MOOCs on the Context of Software Engineering Teaching and Training: Trends and Challenges

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***Abstract*—This Research Full Paper presents an analysis of the challenges and advantages on applying MOOCs in software engineering teaching and training contexts. Software engineering is a constantly evolving discipline in which educators are involved with a constant flow of new tools, resources and techniques in software development. This scenario makes the act of teaching and contributing to the students' academic education more complex. The insertion of educational technologies brings contributions in this context, causing a transformation in the current scenario of teaching. An example of these new technologies are the MOOCs (Massive Open Online Courses) - open and online courses that are available in providers in partnership with reputable universities. Considering this scenario, this paper aims at identifying the challenges and trends of MOOCs application in software engineering domain, by means of a systematic mapping of the literature (SML). During the SML it was performed an analysis of 5100 papers and selection of 96 primary studies. The outcomes indicate that there is a potential in using MOOCs on teaching or training, as they are an alternative to offer courses applying traditional methods of learning. In addition, the challenges of this direction are analyzed and discussed.**

***Index Terms*—Software Engineering; MOOC; Massive Open Online Courses; Teaching, Training**

I. Introduction

Software engineering can be defined as a systematic and disciplined approach to software development. It is related to all aspects of software production, starting from the initial stages of the system specification to its maintenance phase [35, 46]. In addition, the *Software Engineering education Knowledge* (SEEK) [44] says that students should be able to work as a team, understanding the process of determining customers' needs and translating them into software requirements and reconcile the conflicting goals, finding acceptable solutions within the constraints of cost and time.

In recent years, different software engineering educational strategies have been implemented. Innovations such as flipped classroom, personal software process (PSP), simulated development environments (games), open source tools and projects, programming marathons and community projects have emerged [18]. Moreover, studies that insert practical activities in teaching have been proposed [12, 32, 43].

MOOCs (Massive open Online Courses) are open and online courses available in providers such as *Coursera* and *edX* in partnership with universities that can be used in teaching [1, 20, 28, 41]. In recent years MOOCs have gained high popularity in several prestigious universities, achieving recognition among educational researchers, instructors and students [15, 36].

It is evident the success of providers such as *Coursera*, in which the demand for courses and the growth of the number of participants are increasing [4]. Most of these courses are free and open, which are means of knowledge updating and enrichment of the curriculum. They are also flexible, which gives the opportunity to participants to study at their own pace and time [25, 38, 48].

In order to monitor technological advancement, software engineering education should be evolved enough to meet new challenges and develop better practices [49]. Software engineering educators should be upgraded to the emergence of new tools, resources and techniques (MOOCs, *flipped classroom* etc.), as well as new technologies in software development. In addition, software engineering is a discipline that requires part of its syllabus to be practical [13], which requires a balance between practical and theory.

The goal of this paper is to provide an analysis of trends and challenges of applying MOOCs by instructors who intend to adopt or integrate this approach on their software engineering classes. These trends and challenges were identified after conducting a systematic mapping of the literature, which are means of evaluating and interpreting all relevant research available for an issue or research topic [11].

This mapping followed the protocol proposed by Kitchenham and Charters[22], which is divided into three groups of activities: planning, conducting and publishing the results. The systematic mapping was carried out considering papers in several areas, not just Computing and Software Engineering. This decision was taken because, initially, no published studies in this area were found.

After the application of the qualities criteria, the primary studies were grouped in 4 different points of view: students, industry/private sector, instructors/teachers and HEI's. The results indicate the trends and challenges in the application of MOOCs in several areas. Finally, these results were analyzed from the point of view of teaching and training in software engineering.

The remainder of this paper is organized as follows.

Section II presents the background of massive open online courses. The research method that was used in the systematic mapping is described in Section III. The results obtained from the systematic mapping study are presented in Section IV. Section V contains a discussion on how the identified challenges and advantages can be applied in the of software engineering domain. Finally, we present conclusions for this research in Section VI.

II. Background

A massive open online course (MOOC) is a model that provides open online learning content and is capable of achieving massive amounts of students [1, 28]. The acronym MOOC was conceived in 2008 by Dave Cormier and Bryan Alexander to refer to the course "*Connectivism and Knowledge*", created by George Siemens and Stephen Downes [17].

The course was offered to students enrolled at the University of Manitoba. However, it was open to anyone who intended to participate, aiming to demonstrate the power of connections and networks of collaboration among the participants [37].

MOOCs are usually composed of video lessons, assignments and forums [30, 41]. The video lessons have several presentation types, usually with the length between 5 and 10 minutes. The evaluation assignments are proposed in the form of self-assessment questions (quizzes) of multiple choice or peer evaluation, in which the students themselves evaluate each other [5].

The forums are the means by which students post questions and answer to other students. They are also considered as the main method of interaction and communication between course participants and instructors. MOOCs are courses that are available on digital platforms. By designing them, the instructors and designers structure their courses in a massive, open and online environment [20, 41]:

- Massive: indicates that the course is designed to support the participation of many students, in the order of hundreds of thousands. An advantage in having a large number of participants is the opportunity to establish collaborative networks. The term 'massive' can have another interpretation related to the amount of knowledge that is generated and exchanged among the participants [33].
- Open: it can be interpreted in two different ways. First, it refers to the fact that these courses are offered free of charge. The second interpretation is that the term 'open' relates to the free access to the course; it is allowed the inscription of any person [8, 33].
- On-line: it refers to the technology that allows the operation of a MOOC. The learning activities, the availability of the content and the interactions among the participants occur in a virtual environment, which would be impossible without the support of the Internet and the latest technologies.

III. Methods

Systematic Literature Mappings (SLM) are ways of evaluating and interpreting all relevant research for a research question or topic [21]. They aim is to present a fair evaluation of the research theme using a reliable and rigorous methodology [6, 22, 34]. This study followed the protocol proposed by Kitchenham [22], which is divided into three groups of activities: planning, conducting and reporting. These activities are described in the following subsections.

A. Planning

The mapping protocol was defined in the planning stage. For this purpose, the following activities were performed: (i) defining the objectives; (ii) defining the search string; (iii) defining the research questions.

The first step of the planning consisted in establishing the objectives. There were identified the need and the reasons for performing the SLM. Several works are found in the literature that use MOOCs in several areas, such as Medicine and Engineering. However, few studies deal with the use of this model in Software Engineering.

Through this mapping, the advantages and challenges of the application of MOOCs in different areas of knowledge were investigated. Thus, the main objective of this mapping is to characterize the application of MOOCs by Higher Education Institutions (HEI's) through the analysis of scientific publications. From the definition of the objectives, the following research questions were formulated:

- Q1: How MOOCs are being used by Higher Education Institutions?
- Q2: What benefits and challenges can be identified by using MOOCs by Higher Education Institutions?

The planning of the search for publications was divided into two parts: the definitions of the string and the search sources. The first part is used to perform research on electronic databases. For its formulation, the keywords and their synonyms, alternative terms, abbreviations and alternative spelling and plurals were identified. Table I shows the keywords and their synonyms.

TABLE I
Keywords and Synonyms

Keywords	**Synonyms**
MOOC	Massively Open Online Course Massively Open Online Courses Massive Open Online Course Massive Open Online Courses MOOCs

For this systematic mapping it was designed a generic search string due to the few existing studies describing software engineering MOOC applications. The search string, composed of the keywords concatenated by logical operators, is defined as follows:

- (“MOOC” OR “Massively Open Online Course” OR “Massively Open Online Courses” OR “Massive Open Online Course” OR “Massive Open Online Courses” OR “MOOC” OR “MOOCs”)

The definition of the sources databases consisted in the choice of the digital libraries/electronic databases in which the research papers were searched, which are listed in Table II.

TABLE II
DIGITAL LIBRARIES / ELECTRONIC DATABASES

Database	URL
ACM Digital Library	http://portal.acm.org
IEEE Digital Library	http://ieeexplore.ieee.org
ISI Web of Science	http://www.isiknowledge.com
Science@Direct	http://www.sciencedirect.com
Scopus	http://www.scopus.com

The publications were analyzed according to the inclusion and exclusion criteria. In this way, only publications that describe or discuss the application of MOOCs by HEI’s were selected. The exclusion criteria were the following: publications that did not satisfy any inclusion criteria, publications not written in English language and duplicated studies.

B. Conducting Stage

In conducting stage, primary studies were identified and evaluated according to the selection and evaluation criteria that had been defined in the previous stage. The first step was the execution of the search, applying the search string in the previously established electronic databases. After the execution of the search, 5100 scientific publications were returned.

Subsequently to the search and identification of primary studies, it was performed the pre-selection stage, which consisted in the reading of the title, summary and keywords to evaluate whether the study was relevant or not in answering the research questions. During this stage, the duplicate publications have been excluded.

At the end, 456 primary studies were pre-selected, read and then, the defined filtering criteria were applied. Finally, 96 primary studies were selected. The results of the selection process are detailed in Table III.

After the identification and selection of the primary studies, the data was extracted and synthesized. The result of the synthesis as well as the answers of the research questions are presented in the next section.

IV. RESULTS

The results of the systematic mapping are presented in this section. The Figure 1 shows a ratio between the distribution of the identified primary studies and selected ones by digital database. Most of the studies identified and selected were from the Scopus digital base, which is justified by the higher indexing of publications. It is also noted that this is not a homogeneous distribution.

TABLE III
SELECTED PRIMARY STUDIES

Eletronic Database	Identified Studies	Preselected Studies	Selected Studies
ACM Digital Library	438	36	2
IEEE Digital Library	732	83	27
ISI Web of Science	1295	90	25
Science@Direct	782	9	3
Scopus	1853	238	39
Total	**5100**	**456**	**96**

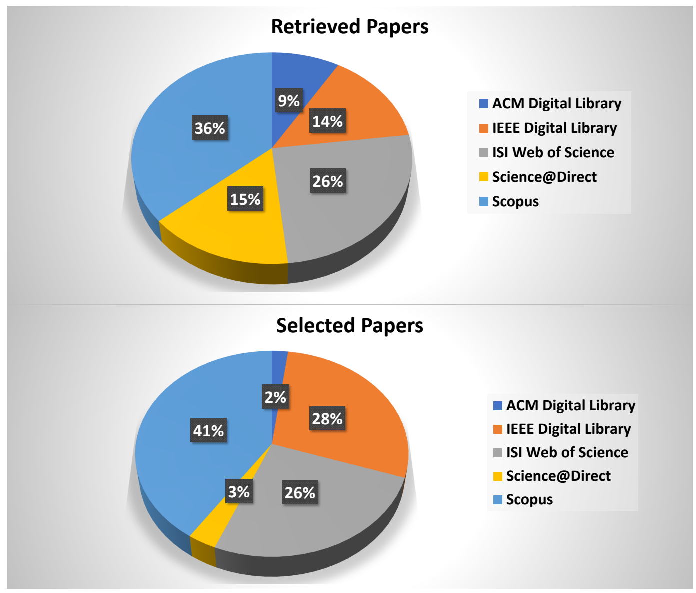

Fig. 1. Representativeness of the digital libraries

The answers to the research questions were based on reading, data extraction and analysis of the 96 primary studies selected after the application of the filtering criteria. The first research question was answered from the perspective of MOOCs knowledge areas. This investigation can be divided into two different ways: the application of MOOCs in general knowledge areas and in Computing subareas. As illustrated in the Figure 2, there is a variety of areas that apply or discuss MOOCs, with emphasis on Engineering, Computing and Medicine.

The second part is related to the specific areas of Computing. In Figure 3, the subareas in which MOOCs are applied are presented. In this mapping, most of the found studies was about programming – these are studies that exploit MOOCs in the teaching of programming languages. There were also found studies in Artificial Intelligence and Database, however in small numbers. In Software Engineering, few studies that apply MOOCs have been identified.

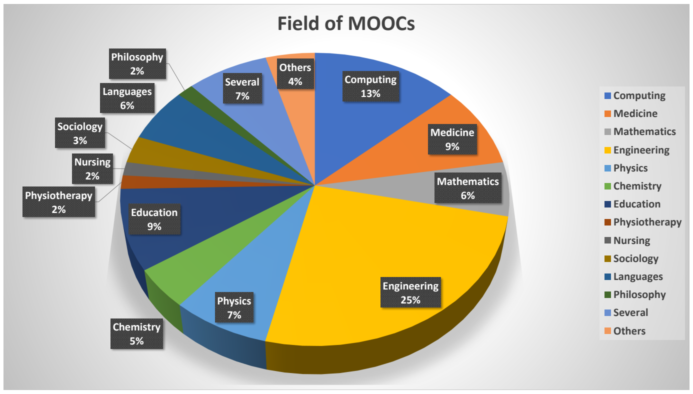

Fig. 2. Representativeness of the field of MOOCs

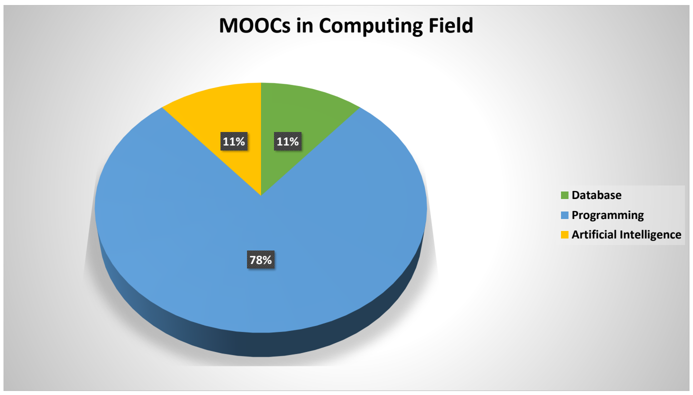

Fig. 3. Representativeness of the field of Computing MOOCs

After the analysis of the areas in which the MOOCs have been used, the examination of how they are being applied was carried out. The main applications involve the adoption of new teaching methodologies, such as distance or semi-presence in undergraduate courses. These and the other applications are illustrated in the Figure 4 and presented below:

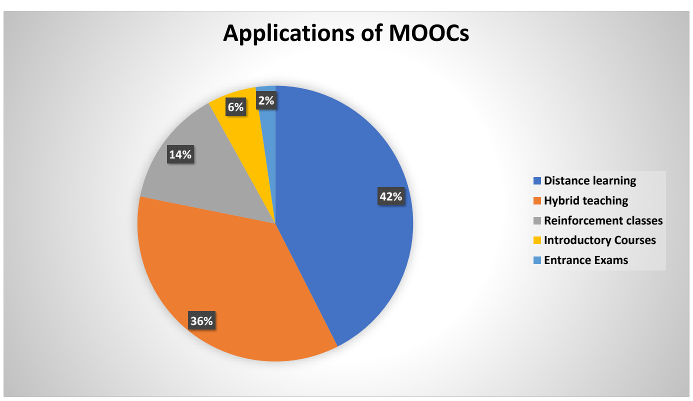

Fig. 4. Applications of MOOCs

- Distance learning: MOOCs are applied in lieu of classroom teaching, i.e. undergraduate disciplines are offered through this course modality. However, there is a great controversy surrounding the credits issue of these disciplines: issues such as plagiarism and authenticity of the proposed assignments are obstacles to the recognition of these credits.
- Hybrid teaching: In this teaching methodology, the MOOCs are accounted for part of the hourly workload of undergraduate disciplines. Thus, extra-class activities can be accomplished through participation in MOOCs. They can also be applied in conjunction with pedagogical models such as flipped classroom.
- Reinforcement classes: MOOCs are used as a complement to traditional classes. In this application, they serve as support for undergraduate disciplines, so that students can reinforce concepts seen in the classroom or even learn new concepts.
- Introductory Courses: MOOCs can be used as an introductory course of some discipline in which there are required (or desirable) prerequisites.
- Entrance Exams: this is a less common application for the employment of MOOCs, as an entrance exam in universities.

The second research question was answered after the identification of the advantages and challenges of the application of MOOCs. These pros and cons were grouped according to the stakeholders: students, instructors (or teachers), industry (or private sector) and Higher Educational Institutions (HEI's). However, some of the advantages can be classified into more than one group. For example, the high approval rating is a benefit for everyone involved: students, instructors, HEI's and, if applicable, industry. In this scenario, the paper was accounted in all groups.

The first results were grouped from the point of view of the students. MOOCs are supported by the connectivism theory, therefore the interaction among the students is considered so important and advantageous. The autonomy and exploitation of resources are also highlighted during the course. The advantages from students' perspective are summarized in the Figure 5.

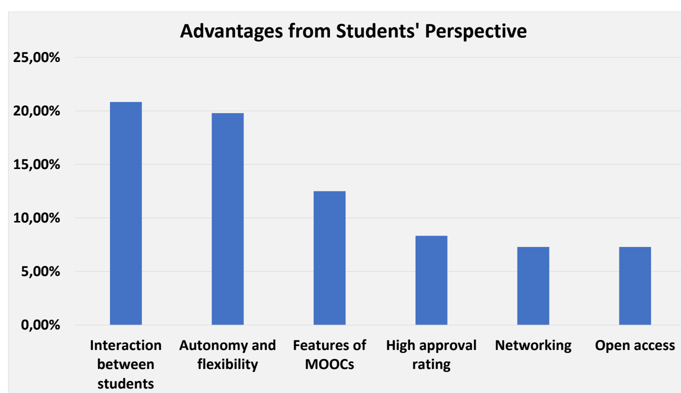

Fig. 5. MOOC advantages from students' perspective

The interaction between students is the main advantage pointed out from students' perspective [2, 23, 53]. The knowledge is generated through the exchange of information between participants from different backgrounds. The interaction also allows the creation of collaboration networks between students within and, subsequently, outside the MOOC environment [3, 53].

In addition, participants have autonomy and flexibility; they can perform the MOOC at their own pace and time, but must comply the deadlines imposed by the instructors [10, 26, 39]. They also have the independence to be able to discard the content they are familiar with, completing the course in a shorter time.

The features of the MOOCs, such as videos, quizzes and forums are explored by students and instructors, assisting in the generation of knowledge [10, 53]. Besides, the open access allows any interested individual to perform the enrollment on MOOC, that usually achieves a high approval rating. After the end of the MOOC, reports and satisfaction surveys point to a high rate of approval of students [9, 29, 31].

During the MOOC development process, it is possible to establish partnerships between HEI's and private sector. The incentive to the private sector participation is important in the fundraising by means of sponsorships, contributing to the coverage of the MOOCs costs. The advantages of the private sector point of view are shown in Figure 6.

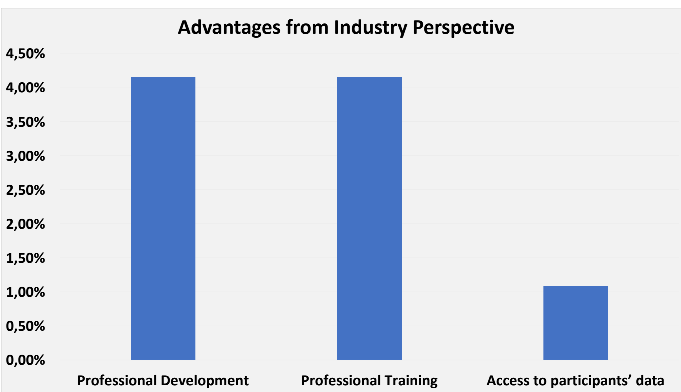

Fig. 6. MOOC advantages from Industry perspective

The first advantage from Industry perspective is related to professional development. MOOCs are alternatives in areas where professional updating or continuing education is required [42]. Also, they can be used in professional training; industry can employ MOOCs in replacement or complement of traditional training [42]. The companies have access to participants' data, which can be used in recruitment process. The MOOCs' participants are prospective potential employees.

Teachers, who also perform the role of instructors and vice versa, can apply MOOCs in substitution or complement to traditional methods of teaching. These and the other advantages are shown in Figure 7.

MOOCs can be used in support of pedagogical models such as flipped classroom and blended learning [9, 29, 40, 47]. With this application, there is a bigger participation and support from the instructor. Thus, major student-instructor interactions are established in addition to the constant feedback to students.

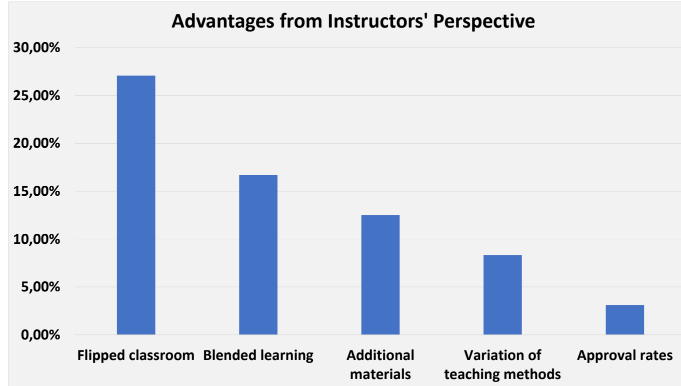

Fig. 7. MOOC advantages from instructors' perspective

Another advantage is their use as an additional material for traditional courses, assisting the teacher in complying the course syllabus and making possible a variation of traditional methods of teaching [39, 51]. The adoption of MOOCs corresponds to an alternative in the application of strategies to diversify traditional learning, instigating the interest of the student.

Using MOOCs can provide an increase in the approval rates of the courses. There are reports describing how MOOCs can contribute to the improvement of the performance of students in course disciplines that are traditionally considered difficult.

Finally, the advantages from the perspective of Higher Education Institutions are illustrated in the Figure 8 and presented below. These are benefits not only for HEI's themselves, but also to society.

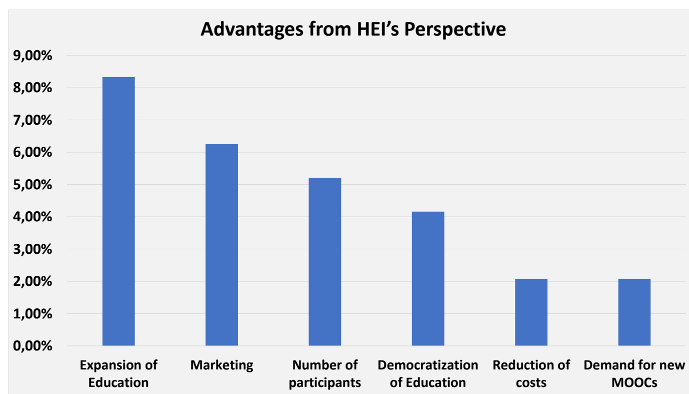

Fig. 8. MOOC advantages from HEI's perspective

The expansion of Education can be performed by using MOOCs. HEI's can apply these courses as a set of strategies to expand knowledge beyond its borders. In addition, MOOCs can serve as indirect marketing strategies [51]. Generally, MOOCs are massive, which implies a large number of subscribers, increasing the visibility of HEI's and attracting new students to undergraduate and graduate courses.

The HEI's' financial aspect also benefits by the reducing of costs [3]. With the adoption of non-face classes, there may be a cost reduction in universities. On the other hand, the openness of MOOCs allows the inscription of students from various regions and social classes, contributing to the democratization of Education [19]. Finally, there is a demand for new MOOCs. Their high approval ratings serve as an incentive for the creation of new ones.

The presentation of the results of the challenges in the application of MOOCs follows the same previous structure, i.e., the mapped data were grouped in the same four groups. However, no challenges were identified from the point of view of the private sector/industry.

The challenges discovered from the students' point of view range from technical problems to personal issues, such as motivation and dedication to a MOOC. In Figure 9 these challenges are illustrated.

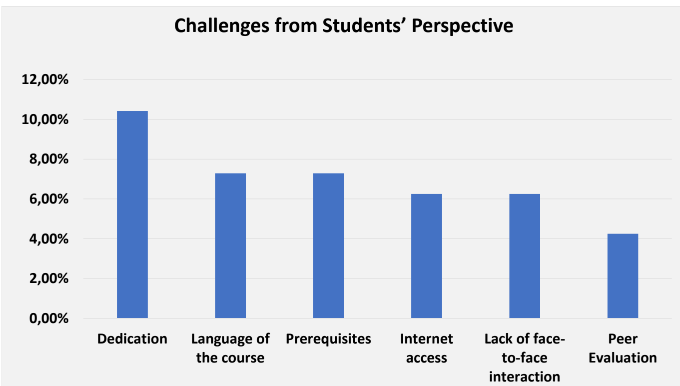

Fig. 9. MOOC challenges from students' perspective

The success of the MOOC depends on the commitment and dedication of the participants. Students should present proactivity and motivation throughout the course [31]. However, the language of the course can be an impediment. Usually, MOOCs are offered in the English language, which requires fluency from the participants [45].

There are cases that students enroll for a MOOC without the necessary prerequisites [9, 39]. The open and often free features of MOOCs instigate the inscription of many students. Nonetheless, in some situations students do not have the prior necessary knowledge for the participation in the MOOC. MOOCs are offered in online environments, then Internet access is necessary.

On the other hand, enrolled students may face some difficulties accessing the Internet [39]. The online feature also implies a lack of a face-to-face interaction between the participants and hampers the evaluation process [53]. An adopted evaluation strategy is peer-review, in which students evaluate each other. However, it may cause some difficulties, such as the lack of preparation of the evaluator or multiple interpretations [24].

In Figure 10, the challenges of the MOOC instructors' point of view are shown. The difficulties of monitoring the activities and evaluating are pointed out as the biggest challenges when applying this modality of course. The development process is costly, requiring time and effort of the instructors in preparing the course material. The other challenges are discussed below.

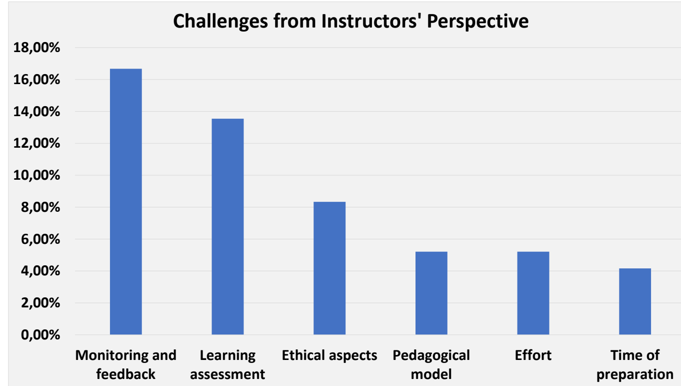

Fig. 10. MOOC challenges from instructors' perspective

Instructors face difficulties on monitoring or giving feedback to the participants, due to the large number of students [40]. Also, there is complexity in evaluating many participants [50, 53], which is usually done by means of automated evaluation (e.g. quizzes). The application of a pedagogical model (or lack of pedagogical rigor) in the teaching of many people at the same time is pointed out as a great challenge [45].

The online characteristic of the MOOCs hinders the investigation of cases of plagiarism and fraud in the execution of activities and evaluations [2]. In this sense, methods of authenticity have been investigated. The preparation of a MOOC demands an effort and preparation time. An effort is needed in its production and management [45]. Meanwhile, a considerable amount of time is spent in the planning, preparation and execution.

Considering the HEI's, the main challenges are the drop rate and the production cost. Nearly 4% of subscribers complete a MOOC, while its production requires human and financial resources. The other challenges are illustrated in Figure 11 and discussed below.

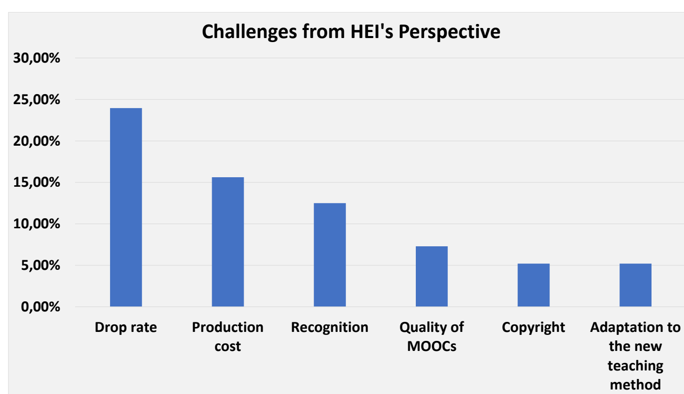

Fig. 11. MOOC challenges from HEI's perspective

The main challenge is to find means of decreasing the drop rate [7, 26, 51]. The number of students who completes a MOOC is very low. Another challenge is the recognition of the application of MOOCs [26]. There is a discussion about how these courses should be integrated in the curriculum of the HEI's courses. It involves issues such as the definition of the number of credits and even if them can be used as credits in regular courses [45]. The adoption is complex because it depends on legal formalities.

MOOCs have a relatively high development cost, especially in the production of videos [16, 27, 45]. Besides, HEI's should be concerned with the quality of their MOOCs, because their reputation may be damaged. Another concern involves issues such as the license on which MOOC is offered [14, 45]. In addition, it is essential to reflect about some questions: can the available material be modified? Who owns the copyrights of the MOOC, developers or HEI's?

Finally, it is necessary perform an adaptation to new teaching methods. HEI's should be prepared to include new educational resources in their programs, such as MOOCs. It is a process that requires adaptation, effort and time.

V. Discussion

In this section the results presented in the previous section are analyzed and discussed from the perspective of software engineering education and training. A wide variety of advantages and challenges have been identified in different perspectives, as summarized in Table IV.

Among the advantages of the students' point of view is the interaction between students, in which participants can exchange experiences from academia and industry. The autonomy and flexibility provide participants to discard familiar software engineering content, completing the course in a shorter time.

The features of MOOCs can be explored aiming the teaching and evaluation of the learned concepts during the course. The networking is important in all areas, including software engineering. Students can exchange information about the job market or academic life. In addition, open access allows any person interested to learn software engineering to subscribe on a MOOC.

The software industry can benefit from using MOOCs. It is important to note that Software Engineering is an area in continuous evolution; the emergence of new methods and tools is constant. MOOCs can be applied as professional updating and training, thus there is a contribution to the cost reduction with training. Besides, the data collected from the participants can be used in recruitment processes, what opens another perspective to have benefits from MOOCs.

Teachers can use MOOCs on software engineering classes in conjunction with pedagogical models such as flipped classroom and blended learning. In those models there is a constant participation of the teacher in learning process. In this sense, MOOCs provide means of student-instructor interaction that assist the teacher in this process.

There is still the possibility of increasing the teaching activities with the addition of extra materials. Software tools can also be integrated into these activities in the development of hands-on assignments.

TABLE IV
Summary of results: MOOCs advantages and challenges

Perspective	**Advantages**	**Challenges**
Students	Interaction between students	Dedication of the participants
	Autonomy and flexibility	Language of the MOOC
	Features of MOOCs	Students without necessary prerequisites
	High approval rating	Internet access
	Networking	Lack of face-to-face interaction
	Open access	The difficulty in peer evaluation
Industry	Professional development	No challenges were identified
	Professional training	
	Access to participants' data	
Instructors	Applicationin conjunction with flipped classroom	The difficulty of monitoring or giving feedback to the participants
	Application in conjunction with blended learning	Limited methods of learning assessment
	Additional materials	Ethical aspects
	Variation of traditional methods of teaching	The application of a pedagogical model
	Increasing the approval rates in the courses	Effort spent
		Preparation time of the MOOC
HEI's	Expansion of Education	Drop rate
	Marketing for HEI's	Production cost
	Large number of participants	Recognition of the application of MOOC
	Democratization of Education	Quality of MOOCs
	Reduction of costs	Copyright
	Demand for new MOOCs	The adaptation to the new teaching method

Higher Educational Institutions (HEI's) have an important social role in the democratization of education. In this sense, the teaching of software engineering can be offered to the external community by means of the MOOCs. In addition, it may be a mean of marketing and dissemination of their software engineering and Computing courses.

Just as in other areas, it is essential the dedication, proactivity and motivation from the participants during software engineering MOOCs. Due to the large number of participants, instructors can find difficulties in monitoring, giving feedback and evaluating participants. The time, cost and effort in preparing the MOOC are also challenges in the preparation of software engineering courses.

VI. Conclusions

In this paper the results of a systematic mapping of literature (SML) on the application of MOOCs are shown. More recently, MOOCs have gained popularization between higher education institutions and the population. According to the SML results, MOOCs have been used for diverse purposes, such as professional updating, training and applied in conjunction with teaching methodologies (flipped classroom, blended learning).

The use of MOOCs has been successful in most diverse areas, but there are still few resources exploited in software engineering. There were not found primary studies describing applications of MOOCs in the software engineering field.

However, the advantages presented in Table IV and the consequent success of MOOCs application in other areas such as Medicine, Physics and Computing (programming, mostly), makes us believe that there is a potential to transpose this tendency towards the domain of software engineering.

On the other hand, there are some obstacles to overcome that can also be barriers on MOOCs in the field of software engineering, such as high evasion rates and little interaction between instructors and students.

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