Examining Effects of Badge Repeatability and Level on Users' Knowledge Sharing in Online Q&A Communities

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Abstract

This study investigates the differential effects of badge repeatability and level on users' knowledge sharing behaviors in an online Q&A (Question & Answer) community. Drawing on reinforcement theory and attribution theory of motivation, we conjecture that nonrepeatable badges reinforce individuals' behaviors primarily by promoting internal attributions that strengthen their self-determination motivation, while repeatable badges reinforce people's behaviors mainly via external attributions that undermine their self-determination motivation. By using fixed-effects models to analyze a panel data, we observe that nonrepeatable badges can better motivate users to share their knowledge than repeatable badges. In addition, the results show that attaining a higher level of nonrepeatable badges is associated with an increased effect for knowledge sharing, and that attaining a higher level of repeated badges leads to a decreased effect. These findings can contribute to extant literature by offering a probable explanation regarding why some gamified awards can motivate people better than others.

Keywords: Online Q&A Communities, Badge Repeatability, Badge Level, Reinforcement Theory, Attribution Theory of Motivation, Knowledge Sharing.

1. Introduction

The sustainability of an online Q&A (Question & Answer) community, such as Stack Overflow and Quora, requires proactive, voluntary knowledge sharing by users to help online others. Despite essential sources of motivation for individuals' knowledge sharing behaviors can be attributed to their intrinsic motivation, many Q&A communities seek to elevate such motivation by offering gamified awards that include leaderboard, points, badges (Bornfeld & Rafaeli, 2019; Richter et al., 2018). Among them, badges represent a common form of gamified awards and serve as an intuitive road map to guide users toward obtaining "benefits of providing 'public' goods by recognizing them in front of their peers" (Goes et al., 2016, p. 498). For example, Stack Overflow awards its users with distinct badges to motivate their voluntary knowledge sharing.

Notwithstanding their benefits, gamified awards (e.g., badges) may create unanticipated impacts on knowledge sharing too (Zhao et al., 2016). Toward that end, a common research interest is to examine whether badges are effective for steering people to behave in anticipated, desirable ways. Yet the effects of badges on individuals' knowledge sharing appear not consistent or conclusive. Some research suggests that earning badges can lead to a drop in knowledge sharing. To illustrate, Anderson et al. (2013) suggest the steering effect of badges, arguing that people increase knowledge sharing efforts before attaining a badge but decrease the effort after the badge attainment. Yanovsky et al. (2021) follow this view and further contend that the steering effect may vary with user types. On the other hand, other studies show that badges can promote users' knowledge sharing, with some types of badges leading to greater motivation than others, perhaps due to their unique designs. For example, several recent studies (Cavusoglu et al., 2021; Chen et al., 2019; Ma et al., 2022) that examined the hierarchical badge design reported differential effects of distinct badge levels on people's knowledge sharing in an Q&A community.

While previous research has acknowledged the importance of examining badge designs to explain the differential effects, few studies are devoted to investigating how two essential design aspects, badge repeatability and level, can jointly influence users' knowledge sharing in online Q&A communities. In general, badge repeatability indicates whether a badge can be granted to a user repeatedly. In an online community, a nonrepeatable badge can be earned by people only once in their tenure, whereas people can receive a repeatable badge multiple times. To illustrate, Stack Overflow explicitly states, "Many badges can be awarded multiple times, so don't stop after you've

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earned a badge once." [1] Conceivably, badge repeatability is often assumed to continually boost users' intrinsic motivation of knowledge sharing. However, it is unclear whether repeatable badges in effect can motivate people effectively, which indicate the need of (more) empirical investigations. Furthermore, another important badge design aspect is badge level, which reveals the difficulty of obtaining a specific badge and hence signifies user achievement. Existing literature suggests that people are more likely to be encouraged by high-level than low-level badges, because high-level badges fit their self-determination motivation better (Cavusoglu et al., 2021). But no efforts have been undertaken to examine how the combination of badge repeatability and level can influence users' knowledge sharing in a unison, so their differential effects remain mostly unexplored. We thus seek to answer two fundamental questions:

1. Do repeatable badges differ from nonrepeatable ones for motivating users' knowledge sharing in a Q&A community?
2. How can badge repeatability and level jointly influence users' knowledge sharing in the community?

By answering these questions, we can make two important contributions. First, we analyze and empirically test badge repeatability as an important design aspect, in addition to badge level, which can complement research that emphasizes hierarchical design of gamified awards (e.g., badge level). Second, our study advances existing research and practice by indicating how badge repeatability may interplay with badge level. According to our results, nonrepeatable badges can exert a promoting effect on individuals' motivation, such that earning more high-level badges leads to greater knowledge sharing. Repeatable badges may have an undermining effect on people's motivation, so earning more high-level badges could decrease their knowledge sharing. These findings can guide community operators and gamification designers to better leverage badge designs for motivating user knowledge sharing in an online Q&A community.

2. Literature Review

Extant literature suggests whether gamified awards can motivate people's knowledge sharing depends on if awards can better fit their intrinsic motivation, such as desire for community recognition or self-determination (Bhattacharyya et al., 2020; Cavusoglu et al., 2021). Community recognition entails a public recognition of people's achievements and contributions to the community (Beck et al., 2014; Safadi et al., 2021). Being recognized by the community and its users is a critical driver for people's knowledge sharing, because it helps fulfill their intrinsic motivation, such as knowledge self-efficacy and enjoyment in helping others (Wang & Hou, 2015). To illustrate, peer awards can foster voluntary sharing in online communities, due to increased self-efficacy (Burtch et al., 2022; Gallus, 2017). Prior studies also show that votes, as a form of community recognition, influence individuals' knowledge sharing significantly, because it increases their enjoyment (Chen et al., 2019; Kang, 2022). Additionally, several studies (Cavusoglu et al., 2021; Chen et al., 2022; Zimmerling et al., 2019) report that gamified awards motivate knowledge sharing, because badge-awarding events fit people's self-determination desires, including autonomy, competence, and relatedness. However, gamified awards could be a double-edge sword. As Zhao et al. (2016) indicate, gamified (virtual) awards impede people's enjoyment in helping others; as a result, people engage in less knowledge sharing when such awards are granted.

A plausible explanation for the inconsistent effects is that gamified awards can be designed differently. Existing literature has considered several types of gamified award , such as reputation (Chen et al., 2022), points (Goes et al., 2016; Richter et al., 2018), level (Chen et al., 2022; Khansa et al., 2015), peer award (Burtch et al., 2022), and badge (Bhattacharyya et al., 2020; Cavusoglu et al., 2021; Yanovsky et al., 2021; Zhang et al., 2020). Jointly, these studies offer two important findings. First, gamified award repeatability is important, because people may perceive an award differently if they are allowed to earn it repeatedly (Bhattacharyya et al., 2020; Zhang et al., 2020). Second, award level matters and might have differential effects on individuals' knowledge sharing (Cavusoglu et al., 2021; Chen et al., 2019, 2022; Goes et al., 2016).

Our review of extant literature indicates three important research gaps. First, few studies consider badge repeatability, despite its prevalent usage in many online communities that include Stack Overflow and Yelp. Repeatable badges, by design, should help keep users' knowledge sharing at a higher level. But recent studies (Bhattacharyya et al., 2020; Zhang et al., 2020) show that people may not benefit from earning the same badge repeatedly. Hence, it is important to investigate whether using repeatable badges can better motivate users' knowledge sharing in a Q&A community than nonrepeatable ones. Second, the interplay of badge repeatability and level are crucial but has been mostly overlooked, despite their potential to shed a new light

[1] https://stackoverflow.com/help/what-are-badges, accessed on September 1, 2022

on the inconsistent results in prior studies. For example, Chen et al. (2019) suggest that bronze badges motivate people more than silver or gold badges do, but Cavusoglu et al. (2021) report that people are more motivated by gold and silver badges than bronze badges. These results imply the need to examine the effects of distinct badge levels, in conjunction with the repeatable versus nonrepeatable nature of badges. Third, theory-guided analyses and empirical tests of badge effects on people's knowledge sharing quality are lacking. Most prior research (Cavusoglu et al., 2021; Chen et al., 2022; Khansa et al., 2015) focuses on knowledge sharing effort that is measured by the number of posted answers. To mitigate these gaps, we investigate the differential effects of badge repeatability and levels more fully by considering both knowledge sharing effort and quality. In line with Safadi et al. (2021), we measure knowledge sharing quality by using the number of accepted answers provided by a user, mainly because "accepted answers, as denoted by the question author, signal that the answer provided a solution to their problem" (p. 759). We summarize some representative studies in Table 1, in comparison with our study, to convey the research gaps that motivate our investigation.

Table 1. Representative studies in comparison with our investigation.

Study	BR	BL	KS Effort	KS Quality
Anderson et al. (2013)	No	No	Yes	No
Beck et al. (2014)	No	No	No	Yes
Bhattacharyya et al. (2020)	Yes	No	No	No
Bornfeld & Rafaeli (2019)	No	No	No	No
Burtch et al. (2021)	No	No	No	No
Cavusoglu et al. (2021)	No	Yes	Yes	No
Chen et al. (2019)	No	Yes	Yes	No
Chen et al. (2022)	No	Yes	Yes	No
Gallus (2017)	No	No	Yes	No
Goes et al. (2016)	No	Yes	Yes	No
Kang (2022)	No	No	No	No
Khansa et al. (2015)	No	No	Yes	No
M. Zhang et al. (2020)	Yes	No	No	No
Richter et al. (2018)	No	No	Yes	No
Safadi et al. (2021)	No	No	No	Yes
Yanovsky et al. (2021)	No	Yes	No	No
Zhao et al. (2016)	No	No	Yes	No
Zimmerling et al. (2019)	No	No	No	No
This study	*Yes*	*Yes*	*Yes*	*Yes*

Note: BR = Badge Repeatability; BL = Badge Level; KS = Knowledge Sharing.

3. Theory and Hypotheses

How badge attainment motivates users can be analyzed with reinforcement theory (Skinner, 1953), positing that earning gamified awards can act as a social reinforcer to drive human behaviors (Bhattacharyya et al., 2020). This theory also suggests that gamified awards need to be carefully scheduled for reinforcement to take effect (Shen et al., 2019). Two fundamental but different award schedules are identified: continuous and intermittent (Richardson, 2013). With a continuous schedule, people receive the same award repeatedly when they perform desirable behaviors. To illustrate, awarding users with a particular badge every time they have answered a prespecified number of questions is an exemplary continuous award schedule. In contrast, with an intermittent (partial) schedule, people receive an award only part of the time. For example, awarding a user with a particular badge only the first time he or she has answered a specified number of questions is an example of an intermittent award schedule. Arguably, an intermittent award schedule could motivate human behaviors better than a continuous award schedule, due to the "award satiation" in which people no longer are attracted by a gamified award and thus its reinforcement effect decreases (Bhattacharyya et al., 2020; Gewirtz & Baer, 1958; Kahng et al., 2000).

We aim to examine the impacts of badge attainment on knowledge sharing, and thus develop hypotheses that center on two important measures: knowledge sharing effort and quality. Our dependent variable choices are in sync with reinforcement theory, suggesting that badges, as a common form of social reinforcer, can steer people's behaviors in a more frequent and stronger way. The behavioral frequency of reinforcement indicates a user's effort to share knowledge by answering others' questions after badge attainment. The behavioral strength of reinforcement reveals the quality of a user's provided answers after badge attainment.

Despite the explanatory utilities of reinforcement theory, it remains unclear how "award satiation" could occur in a Q&A community, especially when considering different badge levels. We then turn to attribution theory of motivation (Weiner, 2012), which suggests people are "naïve psychologist" who often derive explanations about the causes of events (e.g., earning badges) on the basis of internal versus external attributions (Kelley, 1973). Internal attribution entails a situation where people attribute the causes of an event

to factors internal to them, whereas external attribution refers to situations where people attribute events to external factors. Recent developments of this theory argue that people are more motivated by earning awards when making internal attributions that facilitate the linkage of award attainment and intrinsic motivation; however, when making external attributions to award attainment, people's intrinsic motivation (such as self-determination) may decrease and the motivational effects of gamified award is reduced (Zhao et al., 2016).

We anticipate that people are more likely to make internal attributions when earning nonrepeatable badges, but they are more likely to make external attributions when earning repeatable badges. For example, nonrepeatable badges in Stack Overflow are designed to encourage users to actively explore different activities through the implementation of an intermittent award schedule; i.e., awarding users only once for their first-time achievements. That is, nonrepeatable badges can help people establish internal attributions to badge attainment by informing them what activities can be performed in the online community only once. After attaining a nonrepeatable badge, users are not motivated by this badge, so they can self-determine whether or not to perform the badge-induced activity in the future. In contrast, repeatable badges are designed to keep user contribution at higher level and repeating same activities in the future through the implementation of a continuous award schedule; i.e., awarding users repeatedly for their recurrent achievements. In this case, user behaviors are largely driven by earning more repeatable badges, and therefore their self-determination suffers.

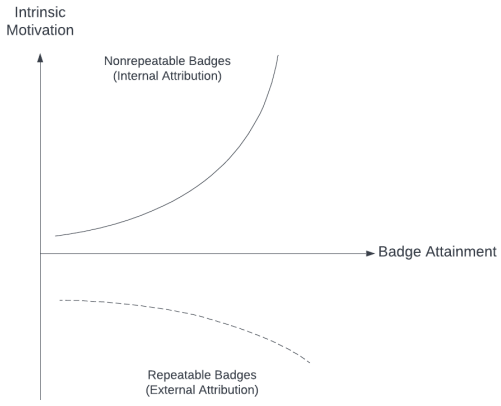

Figure 1. Predicted motivation of nonrepeatable versus repeatable badges.

Accordingly, awarding more nonrepeatable badges is likely to place users in the internal attribution territory where awarding more badges can strengthen people's self-determination. On the other hand, awarding more repeatable badges likely places people in the external attribution territory where their future knowledge sharing behaviors are externally regulated by earning badges repeatedly, and hence they may experience "award satiation" and become less motivated by badge attainment over time. Figure 1 illustrates the predicted motivation of nonrepeatable versus repeatable badges, in light of attribution theory of motivation. Specifically, we test the following hypothesis.

H1: Earning more nonrepeatable badges is associated with a higher level of (a) knowledge sharing effort and (b) knowledge sharing quality than earning more repeatable badges.

In addition to the quantity of badge attainment, badge level also can alter people's intrinsic motivation differently regarding badge repeatability. To illustrate, three levels of badges (i.e., bronze, silver, gold) are defined in Stack Overflow to reflect their increasing challenges. Earning higher levels of badges can motivate more knowledge sharing if earned badges can facilitate individuals' feeling of self-determination (Cavusoglu et al., 2021). In this light, if our conceptualization of nonrepeatable as internally attributed awards is accurate, we should anticipate an increasing effect of nonrepeatable badges, based on the advancement in the badge level (shown in Figure 2).

An explanation of this expectation is that earning higher level of nonrepeatable badges can fulfill people's needs for competence more fully. To illustrate, earning more nonrepeatable silver badges can provide useful feedback to inform users that they have developed an effective plan regarding how to invest their resources and time to get recognized in the community. In another word, nonrepeatable silver badges can make people feel more competent about how to contribute knowledge strategically, instead of merely exploring the community as encouraged by bronze badges. Similarly, earning nonrepeatable gold badges also helps inform users that they no longer aim for planning and are ready to get recognized by taking on more challenging activities in the community. The increased feeling of competence could enhance individuals' knowledge self-efficacy, which in turn, motivates their knowledge sharing behaviors. Therefore, we test the following hypothesis.

H2: For nonrepeatable badges, earning more high-level badges is associated with greater (a) knowledge sharing efforts and (b) knowledge sharing quality than earning low-level badges.

Conversely, if our conceptualization of repeatable badges as externally attributed awards is appropriate, we can expect the motivation of earning repeatable badges to decrease as their levels increase (shown in Figure 2). This is because earning a high-level, repeatable badge carries less informational value to satisfy self-determination needs, because a low-level badge (of the same badge type) also can be earned multiple times. To

illustrate, repeatedly earning a silver badge cannot effectively inform a user that he or she has advanced to a higher level and are ready to take on more challenging activities, because they still can earn the bronze badge (of the same badge type) repeatedly. We thus hypothesize the following.

H3: For repeatable badges, earning more high-level badges is associated with lower (a) knowledge sharing effort and (b) knowledge sharing quality than earning low-level badges.

Figure 2. Predicted motivation of different levels of nonrepeatable versus repeatable badges.

4. Study Context and Data

We study Stack Overflow, a major Q&A community for IT professionals and enthusiasts worldwide. Since its creation, Stack Overflow has implemented a badge award system "to teach new users how Stack Exchange works" and "to encourage activities that are positive to the community".[2] In essence, Stack Overflow awards users with badges for various knowledge sharing activities that include posting questions, answers, voting, and commenting.

We gathered data for the entire year of 2014, including badge awarding records, answer posts, voting activities, and a list of active users. To ensure all users are active during this time period, we exclude inactive users who registered their accounts after the start date of our sample (1/1/2014) and had last access date prior to the end date of the sample (12/31/2014), in line with prior research (Li et al., 2020). Like prior studies that examine knowledge sharing in Q&A communities (Chen et al., 2019; Kuang et al., 2019), our unit of analysis is the monthly behavioral data at the user level; e.g., a user i at a month t.

Two important measures of knowledge sharing are considered: knowledge sharing effort (*AnswerPosted*) and knowledge sharing quality (*AnswerAccpeted*). To analyze the impacts of badge repeatability and level on knowledge sharing, we created two sets of independent variables for our hypothesis tests. For H1, the independent variables are *Nonrepeatable* and *Repeatable*. For each badge, Stack Overflow provides a detailed badge description, including its requirement and an optional statement on whether or not it can be awarded to a user multiple times.[3] We followed the description of each badge and manually classified a badge as either repeatable badge or nonrepeatable badge. Figure 3 shows an example of repeatable badge.

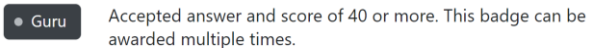

Figure 3. An example of repeatable badge.

For H2 and H3, independent variables are six types of badges separated by the combination of repeatability and level, including *NrBronze*, *NrSilver*, *Nrgold*, *ReBronze*, *ReSilver*, and *ReGold*. Table 2 presents our study design that indicates how badge repeatability can interplay with badge level.

Table 2. Our study design.

		Badge Repeatability	
		Nonrepeatable	Repeatable
Badge Level	Bronze	*NrBronze*	*ReBronze*
	Silver	*NrSilver*	*ReSilver*
	Gold	*Nrgold*	*ReGold*

Moreover, knowledge sharing may be affected by other factors related to community recognition, such as voting (Chen et al., 2019) and tenure (Khansa et al., 2015). Therefore, we also control these effects in the analyses, in addition to the effects of badge repeatability and level. Table 3 provides detailed descriptions of the variables used in the analyses.

Table 3. Descriptions of variables.

Variables	Description
Dependent Variables	
AnswerPosted	The total number of answers posted by a user during a month.
AnswerAccpeted	The total number of accepted answers posted by a user during a month.
Independent Variables	
Nonrepeatable	The total number of nonrepeatable badges earned by a user during a month.

[2] https://stackoverflow.com/help/what-are-badges, accessed on September 2, 2022.

[3] A detailed description of each badge can be accessed on the help page of badges (https://stackoverflow.com/help/badges). If a badge is repeatable, a statement "This badge can be awarded multiple times" is displayed on the badge description page; otherwise, a statement is not shown on the page.

Repeatable	The total number of repeatable badges earned by a user during a month.
NrBronze	The total number of nonrepeatable badges in bronze level earned by a user during a month.
NrSilver	The total number of nonrepeatable badges in silver level earned by a user during a month.
Nrgold	The total number of nonrepeatable badges in gold level earned by a user during a month.
ReBronze	The total number of repeatable badges in bronze level earned by a user during a month.
ReSilver	The total number of repeatable badges in silver level earned by a user during a month.
ReGold	The total number of repeatable badges in gold level earned by a user during a month.
Control Variables	
QueUpVote	The total number of question upvotes a user received during a month.
QueDownVote	The total number of question downvotes a user received during a month.
AnsUpVote	The total number of answer upvotes a user received during a month.
AnsDownVote	The total number of answer downvotes a user received during a month.
Tenure	The total number of months lasts until a month since the date a user joined the community.

In total, our data contains 14,325,396 observations for 1,193,783 unique users. Table 4 presents some summary statistics of the data. On average, users earned more repeatable badges than nonrepeatable badges, due to the repeatability nature. Higher-level badges were less frequent than lower-level ones, reflecting the level of difficulty. As shown in Table 4, the average number of silver or gold badges earned is significantly lower than those of bronze. Furthermore, users, on average, have more answers than accepted answers. These descriptive statistics provide preliminary evidence to support the validity of our data.

Table 4. Summary statistics of our sample.

Variable	Mean	SD	Min	Max
Nonrepeatable Badges Earned	.080	.385	0	30
Repeatable Badges Earned	.101	.563	0	203
Gold Badges Earned	.006	.087	0	17
Silver Badges Earned	.047	.302	0	102
Bronze Badges Earned	.128	.506	0	119
QueUpVote	.236	1.879	0	948
QueDownVote	.016	.221	0	46
AnsUpVote	.563	8.015	0	4,349
AnsDownVote	.014	.187	0	58
Tenure	23.504	15.204	0	77.100
AnswerPosted	.176	2.508	0	920
AnswerAccepted	.068	1.215	0	467

Notes: SD = Standard Deviation, Min = Minimum, Max = Maximum.

5. Empirical Analyses

To test H1 and quantify the respective impacts of nonrepeatable and repeatable badges, we employed a fixed-effects model to analyze the monthly panel data, which is specified as follows:

$$y_{it} = \beta_0 + \beta_1 \cdot Nonrepeatable_{it-1} + \beta_2 \cdot Repeatable_{it-1} + \beta_3 \cdot QueUpVote_{it-1} + \beta_4 \cdot QueDownVote_{it-1} + \beta_5 \cdot AnsUpVote_{it-1} + \beta_6 \cdot AnsDownVote_{it-1} + \beta_7 \cdot Tenure_{it-1} + \delta_i + \theta_t + \varepsilon_{it}, \quad (1)$$

where y_{it} represents the dependent variables, $AnswerPosted_{it}$ and $AnswerAccepted_{it}$, respectively. $Nonrepeatable_{it-1}$ and $Repeatable_{it-1}$ are the numbers of nonrepeatable and repeatable badges earned by a user i in the prior month *t-1*, correspondingly. $QueUpVote_{it-1}$, $QueDownVote_{it-1}$, $AnsUpVote_{it-1}$, $AnsDownVote_{it-1}$, and $Tenure_{it-1}$ are variables controlling for voting and tenure effects. δ_i and θ_t represent user and month level fixed effects, accordingly. All variables are log-transformed due to the high skewness.

As Table 5 indicates, the estimated coefficient of awarding nonrepeatable badges (β_1 = .060, p < .001) is greater than that of repeatable badges (β_2 = .004, p < .001) for knowledge sharing effort; the estimated coefficient of nonrepeatable badges (β_1 = .034, p < .001) is larger than that of repeatable badges (β_2 = .002, p < .001) for knowledge sharing quality too. Specifically, a 1% increase in the number of nonrepeatable badges awarded is associated with a .060% increase in the number of posted answers and a .034% increase in the number of accepted answers. However, a 1% increase of repeatable badges awarded is only associated with a .004% increase in the number of posted answers and a .002% increase in the number of accepted answers. These results offer preliminary evidence of differential effects between nonrepeatable and repeatable badges. We then use Wald test to examine whether the coefficient differences are significant. As we present in Table 6, the

coefficient differences between nonrepeatable and repeatable badges are statistically significant, in support of H1a and H1b, suggesting that nonrepeatable badges can have greater motivation effects on knowledge sharing than repeatable badges can.

Table 5. Comparative effects of nonrepeatable and repeatable badges.

	(1) KS Effort	(2) KS Quality
$Nonrepeatable_{it-1}$	.060***	.034***
	(.001)	(.001)
$Repeatable_{it-1}$	.004***	.002***
	(.001)	(.000)
$QueUpVote_{it-1}$	.009***	.005***
	(.001)	(.000)
$QueDownVote_{it-1}$	.027***	.016***
	(.001)	(.001)
$AnsUpVote_{it-1}$	.066***	.055***
	(.001)	(.001)
$AnsDownVote_{it-1}$	.113***	.088***
	(.003)	(.002)
$Tenure_{it-1}$	.013***	.009***
	(.001)	(.000)
R^2	.492	.522

Notes: KS = Knowledge Sharing; ***p < .001; **p < .01; *p < .05. Standard errors are in parentheses.

Table 6. Testing coefficient differences between nonrepeatable and repeatable badges.

Null Hypothesis	KS Effort χ^2 *Wald*	KS Quality χ^2 *Wald*
$Nonrepeatable_{it-1}$ - $Repeatable_{it-1}$ = 0	3106.6***	2122.0***

Notes: KS = Knowledge Sharing; ***p < .001; **p < .01; *p < .05.

To test H2 and H3, we performed another fixed-effects model to estimate the effects of six unique badge types by considering the interplay between badge repeatability and level. Our model is specified as the following:

$$\begin{aligned} y_{it} = \beta_0 + \beta_1 \cdot NrBronze_{it-1} + \beta_2 \\ \cdot NrSilver_{it-1} + \beta_3 \\ \cdot Nrgold_{it-1} + \beta_4 \\ \cdot ReBronze_{it-1} + \beta_5 \\ \cdot ReSilver_{it-1} + \beta_6 \\ \cdot ReGold_{it-1} + \beta_7 \\ \cdot QueDownVote_{it-1} + \beta_8 \\ \cdot AnsUpVote_{it-1} + \beta_9 \\ \cdot AnsDownVote_{it-1} + \beta_{10} \\ \cdot Tenure_{it-1} + \delta_i + \theta_t \\ + \varepsilon_{it} \end{aligned} \quad (2)$$

where y_{it} represents our two dependent variables, $AnswerPosted_{it}$ and $AnswerAccepted_{it}$. $NrBronze_{it-1}$, $NrSilver_{it-1}$, and $Nrgold_{it-1}$ are the number of nonrepeatable badges earned by a user i in bronze, silver, and gold level, correspondingly. $ReBronze_{it-1}$, $ReSilver_{it-1}$, and $Regold_{it-1}$ are the number of repeatable badges earned by a user i in bronze, silver, and gold level, respectively. Similar to equation (1), $QueUpVote_{it-1}$, $QueDownVote_{it-1}$, $AnsUpVote_{it-1}$, $AnsDownVote_{it-1}$, and $Tenure_{it-1}$ are the control variables.

Table 7 presents the estimated effects of badge levels on knowledge sharing under nonrepeatable or repeatable badges. For testing H2, we first examine the differential effects of badge levels according to nonrepeatable badges. For nonrepeatable badges, the estimated coefficient of awarding gold badges (β_3 = .171, p < .001) is greater than that of silver badges (β_2 = .103, p < .001), as well as that of bronze badges (β_1 = .057, p < .001), for knowledge sharing effort. Similarly, the estimated coefficient of awarding gold badges (β_3 = .165, p < .001) is larger than that of silver badges (β_2 = .085, p < .001), as well as that of bronze badges (β_1 = .031, p < .001), for knowledge sharing quality. Specifically, we notice that a 1% rise in the number of bronze, nonrepeatable badges earned can increase knowledge sharing effort by .057% and knowledge sharing quality by .031%. A 1% increase in the number of silver, nonrepeatable badges earned leads to a .103% increase in knowledge sharing effort and an .085% increase in knowledge sharing quality. In addition, a 1% increase in the number of gold, nonrepeatable badges earned leads to a .171% increase in knowledge sharing effort and a .165% increase in knowledge sharing quality. Together, these results indicate that, as the level of nonrepeatable badges increases, the effects are expected to increase. We then performed Wald test to detect if these increases in coefficient are significant. Table 8 shows that all coefficient differences are significant for each dependent variable, in support of H2a and H2b.

Table 7. Effects of different levels of repeatable badges.

	(1) KS Effort	(2) KS Quality
$NrGold_{it-1}$	.171***	.165***
	(.015)	(.012)
$NrSilver_{it-1}$	.103***	.085***
	(.005)	(.003)
$NrBronze_{it-1}$	.057***	.031***
	(.001)	(.001)
$ReGold_{it-1}$	−.006*	−.005**
	(.002)	(.002)
$ReSilver_{it-1}$	.005***	.002*
	(.001)	(.001)
$ReBronze_{it-1}$	.007***	.004***
	(.001)	(.001)
$QueUpVote_{it-1}$	.009***	.005***
	(.001)	(.000)
$QueDownVote_{it-1}$	.027***	.016***
	(.001)	(.001)
$AnsUpVote_{it-1}$	.064***	.054***
	(.001)	(.001)

$AnsDownVote_{it-1}$	.110***	.086***
	(.003)	(.002)
$Tenure_{it-1}$	.013***	.009***
	(.001)	(.000)
R^2	.488	.492

Notes: KS = Knowledge Sharing; ***p < .001; **p < .01; *p < .05. Standard errors are in parentheses.

Table 8. Testing coefficient differences for different levels of nonrepeatable badges.

Null Hypothesis	KS Effort χ^2 $Wald$	KS Quality χ^2 $Wald$
$NrSilver_{it-1}$ - $NrBronze_{it-1}$ = 0	102.4***	239.1***
$Nrgold_{it-1}$ - $NrSilver_{it-1}$ = 0	19.3***	43.8***

Notes: KS = Knowledge Sharing; ***p < .001; **p < .01; *p < .05.

To test H3, we examined the coefficient of each level for repeatable badges. As Table 7 indicates, for repeatable badges, the estimated coefficient of awarding gold badges (β_6 = -.006, p < .05) is greater than that of silver badges (β_5 = .005, p < .001), as well as that of bronze badges (β_4 = .007, p < .001), for knowledge sharing effort. Similarly, the estimated coefficient of awarding gold badges (β_6 = -.005, p < .01) is greater than that of silver badges (β_5 = .002, p < .05), as well as that of bronze badges (β_4 = .004, p < .001), for knowledge sharing quality. That is, a 1% rise in the number of repeatable bronze badges earned can increase knowledge sharing effort by .007% and knowledge sharing quality by .004%. Moreover, a 1% increase in the number of repeatable silver badges earned can only yield a .005% increase in knowledge sharing effort and .002% for knowledge sharing quality. Yet, a 1% increase in the number of repeatable gold badges earned can produce a .006% decrease in knowledge sharing effort and .005% decrease in knowledge sharing quality. That is, the effects of repeatable badges disappear and become negative when earning more gold-level badges. These results suggest that, as the level of repeatable badges increases, the motivational effects decrease. We also perform Wald tests to see if the effect differences are significant. As shown in Table 9, the coefficient differences are mostly significant across two dependent variables, except for the coefficient difference between bronze and silver badges for knowledge sharing effort. Thus, the data support H3b but partially support H3a.

Table 9. Testing coefficient differences for different levels of repeatable badges.

Null Hypothesis	KS Effort χ^2 $Wald$	KS Quality χ^2 $Wald$
$ReSilver_{it-1}$ - $ReBronze_{it-1}$ = 0	3.3 (p = .067)	7.4***
$Regold_{it-1}$ - $ReSilver_{it-1}$ = 0	16.5***	13.0***

Notes: KS = Knowledge Sharing; ***p < .001; **p < .01; *p < .05.

In addition, knowledge sharing effort and quality may be influenced by other variables, which may not be fully captured by our fixed-effects models. Therefore, the above models are likely to suffer omitted variable bias. To address this concern, we utilize lagged dependent variable models to control for the dependent variables measured from the prior time period. The results are consistent with our main results, even after controlling for lagged dependent variables. Thus, omitted variables bias should not be a major concern in our study. Due to page limit, the results of lagged dependent variable models are provided upon request.

6. Discussion

This study makes several research contributions. First, we analyze and empirically test how badge repeatability can influence users' knowledge sharing, which is crucial but seldom studied. Although Bhattacharyya et al. (2020) and M. Zhang et al. (2020) consider the concept of repeatability, they focus on a singular badge by comparing the first- and second-time badge attainment, before versus after. Instead, this study examines gamified award repeatability by directly comparing the number of nonrepeatable badges earned and that of repeatable badges, using a large-scale data set that contains different badge categories. It transcends previous research and reveals that badge repeatability can profoundly impact knowledge sharing in the online Q&A community.

Second, beyond the common interest in the effects of badge attainment on individuals' knowledge sharing effort, this study extends existing Q&A community research by providing theory-based analyses and empirical results regarding how both knowledge sharing effort and quality can be affected by badge attainment. Both quantity and quality are fundamentally important to users' knowledge sharing in a Q&A community, toward which gamified awards may have unintended consequences on different aspects of their contributions. In that regard, this study provides a fuller depiction of badge effectiveness and indicates that nonrepeatable badges can better motivate users than repeatable badges for knowledge sharing effort and quality.

Third, unlike most prior research that focuses on badge repeatability or level exclusively, we explore their combined effects. According to our results, badge repeatability determines whether earning higher-level badges can create a promoting or diminishing effect on users' knowledge sharing. As Figure 4 shows, users are more motivated for knowledge sharing by a higher-level badge only if this badge is awarded non-repeatedly. Interestingly, people become less motivated for knowledge sharing by higher-level badges if they can be awarded repeatedly (shown in Figure 5). Taken together,

these comparative findings offer a legitimate lens to interpret and dissect the inconsistent results in prior research and further provide empirical evidence to support attribution theory of motivation.

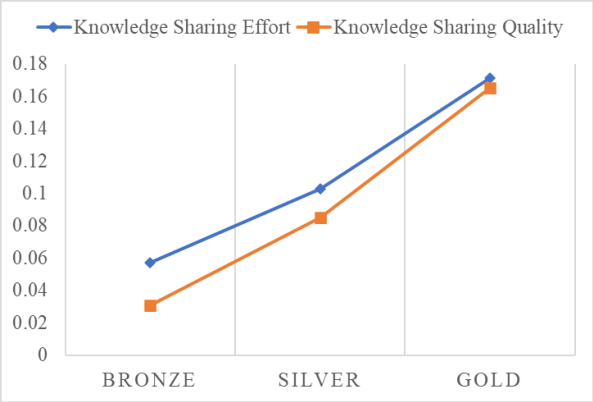

Figure 4. Coefficients of different levels of nonrepeatable badges.

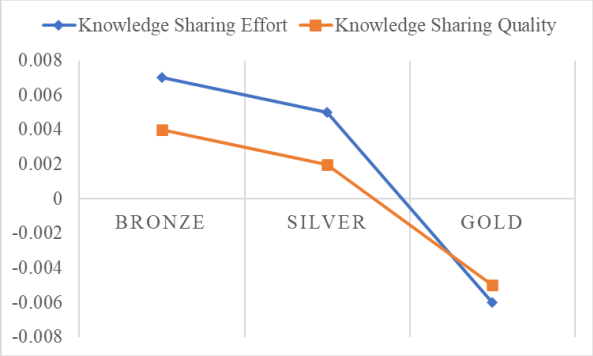

Figure 5. Coefficients of different levels of repeatable badges.

In addition, our study offers several insights for online Q&A community operators, developers, and managers regarding the design and implementation of badge award systems. First, our results can provide design guidelines for Q&A communities when introducing a new badge. For example, when designing a new badge, a Q&A community should emphasize how to recognize users' contributions by assessing if the badge can be attained non-repeatedly or repeatedly.

Our findings also caution Q&A communities to be mindful of how badge repeatability can interact with different badge levels to create joint effects. Specifically, designing challenges and difficulty levels in badges can be a viable approach to motivate user contributions only for nonrepeatable badges. In a related sense, communities should pay attention to the probable award satiation associated with repeatable badges. Particularly, the effect can become more prominent as the badge level increases. As our results show, earning more gold-level of repeated badges in effect reduces users' knowledge sharing in the online community. Therefore, online communities should consider more balancing approaches on how to design different types of badges to facilitate and foster desired user behaviors.

7. Conclusion and Limitation

As a point of departure from previous research, this study investigates the differential effects of badge repeatability and level on users' knowledge sharing effort and quality in Q&A communities. From the lens of reinforcement theory and attribution theory of motivation, we produce evidence suggesting the effectiveness of nonrepeatable badges over repeatable badges for motivating knowledge sharing behaviors.

While contributing to research and practice, this study has several limitations that indicate promising future research directions. For example, our study targets Stack Overflow that specializes in IT-related knowledge sharing. Continued research should examine the effects of badge repeatability and level in other Q&A communities, such as Reddit, to produce robust and generalizable results. In a related sense, our study uses monthly data in a one-year window. Future research can consider weekly data over a longer time period to assess the longitudinal effects. Also, this study focuses on badges, a common form of gamified awards, which is appropriate for its investigated intent. Future studies should consider other types of gamified awards, such as points and leaderboard, to further test whether the observed differential effects still exist. Moreover, the observed results imply effect causations, which can be subject to methodological constraints. Continued investigations can benefit from additional methods, such as controlled and field experimentations, to examine the effect causations more fully. Furthermore, future study can consider the interaction between nonrepeatable and repeatable badges as users can earn both types of badges simultaneously. In addition, knowledge sharing quality can also be measured in other, alternative ways (e.g., numbers of votes received, the ratio of answers accepted), so future studies will consider other variables indicative of knowledge sharing quality to gain a fuller understanding. Last but not least, this study only considers the direct effects of badges on user knowledge sharing, without explicating the underlying effect mechanisms. An important future research direction is to consider probable psychological mechanisms through which badge repeatability and level can affect people's knowledge sharing in online Q&A communities.

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