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Influences of Leaderboard Direction on Learning Performance and Satisfaction in Gamified E-Learning

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ABSTRACT

The fast-growing use of gamification in e-learning underscores its potential to enhance individuals' learning performance and experience. However, the mechanisms through which key gamification element influences people's learning remain unclear. This study addresses this gap by investigating how distinct leaderboard directions influence individual learning performance and satisfaction. We conduct a randomized experiment to examine these effects and explore the underlying mechanisms. Our results show that upward leaderboard improves learning performance and satisfaction by fostering learning effort and active exploration. In contrast, downward leaderboard enhances learning performance and satisfaction through self-efficacy and self-expansion. Interestingly, the effect of lateral leaderboards on learning satisfaction appears not associated with the development of personal meaning. This study contributes to current research and practice by providing important insights for effective gamified e-learning design, implementation, and use.

KEYWORDS

Gamified E-Learning, Leaderboard Direction, Learning Performance and Satisfaction, Social Comparison Theory, Aesthetic Experience

INTRODUCTION

E-learning has gained increasing popularity worldwide, partially due to the global COVID-19 pandemic and its subsequent impacts (Alqahtani & Rajkhan, 2020; Mehla et al., 2021). E-learning provides individuals with a learning "environment in which a single user interacts with technology and attempts to self-direct and complete a training course" (Santhanam et al., 2008, p. 28). Although e-learning supports flexible, contact-free environments, self-paced learning, and convenient access anytime and anywhere, its use might prompt diminished user experience, which results in technostress (Sethi et al., 2021), dissatisfaction (Abbas et al., 2023; Wan et al., 2012), or procrastination (N. Huang et al., 2021). To alleviate these drawbacks, e-learning platforms and applications have turned to gamification for solutions (Jayawardena et al., 2021). This shift is evident by the increasing use of gamification to enhance user satisfaction (J. Huang et al., 2022), enjoyment (Kaur et al., 2023), and

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playfulness (Wang et al., 2022), thereby fostering user adoptions and engagements. For example, Duolingo, a language training platform, features leaderboards (leagues), experience points, progress bars, and streaks to motivate users to complete more learning tasks.[1]

Although incorporating gamification, some platforms and applications might still fail to achieve their anticipated or full benefits of e-learning if gamification does not match the intended goal of e-learning to enhance individuals' learning performance and experience (Liu et al., 2017). Several studies consider gamified e-learning holistically and suggest that gamification can increase users' learning performance (Jurgelaitis et al., 2019; Özdener, 2018; Yildirim, 2017), but others assert that its use is not helpful (Hanus & Fox, 2015; Kwon & Özpolat, 2021). These inconsistent results might arise because a gamification object can be designed and conceived in different ways, and, as such, users are likely to respond distinctly.

Few efforts have been devoted to examining how different designs of a gamification object influence individual experiences in gamified e-learning. Using a leaderboard as an example, this frequently deployed gamification object conveys essential comparison feedback. The comparison direction arguably matters due to a person's tendency to concentrate only on segments within the leaderboard, instead of its entirety (Bai et al., 2021). Perhaps, this tendency reflects people's preference for reducing the complexity of feedback information by using categorical thinking (Festinger, 1954). As Santhanam et al. (2016) and Zhang et al. (2018) caution, user experience might differ depending on the social comparison references they use (e.g., better- versus poorer-performing peers). Such peer referencing implies that leaderboard directions (e.g., upward, downward, lateral) might influence people's performance and satisfaction in gamified e-learning.

In response to the limited research that analyzes and empirically tests the mechanisms through which distinct leaderboard directions might influence users, we first turn to social comparison motives—self-enhancement, self-improvement, and self-assessment (Diel et al., 2021)—as a lens for understanding these effects. For example, a downward leaderboard reveals least-performing others and peers immediately below a focal user, which could activate a self-enhancement motive that features people's prior success (e.g., How did I do?) and encourages them to conceive of greater action possibilities, assuming they feel able to successfully complete tasks relative to others (Martin et al., 2002). By displaying top leaders and better-performing others adjacent to a focal user, an upward leaderboard might instead promote a self-improvement motive that emphasizes future success (e.g., How can I do it better?) and thereby increases effort investments, as long as the user targets successful (superior) others as role models (Diel et al., 2021). A lateral leaderboard shows peers with comparable performance, immediately above or below a focal user; thus, it might evoke a self-assessment motive that centers on personal relevance and meaning (e.g., Is it relevant to me?). A lateral leaderboard could foster positive experiences through social comparisons by developing personal meaning, or "the extent to which an individual comes to understand the meaning of an activity" (Suh et al., 2017, p. 272), because users obtain accurate feedback about themselves relative to comparable others (Sedikides, 1993). These distinct motives can inform analyses of leaderboard direction effects, guide empirical examinations of how people conceive comparative information about reference peers and the resulting effects on their e-learning performance and satisfaction, and shed light on the underlying mechanisms through an appropriate theoretical lens.

In investigating the leaderboard as an important and prevalent gamification object, we aim to answer a fundamental research question: Do different leaderboard directions affect individuals' e-learning performance and satisfaction, and if so, how? We use social comparison theory (Festinger, 1954) as a foundation to conceptualize potentially distinct effects. In gauging e-learning performance and satisfaction, we recognize both instrumental and experiential outcomes (Dincelli & Chengalur-Smith, 2020; Kwon & Özpolat, 2021; Santhanam et al., 2016; Wan et al., 2012). According to the dual-outcome principle (Liu et al., 2017), instrumental outcomes manifest the main functions of a gamified e-learning system, and experiential outcomes reflect users' experiential values (Liu et al., 2017). Toward that end, learning performance constitutes a principal instrumental outcome, and satisfaction represents a crucial experiential outcome (Dincelli & Chengalur-Smith, 2020). Both are central to users' meaningful engagement, or the extent to which the use of gamified e-learning helps them achieve "the dual goals of instrumental and experiential outcomes" (Liu et al., 2017, p. 1011), which are indispensable for successful gamified e-learning.

To answer this fundamental research question, we develop several hypotheses and test them in a randomized experiment in which we manipulate leaderboard direction. For instrumental outcomes, the use of a leaderboard might enhance people's e-learning performance, potentially through different mechanisms. To illustrate, a downward leaderboard enhances e-learning performance through self-efficacy, or the degree to which people believe they have the ability to perform activities and tasks (Bandura, 1977). An upward leaderboard improves performance through increased learning effort. For experiential outcomes, an upward leaderboard might enhance people's e-learning satisfaction through active discovery, while a downward leaderboard does so through self-expansion. A lateral leaderboard directly improves satisfaction, without establishing personal meaning first.

This study makes three important theoretical contributions. First, beyond a well-recognized self-improvement effect by which individuals exhibit "a unidirectional drive upward" when they engage in social comparisons (Festinger, 1954), we provide empirical evidence of an intriguing phenomenon, by which a downward leaderboard also appears effective for motivating people to achieve greater e-learning performance. Our results add to social comparison theory by revealing that, in addition to upward comparisons, downward comparisons enhance users' performance, whereas lateral comparisons seem effective mainly for improving their satisfaction. Second, this study explores distinct motivational mechanisms that can be effectuated by different leaderboard directions. Our theory-guided analyses and empirical results shed new light on how leaderboards can evoke desirable e-learning outcomes, both instrumental and experiential. Third, our findings contribute to extant global information management literature by providing insights into how gamification can promote desirable user behaviors and satisfaction across diverse cultures and technological contexts such as e-learning (Abbas et al., 2023; Dolmark et al., 2022), employee security training (Ifinedo et al., 2022), organizational knowledge sharing (Mutambik et al., 2023; Rahman et al., 2022), telework (Fuhrer, 2023; Van Slyke et al., 2022), and team building (Chang et al., 2023).

The remainder of this article is organized as follows. In section 2 (Literature Review), we review several related streams of research and specify the gaps we seek to address. Section 3 (Theoretical Foundation) describes the theoretical foundation for conceptualizing effects of distinct leaderboard directions. Building on this foundation, we then develop several hypotheses in section 4 (Hypotheses) to explicate how different leaderboard directions likely influence people's e-learning performance and satisfaction. We provide details of our experimental design and data collection in section 5 (Study Design), followed by important key results in section 6 (Analyses and Results). After discussing some important implications for research and practice in section 7 (Discussion), we conclude in section 8 (Conclusion and Future Research Directions) with a summary and several promising research directions.

LITERATURE REVIEW

The use of gamification is not a universal solution for enhancing e-learning, because game playing might create negative impacts on individuals (Shin & Ahn, 2013). Some comparisons of traditional and gamified e-learning (De-Marcos et al., 2016; Jurgelaitis et al., 2019; Özdener, 2018; Park et al., 2019; Tenório et al., 2016; Yildirim, 2017) show that users in gamified e-learning attain better performance, but several other studies (Christy & Fox, 2014; Dincelli & Chengalur-Smith, 2020; Hanus & Fox, 2015; Kwon & Özpolat, 2021; Kyewski & Krämer, 2018; Mekler et al., 2017) question whether gamified e-learning affects knowledge acquisition, performance, satisfaction, or overall experience positively. In efforts to analyze why the use of gamification may be effective in some but not all scenarios, researchers attempt to identify key factors that pertain to individual users, gamification objects, or gamification mechanics. These research streams inform our study.

Individual Factors

The differential effects of gamified e-learning on users' learning outcomes could be attributed to individual factors that might enhance or inhibit its influences, such as learning style and personality traits (Buckley & Doyle, 2017), achievement (Sanchez et al., 2020), employment status (Tsay et al., 2018), educational background (Legaki et al., 2020), or attitudes (Landers & Armstrong, 2017). Not all users perform better in gamified e-learning settings. For example, Buckley and Doyle (2017) argue that extraverted people with sequential learning styles exhibit more positive perceptions, engagement, and performances in gamified e-learning, whereas those with an active learning style and conscientiousness are less motivated by its use. Gamified e-learning also seems more effective for motivating users with higher rather than lower prior achievements (Sanchez et al., 2020).

The mediating roles of individual factors might explain how the use of gamified e-learning affects users' learning performance and satisfaction. For example, extant literature (Shin, 2017, 2022) highlights the mediating roles of affordances in influencing how usability impacts the learnability in e-learning context and playability in game settings. Silic and Lowry (2020) draw on flow theory to study how a person's perceived ease of use affects his or her intention to use gamified e-learning; they identify several mediating factors that include perceived intrinsic usefulness, curiosity, control, and challenge. Hanus and Fox (2015) report that the use of gamified e-learning negatively affects people's intrinsic motivation for learning, which then dampens their learning performance. In addition to noting the significance of individual factors, this research stream also acknowledges potential indirect effects on users' performance and satisfaction.

Gamification Objects

Research on gamification objects, "the basic building blocks of a gamified system" (Liu et al., 2017, p. 1013), also is closely related to our study. These objects can shape users' sensory and cognitive experiences, which in turn determine whether, and how, gamified e-learning can be leveraged effectively (Liu et al., 2017). Several important gamification objects are identified, such as a three-dimensional virtual environment (Shin et al., 2013), virtual reality (Shin, 2017), animation (Shin & Park, 2019), second screen (Shin et al., 2016), leaderboard (Amo et al., 2020; Bai et al., 2021; Christy & Fox, 2014; Landers et al., 2017; Leung et al., 2023), points (Attali & Arieli-Attali, 2015), badges (Kyewski & Krämer, 2018), puzzles (J. Huang et al., 2022), and narrative or story (Dincelli & Chengalur-Smith, 2020; Landers & Armstrong, 2017; Sailer & Homner, 2020). Although gamification objects seemingly should influence people's learning outcomes positively, several researchers argue that not all objects do so effectively. For example, Attali and Arieli-Attali (2015) study adult and teenaged users, and report that the use of points does not affect their learning performance. According to Kyewski and Krämer (2018), the use of badges does not increase individuals' intrinsic motivations, active participation, or learning performance, relative to a control group that has no gamification objects. Drawing on goal-setting theory, Landers et al. (2017) assert that people supported by a leaderboard exhibit e-learning performance comparable to that of people who set a difficult goal for themselves. In general, gamification objects seem to affect people's e-learning performance, toward which theory-guided analyses are essential but lacking.

Gamification Mechanics

Liu et al. (2017) describe gamification mechanics as "rules [or designs] that govern the interaction between users and game objects" (p. 1014). Such mechanics can shape user perceptions and experiences. A notable example mechanism is the feedback design, which then informs how people conceive of and interpret their current situation or standing, especially in comparison with peers (Tenório et al., 2016). In their study of competitive feedback designs, Santhanam et al. (2016)

assert that people receiving positive feedback, in comparison with lesser-skilled others, achieve greater e-learning performance than if the comparison involves higher- or equally skilled others. Yet some comparative studies of competitive versus cooperative feedback designs report no significant differences in e-learning performance (Dindar et al., 2021; Jagušt et al., 2018). The collective results suggest the importance of feedback design, which could explain the effectiveness of gamified e-learning, because people tend to conceive feedback information differently and therefore exhibit heterogeneous outcomes.

Thus, it is crucial to examine how different feedback designs of an important gamification object can affect users' performance and satisfaction in gamified e-learning. Zainuddin et al. (2020) consider three competitive, gamified feedback designs (SpaceRaces, leaderboard, and scoreboard), and report effects that vary across them. Christy and Fox (2014) consider gender and compare the effects of female- and male-dominated leaderboard designs on users' e-learning performance. Another proposition argues that e-learning engagement and performance differ between relative and absolute leaderboard designs, according to relatedness concepts. Whereas Ortiz-Rojas et al. (2019) report that neither relative nor absolute leaderboard designs increase people's learning performance, Bai et al. (2021) find greater performance by people with higher rankings in a relative leaderboard. Furthermore, Leung et al. (2022) suggest that personal and social comparison feedback interacts with users' goal orientation to jointly determine e-learning engagement and efficiency. Overall, this research stream suggests that feedback designs might determine the effectiveness of gamified e-learning, due to users' tendency to conceive distinct designs differently and thus behave heterogeneously in response to them (Schöbel et al., 2020).

Gap Analysis

The preceding review reveals two important research gaps. First, despite the efforts to analyze the impacts of gamification objects, few studies examine distinct feedback designs for a particular gamification object, such as a leaderboard. In particular, the respective effects on e-learning performance and satisfaction remain unclear. As an important and prevalent gamification object, a leaderboard has different designs for conveying comparison information to users. As a result, people's behaviors likely vary with the leaderboard's design, such as its direction, which informs their comprehension and interpretation of the comparison information displayed (Leung et al., 2023; Zhang et al., 2018). Several studies (Bai et al., 2021; Christy & Fox, 2014; Ortiz-Rojas et al., 2019) acknowledge that how people make sense of a leaderboard is important, but the precise effects of distinct leaderboard directions—upward, lateral, and downward—on users' e-learning performance and satisfaction have not been adequately investigated.

Second, leaderboard directions might result in desirable but distinct learning outcomes. However, insights into the mechanisms underlying the effects of different leaderboard directions are lacking. We conjecture that three self-evaluation motives are relevant and important for explaining how different leaderboard directions might affect learning outcomes (both instrumental and experiential): self-enhancement, self-improvement, or self-assessment. In this effort, our study responds to the call regarding "more theory-guided empirical research is needed to work toward a comprehensive theoretical framework with clearly defined components that describes precise mechanisms by which gamification can affect specific learning processes and outcomes" (Sailer & Homner, 2020, pp. 106-107). We summarize some representative gamified e-learning studies in table 9 located in the appendix, which motivate our theorizing and convey how this study differs from previous research and contributes to existing literature.

THEORETICAL FOUNDATION

Social comparison theory (Festinger, 1954) provides a legitimate lens for conceptualizing the effects of different leaderboard directions on individuals' e-learning performance and satisfaction.

Social comparisons entail the "process of thinking about information about one or more other people in relation to the self" (Wood, 1996, pp. 520-521), which then affects users' feelings and behaviors, due to their tendency to evaluate themselves relative to others. In line with this theoretical anchor, leaderboards can facilitate social comparisons by providing continual feedback on user performance, which serves as a confirmation and self-evaluation to enhance satisfaction and thus affect user intention to engage in e-learning positively (Shin et al., 2013). The direction of social comparison is crucial and can facilitate distinct self-evaluation motives (Taylor et al., 1995), which in turn influence individuals' feelings and behaviors differently (Dijkstra et al., 2008). As Festinger (1954) indicates, social comparisons can proceed in upward, lateral, or downward directions. For example, people compare themselves with better-performing others in upward comparisons, and with those of lower performance in downward comparisons. In addition, lateral comparisons entail comparisons with comparably performing (i.e., similar) peers. These comparison directions might influence how a person feels and behaves in gamified e-learning, and could vary in their underlying self-evaluation motive, such as self-enhancement, self-improvement, or self-assessment (Diel et al., 2021; Taylor et al., 1995; Zhang et al., 2018).

Downward Comparisons and Self-Enhancement

Downward comparisons can shape a person's positive self-conception by directing his or her attention to comparison feedback that promotes favorable inferences, while avoiding information that conveys unfavorable insinuations (Wood, 1996). Such comparisons provide a viable means to facilitate self-enhancement, congruent with people's "desire to enhance the positivity of their self-conceptions or protect the self from negative information" (Sedikides, 1993, p. 318). According to a proxy model of social comparison, self-enhancement motivates learning performance through the development of self-efficacy about each person's ability to perform tasks successfully (Blanton et al., 1999; Martin et al., 2002; O'Mara & Gaertner, 2017; Wheeler et al., 1997). This reasoning implies that a downward leaderboard might help people perform better by making them understand how to visualize their abilities to achieve desirable outcomes, as manifested by their prior, superior performance conveyed by the leaderboard, in comparison with poorer-performing peers.

The positive effects of downward comparisons rely on whether the feedback information emphasizes their prior success and contributes to their self-enhancement (Wills, 1981). As Buunk et al. (1990) explain, in comparisons with poorer-performing others, people become happier if the comparison helps them develop a sense that "you are not as badly off as everyone" and avoid the conception that "it is possible for you to get worse" (p. 1239). These two criteria resonate with the intrinsic features of downward leaderboards, which highlight others' inferior performance relative to the focal user's current rank (score) and mitigate the likelihood of focusing on better-performing peers who likely raise concerns about the focal user getting worse in the future. A principal tenet is that a downward leaderboard stresses users' prior success and superior outcomes, without prompting concerns about their future performance. The conveyed feedback emphasizes prior, desirable outcomes, which makes people more confident, while distancing them from worrisome threats of worse performance in the future that can cause such fear or contempt (Buunk et al., 2005; Smith, 2000). As a result, a downward leaderboard should make people feel better and more satisfied.

Upward Comparisons and Self-Improvement

Self-improvement entails a person's desire to improve competence and performance by setting higher standards or goals (Taylor et al., 1995). Unlike self-enhancement that emphasizes people's previous task successes, self-improvement centers on how they can perform better and achieve more in the (near) future. This motive also can enhance a person's performance by motivating him or her to recognize improvement potentials and strive to achieve them (Sedikides & Hepper, 2009). According to social comparison theory, comparisons with others who have achieved superior performance can reveal these improvement potentials. Upward comparisons thus might increase people's task

Table 1. Proposed effect mechanisms of distinct leaderboard directions

Leaderboard Direction	Effect Mechanism for Performance	Effect Mechanism for Satisfaction
Downward	Self-efficacy	Prior success
Upward	Effort investment	Future success
Lateral	No effect	Personal meaning (relevance)

performance by encouraging them to set higher standards that "motivate efforts towards these new and more challenging goals" (Blanton et al., 1999, p. 421).

The positive effects of upward comparisons are contingent on whether the comparison information implies their future success, with the assumption that they obtain self-improvement (Wills, 1981). For example, if the comparison involves marginally better-performing peers, people likely gain a sense that "it is possible for me to be better than I am" instead of feeling as if "I am not as well off as others" (Buunk et al., 1990, p. 1239). In support of this reasoning, an upward leaderboard grants people the ability to benchmark themselves against inspiring peers who are atop the leaderboard, as well as those within reach of their current ranks or scores. A typical, upward leaderboard in gamification settings showcases top performers and peers immediately above a focal user, which prompts thoughts about the feasibility of future success. With this design, a user's comparison goal appears more achievable, because the leaderboard displays the difference between the focal user and adjacent, better-performing reference peers. This design rationale is congruent with previous research (Buunk et al., 2005; Smith, 2000) that recommends prompting upward comparisons in educational contexts to evoke users' positive feelings (e.g., hope, optimism, admiration), via their observations of suitable peers who give them a sense of reachable probability of future success. Thus, people should feel better and become more satisfied, due to the inspiring feedback that illuminates future success possibilities rather than disappointing prior performance, which could create negative feelings (Bruchmann, 2017; Collins, 1996; Dijkstra et al., 2008).

Lateral Comparisons and Self-Assessment

Lateral comparisons can fulfill a person's need for self-assessment (Taylor et al., 1995), such that he or she seeks relevant and meaningful self-evaluations (Sedikides, 1993). Such feedback focuses on users themselves instead of comparative others (Dijkstra et al., 2008) and convey no clear comparative information about status differences that could motivate people to change their behaviors (Taylor et al., 1995). In displaying current ranks or scores of peers with comparable performance, a lateral leaderboard should help people gain relevant, meaningful information for their own self-appraisals, rather than revealing their ability and performance improvement potentials in comparison with others. It stresses self–other similarity, instead of self–other performance discrepancies. As a result, the use of a lateral leaderboard might not enhance people's performance significantly, but by facilitating their fulfilling self-assessment desire, it makes them more satisfied. As an essential precursor of satisfaction enhancement, lateral comparisons would need to inject a sense of personal meaning, so users can perceive that the comparisons adjust dynamically, reflecting their skills and abilities (Diel et al., 2021; Santhanam et al., 2016; Taylor et al., 1995). This reasoning is congruent with a unique feature of lateral leaderboards: People consider comparably performing peers only, which may make them more satisfied with their e-learning experience than if no such gamification mechanism exists. Table 1 summarizes our reasoning about how distinct leaderboard directions affect e-learning performance and satisfaction through different effect mechanisms.

HYPOTHESES

We consider three leaderboard directions: upward, downward, and lateral. We predict that these different leaderboard directions affect people's e-learning performance and satisfaction, relative to a baseline without any leaderboard. Moreover, we explicate the underlying effect mechanisms of the respective leaderboard directions and test them empirically.

Effects of Different Leaderboard Directions on E-Learning Performance

Drawing from our theoretical foundation, we conjecture that upward and downward leaderboards promote users' self-efficacy and effort investment, respectively, by facilitating essential motivations for behavioral changes. Self-efficacy can be established by vicarious experiences and persuasion (Bandura, 1977). We anticipate that a downward leaderboard elevates e-learning self-efficacy in two ways. First, it emphasizes poorer-performing others and hence could promote vicarious experiences that make users more confident about their ability and competence. Second, a downward leaderboard places a focal user on the top of the display, so the user likely recognizes and becomes convinced of his or her ability and maintains a positive self-image. This effect is especially prominent in online settings where people often exhibit strong self-presentation desires (Kim et al., 2012). Therefore, we predict that a downward leaderboard induces greater confidence about abilities to perform e-learning tasks, which boosts performance.

A person's effort investment also can be elevated by "motivational pushing" (Diel et al., 2021). An upward leaderboard can "push" people by placing them at the bottom of the display, such that they clearly sense the future improvement potential, as exemplified by best- and better-performing peers. They likely invest more efforts if they believe these efforts will enable them to achieve better performance (Diel et al., 2021). With an upward leaderboard, users pay attention to better-performing others and then reevaluate themselves and set higher performance goals, which should encourage more future effort than would be the case with no leaderboard. Finally, a lateral leaderboard has little effect on e-learning self-efficacy or effort investment; it might not be associated with greater e-learning performance, compared with no leaderboard. When users direct their attention to comparably performing peers, they likely cannot effectively gauge their learning ability or identify future improvement potentials. Therefore, we hypothesize:

H1: Compared with no leaderboard, the use of a (a) downward or (b) upward leaderboard enhances people's e-learning performance, but (c) a lateral leaderboard cannot.

Meanwhile, a downward leaderboard might enhance individuals' e-learning performance by increasing their perceived capacities to complete learning tasks (Kim et al., 2012), in line with a probable mediation role of e-learning self-efficacy. Self-efficacy generally has a positive effect on knowledge acquisition (Wan et al., 2012). A downward leaderboard could contribute to perceived e-learning self-efficacy, as comparisons with poorer-performing others should increase the focal user's perceived ability to complete learning tasks, through vicarious experiences and succinct, visual persuasion (Bandura, 1977). We predict that it increases people's e-learning performance by enhancing e-learning self-efficacy.

H2: Compared with no leaderboard, the use of a downward leaderboard enhances people's e-learning performance through greater e-learning self-efficacy.

An upward leaderboard also can motivate e-learning performance by encouraging more investments in effort to fulfill self-improvement desires. This effect mechanism suggests a mediating role of learning effort, manifested by the amount of time users spent on learning activities (Everaert et al., 2017). By paying attention to best- and better-performing others, the user likely feels "pushed" by a recognition of others' success and superior performance. Such observations of superior performance by others, in turn, may motivate people to set higher goals and invest more effort in achieving them (Diel et al., 2021). We thus test the following hypothesis:

H3: Compared with no leaderboard, the use of an upward leaderboard enhances people's e-learning performance through greater learning effort.

Effects of Leaderboard Directions on E-Learning Satisfaction

Our theoretical foundation suggests general effects of a leaderboard on satisfaction, regardless of its directions. Yet the underlying mechanism might differ. Both Dijkstra et al. (2008) and Wills (1981) argue that downward comparisons enhance learning satisfaction, because people notice poorer-performing others in comparison and develop a sense of self that reflects their own prior performance and success. The performance feedback revealed and highlighted by a downward leaderboard should boost users' self-confidence and increase their satisfaction with e-learning.

An upward leaderboard also might enhance people's e-learning satisfaction if they develop a sense of self by proactively seeking greater challenges and future successes (Buunk et al., 1990, 2005). Thus users might set future goals based on their observations of top- and better-performing others, who provide comparison feedback about achievable future performance goals, as well as "hope and inspiration, and increase the motivation to improve oneself in the future" (Wolff et al., 2018, p. 880). When users set goals to move up in the leaderboard, they are less likely to view their relatively lower prior outcomes as hindrances. Instead, in internalizing the comparison information, they set goals for self-improvement. As a result, they might become more satisfied than without a leaderboard.

Finally, a lateral leaderboard helps users obtain self-relevant feedback. Personally relevant, meaningful comparisons are important means to mitigate negative experiences (Santhanam et al., 2016). Because a lateral leaderboard enables users to focus on similar peers, they might be less likely to lose interest in learning, as can occur due to a sense of inequity in social comparisons (Cohen-Charash & Mueller, 2007). This reasoning is in line with prior research that suggests people enjoy game settings more when they consider comparable competitors (Liu et al., 2013; Santhanam et al., 2016). We hence hypothesize:

H4: Compared with no leaderboard, the use of a (a) downward, (b) upward, or (c) lateral leaderboard increases people's e-learning satisfaction.

We also anticipate indirect effects through which leaderboard direction might enhance people's e-learning satisfaction by establishing a sense of self through social comparisons (e.g., prior success, future success, personal meaning). People can conceive a sense of self through aesthetic experience (Jennings, 2000; Suh et al., 2017). Suh et al. (2017) describe aesthetic experience (AE) as the extent to which people feel a sense of self in interactions with a technology artifact. In gamified e-learning, users can benefit from the use of gamification by reflecting on what they have learned and how their self-growth has been enhanced, instead of focusing solely on game-specific experiences, such as enjoyment and immersion (Suh et al., 2017). In general, AE can be established via self-expansion, active discovery, or personal meaning. We leverage these means to scrutinize distinct effects of different leaderboard directions on individuals' e-learning satisfaction. In particular, a downward leaderboard can promote users' sense of self-expansion, or "the extent to which they sense an expanded self with information that broadens their perspective" (Suh et al., 2017, p. 272), because it emphasizes prior success in outperforming others. Taylor et al. (1995) indicate that downward comparisons "construe feedback in the most positive light possible, amplifying successes and minimizing failures" (p. 1278), which should encourage self-expansion by providing evidence that their ability already has increased, leaving the users more satisfied. Therefore, we hypothesize:

H5: Compared with no leaderboard, the use of a downward leaderboard increases people's e-learning satisfaction through enhanced self-expansion.

Active discovery instead pertains to how a person feels about "actively seeking answers or resolutions to cognitive challenges to achieve his or her personal goals" (Suh et al., 2017, p. 272). An upward leaderboard can promote active discovery, because it stresses best- and better-performing peers, such that it issues a challenge, to achieve future success by outperforming them. As Taylor et al. (1995) explain, upward comparisons help people recognize "useful models on whom to pattern one's behavior" (p. 1279). An upward leaderboard thus provides role models, a challenge-seeking inspiration, and a strong goal-setting mindset. As a result, users could feel more satisfied than if no leaderboard existed. We test the following hypothesis:

H6: Compared with no leaderboard, the use of an upward leaderboard increases people's e-learning satisfaction through improved active discovery.

The use of a lateral leaderboard might enhance users' e-learning satisfaction through increased personal meaning. For example, by deemphasizing direct competitions and social comparisons, a lateral leaderboard can foster a sense of self progress and accomplishment, which should improve users' experiences. When people pay attention to their own improvement and growth by comparing similar users, instead of outperforming others, they can sense and relate to the progress in a way that is meaningful for their own performance. In addition, the lateral leaderboard offers a visual representation of users' progress over time throughout the learning process, which promotes a sense of personal investment and encourages users to take ownership of the learning journey. Finally, as users progress and earn points, the leaderboard reveals their improved rank relative to their previous performance accordingly, which helps sustain their progress and creates a sense of personal meaning and accomplishment. Jointly, these effects can result in increased e-learning satisfaction. We therefore test the following hypothesis:

H7: Compared with no leaderboard, the use of a lateral leaderboard increases people's e-learning satisfaction through increased personal meaning.

STUDY DESIGN

Participants

We targeted undergraduate students who were enrolled in an introductory business course at a major university in the United States. This participant pool is appropriate for our research objective and offers two advantages. First, universities have increasingly switched to online learning amid the global COVID-19 pandemic, so these participants are familiar with e-learning and can provide realistic, evaluative responses. Second, our participants, sophomore or junior students, are interested in data mining and have little prior knowledge about it, which helps reduce the potential confounds of prior knowledge, lack of interest, or topic familiarity (Santhanam et al., 2016). Participation in the study was voluntary, with all participants receiving an equal monetary compensation for their time and effort upon completion, irrespective of their actual performance in the study.

Gamified E-Learning Application

The gamified e-learning application includes both learning and assessment activities. The learning materials and assessment questions were adapted from an existing introductory data mining course at the studied university. The primary gamification design element utilized in the study is a leaderboard. To facilitate gamification, we also implemented a 90-second timer to make each participant aware of the time he or she spent answering questions in the experiment. The timer length was determined in consultation with experienced instructors who teach introductory data mining courses and use multiple-choice questions to assess students' learning. This timer not only helps participants keep track of the amount of time they spent on each question but also serves as a source of bonus points to construct the leaderboard in the experiment. Table 10, located in the appendix, illustrates gamification designs (leaderboard directions), each corresponding to a treatment condition in the experiment, whereas table 11, located in the appendix, provides exemplary learning topic and assessment questions.

Experimental Design

We adopted a randomized design that includes one control (non-gamified) and three treatment (gamified) conditions that feature distinct leaderboard directions. To reduce the potential for self-selection bias, participants were randomly assigned to an experimental condition upon their arrival. Although random assignment is commonly used in experimental studies as a means to reduce the impact of confounding factors, we recognize that additional factors need to be considered by future research, which we discuss in a later section. Each participant used the designated gamified application to learn about six introductory data mining topics in a predefined order: (1) overview of data mining, (2) common techniques and applications, (3) supervised and unsupervised learning, (4) classification analysis, (5) classification process, and (6) evaluation metrics. Participants were instructed to learn as much as they could in each module and then answer three multiple-choice questions about that topic. Table 11, located in the appendix, provides examples of learning topics and multiple-choice questions.

Unlike those in the control condition, participants in each treatment condition saw a real-time leaderboard, constructed and updated immediately after they answered each question. The leaderboard displays each participant's total score. If they answered a question correctly, participants received 100 points, in addition to the efficiency bonus points that were determined by the time remaining on the 90-second timer. They received a score of 0 if their answers were incorrect. A time efficiency score is common on e-learning platforms that calculate users' scores, then assign them ranks in leaderboard updates.[2] After participants answered each question, the leaderboard immediately displayed their current total score, along with the scores of other participants, in ranked order. All participants answered 18 questions and those in the treatment conditions saw the leaderboard 18 times. Because participants entered the experiment at different timepoints, the leaderboard was constructed asynchronously.

Experimental Procedure

Guided by existing e-learning literature (e.g., Shin & Park, 2019), we conducted a between-subjects experiment to test our hypotheses. Before the experiment, two experienced information systems researchers helped fine-tune the gamified e-learning application, surveyed items, and completed a data collection procedure. A pilot study was conducted with 26 voluntary participants to validate the experimental application, confirm participants' ability to follow the experimental flow, complete learning tasks, and provide evaluative feedback that is correctly captured by the experimental application. This pilot also helped us understand the amount of time likely needed to complete the entire experiment. We included these participants in the leaderboard to mitigate the cold start problem, but excluded them from the subsequent analyses.[3] We present the overall experimental procedure in figure 2, located in the appendix.

With the assistance of several instructors, we distributed a virtual invitation containing a hyperlink to our e-learning application. This invitation describes the study's purpose and the tasks to be performed. When they clicked on the link, participants were directed to an introduction page that contains a consent cover letter, experimental details, learning topics, and tasks. After consenting to participate online voluntarily, each participant was randomly assigned to an experimental condition and received the relevant instructions, which explain the learning topics and their order, as well as the required tasks. In each treatment condition, participants were explicitly informed of the leaderboard direction they would see and how their score would be calculated. Then, at the start of the actual experiment, a welcome page greeted participants and confirmed their awareness of the assigned experimental condition. They received the learning materials for each topic and answered three multiple-choice questions about that topic. After answering all 18 questions, participants in the treatment conditions answered a manipulation check question, as well.[4] Finally, all participants responded to the survey questions.

Measurements

We used both quantitative variables and surveyed constructs to test the hypotheses. The system recorded the measures for the quantitative variables. To gauge e-learning performance, we relied on the number of questions each participant answered correctly on topics 2–6, together with time efficiency scores.[5] Learning effort was assessed by the total time spent viewing the learning materials for topics 2–6. The survey items, adapted from previously validated scales, were adjusted to fit the study's context and participants. E-learning satisfaction was measured with items from Hu & Hui (2012) and Nelson et al. (2005). We operationalized active discovery, personal meaning, and self-expansion with three items each from Suh et al. (2017). In addition, we also controlled for participants' learning orientation, as well as avoidance and approach performance orientations, which might have confounding effects on their e-learning performance and satisfaction (Santhanam et al., 2016; Wan et al., 2012). All question items employed seven-point Likert scales (1 = "strongly disagree" and 7 = "strongly agree"), as listed in the appendix (List of Measurement Items and Their Sources).

ANALYSES AND RESULTS

Among the 258 participants who took part in the experiment, 21 did not complete the survey, and an additional 23 failed the manipulation check and therefore were excluded. The sample of 214 participants represents a completion rate of 82.95%. The control, upward, downward, and lateral conditions have 54, 50, 50, and 60 participants, respectively. Table 2 provides some descriptive statistics. The results of a one-way analysis of variance (ANOVA) show no significant differences across different conditions for these variables, with the exception of gender, which suggests the appropriateness of our random assignments of participants to different conditions in the experiment. We controlled for these variables in the subsequent analyses, as covariates, to minimize any potential confounding effects.

Measurement Item Analyses

We assessed the reliability and convergent and discriminant validity of the items that measure each construct. We removed items with factor loading less than 0.70 and evaluated the remaining items' construct reliability in terms of Cronbach's alpha and composite reliability values, using the common threshold of 0.70 (Götz et al., 2010). Next, we used both the Fornell-Larcker criterion (Fornell & Larcker, 1981) and cross-loadings to assess their discriminant validity. To signify discriminant validity, the square root of the average variance extracted for each latent variable should be greater than the pairwise correlations between any constructs (Hair et al., 2012). As Table 3 shows, all the criteria were satisfied in an initial analysis of the first-order measurement model, which we then used

Table 2. Descriptive sample statistics

Characteristic	All	Control	Upward	Downward	Lateral	ANOVA F(*p*-value)
Age (mean)	20.43	19.61	20.48	20.92	20.73	1.53(0.21)
Male (percentage)	63.1%	70.4%	50.0%	74.0%	58.3%	2.74*(0.05)
Learning orientation (mean)	5.76	5.53	5.88	5.94	5.72	1.36(0.26)
Approach performance orientation (mean)	5.46	5.22	5.67	5.74	5.27	1.88(0.14)
Avoidance performance orientation (mean)	3.95	3.94	4.02	3.95	3.89	0.07(0.98)

Note. *$p < 0.10$.

Table 3. Measurement model

	Mean	SD	CA	AVE	APPO	AVPO	LO	SA
APPO	5.46	1.44	0.93	0.73	0.85			
AVPO	3.95	1.51	0.85	0.87	0.27	0.93		
LO	5.76	1.14	0.89	0.72	0.38	-0.06	0.85	
SA	4.92	1.21	0.92	0.81	0.06	-0.13	0.16	0.90

Note. SD = standard deviation; CA = Cronbach's alpha; AVE = average variance extracted; APPO = approach performance orientation; AVPO = avoidance performance orientation; LO = learning orientation; SA = e-learning satisfaction.

Table 4. Collinearity statistics

Independent Variable	APPO	AVPO	LO	SA
APPO	-	1.18	1.08	1.29
AVPO	1.02	-	1.10	1.12
LO	1.01	1.18	-	1.20
SA	1.02	1.00	1.02	-

Note. APPO = approach performance orientation; AVPO = avoidance performance orientation; LO = learning orientation; SA = satisfaction.

to test the direct effects of different leaderboard designs on individuals' e-learning performance and satisfaction.

We examined the common method bias (CMB) in a two-fold effort. First, we performed Harman's single-factor test; a single-factor model accounts for only 31.83% of variance, suggesting CMB is not a serious concern. Second, we conducted a full collinearity assessment and calculated variance inflation factors, which are lower than the 3.3 threshold (Kock, 2015). The result signifies no potential model contamination by CMB. We performed four partial least squares factor analyses using a latent variable that represents the dependent variable each time. As Table 4 indicates, all collinearity statistics (factor-level variance inflation factors) were below the common threshold, which again suggested CMB was not a serious concern.

Hypothesis Test Results

To test H1 and H4, we relied on analyses of covariance (ANCOVA) and assessed the total effects of each leaderboard direction to detect any significant differences across experimental conditions. With the control group as a baseline, we performed pairwise comparisons in which Fisher's least significant difference reflects the effects of different leaderboard directions on e-learning performance and satisfaction. Although Fisher's least significant difference does not account for multiple comparisons,

Table 5. Effects of leaderboard directions

Dependent Variable	Performance (H1)	Satisfaction (H4)
Difference across groups (F-value)	2.974**	2.468*
Pairwise Comparisons: Mean Difference (Treatment – Control)		
Downward leaderboard (a)	1.365**	0.401*
Upward leaderboard (b)	0.820*	0.493**
Lateral leaderboard (c)	0.464	0.572**

Note. **p* < 0.10, ***p* < 0.05, ****p* < 0.01.

it is appropriate for comparing a small number of groups, with each comparison made relative to the baseline group (Howell, 2016). Table 5 presents the effects of different leaderboard directions. E-learning performance in both the upward and downward leaderboard conditions is significantly higher than that of the control group, and does not differ for the lateral leaderboard condition, in support of H1. All leaderboard directions have significant, positive effects on users' e-learning satisfaction; that is, the data supports H4. These results affirm the direct effects of each leaderboard direction on e-learning performance and satisfaction; they also establish the necessary bases for testing the hypothesized mediating effects.

We applied the PROCESS model to explore probable mediations that channel the effects of distinct leaderboard directions on e-learning performance and satisfaction. We split the sample into three comparison data sets: downward direction versus control group, upward direction versus control group, and lateral direction versus control group. For each data set, we followed the same analysis procedure to ensure the measurement items' reliability and validity. The results again indicate the satisfactory reliability and validity for each data set.

Next, we tested the hypothesized mediations by applying bootstrapping with 5,000 resamples to estimate a 90% confidence interval. As Table 6 shows, we observe a significant mediation of e-learning self-efficacy, in support of H2. The direct effect of downward comparisons on e-learning performance remains significant when incorporating this mediation effect, suggesting a partial mediation of e-learning self-efficacy. In addition, the use of a downward leaderboard increases people's e-learning satisfaction through increased self-expansion, while its direct effect becomes insignificant statistically. These data support H5 and suggest full mediation. Learning effort also fully mediates an upward leaderboard's effect on e-learning performance; active discovery fully mediates its effect on e-learning satisfaction. These data support both H3 and H6. Yet the effect of a lateral leaderboard on e-learning satisfaction does not appear mediated by personal meaning, so we cannot confirm H7. Its direct effect on satisfaction remains statistically significant, which implies the need to consider other mediators that might explain the observed effect. Jointly, these results shed new light on how leaderboard directions influence users' performance and satisfaction in gamified e-learning.

Ex Post Analyses

We performed three *ex post* analyses of the observed effects. First, we explored other indirect paths for the effects of each leaderboard direction by considering alternative mediations, beyond those we hypothesized. To ensure the intended focus on the effects on e-learning performance and satisfaction, we switched the dependent variable, e-learning performance or satisfaction, then tested the resulting new paths using the same mediation analysis (i.e., PROCESS). For example, learning effort might mediate an upward leaderboard's effect on e-learning satisfaction, instead of e-learning performance. As Table 7 indicates, most of these paths are not significant statistically, which provides additional evidence in support of the hypothesized mediation effects.

Table 6. Indirect effects of different leaderboard directions

Effect Mechanism	Effect	LLCI	ULCI	Mediation
Downward leaderboard → e-learning self-efficacy → e-learning performance (H2)	0.216	0.028	0.450	Partial
Upward leaderboard → learning effort → e-learning performance (H3)	0.395	0.106	0.783	Full
Downward leaderboard → self-expansion → e-learning satisfaction (H5)	0.266	0.035	0.513	Full
Upward leaderboard → active discovery → e-learning satisfaction (H6)	0.229	0.045	0.440	Full
Lateral leaderboard → personal meaning → e-learning satisfaction (H7)	0.162	-0.087	0.405	Significant direct effect but insignificant mediation effect

Note. LLCI = lower level of 90% confidence interval; ULCI = upper level of 90% confidence interval.

Table 7. Results of ex post analyses of alternative indirect effect paths

Effect Mechanism	Effect	LLCI	ULCI	Mediation
Downward leaderboard → e-learning self-efficacy → e-learning satisfaction	0.249	0.062	0.474	Full
Downward leaderboard → self-expansion → e-learning performance	0.090	-0.030	0.322	No
Upward leaderboard → learning effort → e-learning satisfaction	0.033	-0.063	0.139	No
Upward leaderboard → active discovery → e-learning performance	0.051	-0.108	0.239	No
Lateral leaderboard → personal meaning → e-learning performance	-0.029	-0.154	0.070	No

Note. LLCI = lower level of 90% confidence interval; ULCI = upper level of 90% confidence interval.

Second, Ortiz-Rojas et al. (2019) and Bai et al. (2021) argue that users' achievements, as displayed by the leaderboard (e.g., rank, score), may augment or restrict their e-learning performance, in addition to the leaderboard direction. Therefore, we explored the moderating role of user achievement by comparing high- versus low-achievers. In each experimental condition, we calculated the median user score, then split participants into high- and low-achieving groups. A two-way ANCOVA was performed to estimate the interaction effect of leaderboard direction and user achievement level, while controlling for individual (demographic) variables. The insignificant interaction, $F(3, 201) = 0.585$, $p = 0.626$, $\eta^2 = 0.009$, suggests that the effects of leaderboard direction on e-learning performance are comparable between user achievement levels.

Third, prior research reports differential effects of distinct leaderboard directions on e-learning performance (Dijkstra et al., 2008). We further analyzed whether a specific direction effectuates greater e-learning performance and satisfaction than others. In tests of H1 and H4, we performed ANCOVAs to compare one treatment group versus all other treatment groups combined, instead of using the control group as the baseline. Table 8 presents the results. A downward leaderboard seems to motivate people to achieve desirable e-learning performance more effectively than other leaderboard directions. We observe no significant differences for satisfaction. That is, users seemingly exhibit comparable satisfaction, regardless of leaderboard direction. These findings are consistent with the hypotheses test results and further underscore the need to consider indirect effects to depict accurately how leaderboard directions enhance people's e-learning satisfaction.

Table 8. Comparisons of different leaderboard directions

Type of Comparison	Performance: Mean Difference (F-value)	Satisfaction: Mean Difference (F-value)
Downward > Upward and Lateral	0.712 (2.765)*	-0.096 (0.217)
Upward > Downward and Lateral	-0.026 (0.004)	-0.023 (0.012)
Lateral > Upward and Downward	-0.616 (2.298)	0.107 (0.299)

Note. *$p < 0.10$.

DISCUSSION

The experimental results show that leaderboard directions matter. We find support for most of our hypotheses and produce empirical evidence that helps explain how different comparison directions affect users' instrumental and experiential outcomes in gamified e-learning.

Research Implications

Gamification differs from ordinary games, because it facilitates individuals' task performance and creates desirable experiences (Te'eni, 2016). Different designs of a gamification object (e.g., leaderboard) can help people achieve more and feel more satisfied with their e-learning. Our results provide several research implications. First, the observed effects of distinct leaderboard directions reinforce the role of social comparisons in user perceptions and outcomes (both instrumental and experiential). We add to extant literature by scrutinizing the effects of different leaderboard directions, which offer new insights for research by providing finer-grained analyses and results. For example, comparisons with better- or poorer-performing peers can motivate users to improve their e-learning performance, but comparisons with comparable performers may not. This study extends social comparison theory, which primarily emphasizes the motivational effect of upward comparisons on performance, by providing empirical evidence of a motivational effect of downward comparisons on e-learning performance, as well. A leaderboard has a unique ability to convey essential comparisons in a one-to-many manner (i.e., focal user versus multiple reference others). Thus our study can advance social comparison theory (Diel et al., 2021; Wood, 1996), which typically targets one-to-one comparisons, a focal user versus another user, by examining whether the effects of comparison directions might be extended to one-to-many comparison references. Our results reveal that both upward and downward comparisons can result in greater learning performance, regardless of the number of reference targets displayed. The *ex post* analyses further indicate that the use of a downward leaderboard can result in better e-learning performance than an upward or lateral leaderboard. In comparison-oriented gamification, people's learning performance appears more positively affected by confidence gained from comparisons with lower-ranked others, rather than "pushes" to catch up with higher-ranked peers or relevant comparison feedback from comparably performing ones.

Second, this study contributes to information systems research by explicating the underlying effect mechanisms that clarify how different leaderboard directions affect e-learning performance. Comparisons with poorer-performing peers enhance people's e-learning performance indirectly, through e-learning self-efficacy improvement. This finding reflects the self-enhancement function of a downward leaderboard, in line with Santhanam et al. (2016) and O'Mara & Gaertner (2017) that suggests users perform better if they establish self-efficacy and recognize they are doing better than others. Comparisons with better-performing peers also help improve a person's e-learning performance through increased effort. An upward leaderboard directs people's attention to better-performing others and therefore can improve their e-learning performance by prompting more efforts to become as successful. Our results support this reasoning and suggest a full mediation, which thereby adds to social comparison theory by confirming the important role of self-improvement in upward comparisons.

Third, this study also sheds light on the experiential outcomes of social comparisons. According to social comparison theory, people should feel satisfied if they compare themselves with poorer-performing others (Wills, 1981). Previous gamified e-learning research seldom considered whether upward and lateral comparisons also can enhance satisfaction. We offer theory-guided analyses and empirical evidence suggesting that both upward and lateral leaderboards can affect people's e-learning satisfaction. In a related sense, our study reinforces the dual-outcome principle (Liu et al., 2017) by illustrating how the use of a leaderboard influences both instrumental and experiential outcomes from a social comparison perspective.

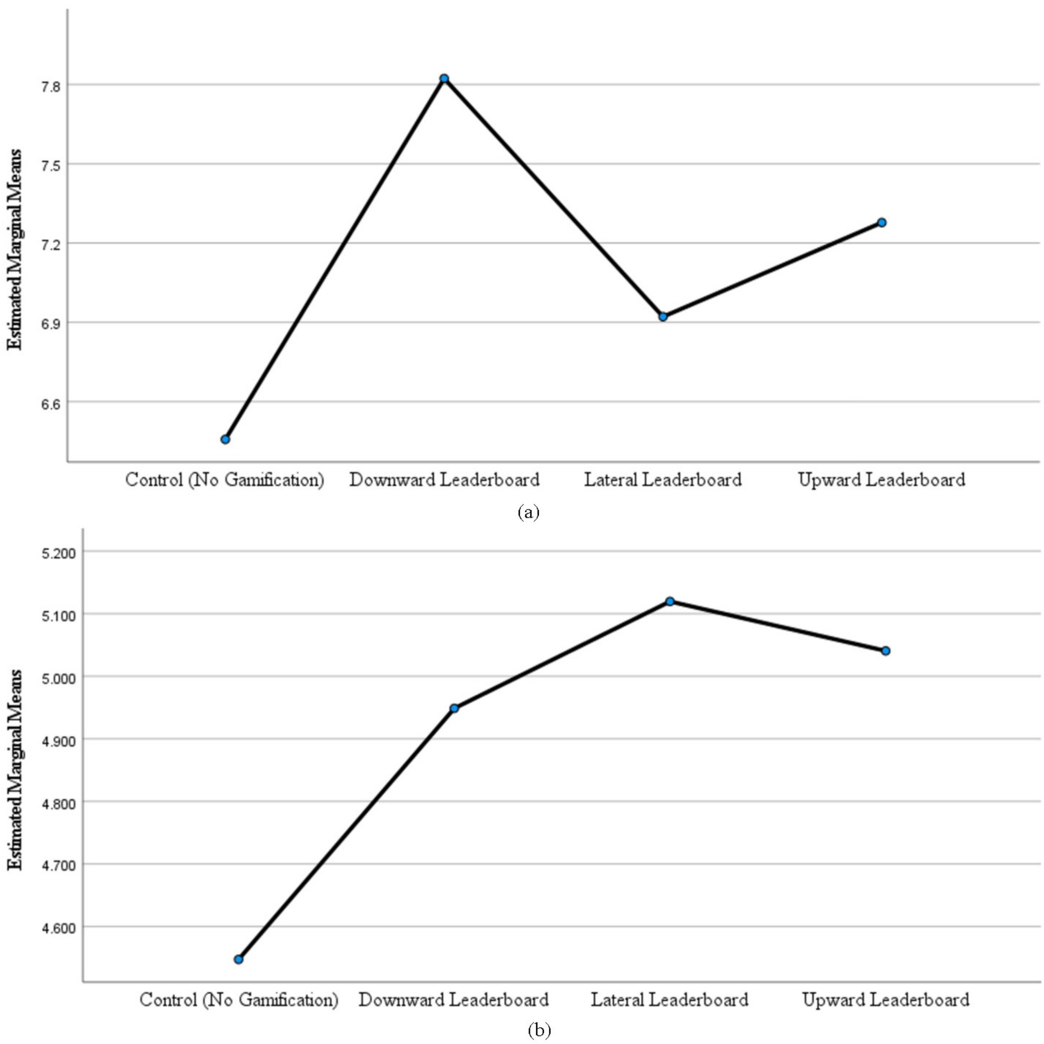
Fourth, and relatedly, this study contributes to existing literature by specifying how distinct leaderboard directions improve users' e-learning satisfaction. Aesthetic experiences are central to meaningful engagement (Suh et al., 2017) and can signal the efficacy of gamified e-learning. But previous research has not shown how a gamification object causes people to feel more satisfied. Toward that end, we offer analyses and evidence that leaderboard directions enable people to develop essential aesthetic experiences (e.g., self-expansion, active discovery), which lead to e-learning satisfaction, beyond the direct effect of a leaderboard (Bai et al., 2021; Christy & Fox, 2014). A downward leaderboard induces satisfaction because comparisons with poorer-performing peers increase users' feelings of self-efficacy and self-expansion. When considering gamification in e-learning, it may be crucial to build users' confidence and encourage them to strengthen themselves by applying what they have learned to reshape how they feel about e-learning. An upward leaderboard also improves e-learning satisfaction, because comparisons with better-performing others elevate desires for active discovery. This finding suggests that challenge seeking is an important determinant of how gamified e-learning affects individual learning outcomes.

Furthermore, our study adds to existing global information management literature by demonstrating how leaderboards, as a gamification object, can address e-learning challenges across different countries and cultures. To illustrate, Abbas et al. (2023) observe resistance to e-learning in Kuwait, due to high workload perceptions, toward which our results show the use of leaderboards capable of mitigating such drawbacks by enhancing user satisfaction and thus representing a viable means to fostering e-learning and user engagement. For example, lateral leaderboards may alleviate people's feeling of overload by offering evaluative feedback about peers with comparable performance, which might make their e-learning experience more tailored and manageable. In particular, such feedback could enhance user engagement and satisfaction in regions that face similar challenges. Our results align with those reported by Dolmark et al. (2022), which emphasizes the importance of readiness for successful gamification implementations, such as leaderboards. Toward that end, the use of an upward leaderboard, which may foster learning effort and active discovery by comparing with better-performing peers, may motivate users who are more ready to embrace technology by setting achievable benchmarks for success, thereby enhancing their engagement through the motivation to reach and surpass these benchmarks. In addition, while Huang et al. (2022) explore the link between aesthetic experience and satisfaction in educational games at large, our study delves into how specific leaderboard directions can enhance the underlying mechanism. As an example, the use of downward leaderboards may enhance e-learning performance by increasing user self-efficacy, mitigating the competitive aspect of games, and providing deeper insights for educational game designers.

Practical Implications

For practice, we suggest several guidelines to enrich the design and use of leaderboards in gamified e-learning. First, leaderboard designs and usage should be expanded, beyond conventional listings of leaders, to reveal the positions of poorer-performing others. Many e-learning platforms and applications that have incorporated gamification focus on upward comparisons and direct people's attention to the top of a leaderboard. For example, Quizizz exclusively uses upward leaderboards to motivate users to improve their performance on online quizzes. As Figure 1 reveals, a downward leaderboard might produce the best e-learning performance, followed by an upward and then a lateral

Figure 1. Estimated marginal means across different leaderboard directions (a) analysis of e-learning performance (b) analysis of e-learning satisfaction



leaderboard. Moreover, Panel B indicates that people supported by a lateral leaderboard exhibit the greatest e-learning satisfaction, followed by upward and then downward leaderboards. These results imply the need to consider lateral comparisons if platforms aim to increase users' satisfaction with gamified e-learning, which in turn should decrease their disengagement or discontinuance behaviors. Our findings could augment current practice. For e-learning platforms and applications, we highlight the utilities of downward leaderboards for e-learning performance and lateral leaderboard for e-learning satisfaction.

Second, the observed effect mechanisms indicate that e-learning platforms and applications should consider more dynamic, flexible leaderboards that allow users to customize their own comparison directions, according to their state and preferences. Arguably, platforms and applications should monitor each user's current state in the gamified e-learning context, then dynamically adjust comparison directions in ways that enhance their immediate performance. For example, if users appear discouraged because they are struggling with the learning tasks (e.g., consecutive incorrect answers), a shift from an upward to a downward leaderboard might boost their confidence and encourage continued engagement; the upward leaderboard can be re-invoked after their state improves. Adaptive leaderboard designs should benefit satisfaction with e-learning too. Platform operators could monitor individual behaviors in recent e-learning activities and distinguish "challenge seekers" versus "self-explorers," for example. An upward leaderboard offered to challenge seekers would likely fulfill their desires for increasing challenges, whereas a downward leaderboard presented to self-explorers would meet their needs for more positive self-views. Another promising option might be to allow users to choose their own leaderboard directions in dynamic designs. A platform could adopt lateral comparisons by default and permit users to choose their preferred comparison direction conveniently, such as clicking to emphasize comparably performing peers in test or quiz scores.

Third, the different effect mechanisms inform desirable feature designs that might overcome the disadvantages of traditional leaderboard features (e.g., score, rank). For example, a probable pitfall of upward leaderboards is that people might become discouraged if they only see better-performing others' scores and ranks. To mitigate this pitfall, the leaderboard could add explicit information about how much time each leader spent, in addition to her or her score, which would signify the amount of effort exhibited by others and increase their expectations of the necessary effort if they seek similar performance. As our results show, an upward leaderboard effectively motivates users with a strong challenge-seeking mindset, whereas a downward leaderboard encourages those with an exploratory orientation. If it provides an upward leaderboard, a platform might add more difficult questions to satisfy users' potential desires for such greater challenges. The platform instead could incorporate additional (external) learning resources to suit people's inclination toward self-expansion if it features a downward leaderboard.

Fourth, our study provides actionable guidelines for implementing leaderboards across various organizational contexts to boost user engagement and satisfaction. Fuhrer (2023) and Van Slyke et al. (2022) indicate that telework could make employees feel isolated and distressed, which in turn reduces their satisfaction and productivity. Leaderboards might serve as a practical remedy for mitigating such challenges by providing continual and visualizable feedback on progress and achievements. For instance, lateral leaderboards may enhance employers' satisfaction by focusing on comparable peer performance, which encourages a manageable competition to maintain satisfaction at a high level and helps them better manage telework-related stress in a resilient way. For team building in an organizational context, our research complements Chang et al. (2023) by suggesting that non-monetary incentives (e.g., team leaderboard) may enhance team dynamics and engagement, in addition to monetary incentives. By highlighting team achievements, a team leaderboard can foster a collaborative environment that essentially mimics the positive impacts of digital gifts (such as e-hongbao in WeChat), fosters social interactions, and strengthens intra-organizational relationships. Conceivably, team leaderboards also can enhance organizational knowledge sharing by facilitating a culture of collaboration and competition. While Rahman et al. (2022) show that training and development moderates the relationship of team orientation and knowledge sharing in an organization, our results imply that team-based leaderboards might encourage people to collaborate and share knowledge through increased engagements and collective satisfaction. In this vein, adding gamification objects, such as leaderboards, could make the sharing of public knowledge more appealing by adding a layer of achievement and competition to intensify key factors (e.g., awareness, usability) that influence individual use of available knowledge content and accessible data (Mutambik et al., 2023). Moreover, our study sheds light on desirable use of gamification for security education and training awareness programs in which user engagement is often low and program effectiveness tends to be limited (Ifinedo et al., 2022). Leaderboards can augment these important programs by creating a competitive environment that rewards compliance and improvements among employees in an organizational context.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

As a departure from previous research that examines gamification objects without specifying the effects of its feedback designs, this study investigates how different leaderboard directions might influence people's e-learning performance and satisfaction, from a theoretical perspective. The experimental results affirm that upward and downward leaderboards enhance people's e-learning performance and satisfaction, and a lateral leaderboard can only improve their e-learning satisfaction. We also explore indirect effects, according to self-evaluation motives, to specify the mechanisms underpinning the influences of each leaderboard direction and test for mediation effects of each motive. The results show that an upward leaderboard enhances people's e-learning performance and satisfaction through increased learning effort and active discovery, respectively. A downward leaderboard enhances e-learning performance and satisfaction through self-efficacy and self-expansion. The positive effect of a lateral leaderboard on e-learning satisfaction appears not mediated by the development of personal meaning.

This study can be extended in several ways. First, future research examining the impact of leaderboard direction in e-learning should consider additional potential confounding factors. Extant literature, including Amo et al. (2020) and Buckley & Doyle (2017), emphasizes the significance of personal traits and personality in shaping gamification experiences. Toward that end, future studies can provide valuable insights by examining how these personal attributes might influence user responses to different leaderboard directions and how their interplays with distinct leaderboard directions could affect learning performance and satisfaction in gamified e-learning contexts. As a point of departure, we provide initial assessments of different leaderboard directions, and more efforts are needed to identify the potential boundary conditions of the observed effects by considering different user groups and subject domains. For example, this study targets data mining, and future research should consider other important information systems topic areas, such as programming and information security. In a related sense, this study involves undergraduate students in an American university, and continued research should include user groups in different regions and cultures. Additional factors also should be considered, such as intrinsic motivation towards the learning subject, prior gaming (or gamification) experience and knowledge, and different learning assessments. Second, while our choice of a between-subjects experimental design is appropriate for testing the hypotheses, future research should further investigate the effects of leaderboard directions by considering other experimental designs. For example, a longitudinal experimental design would allow a pre- versus post-intervention comparison, in which we can measure participants' performance and evaluative responses several weeks prior to their exposure to a treatment (i.e., intervention) to establish a "baseline" and then measure their performance and evaluative responses in the experiment (i.e., after receiving the treatment). Also, personal meaning does not appear to mediate the positive effect of lateral leaderboards on e-learning satisfaction, implying the need to consider other mediating factors that might reveal the influences of lateral leaderboards more comprehensively or accurately. Moreover, the inclusion of other individual factors like cognitive load in future studies could broaden our understanding and provide a more comprehensive view of our findings. Finally, whereas we specify effects of different leaderboard directions, we do not analyze other design elements (such as user anonymity). Continued efforts should consider additional leaderboard elements to examine their independent or joint effects with leaderboard direction on e-learning performance and satisfaction.

CONFLICTS OF INTEREST

The authors of this publication declare there are no competing interests.

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ENDNOTES

1 https://blog.duolingo.com/gamification-design/, accessed on November 28, 2023.

2 For example, Quizizz (https://quizizz.com/) adopts a similar practice to avoid situations in which multiple users receive the same score and thus are assigned to the same rank.

3 The cold start problem arises because the leaderboard contains only few users when the experiment begins.

4 The manipulation check question asked, "Please indicate the particular leaderboard shown to you in the study: (A) I don't know. (B) Leaderboard only showed people ranked higher than me. (C) Leaderboard only showed people ranked lower than me. (D) Leaderboard only showed people ranked closely to me."

5 Participants saw their assigned leaderboard only after they had answered the first exercise question in learning topic 1. We measured their e-learning performance starting with learning topic 2. The results are identical if we include all answers submitted for learning topics 1–6.

LIST OF MEASUREMENT ITEMS AND THEIR SOURCES

E-learning satisfaction (SA), adapted from Hu & Hui (2012) and Wixom & Todd (2005):

- SA-1: All things considered, I am satisfied with this e-learning application.
- SA-2: Overall, my interaction with this e-learning application is satisfying.
- SA-3: I am satisfied with the things I learned from this e-learning application.
- SA-4: I am satisfied with the activities I performed in this e-learning application.

E-learning self-efficacy (SEF), adapted from Santhanam et al. (2008):

- SEF-1: I feel confident using this e-learning application to learn about and apply new concepts.
- SEF-2: I feel using this e-learning application is an efficient way for me to learn new things.
- SEF-3: I am comfortable using this e-learning application.
- SEF-4: I feel that I could successfully use this e-learning application.

Active discovery (AD), adapted from Suh et al. (2017):

- AD-1: While using this application, I feel I exercise powers to deal with challenges I face.
- AD-2: While using this application, I feel I discover new paths to seek answers or resolution.
- AD-3: While using this application, I feel I am aware of how to proceed to fulfill my purposes.

Personal meaning (ME), adapted from Suh et al. (2017):

- ME-1: While using this application, I feel my activities are very important to me.
- ME-2: While using this application, I feel my activities are personally meaningful.
- ME-3: While using this application, I feel my interactions with it is meaningful.

Self-expansion (SE), adapted from Suh et al. (2017):

- SE-1: While using this application, I feel an increased ability to accomplish new things.
- SE-2: While using this application, I feel I have a broader perspective on what I am doing.
- SE-3: While using this application, I feel my activities result in learning new things.

Approach performance orientation (APPO), adapted from Zweig & Webster (2004):

- APPO-1: I care what others think of my performance.
- APPO-2: I am interested in impressing others with my performance.
- APPO-3: I value what others think of my performance.
- APPO-4: It is important for me to impress others by doing a good job.

Avoidance performance orientation (AVPO), adapted from Zweig & Webster (2004):

- AVPO-1: I avoid tasks that I may not be able to complete successfully.
- AVPO-2: Most of the time, I stay away from tasks that I know I will not be able to complete.
- AVPO-3: I do not enjoy taking on tasks if I am unsure whether I can complete them successfully.
- AVPO-4: I avoid circumstances where my performance will be compared to others.

APPENDIX

Table 9. Summary of representative previous research closely related to this study

Study	Dependent Variable	Individual Factor	Gamification Object	Gamification Object Design	Feedback Effect Mechanism
Park et al. (2019)	Knowledge comprehension and task performance	No	No	Levels, avatar evolution, and distinct visuals	No
Tenório et al. (2016)	Essay quality and quantity	No	No	Peer assessment model	No
Amo et al. (2020)	Performance growth, user engagement	Structural and trait competitiveness	Leaderboard	No	No
Armstrong and Landers (2017)	Satisfaction, scores on declarative knowledge and procedural knowledge	Attitudes toward game-based learning	Narrative	No	No
Attali and Arieli-Attali (2015)	E-learning performance and response time	Age (e.g., adult, middle school)	Points	No	No
Bai et al. (2021)	Intrinsic motivation, course engagement, e-learning performance	Users' leaderboard ranks	Leaderboard	Absolute or relative leaderboard	No
Buckley and Doyle (2017)	Engagement and performance	Personality	No	No	No
Christy and Fox (2014)	Math test score	Gender	Leaderboard	Male- or female-dominated leaderboard	No
De-Marcos et al. (2016)	E-learning performance	No	Gamification and social gamification	No	No
Dindar et al. (2021)	Enjoyment, interest, learning, and achievement score	No	No	Competition and cooperation	No
Ding et al. (2017)	Student engagement (e.g., enjoyment, perceived relatedness, autonomous motivation)	No	Badges, thumps-ups, progress bars, and avatars	No	No
Hanus and Fox (2015)	Final exam score	Intrinsic Motivations	No	No	No
Jagušt et al. (2018)	E-learning performance	No	No		No
Jurgelaitis et al. (2019)	Enjoyment, perceived competence, effort, value, intrinsic motivation, evaluation score	No	No	No	No
Kwon and Özpolat (2021)	Quiz/exam scores, satisfaction, experience	No	No	No	No
Kyewski and Krämer (2018)	Intrinsic motivation, e-learning performance, active participation	No	Badge	Badges visible to peers or badges only visible to oneself	No
Landers and Armstrong (2017)	Training valence	Attitudes and experience	No	No	No
Landers et al. (2017)	E-learning engagement and performance	Goal commitment	Leaderboard	No	No
Legaki et al. (2020)	E-learning performance	Reading task	No	No	No
Ortiz-Rojas et al. (2019)	E-learning performance	Intrinsic motivation, self-efficacy, engagement	Leaderboard	Absolute or relative leaderboard	Yes

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Table 9. Continued

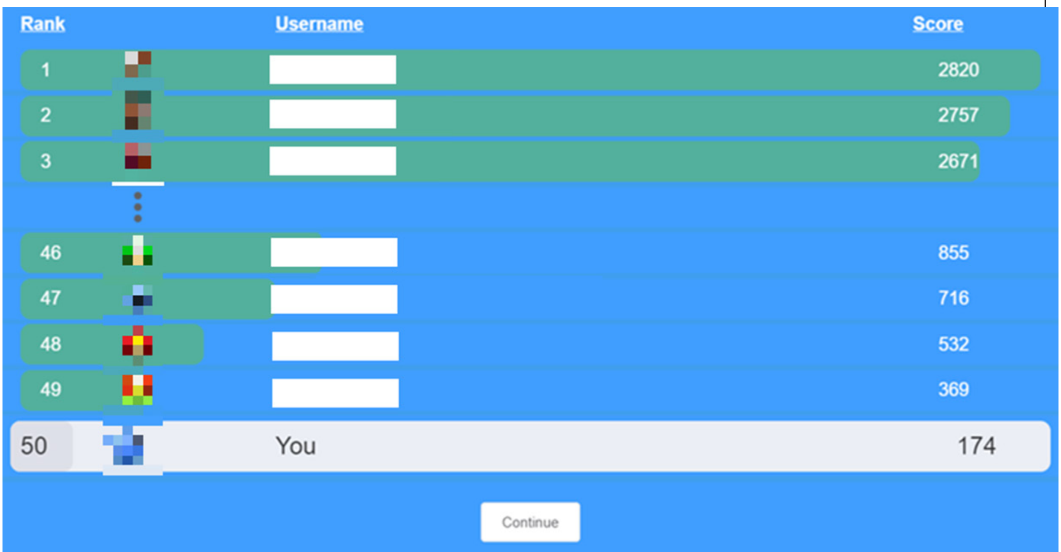
Study	Dependent Variable	Individual Factor	Gamification Object	Gamification Object Design	Feedback Effect Mechanism
Özdener (2018)	Number of Wiki content displayed and edited by participants	No	No	No	No
Sanchez et al. (2020)	Quizzes completed and test score	Students' achievement	No	No	No
Santhanam et al. (2016)	E-learning performance, self-efficacy, immersion, time distortion, enjoyment	No	No	Three types of competition	No
Silic and Lowry (2020)	Security compliance behaviors	Flow constructs	No	No	No
Tsay et al. (2018)	Engagement in online learning activities	Gender and employment status	No	No	No
Yildirim (2017)	Test scores and attitudes	No	No	No	No
Zainuddin et al. (2020)	E-learning performance	No	No	SpaceRaces, leaderboard, scoreboard	No
Dincelli & Chengalur-Smith (2020)	Security training effectiveness and satisfaction	No	Storytelling	Text-based, visual-based Storytelling	No
Shin et al. (2013)	Satisfaction and Intention	Flow, immersion, presence, confirmation, perceived usefulness, perceived ease of use	Three-dimensional virtual environments	No	No
Shin and Park (2019)	Time spent on task, cognitive load, completion rate	No	Animation	Animation with/ without visual cue	No
Shin et al. (2016)	Cognitive and emotional learning outcomes in media multitasking context for open and closed tasks	No	Second Screen	Simultaneous vs. sequential use of a second screen	No
Shin (2017)	Learnability and usability	Affective and educational affordance	Virtual reality	No	No
Sailer and Homner (2020)	Cognitive, motivational, behavioral learning outcomes	Prior knowledge and motivation	Game fiction/story	No	Yes
Shin (2022)	Playability and usability	Instrumental and affective affordance	No	No	No
Shin and Ahn (2013)	Cognitive empathy	Age group	No	No	No
J. Huang et al. (2022)	Learners' satisfaction and learning behavior	Aesthetic experience	Puzzle	No	No
Abbas et al. (2023)	Preferences for online learning	Perceived workload and exhaustion from online learning	No	No	No
This study	E-learning performance and satisfaction	Learning effort, e-learning self-efficacy, aesthetic experience constructs	Leaderboard	Leaderboard directions: upward, lateral, and downward	Yes

Learning orientation (LO), adapted from Zweig & Webster (2004):

- LO-1: The opportunity to do challenging work is important to me.
- LO-2: In learning situations, I tend to set fairly challenging goals for myself.
- LO-3: I always challenge myself to learn new things.

Table 10. Three leaderboard directions investigated in this study

I. Upward Leaderboard



II. Lateral Leaderboard

III. Downward Leaderboard

continued on following page

Table 10. Continued

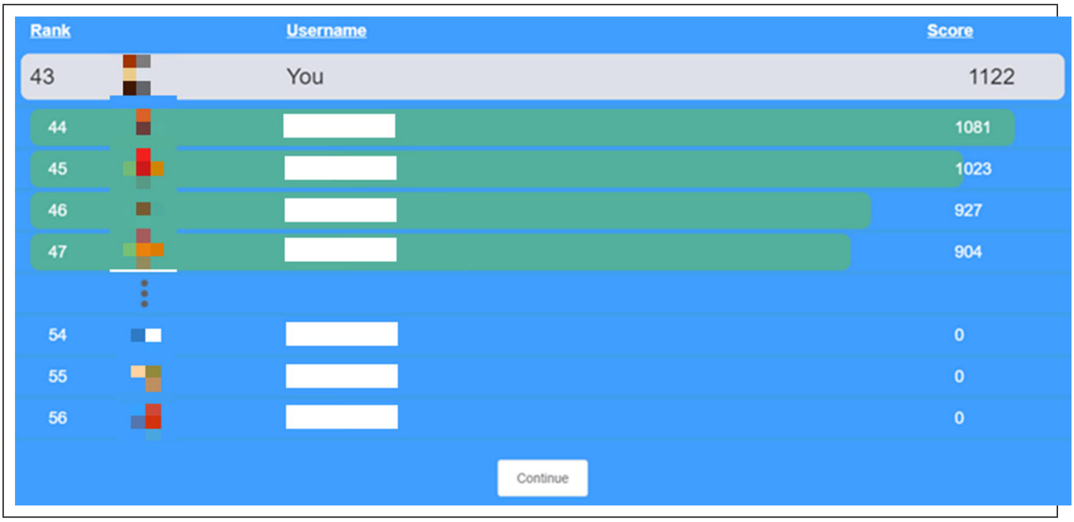
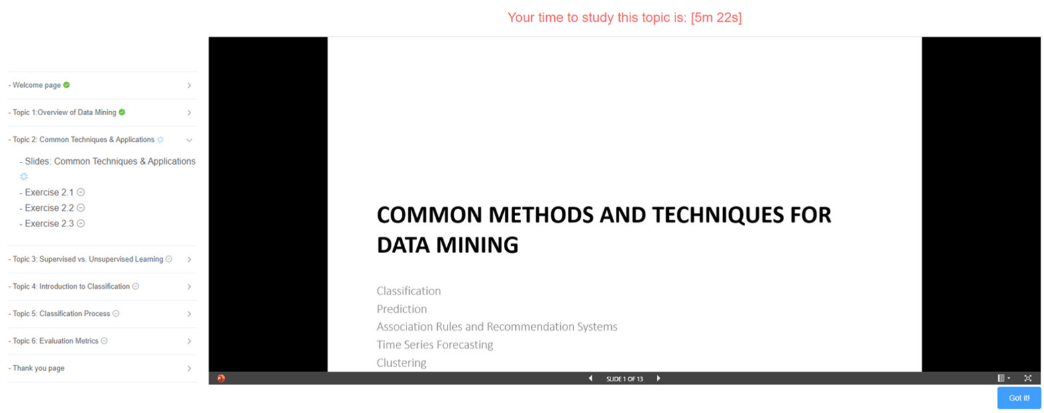


Table 11. Exemplary learning topic and assessment question

I. Learning Topic



II. Multiple-Choice Question

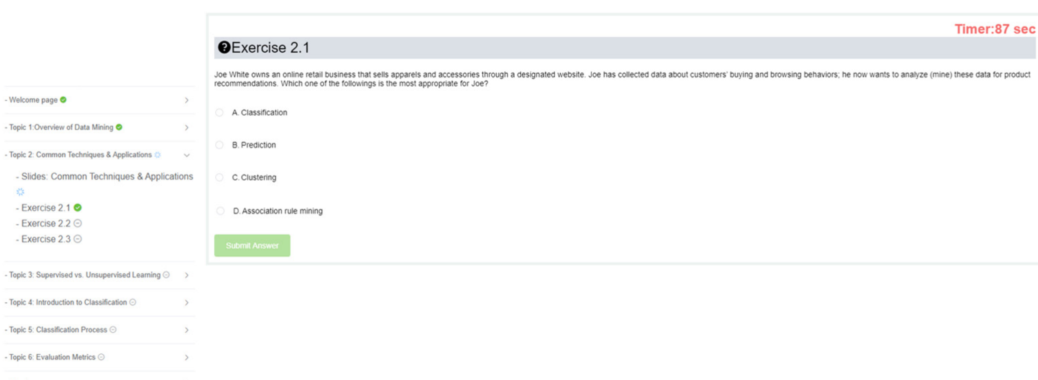
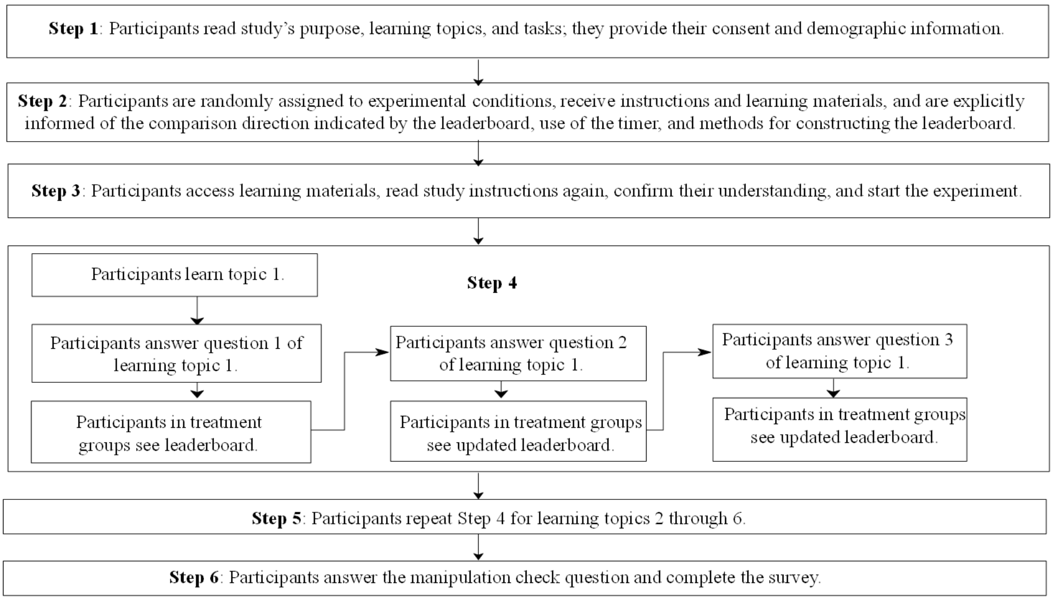


Figure 2. Experimental procedure



- LO-4: The opportunity to extend my range of abilities is important to me.

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