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MOOCS AS A PROMOTER OF GENDER DIVERSITY IN STEM?

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***Abstract**: A very high number of learners take part in Massive Open Online Courses (MOOCs) anywhere and at any time. Some researchers give a broad overview about typical learners in MOOCs, but many questions about social, cultural and ethical dimensions of eLearning are not answered yet. Notwithstanding the above, there are a lot of worldwide initiatives for supporting girls and women in Science, Technology, Engineering and Mathematics (STEM). Nevertheless in some countries, especially in Western Europe, we are still far away from gender parity in STEM. In line with these two aspects this paper focuses on 100.000 learners from more than 190 countries (data collected since 2012 and enhanced with survey data) who take part in MOOCs on computer sciences offered by the online learning platform "openHPI". Our primary interest concerns to the following research questions from a sociological point of view: Who takes part in STEM-MOOCs (selectivity)? Which factors influence the successful participation of men and women in STEM-MOOCs and under which conditions are MOOCs able to promote gender diversity in STEM (e. g. second-chance education and re-entry into the labor market)? The aim of this paper is to raise the potential of MOOCs to educate underrepresented groups in specific fields like women in STEM by analyzing the learning behavior of different kinds of people and giving recommendations for further MOOC offers. Therefore we analyze eLearning in MOOCs in regard of the following social, cultural and ethical dimensions: o age, gender, socio-demographic background, subject field, working experience, social interaction among students (in the forum and in learning groups) and between students and teachers/tutors; o country of residence, values, gender roles; o fairness (e. g. in behalf of peer assessment) and conformity with regulations (e.g. concerning the communication via the forum). We report new results of our multivariate statistics and give recommendations for attracting more women to take part in STEM-MOOCs, e. g. with regard to the role of teachers, course design, learning materials, examples and speech geared to a diverse target group and a suitable learning environment for a very heterogeneous group of learners.*

***Keywords**: MOOCs; STEM; learning analytics; empirical study; gender diversity; lifelong learning*

I. BACKGROUND AND CHALLENGES

Despite of a large amount of worldwide initiatives for supporting girls and women in Science, Technology, Engineering and Mathematics (STEM) in some countries, especially in German speaking countries, we are still far away from gender parity in STEM. Among others Massive Open Online Courses (MOOCs) are handled as revolutionizing the access to education and fostering individualization of education [1]. In line with these expectations we investigate on the question whether MOOCs are able promote gender diversity in STEM.

For acceptance of diverse learners and participation in the digital change MOOCs should be carefully targeted in regard to socio-demographic variables and address specific interests, competences and living situations. We assume that no gender-neutral reality exists.

The concept of MOOCs, proposed in 2008 and then broadly implemented from 2012, represents a culmination of progress in the area of online education. The concept focuses on the learner, for whom full access to collections of information along with communication in open communities is taken for granted. The uniqueness of such massive online courses is characterized by the combination of an offer of teaching and learning content within a social media platform, enabling the course participants to learn

within a virtual community. This community, with its great number of participants, has had a powerful social effect which has turned MOOCs into an attractive learning method [2]. Over the long term it also serves to connect the user directly to the process of learning itself.

1.1 Research Questions

Related research gives a broad overview about typical learners in MOOCs [3], but many questions about social, cultural and ethical dimensions of eLearning are not answered yet or are only answered based on a very small number of analyses which are not able to give generalizable conclusions. Our primary interest concerns the following research questions from a sociological point of view: Who takes part in STEM-MOOCs (selectivity)? Which factors influence the successful participation in STEM-MOOCs and under which conditions are MOOCs able to promote gender diversity in STEM?

1.2 Data and Methodology

During their learning process the large amount of online students in MOOCs produce a large amount of data indicating their learning behavior. In contrast to many traditional studies in education and sociology this new source of data enables a lot of statistical analyses with higher validity. For research purposes we have exclusive access to the learning data of 100,000 learners from more than 190 countries who take part in MOOCs about computer science provided by the online learning platform "openHPI" [4] of the Hasso Plattner Institute (HPI). The data is collected during four years from 2012 to 2016 from more than 200,000 enrolments in 20 courses and is enhanced with survey data. For this paper the focus is on social, cultural and ethical dimensions of eLearning, especially on gender related issues. Therefore, the results in section II are based on the subset of learners of whom we have information about their social background.

Table 1 shows an overview of 20 MOOCs offered by openHPI from 2012 to 2016. All of them are used exclusively as online courses and in the field of computer science. The mix of topics is generally based on the existing curriculum and research topics of HPI. Our traditional MOOCs have a duration of four to six weeks while workshops ran only for two weeks. Some MOOCs have already one to three reruns. The analyzed information is based on a large number of data points generated by the openHPI MOOCS like pre-surveys, videos, quiz, weekly assignments, practical programming exercises, peer assessment, forum discussions, learning groups, additional reading material, final exams, post-surveys and certificates [5].

Table 1 Overview of openHPI-MOOCs (2012-2016)

MOOC	Year	Students	Students (f)	Completers
In-Memory Data Management	2012	18,563	14.6 %	3,074 (16.6 %)
Internetworking with TCP/IP	2012	14,292	17.0 %	1,917 (13.4 %)
Semantic Web Technologies	2013	9,726	17.8 %	1,149 (11.8 %)
Data Management with SQL	2013	10,668	17.4 %	2,156 (20.2 %)
Web Technologies	2013	10,750	18.5 %	2,206 (20.5 %)
In-Memory Data Management	2013	19,205	14.5 %	2,926 (15.2 %)
Business Process Modelling & Analysis	2013	13,731	11.7 %	2,911 (21.2 %)
Parallel Programming Concepts	2014	8,101	11.4 %	1,330 (16.4 %)
Internetworking with TCP/IP	2014	6,960	12.7 %	1,283 (18.4 %)
Semantic Web Technologies	2014	6,510	14.2 %	920 (14.7 %)
In-Memory Data Management	2014	10,217	12.5 %	1,500 (14.7 %)
Playfully Learning to Program	2014	10,598	21.9 %	3,501 (33.0 %)
Internet Security	2014	12,320	16.9 %	4,761 (38.6 %)
Secure E-Mail	2015	6,818	15.4 %	2,758 (40.5 %)
Automated Visual Software Analytics	2015	4,295	10.7 %	851 (19.8 %)
Java for Beginners	2015	14,415	17.6 %	4,371 (30.3)
Web Technologies	2015	11,230	15.5 %	1,988 (17.7 %)
Java Workshop IDE	2015	7,056	17.0 %	1,185 (16.8 %)
Playfully Learning to Program	2015	8,063	21.9 %	2,701 (33.5 %)
Semantic Web Technologies	2016	6,083	14.7 %	791 (13.0 %)
A total of		*209,601*	*16.0 %*	*44,279 (21.3 %)*

II. LEARNING IN STEM-MOOCS

In this chapter the results of our descriptive, bivariate and multivariate analyses are reported based on the subtotal of learners of whom we have information about their social and educational background (N=114,913).

2.1 Who Takes Part in STEM-MOOCs?

In average openHPI-learners are 40 years old and 16 % are female students. This percentage differs according to the level of specialization of the course (table 1). In MOOCs for beginners e.g. "Playfully learning to program" the amount of female students is with 21.9 % two times higher than in MOOCs for technical experts like "Automated Visual Software Analytics" (10.7 % female students). Nevertheless, the participation in MOOCs on computer science is far away from gender equality.

More than 80 % of all female and male students at openHPI are well educated and completed at least a high school degree. 70 % of male and 60 % of female students are advanced or experts in IT. About 46 % of female and 54 % of male learners are already working for more than 10 years. Nearly 60 % of female and 70 % of male learners are professionals. 20 % of female and less than 15 % of male learners are students. Concerning their job position 40 % of all learners are working as technicians, followed by 23 % of project managers, 17 % team leaders and 9 % department heads. Only 11 % of the learners are interns (more than 15 % of female and 8 % of male students).

2.2 Additional Information of an Exemplary Pre-Survey

Before starting the MOOC we asked specific questions to characterize openHPI-learners in more detail. These questions specially designed to our actual research interests and are not identical with the questions of the first MOOC (2012). We limit the following chapters to the MOOC "Playfully Learning to Program (2015)" in which we ascertain gender related topics. 3,197 learners took part in the pre-survey, nearly 75 % of them were male and have contacts which are studying or working in computer science. In average the proportion of learners who already know a programming language before starting the course is higher among male learners (63 %) than among female learners (44 %).

When asked about their motivation of participation male and female learners answered "learning to program" (50 vs. 52 %), followed by other reasons (19 vs. 18 %), getting a certificate (18 vs. 15 %) and testing weather they like computer science or not (13 vs. 15 %). Under the category "other reasons" male and female learners point out various reasons like to have fun with programming and solving exercises. In addition, male learners highlight especially topic-related motives e. g. "developing augmented reality glasses". In contrast, female students mentioned very often "to improve and test their skills".

2.3 Who Takes Part Successfully?

In average 25 % of female and 26 % of male learners complete openHPI-MOOCs successfully by earning a certificate of participation. Chart 1 visualizes that in 60 % of all courses the proportion of male learners who participate successfully is higher than the proportion of successful female learners.

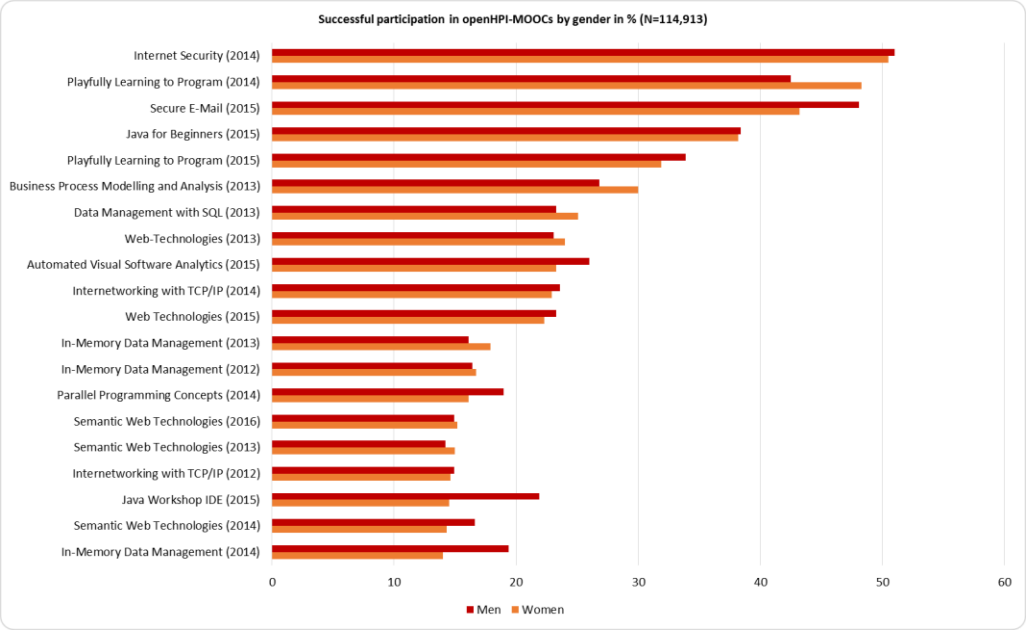

Chart 2 Successful participation in openHPI-MOOCs by gender in % (N=114,913)

One central element of social and collaborative learning in MOOCs is active participation in the forum and learning groups by posting questions, answers and comments. Our analyses show that in average more female learners ask questions in the forum than male learners. There seems to be a low barrier for female learners to ask questions to the extremely large learning community via the forum, which is good for their learning outcome [6].

2.4 Influences on Successful Participation in STEM-MOOCs?

In line with the findings in chapter 2.3 the MOOC "Playfully Learning to Program (2015)" is completed successfully by significant more male learners than female learners. Table 3 shows an overview of bivariate nominal relationships between socio-demographic indicators, social learning indicators and successful participation. The statistical p-value measures the correlation between two nominal variables and has a range between 0 and 1. 0 indicates that both variables are independent while 1 means that both variables perfectly correlate. Three stars indicate significant correlations at the confidence level of 99 % and two stars indicate significant correlations at the confidence level of 95 %. "n.s." means that the correlation is not significant in regard to the entire population. Among all students we found significant, but small correlations between educational background, IT-background, working experience, career status and job position with successful participation (0,1*** to 0,2***). In the subtotal of female learners some of those indicators are not significant for the entire population. The bivariate nominal correlations between indicators of social learning behaviour (posting questions, answers and comments in the forum) and successful participation in MOOCs especially influence female students from 0,3*** to 04***.

Table 3 Overview of bivariate nominal correlations with successful participation (p-value)

Indicator	Students	Students (f)	Students (m)
Highest degree	0,2***	0,2**	0,2***
IT-background	0,1***	0,1 n.s.	0,1***
Working experience	0,1***	0,1 n.s.	0,1***
Career status	0,1***	0,2**	0,1**
Job position	0,1***	0,2 n.s.	0,1**
Posting questions in the forum	0,3***	0,4***	0,3***
Posting Comments on questions in the forum	0,3***	0,4***	0,3***
Posting Answers in the forum	0,3***	0,3***	0,3***
Posting Comments on answers in the forum	0,2***	0,3***	0,3***
N	*8,063*	*529*	*1,870*

To compare the impact of indicators on successful participation we conducted logistic regressions for all students and the subtotals of female and male students. We found that socio-demographic indicators explain 8.5 % of the variance of all students, 9 % of the variance of male students, but more than 30 % of the variance of female students in completing the course successfully.

The social learning indicators explain 12.9 % of the variance of all students, 19.5 % of the variance of male students and 22.8 % of the variance of female students in completing the course successfully: Posting questions and answers in the forum increases the probability of completing the course successfully by the factors 2.5 to 2.3 (for male students by 1.9 to 3.8 and for female students by 3.6 to 3.1). Posting comments on questions and answers raises this probability by the factors 1.7 to 2 (for male students 2.6 to1.9 and for female students by 2.9 to 1.8).

2.5 Evaluation of Gender-Related Issues in STEM-MOOCs

To gain more information on gender-related questions in STEM-MOOCs we asked 1,069 learners (75 % male) after the course "Playfully Learning to Program (2015)" weather the course was attractive for male and female learners. 40 % of male and 64 % of female learners answered with "Yes" while 13 to 16 % thought that the course is more attractive for male than for female learners. Less than 1 % of male and female learners have the opinion that the course is more attractive for female than for male learners and 47 % male and 19 % female learners are undecided. Female students appreciate MOOCs for learning computer science because they can try out everything calmly without negatives comments of other students. Furthermore, they get helpful feedback and answers on their questions instantly by the active community. Students can learn whenever and wherever they want to and use MOOCs for their specific purposes e. g. in regard to lifelong learning and re-entering the labor market after a longer break.

Independent of their gender learners gave the following suggestions to engage more female students in STEM-MOOCs: "Show diverse occupations which are based on programming", "use examples which are interesting for female learners", "show more animations, charts and figures" and "offer a MOOC by female instructors". Especially male learners suggest emotional "reporting of female learners in prior MOOCs" to motivate new students, "offering more interactive and creative exercises which are embedded in an exciting story", "using a gender sensitive design of the online-platform and a more attractive course title", "showing the learning outcome early" and "offering a competition between male and female students in specific exercises". Female learners suggest "a specific announcement that the course is attractive for female students", "using a gender sensitive language", "offering a forum, learning group or whole MOOC exclusively for female students", "offering a printing option for own solutions of creative exercises", "using less technical terms" and "providing more additional information" e. g. a summary of commands, because female students often seek to an operational framework.

III. LESSONS LEARNED AND RECOMMENDATIONS

As discussed in our evaluation, there is a complex selectivity concerning the participation in eLearning in STEM according to the learners' social and educational background. First of all, our analysis of 20 MOOCs in computer science with more than 200,000 enrollments shows a domination of male learners (84 %). Until now the gap concerning the participation of female learners in STEM-MOOCs is similar to the gender gap concerning the participation in STEM in general. Well-educated students with previous knowledge in IT, working experience in a qualified job are more likely to complete online courses in computer science successfully despite of their gender. Social and collaborative learning elements in MOOCs are very important for successful participation in eLearning, especially for female learners.

To use the potential of MOOCs to educate underrepresented groups in specific fields like women in STEM, give second-chance education and possibilities for re-entering the labour market we recommend to engage diverse instructors [7] for further MOOCs, to provide options to choose between different learning materials and designs for engaging a diverse target group and creating suitable learning environments for heterogeneous groups of learners. Above all gender sensitive language and examples should be an inevitable sign of quality of an online course.

IV. FUTUTRE WORK

As we are still at the beginning of studying the digital learning data from a sociological point of view we aim to answer the following research questions: Are there any differences between students according to the number of points achieved in MOOCs? Does the cultural background, gender roles and values have an impact on learners' interests and success? Are there any differences between the learning outcome according to the type of exercises (e. g. quiz, practical programming, and peer assessment)? Do learning curves in MOOCs differ by the type of student? Do we have any learning advantages by using digital media? Is eLearning able to reduce the effort of teaching and to increase the efficiency of learning at the same time? Do we need specific didactical methods for digital education? What can we learn from the findings of other educational disciplines and experiences in other continents e. g. in Asia as one of the most dynamical market for digital education? Among others representative survey data and interviews with experts can help to answer this broad range of future questions.

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