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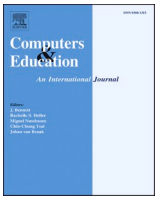

Teaching teachers to use technology through massive open online course: Perspectives of interaction equivalency

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ABSTRACT

Massive Open Online Courses for Educators (MOOC-EDs) provide a new avenue for teaching teachers to use educational technology in classrooms, but a lack of individualized learner-instructor interaction in MOOCs may lead to dropouts. The interaction equivalency theorem implies that MOOCs have the potential to provide a virtually unlimited number of learners with meaningful experiences. Rich opportunities for learner interaction with course content and peers might offset the lack of learner-instructor interaction. However, evidence is largely absent for reconciling interaction equivalency in MOOCs to provide teachers with effective professional development. Therefore, the purpose of this study was to investigate how interaction influenced teachers' course completion and examine teachers' perception of interaction equivalency in a MOOC-based professional development course. A mixed method study was conducted by collecting and analyzing MOOC-ED log data and individual interviews with the teacher participants. The findings confirmed the importance of interactions in MOOCs. In addition, this study indicated learner-content interaction was the predictor of whether teachers completed the course and the very form of interaction that teachers who completed the course had engaged in most frequently. Practical implications for providing teachers with an effective interaction experience and establishing the interaction equivalence in MOOC-based teacher professional development courses are discussed.

1. Introduction

Massive Open Online Courses for educators (MOOC-ED) have increasingly been used in teacher professional development programs with the potential of serving unlimited populations at a low cost (Trust & Pektas, 2018). Teacher professional development is critical to maintain effective education, but traditional teacher professional development convened in the form of one-shot face-to-face workshops has often been limited by time and distance constraints (Castaño-Muñoz, Kalz, Kreijns, & ; Tseng & Kuo, 2014). Especially since the outbreak of the COVID-19 pandemic, the need to provide teachers with access to effective online professional development has been on the rise. MOOC-EDs have thus become a cost-effective and flexible option for online professional development opportunities for teachers (Hadad, Shamir-Inbal, Blau, & Leykin, 2020; Trust & Pektas, 2018).

However, extending access alone cannot ensure effective online professional development for teachers (Hadad et al., 2020; Powell & Bodur, 2019). A low retention rate has been acknowledged as a tradeoff between the scalability and the effectiveness of MOOCs (Tang, Xing, & Pei, 2018). Research has underlined the significance of efficient online interactions, including learner-learner, learner-content and learner-instructor interactions (Moore, 1989) for completing a MOOC (Atapattu, Thilakaratne, Vivian, & Falkner,

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2019; Breslow et al., 2013). One of the main attributors to the low retention rate is the lack of learner-instructor interaction (Hone & El Said, 2016). Due to a large number of enrollments, MOOC learners are unlikely to receive timely feedback from course instructors, which decreases their perceived course satisfaction (Breslow et al., 2013). On the other hand, MOOCs provide learners with a relatively flexible learning space without instructors' rigid structure so learners can quit the course at any time without any penalty during the course of learning (Tang & Carr-Chellman, 2016). Therefore, offsetting the lack of learner-instructor interaction becomes a focus of attention for teacher educators to efficiently deliver MOOC-EDs for online teacher professional development opportunities (Tang, Wang, Qian, & Peck, 2016).

Anderson's (2003) interaction equivalency theorem (EQuiv) implies that a throng of any type of interaction, despite a minimal level of other interactions, can afford meaningful learning in formal settings. Following the EQuiv, Miyazoe and Anderson (2013) argue that the decrease in learner-instructor interactions in MOOCs can be substituted by prolific learner-learner and learner-content interactions without any decrease in the quality of learning experience in MOOCs, following Anderson's (2003) interaction equivalency theorem (EQuiv). To maintain a high-quality professional learning experience, teacher educators need to build an effective interaction equivalence. However, most teachers have their own life or work outside MOOCs that competes with time spent in MOOCs, especially on learner-content and learner-learner interactions (Veletsianos, Collier, & Schneider, 2015). Furthermore, a massive enrollment yields a large number of posts in discussion forums and reading through those posts requires extra time (Tawfik et al., 2017). To provide teachers with an effective interaction experience in MOOC-EDs, an in-depth understanding of teachers' professional development experience and how they perceive each type of interaction afforded by MOOC-EDs is necessary.

Therefore, the purpose of this mixed methods study was to understand teachers' experience with interaction equivalency in a MOOC-ED. Quantitative investigation relied on log data about interactions to identify how each type of interaction influences teachers' professional development experience in the MOOC-ED. Using qualitative methods, the study sought to describe teachers' perceptions of their interaction experiences. The findings of this research advanced existing understanding about interaction equivalency in MOOCs. Moreover, this research provided implications for teacher educators and MOOC designers to foster interaction equivalence in MOOC-EDs for effective teacher professional development.

2. Literature review

2.1. Online teacher professional development

Effective teacher professional development has been critical to successful educational programs (Garet, Porter, Desimone, Birman, & Yoon, 2001). However, the effectiveness of traditional professional development, convened as one-shot in-person workshops, in improving teacher practices and student achievements remains disputed (Dede & Eisenkraft, 2016). Particularly, teachers have to overcome time and distance constraints in order to attend professional development workshops, as they may have time conflicts in their schedule (Organization for Economic Cooperation and Development, 2014). Those one-time workshops also afford limited opportunities for teachers to collaborate with other peers, reflect and continue to investigate the topic after workshop sessions (Powell & Bodur, 2019). In addition, traditional professional development adopts a one-size-fits-all model, and the relatively structured content is unlikely to attend to each teacher's personal interests and needs (Dede & Eisenkraft, 2016; Yurkofsky, Blum-Smith, & Brennan, 2019).

To overcome these barriers, online learning has thus been increasingly integrated in teacher professional development programs. Online professional development programs provide teachers with flexible access so that teachers can overcome time and distance constraints to attend high-quality training sessions and personalize a learning schedule aligned with their own needs and interests (Christ, Arya, & Chiu, 2017; Yurkofsky et al., 2019). For example, video-based online professional development programs allow teachers to revisit the content flexibly and participate in collaborative learning with an extended network of educators (Christ et al., 2017). Given those advantages, online professional development for teachers have garnered increasing attentions.

2.2. MOOC-EDs for teacher professional development

Teacher educators have adopted MOOCs as an option to deliver online professional development. For instance, Vivian, Falkner, & Falkner (2014) launched a MOOC with a focus on modeling teachers' practice of implementing a computing curriculum in Australia. Research has indicated that teachers have been well represented in MOOC enrollment and are also more likely to complete a MOOC than other learners (Castaño-Muñoz et al., 2018; Seaton, Coleman, Daries, & Chuang, 2015). Integrating MOOCs in teacher professional development programs has provided a new avenue to support teachers. However, it does not assure that all MOOCs are designed for teachers' professional development (Hodges, Lowenthal, & Grant, 2016). To facilitate teachers' professional learning in MOOCs, embedding design principles for teachers' efficient online professional development is essential (Hadad et al., 2020; Hodges et al., 2016; Kleiman & Wolf, 2016).

This led to the emergence of MOOC-EDs in 2013 when a series of MOOC-EDs were offered by The Friday Institute for Educational Innovation at North Carolina State University for K-12 educators (Kellogg, Booth, & Oliver, 2014). MOOC-EDs are developed to "provide K-12 educators with self-directed, supported, flexible, yet structured learning opportunities" (Kleiman, Wolf, & Frye, 2013, p.1). Different from an ordinary MOOC, MOOC-EDs have integrated guidelines of effective online professional development for teachers (Castaño-Muñoz et al., 2018; Kleiman & Wolf, 2016). For example, Kleiman and Wolf (2016) summarized four major design principles for MOOC-EDs such as multiple voices, self-directed learning, peer-supported learning, and job-connected learning. Since MOOC-EDs incorporate multiple voices, teachers taking a MOOC-ED are exposed to multiple stakeholders' perspective rather than

only the trainers' view (Kleiman & Wolf, 2016). In addition, MOOC-EDs allow enrolled teachers to self-direct their professional learning and implement active learning strategies to acquire job-embedded skills (Hodges, Lowenthal, & Grant, 2016; Kleiman & Wolf, 2016). Compared to the traditional "sit-and-get" professional development models, MOOC-EDs are more likely to facilitate teachers' transfer of knowledge into the practice (Dede & Eisenkraft, 2016; Hodges et al., 2016; Yurkofsky et al., 2019). MOOC-EDs afford the opportunity of just-in-time learning for teachers, especially when teachers bump into barriers in the midst of applying knowledge to enhance their professional practices (Hodges et al., 2016). Furthermore, MOOC-EDs can leverage the large scale of enrollment in a course to establish an extended peer-supported professional community for teachers (Kellogg et al., 2014; Kleiman & Wolf, 2016).

However, several concerns about MOOC-EDs may constraint their potential in serving a large scale of teachers (Tang, Lin, & Qian, 2020). For example, Seaton et al. (2015) found that teachers completed MOOCs mainly for a recognition for their professional competence, but the validity of MOOCs in their accreditation of learning remains disputed (Castaño-Muñoz et al., 2018; Jobe, Ostlund, & Svensson, 2014). In addition, teachers usually have very limited time to attend professional development aside from those required by the school district (Hodges et al., 2016). To fully benefit from participating in a MOOC-ED, teachers should maintain an effective interaction experience with course content, MOOC instructor, and peers. Overall, MOOC-EDs have the potential to provide a larger community of teachers with a cost-effective and flexible access to video-based online content relevant to their teaching practice (Hadad et al., 2020; Trust & Pektas, 2018), but the concern about maintaining the effectiveness of MOOCs for teacher professional development, especially in affording an effective interaction experience in MOOCs called for continued investigations.

2.3. Interactions in MOOCs

Interaction differentiates the Internet from previous media used in information delivery and is the central mechanism that fosters sustained learner engagement in online learning environments (Johnson & Kaye, 2016). The reciprocal information exchange that happens during interaction is a way for online learners to offset the lack of face-to-face communication (Northrup, 2001). Moore (1989) proposed a model that denotes three types of online interactions, namely learner-content, learner-instructor and learner-learner interaction. Moore (1989) regarded learner-content interaction as the defining characteristic of education in which learners retrieve knowledge through intelligence exchanges with content. According to Northrup (2001), learner-content interaction encompasses attributes like levels of the structure and pacing, the interactivity design and the use of mediums. For efficient learner-content interaction, content must be structured cohesively (Gilbert & Moore, 1998; Sun & Hsu, 2013). Learner-instructor interaction in online courses is different from that of the traditional classroom since online learners gain more autonomy, but instructors are important for assisting learners in widening and applying the knowledge (Moore & Kearsley, 2011). Empirically, learner-instructor interactions are great indicators for predicting the retention rate of an online course (Johnson & Kaye, 2016). Learner-learner interactions flourish in online courses and depict the reciprocal communication among students (Moore, 1989). Online learners cluster together in a virtual space (discussion forum or communication tools) and seek opportunities for collaboration and interaction.

Interaction in its various forms (e.g., learner-learner, learner-instructor, learner-content) is also an integral experience for learners when completing a MOOC. For example, Gillani and Eynon (2014) insisted the merit of MOOCs mainly lies in making connections with a massive scale of learners. Research has suggested that learner-learner interactions are beneficial to sustain students' motivation for continued learning (Kellogg et al., 2014; Tang et al., 2018; Tawfik et al., 2017). Furthermore, learner-content interaction is critical for learners to stay engaged in MOOCs (Hew, 2016; Hone & El Said, 2016). Hone and El Said (2016) identified that learners' efficient interaction with course content is one of the indicators of course retention. Lastly, learner-instructor interaction also plays an important role in maintaining student retention in MOOCs. Breslow et al. (2013) analyzed learner interaction patterns in MOOCs and indicated that learners who completed the course prevailed in interacting with instructors. However, massive enrollments in MOOCs make it unlikely for instructors to provide individualized feedback in a timely manner for each learner (Xing, Tang, & Pei, 2019). Therefore, offsetting the lack of learner-instructor interaction in MOOCs is key to maintain the sustained engagement of learners.

2.4. Interaction equivalence theorem in MOOCs

Existing studies on interaction in MOOCs mainly focused on a quantified measure of learners' interaction and correlated it to their course performance or retentions (Hew, 2016; Hone & El Said, 2016; Mehall, 2021; Tawfik et al., 2017). However, the "just right" equivalence among various forms of interaction in MOOCs remains underexplored (Bozkurt, Koutropoulos, Singh, & Honeychurch, 2020). EQuiv (see Table 1) describes that various types of interaction can be substituted without decreasing the effectiveness of learning experience in a formal setting (Anderson, 2003). This theory opens the possibility of affording an effective learning experience in large-scale courses (Miyazoe & Anderson, 2013). On the one hand, it is noteworthy that boosting one or more types of interactions may significantly increase educational cost. For example, the size of traditional classrooms remains restricted because fostering a large

Table 1
Interaction Equivalency Theorem, quoted directly from Anderson (2003, p.4).

Items	Principles
1	Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student-teacher; student-student; student-content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience.
2	High levels of more than one of these three modes will likely provide a more satisfying educational experience, although these experiences may not be as cost- or time-effective as less interactive learning sequences.

number of interactions between learners and instructors is expensive (Anderson & McGreal, 2012). On the other hand, EQuiv implies that MOOCs have the potential to reach an unlimited number of virtual learners without sacrificing the quality of the learning experience. As EQuiv denotes, the decrease or elimination of learner-instructor interaction in MOOC-EDs is not destructive to the quality of the learning experience as long as other types of interaction occur frequently (Anderson, 2003; Mehall, 2021). Maintaining active learner-content interaction and/or learner-learner interaction can help offset the lack of learner-instructor interaction in order to ensure an effective interaction experience in MOOCs (Miyazoe & Anderson, 2013). For example, even learners who lurk but do not interact with the instructor or peers in discussion forums may continue to have a high level of engagement with course content and can thus still learn effectively in MOOCs (Bozkurt et al., 2020).

However, EQuiv cannot envision a one-size-fits-all solution that ensures the right mixture of interactions to fit the needs of all learners in MOOCs, as learners have individualized preferences regarding interactions (Miyazoe & Anderson, 2013). For example, for learners without adequate academic competence in the course subject, the difficulty in understanding course content without timely guidance from the instructor may result in attrition (Terras & Ramsay, 2015). MOOCs provide learners with opportunities to interact with prominent educational resources. On the contrary, the failure to understand the content is a top contributor to course attrition (Hew, 2016). In addition, MOOCs as self-paced learning environments allow learners to self-determine the level of effort they put forth during various forms of interactions (Tang, 2020). For instance, interaction with peers is not required or graded in most MOOCs. Thus, the average rate of participation in the discussion forum is rather low in MOOCs (Hew, 2016) and the interaction is limited to relatively superficial information exchange (Tawfik et al., 2017). On top of that, learners' interaction experience in MOOCs may not be as effective as expected, despite a large enrollment in MOOCs. For example, learner-learner interaction in MOOCs is sporadically dispersed in various social settings like blogs, emails and synchronous chats, so less experienced learners fail to locate an expert student for support when needed (Veletsianos et al., 2015). Moreover, discussion forums in MOOCs often consist of a number of posts irrelevant to the course topics, which overloaded learners rather than maintaining effective learner-learner interaction (Tawfik et al., 2017).

Interaction in MOOCs is a complicated topic, and the mixture of interactions requires further investigation. The lack of individualized learner-instructor interaction can theoretically be substituted by frequent learner-content or learner-learner interaction in MOOCs (Miyazoe & Anderson, 2013), but there is still a gap in the current literature regarding how to design effective interactions in MOOC-EDs. Therefore, this exploratory study investigated the following research questions to understand teachers' experiences with and perceptions of interaction equivalency in MOOC-EDs.

1. How does each form of interaction influence teachers' performance in a MOOC-ED?
2. What is teachers' experience with each form of interactions in a MOOC-ED?

3. Methodology

A convergent mixed methods design (Creswell & Plano Clark, 2017) was applied in this study to investigate how interactions influenced teachers' professional development experience in a MOOC-ED. Aligned with the purpose, the quantitative approach explored the relationship between interactions and teachers' completion of the MOOC-ED. The qualitative inquiry tapped into teachers' perspective of interactions in the MOOC-ED and further generated an in-depth description of their perceptions in their own words (Gikas & Grant, 2013; Merriam, 1998). Quantitative and qualitative results were converged to provide a comprehensive understanding of the interaction equivalence in the MOOC-ED for effective teacher professional development.

3.1. Participants and contexts

This research was based on a five-week MOOC-ED offered via the Canvas Network for teaching K-12 educators about integrating educational technology into online instruction. The final project was to develop a self-paced online course for their own classroom. Each week had a module about a specific learning theory and educational technology tools (see Fig. 1). This MOOC-ED applied design principles of effective online professional development for teachers (Hadad et al., 2020; Hodges et al., 2016; Kleiman & Wolf, 2016) to elaborate each form of interaction patterns. For example, to boost learner-content interaction, learners enrolled in this course needed to review course lectures and then complete weekly hands-on assignments as a component of the final project. Explicit tutorials and examples were also provided for learners with various levels of prior knowledge and technological skills to be able to successfully

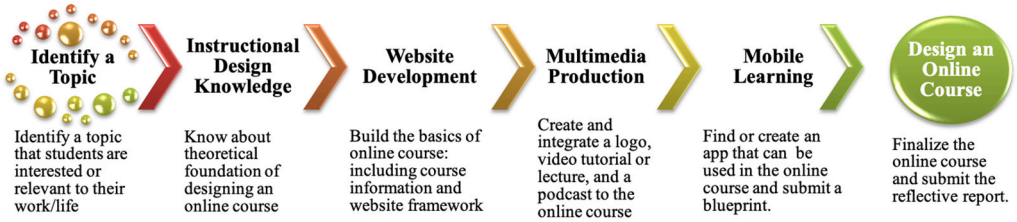

Fig. 1. Course logistics.

submit the assignment. In addition, to encourage learner-learner interaction, discussion forums and emails were enabled. Particularly, learners were required to participate in forum discussions by creating their own posts and responding to two of the peers' posts. Adding to learner-instructor interaction, instructors attempted to increase their presence by regularly sending assignment reminders and weekly announcement as well as hosting virtual meetings. Those interaction patterns were all recorded and could be retrieved as an anonymized dataset.

A total of 529 users across the globe enrolled in this free course, 393 of whom interacted with this course. Those 393 users were the participants for the quantitative investigation. The qualitative inquiry focused on a purposive sample of the participants who met the criteria including 1) those who completed the course; 2) those who were currently in-service teachers. Teacher participants who completed the course were included because they were better informed of what efficient interaction was like and how interactions influenced course retentions (Veletsianos et al., 2015). An institutional review board (IRB) protocol was approved ahead of the recruitment of interviewed participants. The course instructors emailed consent forms and participation request to participants who met the criteria at the end of the course, and eight of them (six female, two male) agreed to voluntarily participate in the interview. To protect the participants' privacy, the researchers assigned an alias to each participant (see Table 2). They came from various countries and taught different grade-level students. Seven participants had registered for MOOCs, four of whom had completed at least one.

3.2. Data collection and analysis

3.2.1. Quantitative data collection and analysis

An anonymized dataset of user interaction patterns was used for quantitative investigation. This dataset, including click stream data and Canvas Application Program Interface (API) data, was retrieved after the course was completed, abiding by ethical and learner privacy requirements. This dataset provided detailed information about each learner's interaction patterns on each page of the course within the Canvas platform as well as performance metrics such as their grade and whether they have completed the course. Those 393 participants recorded a total of 15,140 patterns. Then, the researcher categorized those interaction patterns into learner-content, learner-instructor and learner-learner interactions (see Table 3).

A binary logistic regression analysis was conducted to ascertain the effect of three types of interactions on whether participants completed the MOOC-ED that they were enrolled in. Specifically, the sum of the frequency for each type of interaction patterns for each participant was recorded. In addition, whether the participants completed the MOOC-ED was coded into a binary variable, with "0" indicating incompletion and "1" denoting completion.

3.2.2. Qualitative data collection and analysis

Interviews were used to examine how teachers made sense of their interaction experience in this MOOC-ED (Crewell, 2017). The researcher conducted individual interviews with each participant using a video-conferencing tool (Zoom or Skype per participants' preference and the tool availability). Each interview lasted around 45–60 min with a semi-structured interview protocol being used to probe participant understanding about interaction and also flexibly attend to newly emerged meaning during the interview (Gikas & Grant, 2013). Each interview was conducted in English as all of the participants felt comfortable talking in English. All the participants approved the researchers' request to record the interviews. Upon the completion of interviews, the researcher transcribed all of the recorded sessions for data analysis.

Thematic analysis was conducted via two cycles of coding to analyze the qualitative data (Creswell, 2017). The first cycle of coding applied in vivo coding to create initial codes using participants' voices (Saldaña, 2016). Two researchers with abundant experience in conducting qualitative studies on online learning and K-12 education coded the transcript. Each of them individually read through the transcripts to become familiar with the transcript. Then each researcher identified in vivo codes for each segment of the sentences in the transcript. Before meeting to review the codes together, each researcher checked their own in vivo codes and then revised, replaced, or merged codes if needed. Inter-coder reliability for this cycle of coding was measured by a Cohen's Kappa ($k = 0.862$), suggesting an acceptable level of agreement between two researchers (Cohen, 1960). In the meeting, the two researchers reviewed the codes together and reached an agreement on the discrepancies. This cycle yielded a total of 92 in vivo codes such as "connect with others," "resources engaged me," "pick up own topics" and "email instructors." For the next cycle, the researchers applied pattern coding to synthesize those in vivo codes into more condensed meaning units as pattern codes (Saldaña, 2016). Upon mutual agreement between the two researchers, pattern coding generated a total of 20 pattern codes such as "initial engagement," "peer interaction waned" and "interactions motivated learners." After two cycles of coding, the researcher further synthesized the pattern codes into

Table 2
The demographic information about the interviewed participants.

Participants	Gender	Country	Grade	Highest Degree	MOOCs completed/registered
Eva	Female	USA	High school	Master's	11/12
Sarah	Female	USA/Malawi	Elementary	Bachelor's	0/0
Derry	Female	USA/Italy	High school	Bachelor's	2/7
Yao	Female	China	High school	Master's	1/4
Maggie	Female	Columbia	Middle school	Master's	2/2
Rob	Male	Columbia	Middle school	Bachelor's	0/2
Mack	Male	Italy	High school	Bachelor's	0/3
Rada	Female	India	Elementary	Bachelor's	0/1

Table 3
Categories of interactions and interaction patterns.

Interaction(s)	Pattern(s)
Learner-Content	Assignment, Attachment, Content, Files, Home, Modules, Quizzes, Syllabus, Topics
Learner-Instructor	Announcement, Attachment (Instructor Page), Conference (Instructor)
Learner-Learner	Discussion, Collaboration, Roster, Wiki

categories and themes. Guided by the research questions, four relevant themes (see Results) were defined and presented with thick and rich quotes. Then, qualitative and quantitative results were converged to deliver a comprehensive understanding of participants' interaction experience in this MOOC-ED.

3.3. Rigor and trustworthiness

Three measures were conducted to ensure the rigor and trustworthiness of the qualitative results. First, the researcher conducted a peer debriefing (Lincoln & Guba, 1985) on the identified themes with a qualitative researcher with research experience on K-12 online education and teacher education. A total of four 1-h peer debriefing sessions with a qualitative researcher were set up. The first two sessions focused on the review of the codes generated during each round of coding. The following two sessions mainly checked the categories and the themes. Those peer debriefing sessions concluded with a mutual agreement among researchers on those codes, categories and themes. Second, member checking was used to verify that the findings aligned with participants' experience and perception (Creswell, 2017). The researchers sent all the interviewed participants a summary of the findings, and seven of them replied with confirmation. Finally, numerous direct quotes were used for readers to assess the rigor of this research (Merriam, 1998).

4. Results

4.1. How does each form of interaction influence teachers' performance in a MOOC-ED?

This research question was answered by quantitative and qualitative data. For quantitative investigation, the binary logistic regression analysis on three types of interactions was performed with the dependent variable of course completion. In addition, one of the themes that emerged from qualitative data helped answer how each type of interaction influenced course completion in this MOOC-ED.

4.1.1. Binary logistic regression results

Descriptive statistics results show that the frequency of learner-content interaction ($M = 28.86$, $SD = 49.33$) was the highest, followed by learner-learner and learner-instructor interaction. Particularly, the dataset recorded the least learner-instructor interaction patterns ($M = 2.21$, $SD = 7.35$). A test of the full model with all three variables against a constant-only model was statistically significant, χ^2 (3) = 82.043, $p < .001$. The result (see Table 4) confirmed that those three types of interactions reliably distinguished between participants who completed the MOOC-ED and those who did not. The Nagelkerke R^2 value suggested that this model explained 71.2% of the variance in participants' completion of the course. This model correctly classified 98.2% of cases (57.1% for completion and 99.7% for incompletion) with a cut-off point at 0.50. The Wald criterion indicated that only the frequency of learner-content interaction ($p < .001$) significantly predicted whether the participants completed the MOOC-ED. Odds ratio value for the learner-content interaction [Exp(B) = 1.039] was greater than 1, showing that participants were 1.039 times more likely to complete the MOOC-ED when their interaction with course contents had a one-unit increase (Tang & Bao, 2020).

4.1.2. Theme 1: interaction experience was integral to complete the MOOC-ED

All the interviewed participants perceived interactions as an integral process for them to stay on track and complete the MOOC-ED. For example, Eva commented "[I]t is important to get the feedback from somewhere; otherwise, you don't know whether you are going on the right direction or you might wonder why I am doing it in this way." Sarah thought interaction was valuable, as "people who did not do that probably did not get much out of the course."

The participants perceived each form of interaction as important contributors to completing the course. Particularly, most participants (n = 6) insisted that interaction with the content sparked their interest in the course and helped them to maintain their

Table 4
The binary logistic regression analysis results.

Variables	B	S.E.	Wald	Sig.	Exp(B)
Learner-Content Interaction	.038	.011	12.393	.000*	1.039
Learner-Instructor Interaction	-.185	.129	2.065	.151	.831
Learner-Learner Interaction	.034	.019	3.142	.076	1.034
Constant	−6.959	1.264	30.291	.000*	.001

Note. Model $\chi^2 = 82.043$, df = 3, $p < .001$. Nagelkerke $R^2 = 0.712$.

engagement. For example, the elaborately structured, novel content was the primary resource for Maggie and Eva to become interested in and perhaps even pursue further study in the field. In addition, the components intentionally designed for inexperienced teachers, such as theoretical foundations and step-by-step tutorials for hands-on projects, were highly rated by Rob as contributors to his sustained engagement.

> Maggie: I have to finish because I was engaged in the course … I was very interested in resources on the site that I want to learn. For me, it is very important to learn new things … All the things you give is very important for me, because they are new for me as a teacher and as a learner.
>
> Eva: The new content engaged me, got me familiar with what I am not familiar with. Another words, introducing me to new things. Stretched me, made me uncomfortable, and that is why I like this course. It is totally different from like what I already knew about everything and I do not need to put effort in it.
>
> Rob: Content is very important. Before taking this course, sometimes I can find pages, some webpages, about tools. They are amazing and decent, but teachers cannot make use of those tools successfully without great understanding about the theory. Your course gave a lot of documents about learning, about theory. Those are very useful that gave me the foundational work to understand the use of those tools.

In addition, most participants (n = 7) perceived interaction with other learners beneficial for them to develop a rapport in an unfamiliar environment. They relied on this form of interaction to be informed of what peers did in the course and to learn from peers. Participants also realized that they had a particular responsibility in this rapport when someone was paying attention to their work and partnering with them, but this responsibility was limited to interaction with one or a few learners rather than a community.

> Sarah: You definitely had to look at other people's websites and take the time to see what they created to make it worthwhile because if you skipped this experience, you are not learning from other people.
>
> Derry: For me, it was a bit motivated in that because if you feel like someone was following your work and checking out, you know, your tasks and they were kind of saying, oh, you know, what have you done? Have you finished your paperwork? Have you finished your blogs? Have you finished your podcasts? They can spur you. That is good.

Lastly, most participants believed that the interaction with instructors provided them with reliable guides. For instance, Yao discussed her expectation of instructors' guidance, especially to ensure she was on a right track. Participants thought of course instructors as experts in the field, so they preferred receiving professional advice and/or inspirations from instructors.

> Yao: We have all of the various learners, but we need the instructor to make sure we're on the right path here. If you go down a bad route, you know, it is gonna be problematic … the instructor would pop in periodically with 'yes, that's right', or 'no, that is not', or like, 'did you think of this?' So, it is really a conversation just like a real classroom with the teacher.
>
> Maggie: It was different from all the courses. Because each of [the instructors] gives us the insight in the process and content, [and] help us do projects. That is very inspiring for the learner. For the [learner-instructor] interaction, it was important.

4.2. What is teachers' experience with each form of interactions in a MOOC-ED?

This research question was answered by qualitative findings. The following themes presented participants' descriptions of their experience with each form of interaction in this MOOC-ED.

4.2.1. Theme 2: learner-content interaction was the initial point of engagement in this MOOC-ED

This theme described that learner-content interaction was the form that most participants (n = 7) engaged with initially in this MOOC-ED. Two categories subsumed under this theme were "starting to engage" and "the start of a weekly plan".

Specifically, the first category was built upon the consensus that all participants started interacting with course content and were determined to spend considerable time in going through the content. Participants (n = 7) shared that an effective experience of learner-content interaction encouraged them to sustain active participation in the course as they developed interests in course content and demanded new content for each week. As Eva described, she would like to start interacting with course content whenever new resources or readings were published in the course.

> Eva: When possible, I am trying to take a look at what I know and what would work for me. And go on with new stuff after that. When readings were available, I read. I was just trying to take advantage of everything you guys give us. And I just try to do as much as I could within the time I had.

In addition, the second category described that most participants (n = 6) maintained a weekly plan to complete course units, which started with learner-content interaction. Participants thought reviewing course content would empower them to do well in other forms of interaction. For instance, Maggie explained that individually viewing lecture materials before posting in the discussion forums and interacting with her peers was necessary to secure the quality of her interaction experience.

> Maggie: I have to read instructions … That is the first thing! To read all the things you recommended to do the work … I have to learn little by little. I have to read materials you give us and then started working on the site. Also, opinions [posted in the forum] have to be very creative. And to respond to that [peers' posts] also requires you to work harder in reviewing the content. You have to do a lot to finish the course.

4.2.2. Theme 3: learner-learner interaction waned after the initial upsurge

This theme described that participants' interaction with peers was affluent at the beginning of the course but gradually faded as the course progressed. Almost all participants (n = 8) reported they actively participated in the interactions with peers at the beginning of the course. Participants had a lot of learner-learner interaction at the beginning because they were curious about other people's work and then "found it beneficial to see what other people were doing." In addition, participants reported that they had more questions about the course at the beginning. When they encountered problems, most participants would "first post it to the online forum," because "If I put it up there, all levels [of learners] can see it. And responses always come back … And let everyone see those responses when they come back too." In addition, most participants actively responded to problems posted by peers because, as Rob added, "people are expecting answers from you… So you hold the responsibility for helping out."

> Eva: It was, we knew our topic, we would go and talk about what we were doing and where we were having trouble … everyone in the class was very good about jumping in on each other's threads, providing suggestions, responses, and help.
>
> Rob: [You] encouraged us to involve in the group and you saw I was in the group. We have contacted by email. But when I have problems, I go discussion board. That is the place. The discussion is the place that we met everybody.
>
> Rada: I think, first, it was a little intimately because I have done it before, and, um, I was also, you know, was trying to figure out what everyone else is doing around the world, you know, in their own line of the work. And in the end, as we got to know each other, and what people were doing, and what their goals were, I found it was very beneficial to kind of see what other people were doing.

Another part of this theme was about a shared perception by a majority of participants that learner-learner interaction taking place in the forum decreased as time proceeded. Participants thought the decrease in learner-learner interaction was partly because some learners had already identified "expert students" and primarily initiated new interactions within a small group of learners instead of forming an overall community. For example, Maggie formed an informal partnership with Eva to discuss some questions about Weebly and also sought peer feedback. In addition, as participants could not receive timely responses to their questions or posts in the forum, their participation in learner-learner interaction decreased and they resorted to learner-content interaction to maintain an effective learning experience.

> Maggie: [Eva]is very experienced. She used Weebly a lot based on whatever questions she responded. So, I spent a lot of time looking at hers.
>
> Derry: I comment sometimes on the discussion board, but people did not respond to my posts too much. It is probably my fault because I did not go on to the forum so often. When I did write something to someone [in the forum], I did not get too much response back. So I just learnt mostly by myself by watching your videos, by tutorials, by your example website.

4.2.3. Theme 4: instructor presence was necessary to substitute for a low level of learner-instructor interaction in this MOOC-ED

This theme described that all participants perceived that instructor presence was maintained by weekly announcement, regular assignment reminder, and prompt email responses, and that those were critical to offset a lack of learner-learner interaction in this MOOC-ED. A majority of participants spent the least amount of time on learner-instructor interaction, but most participants (n = 8) shared that instructors' active presence encouraged participants to invest effort in the course, which seemed to seldom occur in their previous courses.

> Mack: The reason why we want to work with you is because you seem to care. You are very involved. That is what I have never seen in previous courses I took. We feel like [we are] in a real classroom.
>
> Rada: This (instructors' active presence) is very different from my prior courses. [T]hey seem never to respond to my questions… maybe because they have thousands of students to take care of.

5. Discussion

This mixed method study tapped into a new perspective of interaction to understand the effectiveness of integrating MOOC-EDs in teacher professional development. MOOC-EDs extend access of online professional development opportunities to a massive number of teachers (Castaño-Muñoz et al., 2018; Trust & Pektas, 2018) but access does not naturally yield effectiveness (Hadad et al., 2020; Powell & Bodur, 2019). The findings of this study filled the gap in existing evidence by adding teachers' voices to the effort to provide teachers with effective interaction experience in MOOC-based professional development. The quantitative results confirmed that interactions with course content predicted whether teachers completed the MOOC-ED. The qualitative results revealed that teachers who completed the course perceived interaction to be integral to their course experience, with each form of interaction contributing to their sustained engagement. The findings of this study parallel with previous findings indicating the significant role of interaction for learner retention in MOOCs (Atapattu et al., 2019; Hew, 2016; Hone & El Said, 2016). Within the framework of the EQuiv theorem (Anderson, 2003; Anderson & McGreal, 2012; Miyazoe & Anderson, 2013), this study provides implications for affording effective interaction experience in MOOC-based teacher professional development.

First, the findings of this study confirmed the significance of learner-content interaction for an effective course experience in the MOOC-ED, concurring with a prior study about interaction in MOOCs (Hew, 2016; Hone & El Said, 2016; Terras & Ramsay, 2015). The interaction with course content is a predictor of whether learners can complete the MOOC-ED in that an increase in the frequency of

visits to content pages can result in an escalation in the likelihood of completing the course. The interviewed teachers perceive that interaction with content allows them to develop an interest in the topic and then motivates them to stay engaged in the course. This finding reinforces the importance of providing high-quality course content to help learners stay engaged (Hew, 2016; Terras & Ramsay, 2015), such as providing well-structured novel content and implementing innovative pedagogy to prompt learner-content interactions (Gilbert & Moore, 1998; Sun & Hsu, 2013). In addition, this finding adds to the literature that profuse learner-content interaction can help offset the lack of learner-instructor interaction in MOOC-based teacher professional development, echoing Miyazoe and Anderson (2013).

On the other hand, participants in this study discussed the importance of providing course content in accessible formats with an appropriate level of difficulty adaptive for learners with various levels of prerequisites. For example, some participants with relatively less exposure to learning theories found that foundational knowledge was needed for them to learn about the use of tools. Similarly, those teachers without sufficient technology skills found that explicit tutorials and example projects helped them stay abreast with the course progress. This personalized content helped avoid attritions due to the difficulties in understanding the content (Terras & Ramsay, 2015). Also, for those participants from relatively resource-constrained areas, course materials provided in both video and text formats made the course more accessible to them. In summary, unlike online courses offered in traditional degree programs, MOOCs are open to all online learners without any restrictions on the prerequisite expertise and conditions for course enrollment (Tang, 2021a). The findings of this research underline that conciliating for interaction equivalence in MOOC-EDs needs to attend to the divergence of learner preference and competence (Tang, 2021b).

Second, learner-learner interaction is not a predictor for teachers' completion of the MOOC-ED in this study, but participants consider this form of interaction necessary for them to build rapport in an unfamiliar learning environment. This finding concurs with prior research that making connections with learners strengthens the merit of MOOCs (Gillani & Eynon, 2014; Hew, 2016; Tawfik et al., 2017). In lieu of a one-way transmission of knowledge from teachers to learners, MOOCs allow learners to make use of the class's collective intelligence to enrich their learning experience and consolidate knowledge. In addition, this form of interaction allows teachers in this MOOC-ED to establish a sense of responsibility for staying engaged in the course. However, it is worth noting that most of the participants only talked about their perceived responsibility for maintaining interactions or participating in peer reviews with one or a few learners, mirroring the concern raised by Jeong, Cress, Moskaliuk, and Kimmerle (2017). It means that those participants did not develop a sense of community or build collective responsibilities towards the community as a whole. This finding opens the discussion about how to further nurture the sense of responsibility developed from learner-learner interactions to build learners' sense of community and thereby sustain their engagement in the MOOC-ED (Gillani & Eynon, 2014; Jeong et al., 2017). Furthermore, the overall learner-learner interaction in this MOOC-ED gradually waned as learners recognized expert students and formed groups around the expert students. This echoed the findings of Tang et al. (2018) that learners' participation in discussion forums varies temporally. This finding reinforced the importance of maintaining an effective discussion forum in MOOC-EDs that can encourage learners' longitudinal participation in learner-learner interaction (Tang et al., 2018, 2019). The participants simultaneously relied on self-directed learning to make sense of the knowledge gained in these groups. This finding reiterates the findings of Gillani and Eynon (2014) about communication patterns in MOOCs. While the small groups might be more efficient for some learners, they reduce the benefits stemming from the "massiveness" and "openness" of the course on students' learning.

Third, this study echoes the prior findings (Breslow et al., 2013; Hone & El Said, 2016; Johnson & Kaye, 2016) that learner-instructor interaction allows teachers in this MOOC-ED to seek professional guidance and to ensure they are on the right track. Meanwhile, the participants also noted their least engagement in the interactions with instructors in this course, which is common for almost all of the MOOCs. Although learner-instructor interaction can be substituted, participants revealed that active instructor presence is beneficial for them to complete the course. Some learners in MOOCs still hope to mimic the settings of traditional classrooms that allow timely feedback from instructors, so they want to stay engaged in a course if the instructor is also actively engaged.

5.1. *Practical implications*

The findings of this study provided important practical implications for the continued endeavors of integrating MOOC-EDs in online teacher professional development. First, MOOC-ED designers can resort to increasing learner-content and learner-learner interaction to offset the lack of learner-instructor interaction in MOOC-EDs, but it is also important to attend to individual difference when affording those forms of interactions. For example, instructional designers can include accessible formats of content to fit teachers' various preferences. Also, instructional designers are recommended to provide explicit tutorials and foundational knowledge as a part of MOOC-EDs so that teachers with divergent levels of prerequisite knowledge and skills can have sufficient expertise to maintain effective interaction with course content. Second, MOOC-ED designers need to provide novel content that is well-structured in line with innovative pedagogy or learning models in order to reinforce learner-content interactions. Learner-content interaction is a predictor of learner retention in this MOOC-ED, so maintaining the quality of the content is important. Third, MOOC-ED designers might consider building a community of teachers and reinforcing teachers' collective responsibility towards the community rather than devoting to interactions with only a few peers. Making connections is a merit of MOOCs, so helping teachers maintain connections within a community can strengthen the benefits of MOOC-EDs for their professional development (Cirulli, Elia, & Solazzo, 2017; Salmon et al., 2015). Fourth, although interactions with instructors can be substituted by increased engagement in other forms of interactions, MOOC-ED instructors are recommended to maintain an active presence in the course via sending weekly reminders and announcements, and also maintaining frequent forum participation.

5.2. Limitations and future research

The findings of this study are limited by several concerns. This study adopted a mixed method design to triangulate the findings of two sources of data, quantitative and qualitative (Creswell & Plano Clark, 2017), but its qualitative inquiry cannot avoid possible influence of personal subjectivity on the validity of the findings (Creswell, 2017; Merriam, 1998). Another limitation of this study was to only include learner interaction patterns recorded in the Canvas dataset. Some valuable data points such as learners' peer review on their portfolio was missing from this investigation. In addition, all participants were recruited from the same course delivered in one platform, meaning that the findings of this study might not be applicable to other contexts. Furthermore, the study did not include the perspectives of those "dropout" learners. Doing so would have provided a more comprehensive understanding of the EQuiv theorem in MOOC-EDs.

To expand upon this study's findings, future research should consider more inclusive samples of participants registering for different MOOC-EDs on various platforms. Dropout learners' authentic perceptions of their course experiences would also provide a useful addition to the existing evidence. In addition, future research may consider the temporal dimension of interaction in the investigation (Tang et al., 2018). The findings of this research shed light on the varied roles that each type of interaction plays at different time points over the course. To improve teachers' interaction experience in MOOC-EDs, understanding the temporal dimension of learner interaction may inform more granular implications on the design of MOOC-EDs. Furthermore, future research may consider including learner interaction patterns beyond the platform as learning in MOOC-EDs also occurs outside the course platform. For example, future research may collect data about peer review comments on participants' portfolio that is not recorded by the platform to present a comprehensive picture of their interaction experience. Lastly, future research may continue to contextualize the EQuiv theorem in MOOC-EDs, such as contextualizing the concerns about the balance between the costs and high-quality interaction in MOOC-EDs. Educators and researchers might use the EQuiv theorem to identify a cost-effective and productive MOOC-ED design for online teacher professional development.

6. Conclusion

This research adds to the effort to afford effective MOOC-based teacher professional development to benefit a large scale of teachers, especially during the distance education period resulting from the outbreak of COVID-19 (Atapattu et al., 2019; Castaño-Muñoz et al., 2018; Hadad et al., 2020; Powell & Bodur, 2019). Overall, the study seeks to understand how to offset the lack of learner-instructor interaction with potential options of burgeoning interactions with course content and/or peer learners in this MOOC-ED, following the EQuiv theorem (Anderson, 2003). The findings of this study concur with the assumption of the EQuiv theorem that improving learner-content or learner-learner interactions in the MOOC-ED can maintain the quality of learning experience despite the lack of learner-instructor interaction (Miyazoe & Anderson, 2013). Learner-content interaction is a significant predictor for learner retention in this MOOC-ED, but it is worth noting that each form of interaction has its influence on teachers' course experience. In addition, the findings of this study shed light on the temporal variation of interaction patterns, such as learner-learner interaction which gradually waned over the course. Accordingly, whether the adjusted mixture of interaction works for a given learner may also vary by time. Therefore, future endeavors to reconcile the interaction equivalence in MOOC-EDs may attend to the temporal dimension of interaction in order to provide an effective interaction experience for teachers enrolled in the course.

Author credit statement

Hengtao Tang: Conceptualization, Methodology, Data Curation, Writing - Original Draft, and Writing - Review & Editing.

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