Using Social Network Analysis to explore Learning networks in MOOCs discussion forums

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Abstract. Learning and educational challenges in the field of indoor climate and building services like energy systems are mainly due to the transformation of professional practices and learning networks, a big shift in the way in which people work, communicate, and share their knowledge and the need for additional workforce, either juniors or coming from other disciplines. One of the most important factors that highly influence professional development and workplace learning is networked learning. Our goal in this study, is understanding the learning networks characteristics and patterns of interaction using Social Network Analysis techniques in three MOOCs discussion forums. The result of this study shows not only the importance of Learning networks and peer support on professionalization of learners, but also how pedagogical approach of instructors in MOOCs can foster learning networks. This novel approach in developing learning networks and communities is not only able to help connect young professionals and experienced practitioners digitally, but also it can promote professional development and innovation in the energy installation sector.

Keywords. Professional learning networks, social network analysis, lifelong learning, Massive Online Open Courses.
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1. Introduction

Massive Open Online Courses (MOOCs) have received a great amount of attention in the last few years. MOOCs provide an opportunity for students and professionals to educate or up-skill themself, learn new skills and communicate and build a professional network. Through MOOCs, several thousand learners, actively engage in a learning process with self-organized participation and with different goals, backgrounds, knowledge, and skills but with a common interest [1]. Many MOOCs users, use this learning opportunity for continued education and professional development for different reasons, from satisfying personal and intellectual curiosity to enhancing workplace or professional skills.

Learning and educational challenges in the field of indoor climate and building services like energy systems are mainly due to the transformation of professional practices and learning networks, a big shift in the way in which people work, and the need for an additional workforce, either juniors or coming from other disciplines. Therefore, we believe that MOOCs and the learning opportunities that they provide can tackle many educational challenges and help professional development in the field. Besides the above-mentioned benefits of MOOCs for professional development, they also provide a great opportunity for learners to communicate with their peers and shape a learning community or network. As also mentioned by [1], MOOCs can "model and build collaborative networks of unprecedented size that transcend time and space" and the "network ties created between people during a MOOC have the potential to continue as sustainable and relevant personal and professional connections beyond the boundaries of the course itself" (p. 35). Therefore, there is a big need to understand the learner's behavior and learning networks in MOOCs.

To build knowledge about how professional learning in MOOCs can serve as a catalyst for the development of learning networks and foster

continued networked learning amongst peers driven by workplace challenges as experienced in daily practice, in this research we investigate peer interaction and support in MOOCs developed for Buildings as Sustainable Energy Systems (BSES) professional certificate program in EdX platform by researchers at TU Delft, the Netherlands.

In the last 15 years, online social networks have grown dramatically and enabled companies like Facebook, Twitter, and Linked-In to collect and analyze users' data in detail. These social network technologies have also been used to support and develop Learning Networks (LN). Social Network Analysis (SNA) can be used to understand and help educational communities and learning networks to identify structures and important topics and links to enhance the learning outcomes and professional exchange [2, 3, 4, 5].

Siemens [6] in explaining the theory of connectivism mentioned that learning is a process of network formation and connections are the key to networked learning. And reviewing literatures have shown that the use of learning communities and learning networks can improve the capability of individuals and organizations to learn [7,8]. As Lave and Wenger (1991) [9] describe, learning communities have been used for a group of people who interact regularly, share the same concern or passion for something, and aim to improve their knowledge and practice. Networks of Practice (NoP) or learning networks [10] have been used to describe a more informal and developing social network that encourages and supports the sharing of knowledge and information between a group of people who gather around the same practice and profession. Social Network theory claim that the structure of social relations cannot only explain the different variables in social science but also, they can facilitate or hinder the results for individuals [11]. Reviewing the literature in online learning settings show the correlation between network structure and measures and academic achievements like academic performance [12, 13], knowledge construction [14; 15], and a more positive attitude toward the learning experience [16, 17].

Therefore, there is a need for conducting more research in network learning in the online learning environment. Also, exploring the mechanisms that are involved in shaping networks and having knowledge about the structure of learning networks, and in general, network thinking can expand our knowledge of the learning process as a social phenomenon. Given these questions this case study tries to address the important aspects of the social learning process and professional development in the MOOC using Social Network Analysis (SNA) techniques.

2. Research Methods

For this study, we use the discussion forum posts of participants who engaged in three MOOCs. Course 1: Energy Demand in Buildings (EDB), course 2; Energy Supply Systems for Buildings (ESSB), and course 3: Comfort and Health in Buildings (CHB). These online courses are part of the "Buildings as Sustainable Energy Systems professional certificate program" on the EdX platform provided by researchers at TU Delft, the Netherlands. The MOOCs are freely available, and students pay only if they want a certificate and are described in another paper in this conference. MOOC's discussion forum data was arranged in a MongoDB database. A Python script was used to extract three variables, discussion id, discussion creator, and discussion poster. Each thread created in the forum is a discussion id. The discussion creator refers to the user id that initially created the thread the participants who participate in that thread named discussion poster.

Course one Energy Demand in Buildings (EDB) was the biggest course by over 6500 participants and courses 2 and 3 were smaller by around 5000 participants. As we mentioned earlier, these courses were freely available to everyone, but the participants also had a chance of receiving the certificate by doing the courses' assignments and paying for the course and we called this group the "Certified" participants. Therefore, only 7-10 percent of participants were certified. In the result section, we will explore if there is any difference between these two groups of participants. Also, three tutors and moderators were also involved in discussion forums to mediate the discussions and answer participants' questions. Participants of these MOOCs include a range of people; from high school students who are interested in indoor energy systems to senior HVAC designers who want to update or upscale their knowledge.

In our Analysis, we entered all the posts in each course discussion forum. These courses were presented for the first time, and we analyzed the first round of data from these courses. This series of courses were designed in a way that promote learning through social interaction and focused more on student-centered structure instead of only teacher-centered interaction (for example, students were expected to answer questions from teachers and address learning tasks based on video lectures).

3. Results

Social Network Analysis allows us to have a descriptive overview of our network structure and identify patterns. We summarized the descriptive overview of the network of forum interaction in table 1.

As it is shown in the table, the number of replies to peer posting (edges) increases with the number of participants in the forum (vertices). Graph density measures how many ties or connections exist

between learners, compared to how many connections or ties between learners are possible. Evaluating the network's density can help us understand how connected the networks are in comparison with how connected they might be and in this research, it can also reveal the difference between networks. In This case, our graph density which is the number of unique edges (replies to peer posting) out of all possible edges decreased in the MOOC one, which had a higher number of participants (the number of possible replies to peer posting increased steadily with the number of vertices (participants) in the network).

Tab. 1 - Network measures

Network Metrics	CHB MOOC 3	ESSB MOOC 2	EDB MOOC 1
Vertices	100	98	278
Unique edges	161	156	503
Edges with Duplicates	112	128	274
Total edges	273	284	777
Edge weight avg.	2.69	1.93	2.92
Reciprocated vertex pair ratio	0.02	0.03	0.04
Reciprocated edge ratio	0.04	0.06	0.09
Graph density	0.03	0.01	0.006
In/outdegree avg.	1.98	2.07	2.12
In/outdegree median	1	1	1
Indegree range	0-14	0-12	0-89
Outdegree range	0-30	0-30	0-57

We can define the Reciprocated vertex pair ratio as the ratio between ingoing and outgoing connections. The higher ratio can show that a person engages in more two-way interaction or exchange. Our first MOOC, with the higher number of active participants in the forum, had a higher Reciprocated vertex pair ratio in comparison with MOOCs 2 and 3. The percentage of replies to peer posting that has a reciprocal relationship (mutual interchange) can be defined as Reciprocated edge ratio. Again, our first course had a higher score which replicates the higher number of mutual interactions in peer replies.

In an Edge-Weighted network, weight may represent the length of the edges (in this case, replies to peer posting). Therefore, considering the average edge weight in our MOOCs, they show that participants in course two (Energy Supply Systems for Buildings (ESSB)), were less interested to communicate with their peers in comparison with courses 1 and 3. Furthermore, although the number of participants in course one was around 20 percent more than the two other courses, the total number of vertices and edges in this course are significantly higher.

But when we categorize the participants into certified and not certified participants, we can see that certified participants were more active in the discussion forums. They tried to shape more mutual relationships with their peer and interact more. In table 2, more information about the networked measures of these two groups of participants is presented.

Tab. 2 – Network measures for Certified and Not certified

Network Metrics	MOOC 3		MOOC 2		MOOC 1	
	Not certified	Certified	Not certified	Certified	Not certified	Certified
Vertices	9	52	24	55	35	140
Unique edges	8	68	18	85	38	218
Edges with Duplicates	2	23	23	48	64	184
Total edges	10	91	41	133	102	402
Edge weight avg.	1.2	1.37	8.90	1.73	7.84	3.73
Graph density	0.11	0.02	0.03	0.02	0.03	0.01

But besides the differences between these three networks, we can detect some basic patterns. In directed networks, like discussion forums (someone answers someone else post and receive an answer), we have two measures of the connections linked to a vertex. In-degree is considered as the total number of connections that point inward at a vertex (In our case, the number of replies that someone receives for the post) and out-degree is the total number of connections originated from a vertex (number of replies that someone gives to someone else post) [18]. Here in our sample, all three networks show a similar pattern in the distribution of in/outdegree average. As you can see in figure 1. A big part of network actors had support ties with around two other peers which we considered as "core" participants. Also, edge weights show that most ties between participants are not just a single communication, but they tend to have more responses. This can represent the depth of

discussions which is necessary for shaping the productive learning network.

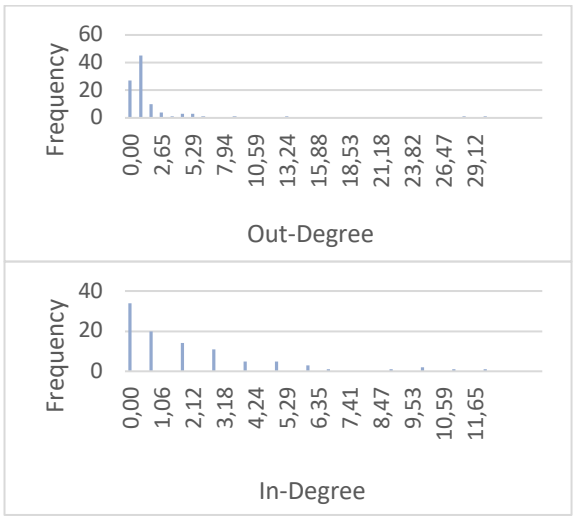

Fig.1- Proportion of out and in-degree distribution in MOOC 2

4. Discussion

Social Networks can be considered as "a set of relations, interactions, and connection with affordances for learning, such as information flows helpful linkages, joint problem solving, and knowledge creation" [19, p. 9]. In this research, we investigated the role of the discussion forums in facilitating professional networks and networked learning in MOOCs. Understanding learners' behavior in learning networks in MOOCs, the structure of these networks, and patterns can help us understand the fundamental of professional development.

In agreement with current findings [20], our results show the fundamental role of MOOCs design and pedagogical approach of MOOCs' instructors in gaining the desired out of these new online learning opportunities. Social network measures can help the energy sector on how to go forward with a networked learning-based approach to promote network community-based peer learning given challenges experienced in their workplace. Professional networks allow for raising challenges from a variety of workplaces and promote learning and problem solving based on a rich and diverse context of professional experiences. Based on our results of Social Network Analysis, we can suggest several design elements for future MOOCs in the technical field like energy management systems in the buildings. Building successful online communities have been studied and extensively discussed in Kraut & Resnick [21] and introduced designs that can encourage learners to share and exchange knowledge in online communities. First, it is suggested that a simple contribution request can raise greater compliance among learners in comparison with lengthy and complicated requests. Second, in agreement with the previous findings [22], mediators can play an important role in facilitating the discussions, providing quick and practical information about the course contents, solving the learners' challenges during the course. In our MOOCs mediators and tutors were actively engaged in discussion and our networks measures show their effects. Thirds, along with the findings in the medical professional development field [23], participants are more interested to share their knowledge and experience through online discussion forums when their peers have more similar professional roles, work contexts, or experience. For example, in this series of MOOCs, tutors simply asked participants to share their background and personal experiences with others. And we believe that it could increase the interactions (e.g., Measured using in and out-degree in our networks). Finally, we need to focus on not only the quantity of interactions but also the quality of exchanges that can play a significant role in a productive discussion forum [24, 25]. High quality and meaningful interaction can be considered as an exchange that stimulates the intellectual curiosity of learners [26]. Exchanging the information which is directly relevant to the learners' real-life situation and applied to similar culture or applied setting [27], providing clear guidelines for discussions and interactions [26], and setting or defining the expectations of learners, both in formal and informal learning context [28] are the most key strategies to have a successful and a high-quality online discussion forum. Future research can investigate the quality of exchanges in online learning forums using modern content analysis methods to better understand the social learning process and empower the potential of learning networks and communities.

5. Conclusion

Massive Open Online Courses (MOOCs) have been grown very fast in the last few years and the role of this new form of education and learning in professional development is undeniable. In this research, we tried to investigate peer interaction and support in the discussion forums of three MOOCs. We investigated the characteristic of these learning networks and their patterns of interactions to see how our pedagogical approach can affect this learning process.

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Data Statement

The datasets generated during and/or analyzed during the current study are not publicly available because of the data privacy agreement between researchers and data provider but will be available under request.