does not improve participants' digital competencies.

Alternate hypothesis-1 (HA): Participation in MOOCs improves participants' digital competencies.

B. Instruments

For this study, two survey type tests were carried out and validated, which were sent to the participants prior to their participation (pre-test) and followed by the completion of the last activity of the study (post-test) [31]. In addition to the general sociodemographic data (age, gender, city, country, socioeconomic level, and educational level), both questionnaires included four questions on a 4-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). In the case of the pre-test (DC_{PT}), the statements the participants were asked to respond to were as follows:

- 1) I believe I have the necessary competencies to use digital tools such as Web browsers, e-mail, and Office tools.
- 2) I believe I have the necessary competencies to study this course through a technological platform.
- 3) I believe I have the necessary competencies to obtain relevant information on the topics of this course.
- 4) I believe I have the necessary competencies to use social networks for academic purposes.

In the case of the post-test (DC_{POST}), the statements the participants were asked to respond to were as follows:

- 1) I think this course allowed me to improve the digital competencies I already had (e.g., web browsers, e-mail, Office tools).
- 2) I believe that this course allowed me to develop the necessary competencies to use the technological platform properly.
- 3) I believe that this course allowed me to develop the necessary competencies to obtain relevant information on the topics studied.
- 4) I believe that this course allowed me to develop the necessary competencies to use social networks for academic purposes.

These questions were formulated in line with the Digital Competence Framework 2.0 (DCF 2.0) dimensions and indicators of digital competences of the European Commission (2019) [26], referenced *ut supra*. Notably, the "Security" dimension of DFC 2.0 was not included in the questionnaire because it obtained a Cohen kappa (k) of less than 0.5 interjudge coincidences in the expert judgment stage and was not considered related to the objectives of this research.

TABLE II
STUDY DESCRIPTIVE STATISTICS

	N items	Gender	N	Mean	SD	SEMmean
DC _{PT}	4	Male	5814	3.6632	.40897	.00536
		Female	2923	3.6046	.42889	.00793

DC _{POST}	4	Male	3899	3.4540	.48430	.00776
		Female	1874	3.4224	.47061	.01087

DC_{PT}= Digital Competence pre-test / DC_{POST}= Digital Competence post-test

V. RESULTS

The statistical analysis was performed with the IBM SPSS® program; thus, the descriptive statistics were expressed in frequencies and percentages.

Before starting with the analysis of the data according to the objectives, we must emphasize that age was a significant element regarding initial digital competencies (Fig. 1) [r(8384) = 0.032, p < 0.01]. These data are in accordance with the results of the INEGI ENDUTIH of Mexico, considering that more than 94% of the participants in the MOOCs were from this country.

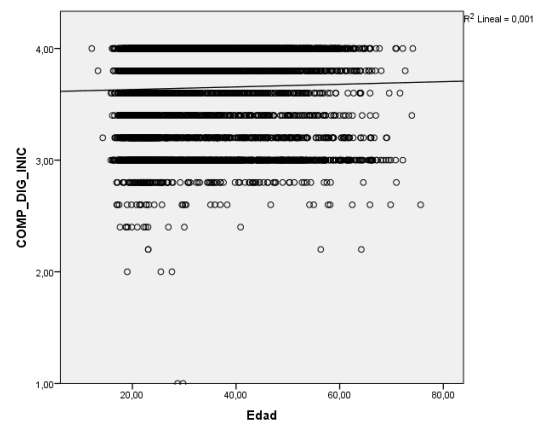


Fig. 1. Relation between age and digital competence

As evidenced by meridians in Fig. 1, users aged between 20 and 50 years demonstrate the greatest initial digital competences (DC_{PT}) (4 on the Likert scale), even though the lower extremes of competence (1) at approximately 30 years of age were not significant. The average line is at an ascent-low perpendicularity, with the bulk of the responses between 3.6 and 3.7 (Average = 3.65). This finding shows that the majority of participants who sign up for MOOCs demonstrate medium-high initial digital competence (DC_{PT}). This situation reaffirms that initial digital competence is a predictor for enrollment in MOOCs, especially in terms of interaction skills rather than informational skills [1] [15].

A. Correlation between the level of digital competence and the effective completion rate of MOOCs

In line with the main objective of this study and responding to RQ1, the correlation between digital competence (DCPT) and the individual trend of successful completion of the MOOC was significant, between positive and moderate [r(5615) = 0.358, p < 0.001]. Gender was a significant factor in both variables because men exhibited higher values in both initial digital competencies [(M_{masc} = 3.66; DT_{masc} = 0.41), (M_{fem} = 3.60; DT_{fem} = 0.43), t(5614.338) = 6.120, p < 0.001], such as in the finals [(M_{masc} = 3.45; DT_{fem} = 0.48), (M_{fem} = 3.42; DT_{fem} = 0.47) t(3792.807) = 2.363, p < 0.05], and the age was only in the initials (Fig. 1) [r(8384) = 0.032, p < 0.01]. In this sense, notably, the initial DCPTs were also determinants in the final

assessment because of the significant, positive, and moderate correlation [$r(5711) = 0.345, p < 0.001$].

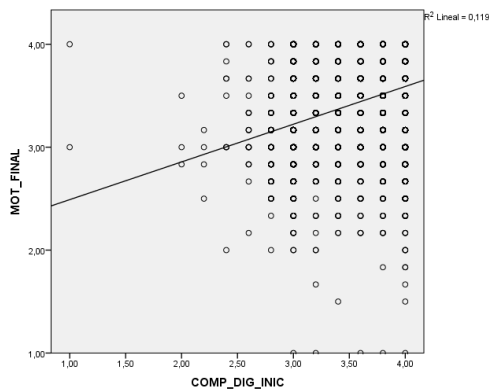


Fig. 2. Correlation between digital competence and completion rates

In Fig. 2, the higher the level of declared digital competence, the greater the number of outflows; thus, in line with H_A , there is a correlation between the level of digital competence of MOOC participants and the completion rates, almost in a directly proportional relationship [$r(5615) = 0.358, p < 0.001$]. In this sense, the higher the level of digital competence of the participant, the greater the tendency to complete the course.

However and notably, in Fig. 2, participants whose initial digital competence levels (DC_{PT}) were low are observed (Fig. 1), which is not reflected in Fig. 2, with the understanding that they did not complete the courses satisfactorily. This finding also supports the idea that a participant's level of digital competence is an effective predictor of his or her tendency to complete a MOOC.

B. Digital competence obtained through MOOCs

Related to the DC_{POST} and considering the $RQ2$, there was no improvement in the levels of digital competence of users, which reaffirms *Null hypothesis-1 (H0)*: participation in MOOCs does not improve the digital skills of participants.

In Fig. 3, most participants (marked in darker circles) assert themselves at the same levels of competence as those with whom they entered the MOOC. In this sense, notably, those

who completed the DC_{POST} were only those who successfully completed the MOOCs.

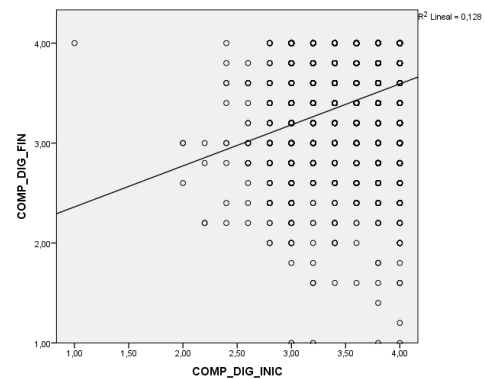


Fig. 3. Levels of digital competence acquired by MOOCs

VI. DISCUSSION AND CONCLUSION

Digital competences should not be analyzed from a static perspective because the continuous and rapid changes in ICT result in the need to understand and interact with emerging technologies both necessary and urgent. In this sense and as aforementioned previously, what is understood today as digital competence may have a radically different meaning in a couple of years.

This study analyzed digital competence as a necessary skill for participation in MOOCs, starting from the fact that from theoretical approaches, digital competence limitations [9] [10] were one of the most frequent causes for abandonment of these courses. This is how $RQ1$ arises: Is there a correlation between the level of digital competence declared by the participants and their tendency to successfully complete the MOOC?

In response to $RQ1$, a significant level of positive to moderate correlation was confirmed [$r(5615) = 0.358, p < 0.001$], highlighting that the initial digital competencies (DC_{PT}) were also a determinant in the final assessment because there was a significant, positive, and moderate correlation [$r(5711) = 0.345, p < 0.001$] (Fig. 2). In this line, an assertion could be that the level of digital competence is a key predictor for approval or desertion in MOOCs.

Second, also consistent with the object of study, $RQ2$ was proposed: Does participation in a MOOC improve the digital competences of the participants?

In response to $RQ2$, most of the participants who responded to the DC_{POST} survey reaffirmed the same levels of digital competence as in the DC_{PT} ; thus, a conclusion that there was no improvement in the levels of digital competence exists. In this regard, the MOOCs under study were related to energy issues (e.g., energy conservation, energy markets, smart grids, energy distribution) and not computer aspects. In this line, because the MOOCs were not related to improving levels of digital competence (information and data literacy, communication and collaboration, digital content creation, safety, and problem solving), the idea that the levels of digital competence would not increase is foreseeable.

This idea opens a line of prospective research because an analysis of the evolution of the levels of digital competence of

the participants in MOOCs related to IT and digital competence is necessary.

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