Post-print of the Construction of a Theoretical Model for Gamified Information Retrieval Systems

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Abstract

[Purpose/Significance] Addressing the needs of new-generation user groups for information retrieval systems, this study proposes a theoretical model for gamified information retrieval systems, aiming to stimulate users' interest in utilizing retrieval systems, support their information retrieval and interaction processes, and encourage sustained usage. [Method/Process] Grounded in fundamental gamification theories, relevant frameworks, and the mechanisms of information retrieval systems, this research combines various game elements and designs function-specific modules while considering the relationships between different game elements and rules, thereby implementing the application of game elements in non-game contexts. [Results/Conclusion] For constructing the theoretical model of gamified information retrieval systems, 20 game elements are identified and categorized by function, leading to the design of 12 types of game modules (including 5 simple modules and 7 composite modules) that endow information retrieval systems with gamification capabilities. The proposed construction approach and theoretical model fill the existing research gaps in the domain of gamified information retrieval, offering a theoretical framework for the development of such systems and future related research.

Full Text

Preamble

Developing a Theoretical Model for Gamified Information Retrieval Systems

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Abstract

[**Purpose/Significance**] To address the needs of new-generation user groups for information retrieval systems, this paper proposes a theoretical model for gamified information retrieval systems aimed at stimulating users' interest in using retrieval systems, supporting their information retrieval and interaction, and encouraging sustained usage. [**Method/Process**] Based on gamification theory, relevant frameworks, and the mechanisms of information retrieval systems, different game elements are combined to design functional modules with specific purposes, considering the relationships between various game elements and rules, thereby applying game elements in non-game contexts. [**Result/Conclusion**] To construct the theoretical model of a gamified information retrieval system, twenty game elements were identified and combined according to their functions to design twelve types of game modules, including five simple modules and seven compound modules, enabling information retrieval systems to possess gaming functionalities. The proposed construction approach and theoretical model address current research gaps in the field of gamified information retrieval and provide a theoretical framework for developing gamified information retrieval systems and guiding subsequent related research.

The field of library and information science is one of the earliest domains to adopt computer technology, and information retrieval systems based on computer technology have flourished accordingly. The development and application of information retrieval systems have significantly improved information storage, access, and utilization, enhancing humanity's capacity for information processing and management. Since their inception, computer-based information retrieval systems have undergone various developmental stages, evolving from an initial system-oriented design approach that focused entirely on system development to today's user-oriented approach that continuously incorporates diverse user-related elements. This evolution has led to continuously improving system usage rates and increasingly friendly, usable systems. Currently, various information retrieval systems have become embedded in people's work and lives, forming an indispensable part of daily human existence.

However, due to insufficient attention to users, some non-entertainment information systems have consistently faced low usage rates. Regarding information retrieval systems specifically, users typically only utilize such systems when driven by specific tasks. Research has shown that when using information retrieval systems, users generally employ only basic query functions such as simple search, while advanced retrieval features are used less frequently. Users typically browse few web pages and input short query statements. Furthermore, current information retrieval systems offer inadequate support for collaborative information retrieval. These systems face the challenge of low user intention for sustained use; high usage rates and acceptance are limited to specific task-driven scenarios or usage contexts. This situation not only hinders the full exploitation of information retrieval system functionalities but also impedes users' ability to

access information resources more comprehensively. Therefore, how to help and motivate users to continuously and effectively use information retrieval systems has remained an important research topic in information science.

Due to the close relationship between the birth of information retrieval systems and scientific research, these systems have traditionally been regarded as serious information acquisition tools designed to provide information and knowledge, improve and enhance understanding of unknown domains, and have no association with entertainment. This philosophy gained widespread acceptance in an era when games and entertainment were relatively marginalized. With the development of user-centered design (UCD) philosophy, attention to users' interactive experiences, usage experiences, and psychological and emotional aspects during system use has become one of the core concepts in system design.

With the rapid development of information and communication technologies and the growth of a new generation of young users, information retrieval systems face a new user group known as "digital natives." Digital natives have grown up alongside the rapid development and popularization of new technologies such as the internet. The earliest digital natives were born in the mid-1990s and are also called Generation Z. For convenience, we collectively refer to them as the new-generation user group. These users exhibit characteristics in cognitive psychology and learning motivation that differ from other groups, with "game-based learning" being one of their prominent features. "Play" is also a human nature, and games have undoubtedly become a major entertainment activity for many users, reflecting this innate tendency. Understanding this human nature, drawing on play and game elements, and applying them to different domains has become a common interest in both academic and practical fields.

The application of game elements in non-game contexts has given rise to the interdisciplinary research field of gamification. Gamification refers to embedding game elements into non-game contexts to provide users with gaming experiences, thereby guiding user-system interaction, increasing user engagement, and shaping user behavior. As an effective approach, gamification plays a positive role in education, corporate innovation and marketing, interaction design, library services, and health. However, in the field of information retrieval, research on gamification remains in the exploratory stage. Therefore, based on existing research on gamification and information retrieval, and according to the current characteristics of new-generation user groups' "game-based learning," we attempt to propose a theoretical model for gamified information retrieval systems. Through the implantation of game elements, this model aims to stimulate more active and effective use of information retrieval systems, support better user-system interaction, and encourage sustained usage intention. Simultaneously, it seeks to improve users' information retrieval capabilities and the performance of information retrieval systems.

2 Literature Review

The field of library and information science is also an early adopter of game applications. First, games have been combined with library services. Integrating games into digital library services aims to enhance the attractiveness of library services and strengthen readers' participatory experiences, such as library games and virtual library services. Game-themed activities represent another way of integrating games into library services, such as gaming tournaments held at Wake Forest University Library and the "escape room" game organized by Peking University Library. Second, games have been combined with information literacy education to conduct various educational activities, including freshman library orientation and literature retrieval courses, such as "Save Xiaobu" developed by Wuhan University Library and the "Smart Town" game developed by Central China Normal University.

However, research on games and information retrieval remains in the exploratory stage. Current gamified information retrieval research primarily focuses on web retrieval and related theoretical exploration. Successful gamified information retrieval systems must break the monotony of the retrieval and browsing process and enhance users' sense of achievement upon successful retrieval. If search engines can provide feedback portals after retrieval errors, it would significantly reduce users' cognitive load during retrieval. Web retrieval research primarily explores the entertainment aspects of gamification, investigating what truly constitutes the "fun" in gamified information retrieval systems, improving retrieval effectiveness through game elements, helping users understand and refine queries, motivating users during the retrieval process, continuously improving users' retrieval capabilities, and providing users with gaming experiences. L. Azzopardi et al. developed a web retrieval game employing four game elements to motivate users: points, badges, leaderboards, and avatars. The game presents users with a webpage and asks them to input what they believe is the most effective query to retrieve that page; during gameplay, users earn more points and other rewards for shorter time consumption and more refined queries, thereby incentivizing web retrieval. J. M. Fernández-Luna et al. proposed a vision for gamified collaborative information retrieval. First, it provides users with a comfortable information retrieval environment, establishes individual user accounts, and sets up game avatars. Second, it provides retrieval support through components, awards points after completing specific retrieval tasks, sets up task leaderboards, and allows users to exchange points for virtual prizes. Through these game element designs, user engagement can be increased, task-related challenges reduced, and collaborative behaviors among information retrieval users enhanced.

Some research involves relatively scattered topics, including both theoretical discussions and empirical studies. For example, L. Galli et al. analyzed the connotations of game elements and explored the feasibility of combining different game elements, such as points and levels, at different stages of information retrieval. M. Riegler pointed out that gamification can improve attention to

human visual perception and image scenes, using gamification methods to collect data that previously could only be gathered through time-consuming and expensive eye-tracking experiments.

Thus, research on gamification in information retrieval remains in the exploratory stage, and truly gamified information retrieval systems have not yet emerged. Therefore, we will propose a theoretical model for gamified information retrieval systems based on relevant theoretical frameworks, principles of information retrieval systems, and gamification concepts, providing guidance and reference for the design and development of such systems. Simultaneously, it will provide a platform and environment for exploring the mechanism of game elements and their impact on information retrieval behavior.

3 Construction Approach

The evolution of information retrieval systems has undergone multiple paradigm shifts from system-oriented to user-oriented design. However, regardless of whether information retrieval emphasizes system functionality, individual user characteristics, or user context, the core process of information retrieval has remained largely unchanged. [Figure 1: see original paper] describes this process: users' searches in information retrieval systems generally begin with a problem or need, which is transformed into a query and submitted to the system. The system processes the user's query, matches it against content in the database, and outputs results if successful. Otherwise, users continue to modify their queries, and the process repeats until user needs are satisfied or they eventually abandon the search. We will design a gamified information retrieval system based on this model.

4 Game Element Mechanism

Gamification has been applied in the development and design of different types of information systems, becoming a tool to encourage or mobilize user participation in less attractive tasks and activities. Various behavioral theories, including motivation theory, self-determination theory, flow theory, and achievement goal theory, support and explain how gamification concepts and tools influence and shape user behavior in information systems. Therefore, gamified information retrieval systems have a solid theoretical foundation. The following sections elaborate on the meaning of gamification elements, their mechanism of action, and their impact on user behavior.

4.1 Meaning of Game Elements

Gamification essentially uses game thinking and mechanics to change people's behavior and habits, increase user engagement, and enhance the user experience of gaming products. Game elements or mechanics are the core of gamification design. Transplanting game mechanics or elements into different usage contexts represents the primary approach for combining gamification with research in

different domains. Game elements are not equivalent to games themselves. A game is a system with clear objectives that includes not only game elements but also game design; games are more complex than game elements. Game elements function like a toolbox, where different elements represent different tools that can produce different effects when applied to different contexts. The most commonly used elements are points, badges, and leaderboards, collectively referred to as PBL. Game elements include not only game components (mechanics) but also the game mechanisms behind these elements and the gaming experiences they can achieve. For example, rewards, challenges, and sensations. All visual and auditory elements presented in games, including character actions and feedback, belong to the category of game elements. Therefore, game elements include not only components like points and levels but also the rules/mechanics behind these elements and the experiences/emotions they generate.

4.2 Mechanism of Game Elements

The purpose of games is to generate fun and pleasure for users. However, the purpose of gamification is not fun itself but to psychologically motivate users through the design and application of game elements, arousing their participation motivation. The ultimate goal of game element design and application is to guide user behavior and shape user habits. Therefore, users' psychological and cognitive factors, as well as their social and cultural contexts, are crucial considerations in gamification design. The gamification design process involves the specific application of game elements, triggering different psychological responses in users through the application of different elements. R. Hunicke et al. proposed an MDA (Mechanics, Dynamics, Aesthetics) framework for gamification design, aiming to explain the game process through game elements and rules and to guide game development and design, as shown in [Figure 2: see original paper]. They distinguished game elements into components/mechanics, rules/dynamics, and experiences/aesthetics. Components/mechanics include points and levels, representing gamification tools. Rules/dynamics refer to the functions or effects produced by applying game elements, which have certain dynamic characteristics depending on the results produced by the tools, and also refer to real-time behaviors and their outcomes when different game elements act on users during gameplay. For example, rewards obtained in games, competition with others, and challenges brought by game difficulty. Experiences/aesthetics refer to users' emotional changes during gameplay and interaction with games, representing the effects produced by game elements during the game process. For instance, users may have very pleasant experiences, perceive the game as a virtual world, and experience different storylines within the game.

lists common game elements that can satisfy users' expectations or desires in games. Black dots indicate game elements that best satisfy a particular expectation, while gray dots indicate elements that can additionally satisfy other expectations. The relationship between game elements and mechanisms forms the foundation for constructing gamified information retrieval systems.

4.3 Game Elements and User Behavior

Gamification can improve user performance, work efficiency, and engagement. A. Suh et al. noted that through specific game element designs, different individual behaviors and psychological reactions can be triggered, indirectly satisfying individual psychological needs and thereby generating pleasure during gameplay. When individuals experience fun while using a system, their usage or engagement with the system increases, as shown in [Figure 3: see original paper].

[Figure 3: see original paper] illustrates the relationship between game elements, theories, and user behavior, revised from A. Suh et al. (2015). The integration of MDA with different theories, including achievement goal theory, basic psychological needs theory, motivation theory, and flow theory, explains the impact of game elements on users' psychology and behavior: game elements stimulate users' participation motivation (intrinsic motivation), thereby triggering different gaming behaviors that engage users in game activities, complete tasks or goals (achievement goals), accumulate gaming experience or improve gaming skills. During gameplay, users' different psychological needs (autonomy, competence, relatedness) are satisfied, and users enjoy the pleasure of gaming (flow), continuing to play.

5 Gamified Information Retrieval System Theoretical Model

Based on the above discussion, we attempt to construct a theoretical model for gamified information retrieval systems: implanting game elements into the information retrieval process, integrating different game elements, designing different modules, and achieving the combination of game mechanisms with the information retrieval process. Through the functions of different game modules, the model aims to achieve the goals of stimulating users' interest in using retrieval systems, supporting users' information retrieval and interaction, encouraging sustained usage, and meeting the gaming needs of different user types, such as explorers, achievers, and socializers. [Figure 4: see original paper] shows the gamified information retrieval system theoretical model.

The model consists of three different layers: (1) The theoretical layer—the MDA framework. MDA forms the foundation of model construction. The design process of gamified information retrieval systems essentially involves the application of game elements in non-game contexts to exert their functions. We implant game elements into information retrieval systems to achieve the goals of stimulating usage interest, supporting retrieval and interaction, and encouraging sustained usage. (2) The system layer—game module and interface design. Different game modules are designed based on game elements to achieve different system functions. For example, the personal information module is designed through game elements such as personal profiles and avatars, allowing users to view personal information, retrieval history, and change avatars. Additionally,

the points module is designed through the points element and integrated with the information retrieval process. Users can earn points through active interaction with the system, downloading literature, sharing relevant literature with friends, and assisting friends in completing retrieval tasks. Different modules are then integrated into a single interactive interface as the entry point for the gamified information retrieval system, which users can freely access. (3) The user layer—achieving three system goals through game modules. The personal information module constructs a familiar gaming scenario to stimulate usage interest. During information retrieval, the help module enables users to learn basic and advanced retrieval skills, while the points module encourages interaction, retrieval, and sharing, thereby better supporting user interaction and retrieval. Users advance levels and obtain titles in the level module, encouraging sustained system usage. These modules also provide users with gaming fun and experience during information retrieval, thereby increasing engagement.

In summary, the construction of this gamified information retrieval system theoretical model achieves the application of game elements in non-game contexts by "constructing game mechanisms (MDA)—embedding game modules—achieving system goals," thereby guiding user behavior. The following sections elaborate on the selection of relevant game elements and the design of specific modules.

5.1 Selection of Game Elements

Currently, there is no unified classification of game elements. K. Werbach enumerated 15 game elements including levels, points, badges, avatars, achievements, and leaderboards. The Badgeville game encyclopedia website lists 24 game elements, including not only components such as levels and points but also rules/mechanisms like progress bars and countdowns, as well as gaming experiences/emotions like competition, challenge, and exploration. After analyzing 120 video games, Liu Yan et al. proposed five categories of game elements: visual elements (animation, images), auditory elements (sound effects, music), temporal elements (timing, time), spatial elements (size, direction), and compound elements (rules, feedback), totaling 40 game elements. Based on our definition of game elements, we classified them into components/mechanics, rules/dynamics, and experiences/aesthetics, selecting component/mechanics-type game elements suitable for information retrieval systems through further screening.

The selection principles were as follows: (1) Unify the names of game elements with the same purpose or similar functions. For example, game points and exchangeable points are just different names but have similar functions, so we unified them under "points." (2) Retain as many game elements as possible to meet the needs of different types of users for information retrieval systems. (3) The ultimate goal is not to design a serious game but to develop an information retrieval system containing game elements. Therefore, combat and confrontation game elements were eliminated, such as monster fighting and cutscenes.

Based on these principles, we ultimately identified 20 game elements in five

categories for constructing the gamified information retrieval system theoretical model, as shown in .

In , prize/reward elements refer to rewards users obtain in games, such as points and badges. Social/collaborative elements include game elements involved in user socialization and cooperation in games. Self-expression elements include avatars, titles, and other elements that display user personal information. Level/quest elements mainly include elements involved in user level advancement and experience accumulation in games. Additionally, time and audio elements are included.

In gamified information retrieval systems, different game elements must be combined to work together effectively. For further explanation, we classified the 20 game elements into two categories based on their functions in games: independent elements and embedded elements, as shown in .

Independent elements (14 types) can be used independently in games and function alone, such as avatars and points. Embedded elements (6 types) must be combined with other elements to function, such as trading and gifting, which are only used when users engage in trading or gifting behaviors.

5.2 Design of Game Modules

The integration of game elements with information retrieval systems is not simply about "implanting" game elements into retrieval systems but is achieved through functional modules. When designing modules, certain game elements must be reasonably combined to achieve specific functions. We designed a total of 12 modules for this system, including 5 simple modules and 7 compound modules. Simple modules are composed of single elements and can perform specific functions independently, as shown in .

Simple module design only considers the functions and effects of game elements. For example, for audio, users can turn it on or off according to their preferences or current usage context.

Compound modules are composed of two or more game elements, where different elements must be combined to function together, as shown in .

Compound module design follows two main principles: (1) Based on general game software design conventions and user habits. Users exhibit "learning transfer" when using systems—after learning to use one system, they can more easily use similar systems. Therefore, when designing system modules, we incorporated traditional game design to reduce learning time and effort costs, alleviate users' psychological burden when learning information retrieval systems, improve system usability, and make it easier for new users to get started. For example, the personal information module (P) is typically used to display or change avatars and show points, levels, and related information in social software and game product design. Therefore, following these design and usage conventions, we combined personal information, avatars, and social graphs to

design the personal information module (P). (2) Considering the categories and functions of game elements. Embedded elements often cannot independently perform certain functions and need to be combined with other elements. For example, the "experience" element—in system design, user levels should increase with the accumulation of the embedded element "experience." Therefore, "level" and "experience" together form the points compound module.

Aligned with the purpose of this paper, we used 20 game elements to design 12 game modules that achieve system goals: stimulating usage interest, supporting retrieval and interaction, and encouraging sustained usage. Finally, the 12 modules are integrated with information retrieval functional modules within the same interactive interface, with modules reasonably laid out to achieve the embedding of game modules into the information retrieval system interface. Different modules participate in users' information retrieval processes with different gaming functions—for example, prompting users that they have earned game points when downloading literature. Game elements "real-time" participate in users' information retrieval processes through game modules while satisfying the gaming needs of different user types, such as explorers, achievers, and socializers.

lists the functions of different modules in the system and the types of user needs they can satisfy. Black dots indicate functions or needs that are best fulfilled, while gray dots indicate additional functions.

Unlike traditional information retrieval systems, this system offers the following advantages: (1) Embedding game elements into information retrieval systems makes them entertaining and interesting to meet the needs of new-generation user groups; (2) Supporting users' information retrieval and interaction through game elements makes systems more usable, improves interactive functions, and is particularly more friendly to novice users; (3) Encouraging sustained usage through reward mechanisms, point systems, and social mechanisms motivates users to continue using retrieval systems, achieving the purpose of continuously accumulating knowledge and enhancing learning enthusiasm. The construction of this theoretical model addresses current research gaps between gamification and information retrieval systems.

Based on the problem of low usage rates in current non-entertainment information systems and the characteristics of new-generation user groups' "game-based learning," we propose a development approach and theoretical model for gamified information retrieval systems to meet their needs. Grounded in relevant behavioral theories, this model integrates game elements and mechanisms into information retrieval systems to stimulate usage interest, support retrieval and interaction, and encourage sustained usage, helping new-generation information users better utilize information retrieval systems.

The gamified information retrieval model we constructed has certain limitations. The functions of the designed compound modules still lack support from theory and related empirical research. The relationships between game elements require further clarification. Moreover, the model remains in the theoretical

construction stage and requires continuous adjustment to ultimately meet system design goals. Future work will adopt prototyping methods to evaluate the feasibility of the theoretical model, verify the rationality of compound module design, and further investigate new-generation users' preferences for different game elements, the supportive role of game elements in user-system interaction, and evaluation issues of gamified information retrieval systems through user experiments.

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Author Contributions

Li Yuelin: Responsible for research conception, paper revision, and partial writing;
He Pengfei: Responsible for data collection and paper writing.

Abstract: [Purpose/significance] To satisfy the needs of new-generation users for information retrieval (IR) systems, this article proposes a module-based theoretical model of gamification IR system. This model aims to achieve multiple goals, including stimulating users' interest in IR systems, supporting users' information searching and interaction, as well as encouraging continuous use. [Method/process] Based on the basic theory, relevant framework, and element action mechanism of gamification, the article combined different game elements. Then, according to the relationships between game elements and related rules, it designed modules with specific functions that game elements can be applied to the non-game situation. [Result/conclusion] In order to establish the theoretical model of game information retrieval system, we selected twenty game elements and combined them according to their functions. Then, we designed twelve types of game modules, including five simple modules and seven compound modules. These modules make IR systems have the game function. Both construct ideas and theoretical models make up the deficiency of research in the field of gamification IR, and pave a way for the development of gamified IR systems and further related studies.

Keywords: gamification; game elements; information retrieval systems

Note: Figure translations are in progress. See original paper for figures.