Chang, J. W., & Wei, H. Y. (2016). Exploring Engaging Gamification Mechanics in Massive Online Open Courses. *Educational Technology & Society, 19* (2), 177–203.

Exploring Engaging Gamification Mechanics in Massive Online Open Courses

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(Submitted October 2, 2014; Revised June 30, 2015; Accepted September 13, 2015)

ABSTRACT

Massive open online courses (MOOCs) have developed rapidly and become tremendously popular because of their plentiful gamification designs, such as reputation points, rewards, and goal setting. Although previous studies have mentioned a broad range of gamification designs that might influence MOOC learner engagement, most gamified MOOCs fail to meet learning objectives because of a lack of research regarding suitable game design, as well as poor rationale for or design of gamification mechanics. This study aims to explore and identify engaging gamification mechanics for MOOC learners. We conducted a focus group interview with 25 MOOC frequent users to identify 40 gamification mechanics. This study then determined the relative engagingness of these gamification mechanics by administering an online survey to 5,020 MOOC learners. The results indicated that the 10 most engaging gamification mechanics accounted for more than 50% of the engagingness. The mechanics of the Where's Wally game is extremely engaging for MOOC learners; however, they it is not been demonstrated in previous relevant studies. Finally, we discuss the top five engaging gamification mechanics and their implications.

Keywords

Improving classroom teaching, Interactive learning environments, Gamification

Introduction

Massive online open courses (MOOCs) are a current trend for creating online courses for equipping learning institutions to obtain a free and high quality teaching initiative with relevant visibility on the Internet (Johnson, Becker, Cummins, Freeman, Ifenthaler, & Vardaxis, 2013; Pellas, 2014). MOOCs refer to web platforms that allow millions of learners to access various instructional materials and resources without the constraints of time and place, and additional learning opportunities to supplement traditional classroom instruction, such as Coursera, Udacity, and edX (Lin, 2010; Stoel & Lee, 2003). MOOCs are interactive, online learning tools that support the learning of specific concepts by enhancing, amplifying, and guiding the cognitive processes of learners (Altbach, 2014). MOOCs use the increasing popularity of social networking services (SNSs) such as instant messengers (IMs), Facebook, and Twitter, to facilitate increased social interaction and engage millions of teachers, learners, and parents (Lin, 2010). The learner–learner and learner–instructor interaction created by MOOCs is central to knowledge acquisition and the development of learner cognitive skills, and that interaction is intrinsic to effective instructional practice (Lee & Hammer, 2011; Tobarra, Robles-Gómez, Ros, Hernández, & Caminero, 2014). MOOCs are an alternative to traditional models of face-to-face education, and have even been viewed as a threat to traditional educational institutions and professionals (Millard, Borthwick, Howard, McSweeney, & Hargood, 2013). Thus, the development of MOOCs has received considerable attention from both educators and learning-technology developers.

MOOCs have been an increased focus related to learner participation of MOOCs, given rising tuition costs and concerns regarding learner success and retention rates (Pappano, 2012). Although MOOCs are rapidly developing and gaining enormous popularity, most of them fail to help learners to remain focused on learning content and lead to relatively poor learning efficiency and effectiveness. This phenomenon occurs because most MOOC designs do not provide learners with an engaging experience. Certain researchers have mentioned that MOOCs must enhance learner digital engagement, which refers to the learning and everyday engagement of learners with available technologies in their learning ecologies, including both daily life and school contexts (Gurung & Rutledge, 2014). Therefore, improving learner digital engagement is critical to the development of MOOCs.

Certain studies have proposed gamification as a potential solution to alleviate this problem (Grünewald, Meinel, Totschnig, & Willems, 2013; Skiba, 2013; Dicheva, Dichev, Agre, & Angelova, 2015). Gamification incorporates game mechanics into nongame settings to increase user engagement and enjoyment of a product or service, and to

encourage users to perform certain behaviours (Hsu, Chang, & Lee, 2013). Gamification essentially functions as entertainment that causes learners to enjoy actively participating and engaging with others, such as through reputation points, rewards, and goal setting. Kapp (2012) indicated that gamification is crucial to the development of learning technology because numerous elements of gamification are based on educational psychology and techniques that instructors have been using for years. Simões, Redondo, and Vilas (2013) developed a learning platform for K-6 learners, and suggested that education is an area with high potential for applying gamification because it substantially promotes learner motivation and engagement with the learning platform. Sung and Hwang (2013) proposed a gamification mechanism for course websites to improve the learning performance of learners in their learning attitudes, learning motivation, self-efficacy, and learning achievements. Because of the importance of gamification to learner engagement, certain popular MOOCs such as Coursera, Udacity, and edX effectively attract and maintain learners through various gamification designs such as rewards and badges. These gamification design factors form social engagement loops by providing fun and flow experience as learners interact with websites, which result in more daily visitors and a higher average time spent on sites (Zichermann & Cunningham, 2011). Consequently, gamification plays a critical role in the success of MOOCs.

Previous studies have mentioned numerous gamification design factors for MOOCs, which can be classified into three types of interactivity, as proposed by Moore (1989) (see Figure 1): (a) learner–content interaction, (b) learner–learner interaction, and (c) learner–instructor interaction. Numerous studies have examined the role of learner–content interaction (such as time pressure and status) in facilitating learner engagement through interacting with the subject matter under study to construct meaning, relate it to personal knowledge, and apply it to problem solving (Reeves & Read, 2009; Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011). Some scholars have argued that gamification designs should rely heavily on the mutual support and socializing of learner–learner interaction (such as peer-tutoring and group identification) because the peer group relationship can enhance regular participation (Choi, & Kim, 2004; Williams, Ducheneaut, Xiong, Zhang, Yee, & Nickell, 2006; Chen, Sun, & Hsieh, 2008; Jang & Ryu, 2011; Hou, 2012; Lee & Chang, 2013). Other studies have examined the learner–instructor interaction process that stimulates, enhances, and maintains learner engagement with a subject (such as rewards and goal setting; Ryan & Deci, 1996; Ducheneaut & Moore, 2004; Hsu, Wen, & Wu, 2009).

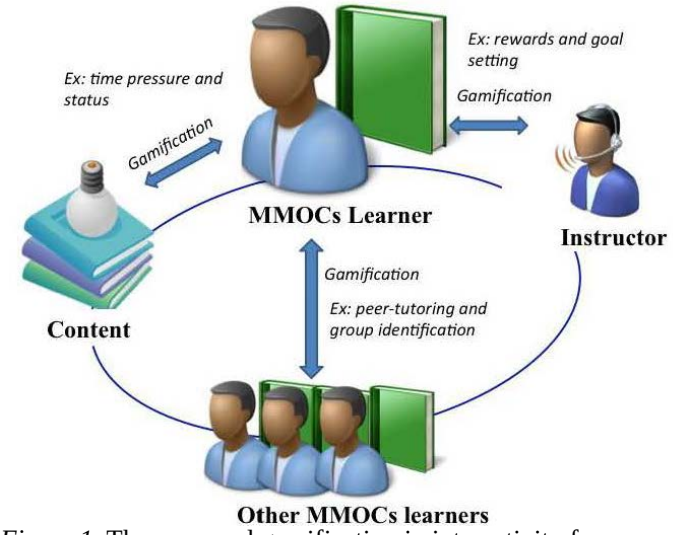

Figure 1. The proposed gamification in interactivity framework

Although the aforementioned studies indicated a broad range of factors that might influence gamification, they depicted neither the actual design mechanics nor the relative engagingness among them. Gamified MOOCs fail to meet learning objectives because of a lack of research regarding suitable game design, as well as poor rationale for or design of gamification mechanics. The selection of crucial gamification mechanics is a multiple-criterion decision-making (MCDM) problem. Previous studies (Kahraman, Cebeci, & Ulukan, 2003; Büyüközkan, 2004; Kim & Nevo, 2008) have regarded the analytic hierarchy process (AHP) as an appropriate method for solving these MCDM problems. Decision makers have to decompose the goal of the decision process into its constituent parts, progressing, from the general to the specific perspective. The structure of AHP has to include a goal, criteria and alternative

levels, ordered into a hierarchy. Each item (criterion, sub-criterion or alter-native) would be divided into an appropriate hierarchy of detail. Specifically, decision makers judge the importance of each criterion in pair-wise comparisons, structured in matrices. The scoring of AHP is on a relative basis, comparing the importance of one decision alternative to another. This study therefore adopted a hybrid methodology combining fuzzy logic techniques and the analytic hierarchy process (FAHP) approach. This hybrid methodology provides a systematic tool for analysing learners' sense of relative engagingness gamification of gamification mechanics and assists decision makers in decomposing the multi-criteria problem into a hierarchical model.

Identifying the engaging gamification mechanics can establish critical milestones in how to create highly effective MOOCs. This study aims to explore the gamification mechanics of MOOCs and determine the relative engagingness of these gamification mechanics. The results can assist MOOC website designers in designing highly engaging MOOCs. The results also identify the engaging gamification mechanics for instructors to enhance learner's engagement.

Gamification in interactivity

Interactivity has been defined differently, each definition reflecting the perspectives of the group using it. Weller (1988) describes interactivity as an event or a process that occurs when a learner actively adapts to information being presented by a form of technology that, in turn, adapts to the learner. Merrill, Li, and Jones (1990) argue that interactivity in learning involves real-time dynamics and mutual give-and-take between an instructional system and a learner—especially in relation to exchanges of relevant information. Apparently, these definitions address interactivity's accounting for the relationships between a learner and the instructional content presented by either an instructor or an instructional system.

All gamification factors discussed in this study includes three main components: learner–content interaction, learner–instructor interaction, and learner–learner interaction. Learner–content interaction implies learners interacting with the subject matter under study to construct meaning, relate it to personal knowledge, and apply it to problem solving (Reeves & Read, 2009; Deterding et al., 2011). Learner–instructor interaction refers to stimulating, enhancing, and maintaining learner motivation (Ryan & Deci, 1996; Ducheneaut & Moore, 2004; Hsu et al., 2009). Learner–learner interaction refers to interaction among individual learners or among learners working in small groups (Choi & Kim, 2004; Williams, Ducheneaut, Xiong, Zhang, Yee, & Nickell, 2006; Chen, Sun, & Hsieh, 2008; Jang & Ryu, 2011; Hou, 2012; Lee & Chang, 2013).

After reviewing gamification factors from literature, we conducted an in-depth interview with five MOOC experts who had more than 3 years of MOOC developing experience. Therefore, through this process, certain factors were excluded because they lacked corresponding applications for MOOCs.

Learner–content interaction

Self-expression

Self-expression refers to peoples' desire to express their autonomy and originality, which shapes their unique personalities (Hsu et al., 2009; Antin & Churchill, 2011). Learner self-expression involves a feeling of social toleration, life satisfaction, public expression, and an aspiration to liberty. Gee (2003) conducted a study on digital-game-based learning and considered that assisting learners to build their self-identity in a virtual world can facilitate learner engagement.

Pattern recognition

Pattern recognition refers to the dynamics of learner-content interaction most associated with unpacking website complexity (Zichermann & Cunningham, 2011). When learners seek to understand the composition of learning content and explore hidden meanings or how complex items interact, they are seeking pattern recognition. When

patterns are detected, learners organize the learning content around those patterns, and typically feel intrinsically rewarded simply for having discovered them.

Time pressure

Numerous game designs use time as a motivator for player activity and action (Reeves & Read, 2009; Antin & Churchill, 2011; Hsu et al., 2013). Time pressure means MOOCs give learners a time limit to perform certain learning behaviours to encourage them to interact heavily or to complete necessary tasks. For learners, creating time pressure can arouse more emotional feedback and encourage greater participation because the time pressure is connected to their goals. For example, certain learning game applications set a 5-s time limit to find targets, which encourages users to interact heavily with the application during this period. When they fail, a new game automatically begins 5-s later.

Status

When learners join a social group, status refers to learners' need for recognition, fame, prestige, attention, and other learners' respect (Antin & Churchill, 2011). Status serves as learners' desire for recognition and encourages learners to achieve goals enthusiastically. For MOOCs, status also represents each learner's contribution to course resources and participation in learning activities. Quantified evaluation is frequently used for representing design mechanics regarding learner status.

Learner–instructor interaction

Goal setting

Goal setting is related to the most motivating goals, which are those that are just out of comfortable reach (Lin & Chang, 2005). In the learning environment, learners are motivated to pursue a specified goal because goal seeking itself is often the primary reward (Antin & Churchill, 2011). Learner goals can comprise personal level goals or group level goals.

Instruction

When new learners (also called newbies) enter a system, certain instructions are required to teach them social norms (Montola, Nummenmaa, Lucero, Boberg, & Korhonen, 2009; Antin & Churchill, 2011). Instruction functions as the social shaping of learning activities and assists learners in mastering an entire system efficiently. Instruction is often used for debriefing and offering feedback so that learners can understand what occurs in a learning system and how these events support the instruction objectives (Kapp, 2012). In the context of MOOCs, instruction assists learners in learning communication and teamwork skills as they collaborate with others.

Rewards

Rewards refer to the gamification factors that satisfy learners' shared need and motivate them to engage in learning activities (Ryan & Deci, 1996). For example, learners are motivated to perform additional problem-solving behaviours to receive additional rewards from websites. The reward mechanism operates by awarding points or equivalents (e.g., frequent-flyer miles) and effectively forms a reward-behavior cycle (Hsu et al., 2009). Learners who invest more time in the encouraged behaviours receive more from the learning system. Rewards can be classified into intrinsic and extrinsic rewards according to their motivation. Intrinsic rewards allow learners to engage in learning for greater self-fulfillment, and extrinsic rewards allow learners to learn for earning something (Lee & Hammer, 2011).

Learner–learner interaction

Reputation points

Reputation points are a mechanism that encourages learner behaviours based on the estimation of recognition held by others inside and outside of an organization (Tulathimutte, 2006; Wolf, 2007). The concept of reputation points has been commonly adopted on online shopping websites such as eBay and Amazon.com to increase system reliability, reduce risks between users, and assist users in deciding whether to interact with and trust a user based on the experiences of other users with that user. Several online games, such as World of Warcraft (WOW) and Ultima Online (UO), use reputation points to recognize users who have fought with other players of comparable experience levels to obtain special titles and items. Learners' desire for reputation points can be considered a motivation for engagement because they play harder to increase their reputation in the game.

Peer tutoring

A peer tutor is anyone who is of a similar status to the person being tutored (Höysniemi, Hämäläinen, & Turkki, 2003; Huang, Yeh, Li, & Chang, 2010). In an undergraduate institution, this is typically other undergraduates, distinct from the graduate students who might be teaching writing classes; in a K-12 school, this is typically a student from the same grade or higher.

Competition

Competition refers to a learner's desire to compete with others, including reaching a higher score and winning over others (Yee, 2006). When a learner competes with others, the learner with the highest score wins a prize or other benefit. Thus, learners enjoy the well-being and continue competing with others.

Altruism

Altruism is a learner's desire to form and maintain relationships with others through certain behaviours, such as gift-giving or asking for help (Antin & Churchill, 2011). Trivers (1971) suggested that altruism is a learner's desire to conduct reciprocal behaviours with others based on trust. Altruists indirectly contribute to their fitness through others who reciprocate. In the MOOC environment, support for gift-giving and charity is the most popular altruistic. Altruism is also considered a strategy to attract new learners (Antin & Churchill, 2011). For instance, learners can receive a gift from someone that draws them into the MOOCs, and are subsequently motivated to send gifts to other learners for reciprocity purpose, eventually creating a great acquisition loop.

Group identification

Group identification represents learners' affective and cognitive loyalty to a learner group (Lee & Chang, 2013; Bergami, & Bagozzi, 2000; Jo, Moon, Garrity, & Sanders, 2007; Pisan, 2007). Learners with higher group identifications are often willing to remain in a group permanently and to strive toward goals, obey the guild manager's commands, and devote themselves to group affairs (Seay, Jerome, Lee, & Kraut, 2004).

Peer appraisal

Peer appraisal has been historically used for logistical, pedagogical, metacognitive, and affective benefits (Sadler & Good, 2006; Conejo, Barros, Guzmán, & Garcia-Viñas, 2013), and offers a promising solution that can scale the grading of complex assignments in courses with tens or even hundreds of thousands of students. When using MOOCs, instructors cannot review essays or other open-ended work from thousands of students as they do in smaller class settings. To remove this limitation, MOOC providers are looking to peer-based assessments, in which students learn to review the work of their cohorts.

Method and result

Identifying gamification mechanics for MOOCs

Materials

The most highly subscribed MOOCs, Coursera, Udacity, and edX, were surveyed in this study. These three MOOCs represent online learning platforms and have myriads of users worldwide.

Subjects and procedures

Twenty-five frequent users including fifteen distance-learning course teachers, four distance-learning students, and six MOOC developers were invited to participate in the interview. All of them have more than two years' experience in using MOOCs. Participants were asked to identify and discuss gamification mechanics of MOOCs based on the gamification factors. The interview questions and record are in the Appendix 1.

Result

To improve gamification mechanics, three human–computer interaction experts with more than 7 years of experience were invited to confirm all of the garnered mechanics. Finally, 40 gamification mechanics were developed following the in-depth interviews, as shown in Appendix 2. To depict the relationship between gamification elements and demonstrate and different levels, a concept map was proposed in Figure 2.

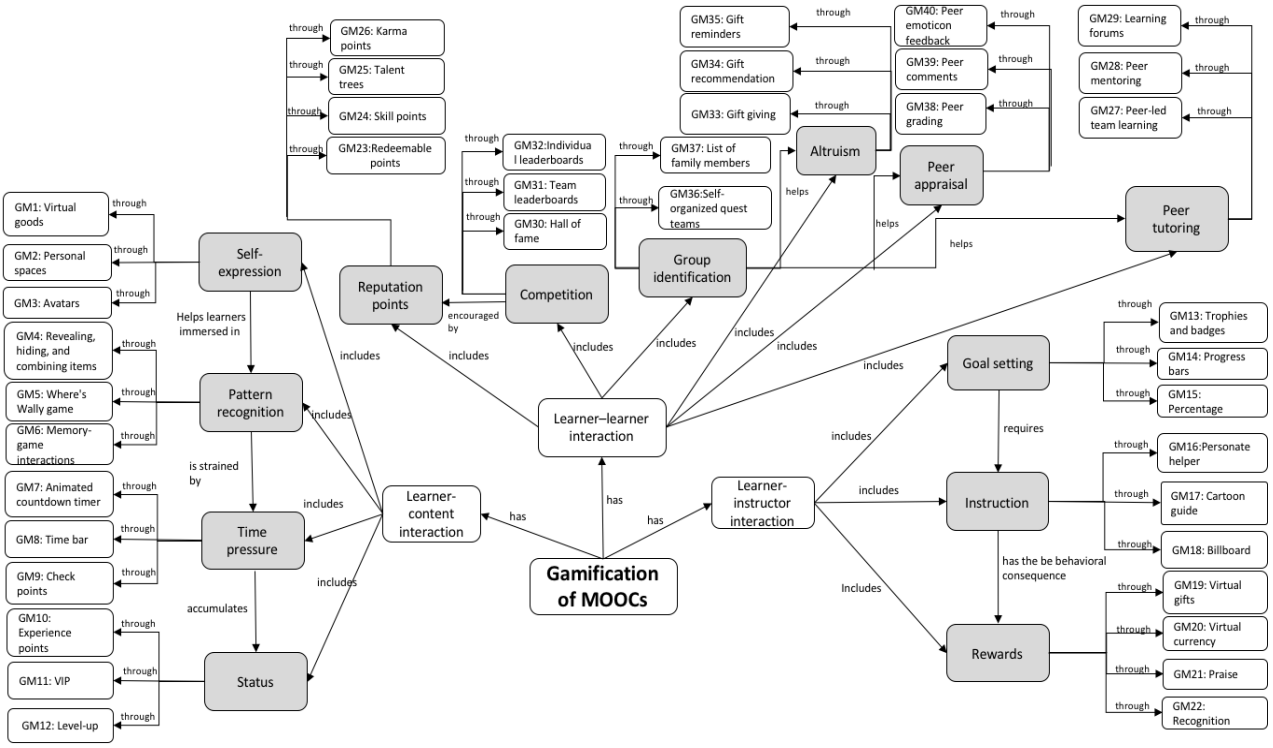

Figure 2. The concept map of all gamification mechanics in MOOCs

Determining the relative engagingness of gamification mechanics

Questionnaire design and data collection

Shown in Appendix 3, AHP questionnaire was developed to gather MOOC learner assessments of the relative engagingness of the gamification mechanics in a pairwise comparison-data input format. Each item was assessed using a 9-point ratio scale, as suggested by Saaty (1990). Each item was scored using a scale comprising equally engaging, moderately engaging, strongly engaging, very strongly engaging, and extremely engaging. This study conducted an online survey to gather data. The survey was advertised on four MOOCs and e-learning online forums in Taiwan to recruit volunteers to participate in this study. After excluding volunteers with incomplete data, 5020 users' data were collected in this study. Table 1 summarizes demographic data of all subjects. Following primary data analysis, we deleted incomplete questionnaires and outlier data, leaving 4,891 valid samples (97.43%) for use in this study.

Table 1. The demographic information of participants in this study

	Participants (N = 296)	N	%
Gender	Male	2437	48.55%
	Female	2583	51.45%
Frequently-used MOOCs	Cousera (https://www.coursera.org/)	2514	50.08%
	Proera (www.proera.com.tw/)	2216	44.14%
	Taiwan open courseware (www.tocwc.org.tw/)	2057	40.98%
	ewant (http://www.ewant.org)	1782	35.50%
	Open edX (https://courses.openedx.tw)	1521	30.30%
	Share Course (http://www.sharecourse.net/)	1305	26.00%
	Taiwanlife (Taiwanlife.org)	1227	24.44%
	NTU MOOC (http://www.ntumooc.org/)	963	19.18%
	Udacity (https://www.udacity.com)	802	15.98%
	edX (https://www.edx.org)	775	15.44%
	Others	750	14.94%
MOOCs use experience	1-12 months	655	13.05%
	12-36 months	2983	59.42%
	>36 months	1382	27.53%
Average age	23.02 years old (Std. = 2.11).		

Data analysis

Our proposed fuzzy-AHP approach included seven steps. We first used triangular fuzzy numbers to construct the fuzzy comparison matrix, as shown in Table 2. Second, we integrated the collected user assessments of each gamification mechanic, design factor, and design component by using the fuzzy average method proposed by Buckley (1985). Third, we computed the fuzzy weight of each gamification mechanic by using the approximation method introduced by Buckley (1985). Fourth, the center of gravity method, a defuzzifying method proposed by Tzeng and Teng (1993), was performed to defuzzify the weight of each gamification mechanic. Fifth, we normalized the weights of all gamification mechanics. Sixth, we aggregated each level of the proposed gamification framework and calculated the relative engagingness value of the fuzzy weight for each mechanic at factor levels. Finally, we computed the consistency index (CI) and consistency ratio (CR) for each fuzzy comparison matrix. The detailed process of data collection and the proposed fuzzy-AHP model are in Appendix 4.

Table 2. Membership function and definitions of fuzzy numbers

Fuzzy number	Membership	Definition
$\tilde{1}$	(1,1,2)	equally engaging
$\tilde{2}$	(1,2,3)	between equally and moderately engaging
$\tilde{3}$	(2,3,4)	moderately engaging
$\tilde{4}$	(3,4,5)	between moderately and strongly engaging

$\tilde{5}$	(4,5,6)	strongly engaging
$\tilde{6}$	(5,6,7)	between strongly and very strongly engaging
$\tilde{7}$	(6,7,8)	very strongly engaging
$\tilde{8}$	(7,8,9)	between very strongly and extremely engaging
$\tilde{9}$	(8,9,10)	extremely engaging

Result

The weight of all gamification mechanics is shown in Appendix 5. Among the 40 engaging gamification mechanics, the top 10 most engaging mechanics, listed in Table 3, can account for more than 50% (51.68%) of engagingness. In our study, the *CR* was $0.072 \leq 0.1$, then the output of the pair-wise comparison can be proven sufficiently consistent.

Table 3. Top10 Most engaging gamification mechanics in MOOCs

Gamification mechanics	Contribution (%)	Accumulative contribution (%)
GM1: Virtual goods	9.52	9.52
GM23: Redeemable points	8.45	17.97
GM31: Team leaderboards	7.34	25.30
GM5: Where's Wally game	4.76	30.06
GM13: Trophies and badges	4.61	34.67
GM38: Peer grading	4.15	38.82
GM40: Peer emoticon feedback	3.93	42.74
GM6: Memory-game interactions	3.31	46.05
GM9: Check points	2.89	48.94
GM24:Skill points	2.74	51.68

Discussion and implications

In this section, we discuss the top five engaging mechanics following the aforementioned analysis. The practical implication for both instructor and MOOC website designer is also discussed (see Table 4).

Table 4. The implication for Instructor and MOOC website designer

Top five gamification mechanics	Instructor	MOOC website designer
Virtual goods	• Quantify learner's contribution to earn virtual goods • Special challenge for special virtual goods	• Virtual goods exchange interface • Display virtual goods on personal page
Redeemable points	• Clear redeemable point's rules. • Integrate the redeemable points into the course content. • Allow learners use the points accumulated from MOOCs to redeem real world' rewards e.g., course material, items, toys, and game software to increase course participation.	• Dialogues should not contain information that is irrelevant or unnecessary. • Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility. • Redeemable points status. • Reminder learners how far they can proceed to next level of rewards.
Team Leaderboards	• Make simple and visible comparisons between learner's teams. • Quantify the team participation	• Local view: allow learners immediately see how they rank among their friends and classmates. • Global view: allows learners to see how they rank among all learners within the system as a whole.

Where's Wally game	• Link the problem solving process with Where's Wally. • Develop learner's pattern recognition, critical thinking, and sense-making skills.	• Give obvious cues as learners are stuck. • Design various faintly discernible cues. • Display different cues according to learner's skill level.
Trophies and badges	• Immediately reward learner's achievement using trophies and badges. • Develop milestone badges to enhance learner's motivation by collecting the badges.	• Trophies and badges ladder • Display the trophies and badges information inside the learner's personal page and information portion of the comment page.

Among the five most engaging gamification mechanics of MOOCs, virtual goods were the most engaging gamification mechanic. Such virtual gifts can be linked to leaner's achievement motivations. The result means learners engage more with the MOOC in order to earn greater achievement. This finding is consistent with Denny's (2013) work. He reported on a large-scale experiment measuring the impact of virtual achievement in e-learning applications and found the virtual achievement has a positive motivational effect on learner's engagement. His result also showed learners prefer earing and owing virtual goods. The practical implication for instructor is to quantify learner's contribution and give learners virtual goods if they achieve a certain level.

Instructors can also provide special challenge for them to earn special virtual goods. Virtual goods work as positive reinforcement for learner's good performance or regular participation. The practical implication for MOOC website designer is to provide a virtual goods exchange interface and display the earned virtual goods in the learner's personal page.

The second most engaging gamification mechanic was redeemable points, which indicate the redeemable points engage learners by supporting their personal achievement motivation. This finding is consistent with Grünewald, Meinel, Totschnig, and Willems (2013)'s work. Grünewald and his colleague (2013) collected 2726 active MOOC participants' data to investigate multiple learning styles and found redeemable points engage learners by strengthening the social incentives. From instructor's perspective, the implication is to integrate the redeemable points into the course content. Instructors can allow learners use the points accumulated from MOOCs to redeem real world' rewards e.g., course material, items, toys, and game software to enhance the course participation. From MOOC website designer perspective, they should design simple and clear redeem user interface to assist learners redeem gifts. Dialogues should not contain information that is irrelevant or unnecessary. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility. The redeem interface also have to display the redeemable points status and reminder learners how far they can proceed to next level of rewards.

The third most engaging gamification mechanic was team leaderboards, which means that learner-learner interaction such as the comparison and competition of teams receives more attention for MOOC learners compared with individual leaderboards. The visible competition among teams encourages team members's highly engagement. This result is consistent with Chiu, Hsu, and Wang's (2006) work. They examined knowledge sharing in a virtual learning community and observed that visible competition among teams substantially increase learners' reliance on team effort rather than on their own effort, and thus engage learners to cooperate with team members. From instructor's perspective, the implication is the instructor should quantify learner's team participation and then encourage simple and visible comparisons between learner's teams. The practical implication for MOOC website designer should provide two types of team leaderboards: local and global view. A local view allow learners immediately see how they rank among their friends and classmates. A global view allows the learners to see how they rank among all learners within the system as a whole, it will assist learners to check the actual learning performance and establish their learning goals.

The Where's Wally game was the fourth most engaging gamification mechanic. This result means learners seek to understand the world around them, and attempt to discover the hidden meaning or complex items interact in MOOCs. The problem-solving process of the Where's Wally game also provides strong motivation for learner engagement, a finding that has not been revealed in the gamification study. In previous learning studies, Where's Wally is considered as a type of wordless figure and which is highly correlated to visual literacy for learners

(Jalongo, Dragich, Conrad, & Zhang, 2002; Crawford & Hade, 2000). The wordless picture are considered as an effective learning tool which encourages readers learning behaviour including sense-making, problem solving, critical thinking, etc. (Avgerinou & Ericson, 1997). Jalongo et al. (2002) also considered the wordless pictures connect learner's visual literacy skills, culture literacy (learning the characteristics and expectations of social groups) and literacy with print. Crawford and Hade (2000) investigated children's reading of wordless picture books, found the children make sense of wordless picture books by using sense-making processes. They also found the wordless picture books let children construct meaning with prior knowledge and experiences, attention to intertextual cues, multiple perspective-taking, reliance upon story language and rituals, and the implementation of active, playful behaviours as part of the reading process. Therefore, we consider Where's Wally game engage learners by connecting learner's visual literacy, which contains critical thinking, learning, construct meaning, creative expression, and aesthetic enjoyment. We also believe the Where's Wally is the important design features for MOOC because the fact that a very high portion of all sensory learning is visual. From instructor's perspective, the implication is linking the problem solving process with Where's Wally and developing learner's visual literacy. Instructors can utilize this visually engaging mechanics to engage learners in the course. The practical implication for MOOC website designer is to design various faintly discernible cues (e.g., the sparkling star or exclamation mark) and display different cues according to learner's skill level. System can also give obvious cues as learners are stuck.

Finally, trophies and badges, the fifth most engaging mechanic, mean that learners are engaged by collecting the trophies and badges provided by MOOCs. Most learners prefer to collect as more types of trophies and badges as possible. This finding is consistent with Law and his colleagues (2011). They examined the relationship between gamification and the sustainability of mobile learning applications, and proposed that a badge collection is a crucial enhancer of users' engagement. Learners who enjoy collecting various types of badges are likely to engage in using mobile applications. From instructor's perspective, the implication is immediately reward learner's achievement using trophies and badges and develop milestone badges to enhance learner's motivation by collecting the badges. The practical implication for MOOC website designer is to design trophies and badge ladder and describe the particularity of them. Moreover, the designer should display the trophies and badges information inside the learner's personal page and information portion of the comment page.

Conclusion and suggestions

In this study, we identified engaging gamification mechanics that influence learners' engagement in MOOCs. We proposed an empirical approach to identify 40 engaging gamification mechanics for MOOCs, among which the mechanic of the Where's Wally game has not been revealed in previous gamification studies. A reasonable explanation might be that learners tend to try something challenging and become immersed in the problem-solving process.

This research has both theoretical and practical contributions. From a theoretical standpoint, although previous studies have mentioned certain gamification design factors, they have not provided a conceptual framework based on a theoretical foundation. Therefore, they have not covered engaging gamification factors comprehensively or identified unnecessary factors. Most studies have failed to provide empirical validation of the gamification factors they have discussed. To solve these problems, we constructed a hierarchical framework of gamification and systematically validated the engaging mechanics.

Previous studies have not established a relation between conceptual factors and concrete gamification mechanics. Therefore, even if MOOC operators know which factors are engaging, they do not know how to implement the concepts into practical system mechanics. This study presents a systematic framework of gamification factors and mechanics, which can assist MOOC operators to improve their users' engagement. Moreover, this paper also provides MOOC operators with empirical data that show which gamification mechanics warrant investigation.

Future research efforts may focus on the connection between the use of gamification mechanics and learning outcomes, since greater numbers of gamification mechanics do not necessary guarantee better learning performance.
The limitations of this research should be noted. We do not suggest that the explored gamification mechanics we have discussed represent an exhaustive list. Future research can use various methodologies, such as longitudinal studies, focus groups, and the ethnography approach, to identify other potential gamification mechanics for MOOCs.

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Appendix 1. Information of focus group interview

1. Focus group semi-structured questions

Learner-learner interaction

(1). What learner-learner interaction that you have experienced with the use of MOOCs is the most important in your learning?

(2). What are the engaging gamification designs for learner-learner interaction that you have experienced with the use of MOOCs? Do you have any example?

(3). What further gamification designs for learner-learner interaction in MOOC is required?

Learner-content interaction

(4).What learner-content interaction that you have experienced with the use of MOOCs is the most important in your learning?

(5).What are the engaging gamification designs for learner-content interaction that you have experienced with the use of MOOCs? Do you have any example?

(6). What further gamification designs for learner-content interaction in MOOC is required?

Learner-instructor interaction

(7).What learner-instructor interaction that you have experienced with the use of MOOCs is the most important in your learning?

(8). What are the engaging gamification designs for learner-instructor interaction that you have experienced with the use of MOOCs? Do you have any example?

(9). What further gamification designs for learner-instructor interaction in MOOC is required?

2. The record of Focus group interview process

Figure 1. The picture of focus group interview

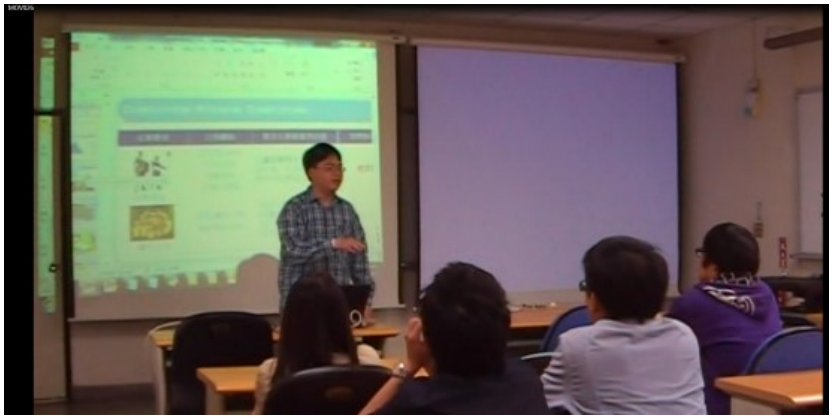

Figure 2. The picture of focus group interview

Figure 3. The picture of focus group interview

Appendix 2. The definition of gamification mechanics in MOOCs

Types of gamification	Gamification factors	Gamification mechanics	Definition
Learner–content interaction	Self-expression	GM1: Virtual goods	Virtual goods are nonphysical objects and money purchased for use in online communities or online games (e.g., new avatar options, clothes, weapons, and items). .
		GM2: Personal spaces	Personal space is the region surrounding a person that they regard as psychologically theirs.
		GM3: Avatars	Avatars refer to the virtual personality connected with the screen name or handle of an Internet learner.
	Pattern recognition	GM4: Revealing, hiding, and combining items	Revealing, hiding, and combining items are web pages contains learning items that enable learners to explore and reorganize.
		GM5: Where's Wally game	Learners are challenged to find a specific learning object hidden in the website.
		GM6: Memory-game interactions	Memory-game interactions are game interactions in which a set of cards are laid face down on a surface and two objects are

			flipped face up after each turn. The objective of the game is to turn over pairs of matching objects.
	Time pressure	GM7: Animated countdown timer	An animated countdown timer is a interface design that counts down in seconds, minutes, hours, and days to any date.
		GM8: Time bar	A time bar is a graphical representation that shows the beginning, the duration, and the end of the learning course in MOOCs.
		GM9: Check points	Learners can receive immediate feedback as they progress in the learning tasks.
	Status	GM10: Experience points	Learners can accumulate quantitative data to demonstrate their mastery of skills or knowledge.
		GM11: VIP	VIPs are specific learners who receive high attention as they log on MOOCs.
		GM12: Level-up	Level-up gives learner's notifications as they achieve certain skill or knowledge level.
Learner–instructor interaction	Goal setting	GM13: Trophies and badges	Trophies and badges are the most common recognition items found in games because of their versatility and flexibility.
		GM14: Progress bars	Progress bar is a visualized representation can be used to show a user how far along he/she is in a process.
		GM15: Percentage	Percentage shows the progress ratio of learners who have completed a specific goal.
	Instruction	GM16: Personate helper	Personate helper is an anthropomorphic robot that guides new learners to become familiar with the system.
		GM17: Cartoon guide	Cartoon guides are characters that instruct learners as they enter the system.
		GM18: Billboard	Billboards are guidelines that guide learner by providing instructional information.
	Rewards	GM19: Virtual gifts	Virtual gifts are nonphysical objects that work as positive reinforcer.
		GM20: Virtual currency	Virtual currency is a type of unregulated, digital money that is issued and typically controlled by its developers, and used and accepted among the members of a specific virtual community.
		GM21: Praise	Praise is the act of making positive statements about a person, object, or idea, either in public or privately.
		GM22: Recognition	Learners can receive recognition from others based on their excellent learning performance.
Learner–learner interaction	Reputation points	GM23: Redeemable points	Redeemable points are what learners earn and use to redeem virtual items/ rewards.
		GM24: Skill points	Skill points are assigned for specific activities within the game and are tangential to both XP and RP. They are a bonus set of points that allow players to gain experience or rewards for activities alongside the core.

	GM25: Talent trees	Talent trees are one of the categories in which a learner's talents are divided. It is so named because the talents branch out, similar to a tree structure.
	GM26: Karma points	Karma points do not allow players to gain benefit from keeping their karma points, only from sharing them. Karma points are frequently given as part of a regular grind, or check-in behavior, for example: 3 karma points are earned for each monthly check in.
Peer tutoring	GM27: Peer-led team learning	Peer-led team learning is a model of teaching undergraduate science, math, and engineering courses that introduces peer-led workshops as an integral part of a course. Students who have performed strongly in a course are recruited to become peer leaders.
	GM28: Peer mentoring	Peer mentoring is a form of mentorship that typically occurs between a person who has lived through a specific experience (peer mentor) and a person who is new to that experience (the peer mentee).
	GM29: Learning forums	Learning forums are platforms that enable learners to share learning tips, experience, resources, and knowledge.
Competition	GM30: Hall of fame	A hall of fame is a structure housing memorials to famous or illustrious learners.
	GM31: Team leaderboards	Team leaderboards list winners' teams and encourage competitions among all learning groups.
	GM32: Individual leaderboards	Individual leaderboards rank MOOC learners according to their learning achievement and list individual winners among all competitors.
Altruism	GM33: Gift giving	Gift giving is an expression of love or friendship by giving virtual gifts/ items to other learners.
	GM34: Gift recommendation	Gift recommendation provides leaners with appropriate gift suggestions for social interaction purposes.
	GM35: Gift reminders	Gift reminders is used for calling attention to the gift-giving behavior of learners.
Group identification	GM36: Self-organized quest teams	Self-organized quest teams allow learners to organize quest teams to solve complex quests or questions.
	GM37: List of family members	Lists of family members allow learners to organize and join learning community to interact and learn together.
Peer appraisal	GM38: Peer grading	Peer grading means a peer arrangement in which people consider the amount, level, value, worth, quality, or success of the products or outcomes of learning peers of similar status.

	GM39: Peer comments	Peer comments are the constructive feedback provided by other learning community members.
	GM40: Peer emoticon feedback	Peer emoticon feedback refers to a meta-communicative pictorial representation of a facial expression that allows learners to interact with each other.

Appendix 3. FUZZY AHP PAIRWISE QUESTIONNAIRE

1. Introduction:

Please compare in pairs the relative engagingness between two given item statements regarding the engaging gamification mechanics. If a criterion (or sub-criterion) on the left is more engaging than the one matching on the right, put your check mark to the left of the engagingness "Equal" under the engaging level you prefer. If a criterion (or sub-criterion) on the left is less engaging than the one matching on the right, put your check mark to the right of the engagingness ''Equal" under the engaging level you prefer. The notations of relative engagingness are following: (1) Absolutely – Absolutely more engaging (2) Very strongly – Very strongly more engaging (3) Strongly – Strongly more engaging (4) Weakly – Weakly more engaging (5) Equally – Equally engaging

2. The definition of gamification:

Gamification means game mechanics into nongame settings to increase user engagement and enjoyment of a product or service, and to encourage users to perform certain behaviors. Gamification essentially functions as entertainment that causes learners to enjoy actively participating and engaging with others, such as through reputation points, rewards, and goal setting.

3. The definition of gamification mechanics in Massive open online courses (MOOCs)

Types of gamification	Gamification factors	Gamification mechanics	Definition
Learner–content interaction	Self-expression	GM1: Virtual goods	Virtual goods are nonphysical objects and money purchased for use in online communities or online games （e.g., new avatar options, clothes, weapons, and items）.
		GM2: Personal spaces	Personal space is the region surrounding a person that they regard as psychologically theirs.
		GM3: Avatars	Avatars refer to the virtual personality connected with the screen name or handle of an Internet learner.
	Pattern recognition	GM4: Revealing, hiding, and combining items	Revealing, hiding, and combining items are web pages contains learning items that enable learners to explore and reorganize.
		GM5: Where's Wally game	Learners are challenged to find a specific learning object hidden in the website.
		GM6: Memory-game interactions	Memory-game interactions are game interactions in which a set of cards are laid face down on a surface and two objects are flipped face up after each turn. The objective of the game is to turn over pairs of matching objects.
	Time pressure	GM7: Animated countdown timer	An animated countdown timer is a interface design that counts down in seconds, minutes, hours, and

			days to any date.
		GM8: Time bar	A time bar is a graphical representation that shows the beginning, the duration, and the end of the learning course in MOOCs.
		GM9: Check points	Learners can receive immediate feedback as they progress in the learning tasks.
	Status	GM10: Experience points	Learners can accumulate quantitative data to demonstrate their mastery of skills or knowledge.
		GM11: VIP	VIPs are specific learners who receive high attention as they log on MOOCs.
		GM12: Level-up	Level-up gives learner's notifications as they achieve certain skill or knowledge level.
Learner–instructor interaction	Goal setting	GM13: Trophies and badges	Trophies and badges are the most common recognition items found in games because of their versatility and flexibility.
		GM14: Progress bars	Progress bar is a visualized representation can be used to show a user how far along he/she is in a process.
		GM15: Percentage	Percentage shows the progress ratio of learners who have completed a specific goal.
	Instruction	GM16: Personate helper	Personate helper is an anthropomorphic robot that guides new learners to become familiar with the system.
		GM17: Cartoon guide	Cartoon guides are characters that instruct learners as they enter the system.
		GM18: Billboard	Billboards are guidelines that guide learner by providing instructional information.
	Rewards	GM19: Virtual gifts	Virtual gifts are nonphysical objects that work as positive reinforcer.
		GM20:Virtual currency	Virtual currency is a type of unregulated, digital money that is issued and typically controlled by its developers, and used and accepted among the members of a specific virtual community.
		GM21: Praise	Praise is the act of making positive statements about a person, object, or idea, either in public or privately.
		GM22: Recognition	Learners can receive recognition from others based on their excellent learning performance.
Learner–learner interaction	Reputation points	GM23: Redeemable points	Redeemable points are what learners earn and use to redeem virtual items/ rewards.
		GM24: Skill points	Skill points are assigned for specific activities within the game and are tangential to both XP and RP. They are a bonus set of points that allow players to gain experience or rewards for activities alongside the core.
		GM25: Talent trees	Talent trees are one of the categories in which a learner's talents are divided. It is so named because the talents branch out, similar to a tree structure.
		GM26: Karma points	Karma points do not allow players to gain benefit from keeping their karma points, only from sharing them. Karma points are frequently given as part of a regular grind, or check-in behavior, for example: 3

		karma points are earned for each monthly check in.
Peer tutoring	GM27: Peer-led team learning	Peer-led team learning is a model of teaching undergraduate science, math, and engineering courses that introduces peer-led workshops as an integral part of a course. Students who have performed strongly in a course are recruited to become peer leaders.
	GM28: Peer mentoring	Peer mentoring is a form of mentorship that typically occurs between a person who has lived through a specific experience (peer mentor) and a person who is new to that experience (the peer mentee).
	GM29: Learning forums	Learning forums are platforms that enable learners to share learning tips, experience, resources, and knowledge.
Competition	GM30: Hall of fame	A hall of fame is a structure housing memorials to famous or illustrious learners.
	GM31: Team leaderboards	Team leaderboards list winners' teams and encourage competitions among all learning groups.
	GM32: Individual leaderboards	Individual leaderboards rank MOOC learners according to their learning achievement and list individual winners among all competitors.
Altruism	GM33: Gift giving	Gift giving is an expression of love or friendship by giving virtual gifts/ items to other learners.
	GM34: Gift recommendation	Gift recommendation provides leaners with appropriate gift suggestions for social interaction purposes.
	GM35: Gift reminders	Gift reminders is used for calling attention to the gift-giving behavior of learners.
Group identification	GM36: Self-organized quest teams	Self-organized quest teams allow learners to organize quest teams to solve complex quests or questions.
	GM37: List of family members	Lists of family members allow learners to organize and join learning community to interact and learn together.
Peer appraisal	GM38: Peer grading	Peer grading means a peer arrangement in which people consider the amount, level, value, worth, quality, or success of the products or outcomes of learning peers of similar status.
	GM39: Peer comments	Peer comments are the constructive feedback provided by other learning community members.
	GM40: Peer emoticon feedback	Peer emoticon feedback refers to a meta-communicative pictorial representation of a facial expression that allows learners to interact with each other.

4. The pair-wise questionnaire

Part1: Three gamification dimensions

	Absolutely		Very strongly		Strongly		Weakly		Equally	Weakly		Strongly		Very strongly		Absolutely		
Criterion (or sub-criterion)	9:1	8:1	7:1	6:1	5:1	4:1	3:1	2:1	1:1	1:2	1:3	1:4	1:5	1:6	1:7	1:8	1:9	Criterion (or sub-criterion)
Learner–content interaction																		Learner–instructor interaction
Learner–content interaction																		Learner–learner interaction
Learner–instructor interaction																		Learner–learner interaction

Part 2: Thirteen gamification factors under dimensions

	Absolutely		Very strongly		Strongly		Weakly		Equally	Weakly		Strongly		Very strongly		Absolutely		
Criterion (or sub-criterion)	9:1	8:1	7:1	6:1	5:1	4:1	3:1	2:1	1:1	1:2	1:3	1:4	1:5	1:6	1:7	1:8	1:9	Criterion (or sub-criterion)
Self-expression																		Pattern recognition
Self-expression																		Time pressure
Self-expression																		Status
Pattern recognition																		Time pressure
Pattern recognition																		Status
Time pressure																		Status
Goal setting																		Instruction
Goal setting																		Rewards
Instruction																		Rewards
Reputation points																		Peer tutoring
Reputation points																		Competition
Reputation points																		Altruism
Reputation points																		Group identification
Reputation points																		Peer appraisal
Peer tutoring																		Competition
Peer tutoring																		Altruism
Peer tutoring																		Group identification
Peer tutoring																		Peer appraisal
Competition																		Altruism
Competition																		Group identification.

Competition	Peer appraisal
Altruism	Group identification
Altruism	Peer appraisal
Group identification	Peer appraisal

Part 3: Forty gamification mechanics under factors

	Absolutely		Very strongly		Strongly		Weakly		Equally	Weakly		Strongly		Very strongly		Absolutely		
Criterion (or sub-criterion)	9:1	8:1	7:1	6:1	5:1	4:1	3:1	2:1	1:1	1:2	1:3	1:4	1:5	1:6	1:7	1:8	1:9	Criterion (or sub-criterion)
GM1: Virtual goods																		GM2: Personal spaces
GM1: Virtual goods																		GM3: Avatars
GM2: Personal spaces																		GM3: Avatars
GM4: Revealing, hiding, and combining items																		GM5: Where's Wally game
GM4: Revealing, hiding, and combining items																		GM6: Memory-game interactions
GM5: Where's Wally game																		GM6: Memory-game interactions
GM7: Animated countdown timer																		GM8: Time bar
GM7: Animated countdown																		GM9: Check points
GM8: Time bar																		GM9: Check points

GM10: Experience points	GM11: VIP
GM10: Experience points	GM12: Level-up
GM11: VIP	GM12: Level-up
GM13: Trophies and badges	GM14: Progress bars
GM13: Trophies and badges	GM15: Percentage
GM14: Progress bars	GM15: Percentage

GM16: Personate helper	GM17: Cartoon guide
GM16: Personate helper	GM18: Billboard
GM17: Cartoon guide	GM18: Billboard
GM19: Virtual gifts	GM20: Virtual currency
GM19: Virtual gifts	GM21: Praise
GM19: Virtual gifts	GM22: Recognition
GM20: Virtual currency	GM21: Praise
GM20: Virtual currency	GM22: Recognition
GM21: Praise	GM22: Recognition
GM23: Redeemable points	GM24: Skill points
GM23: Redeemable points	GM25: Talent trees
GM23: Redeemable points	GM26: Karma points
GM24: Skill points	GM25: Talent trees
GM24: Skill points	GM26: Karma points
GM25: Talent trees	GM26: Karma points
GM27: Peer-led team learning	GM28: Peer mentoring
GM27: Peer-led team learning	GM29: Learning forums
GM28: Peer mentoring	GM29: Learning forums
GM30: Hall of fame	GM31: Team leaderboards
GM30: Hall of fame	GM32: Individual leaderboards
GM31: Team leaderboards	GM32: Individual leaderboards
GM33: Gift giving	GM34: Gift recommendation
GM33: Gift giving	GM35: Gift reminders
GM34: Gift recommendation	GM35: Gift reminders
GM36: Self-organized quest teams	GM37: List of family members
GM38: Peer grading	GM39: Peer comments
GM38: Peer grading	GM40: Peer emoticon

	feedback
GM39: Peer comments	GM40: Peer emoticon feedback

Appendix 4. A fuzzy-AHP approach for determining relative engagingness of gamification mechanics in MOOCs

Step1.Constructing the fuzzy comparison matrix

Triangular fuzzy νυμβερσ $\tilde{M}_{ij}$ from $\tilde{1}$ to $\tilde{9}$ was employed to represent the results of users' assessments of the pair-wise comparisons between each of the gamification mechanics by constructing a fuzzy positive reciprocal matrix M. The proposed fuzzy comparison matrix was defined as follows:

$$M = \left[\tilde{M}_{ij}\right]$$

M : fuzzy positive reciprocal matrix

$$\tilde{M}_{ij} = \left(L_{ij}, M_{ij}, R_{ij}\right)$$

L_{ij} : the left value of the fuzzy membership function of the collected subject assessments of design mechanic *j* of decision element *i*

M_{ij} : the middle value of the fuzzy membership function of the collected subject assessments of design mechanic *j* of decision element *i*

R_{ij} : the right value of the fuzzy membership function of the collected subject assessments of design mechanic *j* of decision element *i*

$$\tilde{M}_{ij} = 1 \diagup \tilde{M}_{ji}, \forall i, j = 1,2,\ldots,n$$

Step 2.Integration of the collected subjects' assessments of each decision element

There are many possible approaches to integrating subject assessments when calculating the triangular fuzzy number. In contrast to some studies that apply statistical parameters such as the minimum, maximum, mean ανδ mode to represent the fuzzy numbers, this study applied the geometric mean method proposed by Buckley [59]. The computing process is defined as follows:

$$\tilde{m}_{ij} = \left(1 \diagup n\right) \otimes \left(\tilde{m}_{ij}^{1} \oplus \tilde{m}_{ij}^{2} \oplus \cdots \oplus \tilde{m}_{ij}^{n}\right)$$

$\tilde{m}_{ij}$: Integrated triangular fuzzy numbers

$\tilde{m}_{ij}^{N}$: The value of the pair comparison of the collected subject assessments of design mechanic *j* of decision factor *i*

n: The number of subjects

Step 3. Computation of fuzzy weight

After integrating the collected data and calculating the corresponding triangular fuzzy numbers, we used the Approximation Μετηοδ proposed by Buckley [59] to compute the fuzzy weight. The formula of the Approximation Method for computing the fuzzy weights is defined as follows:

$$\tilde{Z}_i = \left(\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \cdots \otimes \tilde{a}_{in}\right)^{1/n}, \forall i = 1,2,\ldots,n$$

$\tilde{W}_i = \tilde{Z}_i \otimes \left(\tilde{Z}_1 \oplus \tilde{Z}_2 \oplus \cdots \oplus \tilde{Z}_n\right)^{-1}$

$\tilde{Z}_i$: The geometric mean value of the triangular fuzzy number

$\tilde{a}_{ij}$: The triangular fuzzy number of row *i* and column *j* in the fuzzy positive reciprocal matrix

$\tilde{W}_i$: The fuzzy weight of each row of the fuzzy positive reciprocal matrix

Step 4. Defuzzification of decision elements

The weights of the decision elements were represented by fuzzy values. The defuzzification process assigned a distinct number to each of the decision element. We then used the Center of Gravity Method of defuzzification to calculate the center of gravity of the triangular fuzzy number. Given a triangular fuzzy number and its three sides, denoted by Ã= (L_{ij}, M_{ij}, R_{ij}), the defuzzified weight DF_{ij} was calculated using the following formula:

$$DF_{ij} = [(R_{ij} - L_{ij}) + (M_{ij} - L_{ij})]/3 + L_{ij}$$

Step 5. Normalization of defuzzified weights

To compare the relative engagingness of different decision element at different levels, we first normalized the defuzzified weights. The definition of the normalized weights *(NW_i)* of each decision dimension at each level can be defined as follows:

$$NW_i = DF_{ij} / \sum DF_{ij}$$

Step 6. Calculation of the synthesized weight for each element at each level

We calculated the normalized weights of each element at each level after step 5. However, to determine the priority of each mechanic, it was still necessary to synthesize weights for each decision element at each decision level. The larger the value of the synthesized weight, the higher the priority of the dimension. The definition of synthesized weights of each decision element at each level was defined as follows:

$$NW_K = NW_i \times NW_{ij} \times NW_{ijk}$$

Step 7. Checking for consistency

Consistency Index (CI) was employed to designate overall inconsistency for the proposed hierarchy and for each decision dimension. Consistency Ratio (CR) was also calculated to describe the consistency of the pair-wise comparisons. The equations for calculating CI and CR for each decision were:

$$Consistency\ \ Index\ \ (CI) = \frac{\lambda_{Max} - n}{n-1}$$

where λ_{Max} is the maximum eigenvalue, and *n* the number of decision component

$$Consistency\ \ Ratio\ \ (CR) = \frac{CI}{RI}$$

RI is the average index for randomly generated weights obtained from a table of random consistency indices. To judge the consistency of the pair-wise outputs, if *CR* was $\leq$ 0.1, then the output of the pair-wise comparison was sufficiently consistent. On the other hand, if *CR* was > 0.1, then the results of the pair-wise comparison were inconsistent.

Appendix 5. The Fuzzy AHP Weight of Gamifiation factors and mechanics table

Criteria （Layer 1)	Weights	Sub-criteria (Layer 2)	Local weights	Sub-criteria (Layer 3)	Local weights	Global weights
Learner–content interaction	0.281	Self-expression	0.372	GM1: Virtual gifts	0.911	0.09520
				GM2: Personal spaces	0.032	0.00335
				GM3: Avatars	0.057	0.00599
		Pattern recognition	0.420	GM4: Revealing, hiding, and combining items	0.279	0.02293
				GM5: Where's Wally game	0.403	0.04760
				GM6: Memory-game interactions	0.318	0.03310
		Time pressure	0.171	GM7: Animated countdown timer	0.196	0.00942
				GM8: Time bar	0.203	0.00975
				GM9: Check points	0.601	0.02890
		Status	0.037	GM10: Experience points	0.332	0.00345
				GM11: VIP	0.312	0.00324
				GM12: Level-up	0.356	0.00370
Learner–instructor interaction	0.316	Goal setting	0.313	GM13: Trophies and badges	0.466	0.04610
				GM14: Progress bars	0.260	0.02572
				GM15: Percentage	0.274	0.02709
		Instruction	0.259	GM16: Personate helper	0.334	0.02734
				GM17: Cartoon guide	0.333	0.02725
				GM18: Billboard	0.333	0.02725
		Rewards	0.428	GM19: Virtual gifts	0.253	0.02422
				GM20: Virtual currency	0.251	0.02395
				GM21: Praise	0.271	0.02665
				GM22: Recognition	0.225	0.02043
Learner–learner interaction	0.403	Reputation points	0.410	GM23: Redeemable points	0.511	0.08450
				GM24: Skill points	0.166	0.02740
				GM25: Talent trees	0.160	0.02647
				GM26: Karma points	0.163	0.02687
		Peer tutoring	0.052	GM27: Peer-led team learning	0.311	0.00652
				GM28: Peer mentoring	0.311	0.00652
				GM29: Learning forums	0.378	0.00791
		Competition	0.201	GM30: Hall of fame	0.042	0.00340
				GM31: Team leaderboards	0.906	0.07340
				GM32: Individual leaderboards	0.052	0.00420
		Altruism	0.039	GM33: Gift giving	0.423	0.00665

		GM34: Gift recommendation	0.374	0.00587
		GM35: Gift reminders	0.203	0.00320
Group identification	0.043	GM36: Self-organized quest teams	0.613	0.01063
		GM37: List of family members	0.387	0.00670
Peer appraisal	0.255	GM38: Peer grading	0.404	0.04150
		GM39: Peer comments	0.214	0.02200
		GM40: Peer emoticon feedback	0.382	0.03930