Original Paper

The Factors Influencing the Idea Recognition of Open Innovation Platforms: Take LEGO Ideas as an Example

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Abstract

With the influx of users posting their ideas to Open Innovation Platforms (OIPs), there has been widespread interest in how companies screen high-quality ideas. Most of the existing literature on idea quality focuses on the adoption of ideas by companies, while ignoring the recognition among users. Based on the ideas posted by users of LEGO Ideas, this study first analyzes the influence of users' social learning and social network on their innovation ability, and then further investigates the influence of idea authors' innovation ability and idea content's characteristics on idea recognition based on signal theory. The findings suggest that more challenging social learning as well as weighted indegree and betweenness centrality of social network positively affect users' innovation ability and weighted outdegree of social network negatively affects users' innovation ability. Meanwhile, idea authors' innovation ability and the number of pictures, text length, richness, popularity, and emotional polarity of idea content positively affect idea recognition. Distinct from the existing literature, this paper focuses on idea recognition among users, delves into the influence of social learning and social network on users' innovation ability, and integrates the study of factors influencing users' innovation ability into the study of factors influencing idea recognition.

Keywords

open innovation platform, user's innovation ability, idea recognition, social learning, social networks, signal theory

1. Introduction

Innovation is an important way of enterprise development, and the rapid development of information technology requires enterprises to upgrade their innovation models. The traditional enterprise innovation mainly originates from the internal R&D department (McGahan, 2021). Chesbrough first introduced the concept of open innovation in 2003, stating that traditional corporate innovation models tend to be isolated from ideas and technologies external to the firm, and that firms should improve their innovation performance by increasing the permeability of their boundaries and strategically leveraging external ideas and technologies (Chesbrough, 2023). Open Innovation Platform (OIP) is an online community built by companies to implement open innovation (Guo, 2016), which is one of the important channels for companies to carry out open innovation (Nambisan, 2018). Many well-known companies have already built their own OIPs, such as Salesforce's IdeaExchange, Xiaomi's MIUI,

LEGO's LEGO Ideas, etc. With the rapid development and maturity of OIP, a large number of users have flocked to OIP and contributed a large number of ideas. Therefore, how to identify high-quality ideas cost-effectively has attracted widespread attention (Wang, 2022).

The research on OIP is mainly divided into three aspects: platform management (Marchegiani, 2020; Wooten, 2016), user management (Wooten, 2016; Zhou, 2021), and idea management, among which, the research on idea management focuses on the study of factors influencing the quality of ideas. Most of the studies on idea quality have focused on the adoption of ideas by firms (Zhou, 2022; Liu, 2020; Ma, 2019), and a few scholars have focused on the recognition of ideas among users (Wang, 2022). Idea adoption is usually focused on the decision maker level and the process of decision making; however, idea recognition involves a wide range of general users and focuses on their acceptance of the idea. If an idea cannot be recognized among users, the idea may not be widely adopted and applied. Therefore, studying idea recognition helps to understand users' attitudes and acceptance of ideas. Most of the existing studies study the influencing factors of OIP idea quality from two aspects: users' characteristics and ideas' characteristics, but there are the following shortcomings: firstly, there are relatively few studies on idea recognition in the existing literature; secondly, regarding the construction of users' social network, most of the studies only focus on whether there are interactive relationships among users, but ignore the directionality and strength of the interactive relationships; thirdly, although the influence factors of users' innovation ability have been explored in the existing literature, the influence of such ability on idea recognition has not been further considered.

Based on the above background, this paper focuses on the research on the influencing factors of OIP idea recognition, constructs a directed weighted network based on the follow and comment behavior among users, and deeply explores the influence of social network and social learning on users' innovation ability; and further studies the influence of idea authors' innovation ability and the characteristics of idea content on idea recognition based on signal theory. This paper takes LEGO Ideas as the research object, and verifies the influencing factors of OIP users' innovation ability and idea recognition through regression. The theoretical contributions of this paper are: firstly, this paper focuses on the influencing factors of idea recognition, which represents the attitude of a wide range of users toward ideas compared with idea adoption. Secondly, this paper refines the construction of users' social network, considering not only the existence of interactive relationships among users, but also the directionality and strength of interactive relationships among users. Finally, this paper organically combines the research on the influencing factors of users' innovation ability and idea recognition, which provides new ideas for enterprises to screen high-quality ideas from the aspect of users and ideas.

2. Literature Review and Theoretical Background

2.1 Users' Innovation Ability

Open innovation breaks through the boundaries of corporate innovation and is a new way for companies to improve their innovation performance (Chesbrough, 2023). Enterprises can implement open innovation in many forms, among which, OIP is one of the important channels for enterprises to implement open innovation (Abhari, 2020; Adamides, 2021). The ideas released by OIP users provide more thoughts for enterprise innovation, however, the innovation ability of users is uneven, and the quality of ideas released by users with different innovation ability is also different. Existing literature on OIP users' innovation ability focuses on identifying leading users and analyzing the factors influencing users' innovation ability.

Scholars believe that ideas posted by leading users are more valuable (Mahr, 2012) and identify leading users by analyzing their idea information, behavioral data, etc. (Zeng, 2019). Scholars have also explored the factors influencing the innovation ability of OIP users based on different theories. For example, Wang investigated the impact of social learning on users' innovation ability from the social learning theory and found that social learning opportunities contribute to users' sustained knowledge contribution (Wang, 2018). Aggarwal argues that innovation is a reorganization of existing knowledge and that users can acquire new knowledge by interacting with others; therefore, interaction is crucial in the process of user-generated ideas (Aggarwal, 2021). Peng compares the knowledge flows generated by users' participation and browsing of innovation projects from the perspective of knowledge flows and finds that participation in projects can generate more knowledge flows and is more helpful in improving the success rate of innovation projects (Peng, 2019). Wang et al. combined the social learning theory, the theory of planned behavior, and the cognitive load theory to study the effects of social network and knowledge diversity on users' knowledge contribution, and found that the breadth of users' social network positively affects users' knowledge contribution, while users' knowledge diversity weakens the correlation between social network and users' knowledge contribution (Wang, 2022). Liu et al. combined social cognitive theory and self-determination theory to analyze the influence of users' interaction behavior and professional success experience on users' innovation ability, and found that users without professional success experience directly involved in interaction had a stronger positive influence effect on the quality of ideas, while users with professional success experience indirectly involved in interaction had a stronger positive influence effect on the quality of ideas (Liu, 2018).

In summary, factors such as past experience, knowledge diversity and participation behavior of OIP users influence users' innovation ability. With the gradual enrichment of OIP's modules, users gain more opportunities to participate and learn, and are more willing to actively engage in interactions, resulting in the formation of a closer social network, which lead to a more pronounced impact of social learning and social network on users' innovation ability.

2.2 Ideas' Quality

Ideas posted by OIP users provide companies with creative thoughts (Dahlander, 2021), while at the same time, the large number of ideas poses a great challenge for companies to evaluate and screen ideas. Ideas' authors mainly display idea content in the form of pictures and text, in addition, the idea authors' homepage information is also viewable by idea readers. Therefore, existing studies mainly analyze the influencing factors of idea quality in terms of ideas' characteristics and users'

characteristics. Most of the research on idea quality focuses on idea adoption, and only a small portion of the literature focuses on idea recognition.

Some scholars analyze the influence of ideas' text features on idea quality through natural language processing methods. For example, based on signal theory, Wang Yujie et al. classified the signals transmitted by ideas' text into informative and emotional signals, and found that informative uniqueness and emotional validity positively affect idea recognition (Wang, 2022). Chen et al. analyzed the influence of emotional and informational signals of users' posted texts on their support from the platform and found that emotion, language style, and readability positively influence the support of information (Chen, 2020). Lee et al. categorized idea features into lexical and non-lexical features and used them to train a classification model to calculate the probability of an idea being adopted (Lee, 2018). There are also some scholars who combine ideas' characteristics and users' characteristics to analyze the influencing factors of idea quality. For example, based on the exhaustive likelihood model, Wang Nan et al. analyzed the influencing factors of idea adoption from four dimensions, namely, users' community status, contribution behaviors, and community recognition of ideas, and content quality (Wang, 2020). Zhou et al. found that the timeliness and emotional disposition of the idea and the past success of the ideas' authors significantly influenced idea adoption based on the elaboration likelihood model, using the idea's characteristics as the central path and the idea authors' characteristics as the peripheral path (Zhou, 2022). Liu et al. analyzed the effects of users' characteristics, participatory processes, and contextual features on the likelihood of idea implementation, and found that users' past successes and supportive evidence for ideas had an inverted U-shaped relationship with the likelihood of idea implementation, and that the length of an idea was positively correlated with the likelihood of idea implementation (Liu, 2020).

In summary, most of the existing research on idea quality focuses on idea adoption by enterprises, and a few focus on idea recognition among users, which represents the degree of acceptance of ideas by product users and wider adoption. In addition, existing studies have neglected the influence of users' innovation ability on idea recognition, and users' innovation ability, as an important characteristic of OIP users, needs to be taken into account in the model of factors influencing idea recognition.

2.3 Theoretical Background

2.3.1 Social Learning Theory

Bandura formalized social learning theory in the 1970s, which centers on the concept that members of a society observe, learn, or imitate the behavior of others and choose to strengthen or weaken that behavior according to their own goals (Locke, 1987). In OIP, users can participate in the innovation activities organized by the platform, observe their own and other users' innovative thoughts and the recognition of their innovative thoughts, and choose the innovative thoughts with high recognition to learn or imitate, so as to improve their own innovation ability.

2.3.2 Social Network Theory

A social network is a relatively stable system consisting of social relationships among individuals (Wellman, 1988), while a wide variety of social resources are embedded in social networks (Gao, 2021). Social network analysis is an important method and tool for studying social networks to quantify the relationships between social networks as a whole and between individuals (Kong, 2019), which views social members as nodes, and social networks as a collection of nodes and connections between nodes (Tabassum, 2018). In OIP, users are the nodes of the network, and the interaction between users

gradually forms a social network, in which users can obtain the resources they need to enhance their innovation ability.

2.3.3 Signal Theory

Information influences an individual's decision-making process, but there is information asymmetry between individuals (Stiglitz, 2002). Signaling theory provides a framework for understanding how information is transmitted from one party to another (Spence, 1973). The main elements in the number theory include signal sender, signal, and signal receiver (Connelly, 2010). The medium between the signal transmission from the signal sender to the signal receiver is known as the channel, and the signal is observable, high-cost, and difficult to imitate (Ndofor, 2004), and the signal may be disturbed by distortions during signal transmission or at the receiver's terminal (Shannon, 1949). Therefore, enhancing the observability of signals is important for signaling. In OIP, idea readers can receive signals related to an idea through the idea author's homepage and the idea content; therefore, the characteristics of the signals conveyed by the idea authors affect the degree to which idea readers recognize the idea.

3. Research Model and Hypotheses

Social learning theory and social network theory have been widely used to explain how people acquire innovative knowledge and resources in online environments. Previous studies have revealed the influencing factors of users' innovation ability by analyzing OIP users' participation behaviors or interaction behaviors (Jiang, 2022; Dong, 2020). In addition, signaling theory is often used to study the influencing factors of idea quality, and previous studies usually investigate the influencing factors of idea quality in terms of both idea authors' characteristics and idea content's characteristics. Specifically, idea authors' characteristics include personality, experience, and social location, etc. (Chen, 2019; Xin, 2022); idea content's characteristics include timeliness, readability, and emotional orientation, etc. (Zhou, 2022; Wang, 2019). Idea content's characteristics include timeliness, readability, and emotional orientation, etc. (Zhou, 2022; Wang, 2019).

However, most of the existing research on OIP idea quality focuses on idea adoption, and few studies focus on idea recognition, which represents the approval of a wide range of users and helps platforms to screen and assess idea quality. Moreover, with the influx of a large number of users into the OIP, the interactions between users have become closer, therefore, studying the differences in the directionality and strength of the interactions between users can help to further explore the impact of social network on users' innovation ability. At the same time, OIP has gradually opened other modules such as activities and challenges in addition to the core idea module, aiming to provide users with more innovative learning venues and enhance their innovation ability. In addition, most of the previous literature has independently investigated the influencing factors of users' innovation ability and idea recognition, without further considering the impact of users' innovation ability on idea recognition. Therefore, this paper attempts to further explore the influencing factors of OIP idea recognition.

Based on the above discussion and analysis, this paper constructs a research model to analyze the influencing factors of OIP users' innovation ability from the aspects of users' social learning and social network, especially considering the directionality and strength of the interactive relationship between users. On this basis, this paper further combines signal theory to study the influence of idea authors' innovation ability and characteristics of idea content on OIP idea recognition. The research model proposed in this paper is shown in Figure 1.
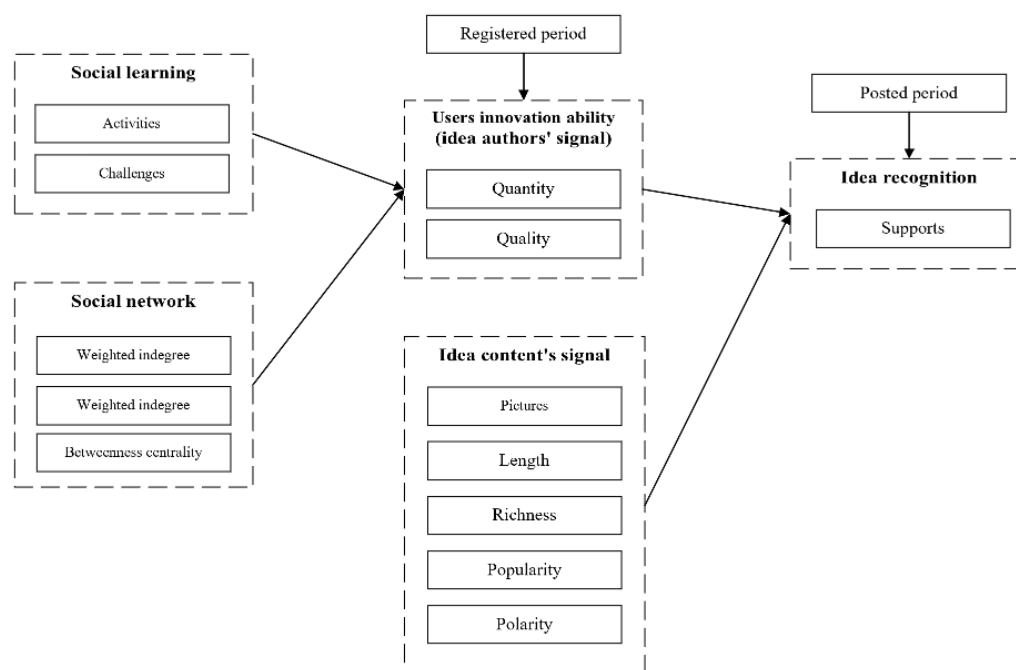
Figure 1. Research Model

3.1 Effects of Social Learning on Users' Innovation Ability

Social learning is considered a way for members of a society to acquire knowledge, whereby members of a society acquire the ability to enhance their own behavior by observing the behavior of others and the consequences it produces. Social learning through participation in platform modules to access tangible and intangible resources (Jiang, 2022), generating knowledge flows that contribute to the success of a project (Peng, 2019), and as knowledge accumulates, users are more likely to connect their own knowledge systems with others to enhance their own innovation ability (Dong, 2020). Scholars have measured the likelihood of users' social learning through their participation in social groups (Jiang, 2022), platform modules, and the number of comments (Wang, 2018), and have found that users' social learning has a significant impact on users' ability to innovate. In OIP, users can participate in the modules carried out by the platform and observe the feedback such as the number of comments and supports for their own ideas and those of other users, so as to determine which ideas are more likely to be recognized, and receive inspiration from them and then implement them into their own ideas to enhance their innovation ability. Therefore, the following hypothesis is proposed in this paper:

H1: In OIP, users' social learning positively affects users' innovation ability.

3.2 Effects of Social Network on Users' Innovation Ability

In this paper, we determine the direction of edges based on users' follow relationships, and determine the weights of edges based on the sum of the number of follows and comments among users to construct a directed weighted OIP users' social network. In social network analysis, the measurement dimensions of nodes mainly include degree and centrality, the former is used to measure the relational embedding of nodes and the latter is used to measure the structural embedding of nodes.

3.2.1 Relational Embedding

In OIP, a user's relational embeddedness refers to the number of various interactive behaviors (follow, comment, etc.) based on the posted ideas, and a higher relational embeddedness represents a closer connection with other users. Social network relationships can provide users with resources such as information and emotions (Gao, 2021), enhance their skill reserves and creativity (Wang, 2022), and thus positively influence their innovative behaviors. The higher the relational embedding of a user in a social network represents the closer the user is to other users, and therefore, the easier it is for that user to obtain resources from the social network, which positively affects his or her innovation ability (Wei, 2023).

In this paper, we take into account the directionality and strength of interactions between users, so that the degree of relational embeddedness of users in social networks can be measured in terms of two dimensions: weighted indegree and weighted outdegree. The weighted indegree represents the extent to which that user receives attention, and the greater the weighted indegree of a user node, the more advice the user receives from others (Liu, 2018) and the more likely he or she is to improve his or her own innovation ability. However, the weighted outdegree represents the degree to which the user pays attention to other users, and the greater the weighted outdegree of the user node, the more the user's energy is distracted to other ideas and is more susceptible to the influence of other ideas (Chen, 2019), which makes it more likely to reduce the uniqueness of his or her own ideas and innovation ability. Therefore, the following hypotheses are proposed in this paper:

H2: In OIP, users' weighted indegree positively affects users' innovation ability.

H3: In OIP, users' weighted outdegree negatively affects users' innovation ability.

3.2.2 Structural Embedding

In OIP, the degree of structural embeddedness of a user reflects his or her position in the network; the higher the degree of structural embeddedness of a user represents the more central the user's position in the social network, the easier it is to obtain valuable information and feedback from other users. Social networks can facilitate users to acquire, transfer, evaluate and apply innovation knowledge and information (Wang, 2022), and the more important the social network position of a user is, the more channels the user has to communicate with other users, and the easier it is to obtain heterogeneous resources (Wei, 2023) and more detailed information needed for innovation (Xin, 2022), which can enhance their own innovation ability. In social network analysis, the degree of structural embeddedness is usually measured using centrality, where betweenness centrality refers to the number of shortest paths between any two user nodes in the network that pass through the node, and represents the degree to which the node plays a role of information transfer in the social network. Compared to degree centrality and closeness centrality, betweenness centrality is a more accurate measure of the degree of structural embeddedness of a node in a network. Therefore, the following hypothesis is proposed in this paper:

H4: In OIP, users' betweenness centrality positively affects users' innovation ability.

3.3 Effects of Idea Author's Signals on Idea Recognition

In OIP, idea readers can click on the idea author's avatar to enter his or her personal homepage, where all the ideas posted by the idea author and their links are displayed. Some scholars have found that the more ideas a idea author posts, the more critical thinking the idea author does, the more likely the idea author is to come up with ideas that have operational and economic value (Wang, 2020; Lee, 2018), and that an idea author's adoption experience positively affects the likelihood that his or her ideas will

be adopted (Ma, 2019). From the perspective of signal theory, the number of ideas and the quality of ideas posted by idea authors are signals that convey to readers their own experience and strength in this platform or domain, which positively affects the recognition of ideas posted by that author. Therefore, the following hypothesis is proposed in this paper:

H5: In OIP, idea authors' idea quantity positively affects idea recognition.

H6: In OIP, idea authors' idea quality positively affects idea recognition.

3.4 Effects of Idea Content's Signals on Idea Recognition

3.4.1 Number of Pictures of Idea

In OIP, the platform allows idea authors to upload idea-related pictures as part of the idea to supplement the idea information. Users can reflect their efforts in the idea generation process through multiple forms of information (Liu, 2020) and the idea details provided by users through multiple forms of information help idea readers to assess the value of the idea (Ma, 2019), which positively affects idea recognition. From the perspective of signal theory, pictures of idea are a kind of signal that can both broaden the bandwidth of idea transmission and reduce the distortion phenomenon of information transmission. Therefore, this paper proposes the following hypothesis:

H7: In OIP, the number of pictures of idea positively affects idea recognition.

3.4.2 Text Length of Idea

In OIP, the idea author elaborates the background, parameters and other information of the idea through text, and the length of the idea text is an indicator of the level of detail of the idea. Some scholars have argued that idea texts that are too long affect the reading time of idea readers and make it more difficult for idea readers to comprehend the information (Zhou, 2022), however, some scholars have pointed out that short texts lack a comprehensive exposition of the product's features, and that longer texts contain more information, which helps readers to understand the product indirectly (Wang, 2019). Idea belongs to abstract and difficult to convey tacit knowledge, and short texts lack sufficient information to be understood by readers (Wang, 2020), which is not conducive to the recognition of idea. From the perspective of signal theory, longer texts provide readers with more background and details of the idea, allowing readers to gain a deeper understanding of the true meaning and value of the idea, thus enhancing the recognition of the idea. Therefore, this paper proposes the following hypothesis:

H8: In OIP, text length of idea positively affects idea recognition.

3.4.3 Richness of Idea

Richness of idea refers to how richly the idea contains information. Scholars have utilized the LDA model to mine the potential topics of user-posted content (Sim, 2021), arguing that the number of potential topics of an idea represents the richness of the idea (Cui, 2020). The richness of an idea reflects the level of knowledge within the user, and ideas proposed by users with a high level of knowledge are more likely to be recognized (Wang, 2022). In addition, the richer the idea is, the more functionality the idea can provide to the user, the higher the potential value (Ma, 2019), and the easier it is to be recognized by the reader. From the perspective of signal theory, the more themes an idea contains, the more signals it corresponds to, and these signals can be transmitted at the same time, increasing the bandwidth of the idea transmission and improving the coverage and transmission efficiency of the signal. Therefore, this paper proposes the following hypothesis:

H9: In OIP, richness of idea positively affects idea recognition.

3.4.4 Popularity of Idea

Popularity of idea refers to the popularity of the idea's contained information on the platform, which helps to attract the attention of authors and readers, thus stimulating the development of that type of idea. Scholars have conducted knowledge clustering of idea content posted by OIP users and found that there is a strong similarity between the words of idea content within each cluster (Dong, 2022), and the more similar idea content there is, the greater the activity of the resulting knowledge field, which is conducive to promoting the value-added and dissemination of the overall knowledge (Wei, 2019). From the perspective of signal theory, the more popular the information contained in an idea is on the platform, the more likely it is to be recognized and understood by the receiver, because the idea possesses information and experience already available to the receiver of the signal. Therefore, this paper proposes the following hypothesis:

H10: In OIP, popularity of idea positively affects idea recognition.

3.4.5 Emotional Polarity of Idea

Emotional polarity of idea refers to the emotional polarity of the idea text. Idea texts convey not only the objective information about the idea, but also the emotions contained in the idea (Lee, 2018). It has been noted that negative emotions are more likely to attract the attention of users and platforms (Zhou, 2022), in addition, users detect negative information faster and are more likely to be impressed by negative information (Chen, 2020), which positively affects idea recognition. Other scholars have not only focused on negative emotions, but have argued that both positive and negative emotional signals hidden within textual information are more likely to be perceived by readers (Zhang, 2021), thus positively affecting idea recognition. From the perspective of signal theory, the greater the emotional polarity of an idea, the easier it is to attract the attention and emotional resonance of the signal receiver, which in turn positively affects the recognition of the idea. Therefore, this paper proposes the following hypothesis:

H11: In OIP, emotional polarity of idea positively affects idea recognition.

4. Research Methodology

4.1 Data Collection

In this paper, we choose LEGO Ideas (https://ideas.lego.com/), an OIP established by LEGO in 2008 to provide a place for users to share their ideas, as the object of our research. LEGO Ideas is selected as the research object in this paper because: a) LEGO Ideas is representative of the platform. As a globally recognized toy manufacturer, LEGO attracts a large number of users to register and share their ideas on the platform. As of May 2023, users have published 41,249 product ideas. b) LEGO Ideas data are available. Information about users' homepages and ideas on LEGO Ideas is available to the public.

The LEGO Ideas platform is divided into 3 modules, namely Activities, Challenges, and Product Ideas. Among them, the Product Ideas module has no time or theme limitations for users to publish their ideas, so users can maximize their innovation abilities to complete their ideas and publish them. Therefore, this paper grabs the data of product ideas and their authors in the whole year from July 1, 2021 to June 30, 2022 as a research sample, and obtains the relevant data of 2,148 ideas and 1,356 users in total.

4.2 Variables and Measurement

4.2.1 Dependent Variables

The dependent variables in this study are users' innovation ability and idea recognition, and consider users' innovation ability in terms of both idea quantity and idea quality. Users can click support to express their approval of the idea (Arora, 2019), the higher the support number of the idea represents the more the idea is recognized by the users (Wang, 2022), and the number of supports is easy to count, which can objectively reflect the degree of recognition of the idea. Therefore, this paper chooses the number of supports as a measure of idea recognition and uses the average number of supports of all the user's ideas to measure the quality of the user's ideas.

4.2.2 Independent Variables

Users' social learning: Based on the characteristics of the platform, this study uses the number of times users participate in other innovation modules of the platform (i.e., activities and challenges) as a measure of user social learning.

Users' social network: First, the OIP users' social network is constructed by taking users as nodes, follow relationships between users as directed edges, and the sum of the number of follows and comments between users as edge weights. Second, Gephi is used to calculate the weighted outdegree, weighted indegree and betweenness centrality of user nodes, which are used to measure the social network characteristics of users.

Idea authors' signals: In this paper, users' innovation ability is the dependent variable when studying the factors influencing OIP users' innovation ability. However, when studying the influencing factors of OIP idea recognition, users' innovation ability as an idea authors' signal is the independent variable, measured as described in 4.2.1.

Idea content's signals: (a) Number of pictures of idea: The number of pictures included in the ideas. (b) Text length of idea: The number of words in the idea text. (c) Richness of idea: The LDA model is used to analyze the themes of idea texts. The number of themes is too small for theme extraction, and the number of themes is too large for model overfitting. Therefore, this paper first tested the consistency of the model with the number of themes ranging between [5,55], and found that the consistency of the LDA model is the highest when K=15. Second, the LDA model is used to classify the idea text into themes to obtain the probability that each idea is generated by each theme, and if the probability that the creative text is generated by a certain theme is greater than the mean (i.e., 1/15), it is considered that this theme is included in the idea. Finally, the number of topics included in each idea was counted as a measure of idea's richness. (d) Popularity of idea: The TF-IDF model was first used to vectorize the idea text, and then the mean of the cosine distance between each idea text vector and other idea text vectors was calculated as a measure of idea's popularity. (e) Emotional polarity of idea: Textblob is used to calculate the emotion score of the idea text, the range of the score is [-1,1], the closer the score is to -1, the more negative the emotion of the idea text is, and the closer the score is to 1, the more positive the emotion of the idea text is; and then the absolute value of the score is calculated as a measure of the polarity of the idea's emotion, and the range of the score is [0,1], the closer the score is to 0, the more neutral the emotion of the idea text is, and the closer the score is to 1, the stronger the polarity of the emotion of the idea text is. The closer the score is to 0, the stronger the emotional polarity of the idea text is.

4.2.3 Control Variables

Due to the early creation of LEGO Ideas, there is a large gap in the length of user registration on the platform, and the length of user registration affects the performance of users' ability to innovate on the platform, so this paper takes the length of user registration as a control variable. Considering that it takes a long time for the formation of innovation ability, this study takes whether the length of registration is 18 months or not as a measurement indicator. In addition, the time gap between the release of the sample ideas is as long as one year, which affects the number of supports for the ideas, so this study takes the length of the idea release as a control variable and adopts the number of days the idea was released as a measure. The definitions and measurements of all variables in this study are shown in Table 1.

Table 1. Description of the Experimental Variables

	Variables	Measure
Social learning	Activities	Number of times a user participated in activities
	Challenges	Number of times a user participated in challenges
Social network	Indegree	Weighted indegree of a user's social network
	Outdegree	Weighted outdegree of a user's social network
	Betweenness	Betweenness centrality of a user's social network
Users' innovation ability (Idea authors' signals)	Quantity	Number of ideas posted by a user
	Quality	Average number of supports for all ideas posted by a user
Idea content's signals	Pictures	Number of pictures included in an idea
	Length	Number of words in the text of an idea
	Richness	Number of topics included in the text of an idea
	Popularity	Average of the similarity of an idea's text to other ideas' texts
	Polarity	Emotional polarity contained in the text of an idea
Idea recognition	Supports	Number of supports for an idea
Control variables	Registered_period	Whether a user has been registered for more than 18 months
	Posted_period	Number of days an idea has been published

4.3 Model Description

This paper explores the factors influencing OIP users' innovation ability and proposes hypotheses based on social learning theory and social network theory. In this paper, user innovation ability is measured from two aspects of idea quantity and idea quality, and both are continuous variables, so linear regression is chosen to verify the research hypotheses, and the regression models are shown in (1) and (2).

$$quantity = \alpha_0 + \alpha_1 activities + \alpha_2 challenges + \alpha_3 indegree + \alpha_4 outdegree \qquad (1)$$
$$+ \alpha_5 betweenness + \alpha_6 registered\_period + \varepsilon_1$$

$$quality = \beta_0 + \beta_1 activities + \beta_2 challenges + \beta_3 indegree + \beta_4 outdegree \qquad (2)$$
$$+ \beta_5 betweenness + \beta_6 registered\_period + \varepsilon_2$$

where α_0 and β_0 are the intercept terms, α_1 to α_6 and β_1 to β_6 are the coefficients' estimates, ε_1 and ε_2 are the random error terms.

This paper also further explores the influence of idea authors' innovation ability and idea content characteristics on idea recognition based on signal theory. Because the dependent variable is a count variable and the variance is much larger than the mean, a negative binomial regression model is chosen to verify the research hypotheses, and the regression model is shown in (3).

$$supports = \gamma_0 + \gamma_1 quantity + \gamma_2 quality + \gamma_3 pictures + \gamma_4 length + \gamma_5 richness$$
$$+ \gamma_6 popularity + \gamma_7 polarity + \gamma_8 posted\_period + \varepsilon_3 \qquad (3)$$

where γ_0 is the intercept term, γ_1 to γ_8 are the coefficients' estimates, ε_3 is the random error term.

5. Empirical Results and Analysis

5.1 Descriptive Statistics

Tables 2 and 3 show the descriptive statistics of the variables in the model of factors influencing OIP users' innovation ability and the model of factors influencing idea recognition, respectively.

Table 2 shows that the average weighted outdegree of OIP users is 47, while the maximum outdegree is 2,623, indicating that there are large differences in the weighted outdegree of OIP users. Table 3 shows that the standard deviation of innovation ability of OIP users, i.e., the standard deviation of idea quantity and idea quality of idea authors are 7 and 1231, respectively, indicating that there are large differences in the innovation ability of different idea authors.

Table 2. Descriptive Statistics for User-related Variables

	Min	Max	Mean	SD.
Activities	0	29	1.062	2.566
Challenges	0	32	1.909	3.703
Indegree	0	683	47.243	55.973
Outdegree	0	2623	47.249	179.148
Betweenness	0.000	0.054	0.001	0.005
Quantity	1	41	3.612	4.973
Quality	12	9339	757.978	1257.352
Registered_period	0	1	0.495	0.500

Table 3. Descriptive Statistics for Idea-related Variables

	Min	Max	Mean	SD.
Quantity	1	41	5.709	6.978
Quality	12	9339	801.947	1230.816
Pictures	1	15	7.700	4.078
Length	39	803	114.003	85.135
Richness	1	9	3.196	1.345
Popularity	0.006	0.449	0.029	0.013
Polarity	0.000	1.000	0.912	0.158
Supports	13	9849	755.577	1221.363
Posted_period	61	425	220.339	107.822

In this study, correlation analysis was performed on the study variables to avoid multi-collinearity among the independent variables. Table 4 shows the correlation coefficients of the variables in the model of factors influencing the innovation ability of OIP users. Table 5 shows the correlation coefficients of the variables in the model of factors influencing the recognition of OIP ideas. As can be seen from Tables 4 and 5, the correlation coefficients between the independent variables are all less than 0.75. In addition, the Variance Inflation Factors (VIFs) of all the independent variables are less than 5, therefore, it can be assumed that there is no serious multi-collinearity between the independent variables.

Table 4. Correlation Coefficients of User-related Variables

	1	2	3	4	5	6	7	8
Activities	1							
Challenges	0.320**	1						
Indegree	0.273**	0.354**	1					
Outdegree	0.108**	0.115**	0.563**	1				
Betweenness	0.070**	0.125**	0.533**	0.243**	1			
Registered_period	0.230**	0.270**	0.213**	-0.033	0.109**	1		
Quantity	0.177**	0.284**	0.539**	0.086**	0.343**	0.324**	1	
Quality	0.042	0.202**	0.400**	0.046	0.313**	0.190**	0.098**	1

Note. * $p<0.05$ ** $p<0.01$.

Table 5. Correlation Coefficients of Idea-related Variables

	1	2	3	4	5	6	7	8	9
Quantity	1								
Quality	0.178**	1							
Pictures	0.052*	0.225**	1						
Length	0.017	0.207**	0.413**	1					
Richness	0.045*	0.143**	0.121**	0.188**	1				
Popularity	0.050*	0.175**	0.145**	0.213**	-0.013	1			
Polarity	0.014	0.133**	0.153**	0.229**	0.000	0.227**	1		
Posted_period	0.071**	0.135**	0.129**	0.130**	0.110**	0.098**	0.091**	1	
Supports	0.159**	0.737**	0.243**	0.232**	0.207**	0.286**	0.139**	0.186**	1

Note. * $p<0.05$ ** $p<0.01$.

5.2 Regression Analyses

Because both dependent variables, idea quantity and idea quality, are continuous variables, linear regression was chosen to test the research hypotheses. Table 6 shows the regression coefficients for the OIP user innovation ability model, model 1 for the idea quantity and model 2 for the idea quality. As shown in Table 6, in terms of users' social learning, user participation in contests positively affects users' innovation ability (model 1, $\beta=0.053$, $p<0.05$; Model 2, $\beta=0.064$, $p<0.05$), while user participation in activities negatively affects users' innovation ability (model 1, $\beta=-0.020$, $p>0.05$; model 2, $\beta=-0.104$, $p<0.05$), H1 is partially valid. The part of H1 that is not valid may be due to platform characteristics, as the activity module of LEGO Ideas is designed to help beginners to practice their innovation skills, so users who are more innovative will not participate or rarely participate in the module, resulting in the regression results showing that the number of activities a user participates in negatively affects the user's ability to innovate. In terms of users' social network, the indegree positively affects users' innovation ability (model 1, $\beta=0.609$, $p<0.01$; model 2, $\beta=0.458$, $p<0.01$), and H2 is valid; the outdegree negatively affects users' innovation ability (model 1, $\beta=-0.270$, $p<0.01$; model 2, $\beta=-0.270$, $p<0.01$), H3 is valid; the betweenness centrality positively affects users' innovation ability (model 1, $\beta=0.060$, $p<0.05$; model 2, $\beta=0.117$, $p<0.01$), and H4 is valid.

Because the dependent variable, idea recognition, is a count variable and the variance is much larger than the mean, a negative binomial regression model was chosen to test the research hypotheses. Table 7 shows the regression coefficients for the OIP idea recognition model. As shown in Table 7, in terms of the idea authors signals, both idea quantity ($\beta=0.018$, $p<0.01$) and idea quality ($\beta=0.001$, $p<0.01$) of idea authors positively affect idea recognition, and H5 and H6 are valid. In terms of idea content's signals, the number of pictures ($\beta=0.029$, $p<0.01$), text length ($\beta=0.001$, $p<0.01$), richness ($\beta=0.034$, $p<0.05$), popularity ($\beta=4.061$, $p<0.05$), and emotional polarity ($\beta=0.318$, $p<0.05$) positively affect idea recognition, and H7-H11 are valid.

Table 6. Results of Linear Regression Estimation (N=1,356)

	model 1 (DV=Quantity)	model 2 (DV=Quality)
Registered_period	0.170**	0.079**
Activities	-0.020	-0.104**
Challenges	0.053*	0.064*
Indegree	0.609**	0.458**
Outdegree	-0.270**	-0.270**
Betweenness	0.060*	0.117**
R-square	0.389	0.229

Note. * $p<0.05$ ** $p<0.01$.

Table 7. Results of Binomial Estimation (N=2,148)

	model 3 (DV=Supports)
Posted_period	0.002**
Quantity	0.018**
Quality	0.001**
Pictures	0.029**
Length	0.001**
Richness	0.034*
Popularity	4.061*
Polarity	0.318*
_cons	4.303**
McFadden R-square	0.057

Note. * $p<0.05$ ** $p<0.01$.

5.3 Robustness Checks

To test the robustness of our model, this study re-collected idea information from January 2023 to March 2023 (610 ideas). Then it was merged with the original idea information (680 ideas) from April 22 to June 2022 to form a new research sample, and the data were analyzed and regressed according to the above method, and the results are shown in Table 8.

Table 8. Results of Robustness Test (N=1,290)

	model 4 (DV=Supports)
Posted_period	0.006**
Quantity	0.012**
Quality	0.001**
Pictures	0.036**
Length	0.001*
Richness	0.068**
Popularity	6.515*
Polarity	0.692**
_cons	3.307**
McFadden R-square	0.069

Note. * p<0.05 ** p<0.01.

6. Discussion and Implications

6.1 Key Findings

This study reveals some important findings. First, the results confirm that social learning has an impact on users' innovation ability. Modules that are more challenging are more helpful in improving users' innovation ability than modules that are designed to help beginners practice their innovation skills, while the former are more suitable for beginners.

Second, the results confirm that social network has an impact on users' innovation ability. In this paper, when constructing the social network of OIP users, the directionality and strength of the interaction between users are considered. For weighted indegree, the more a user is followed by other users, the more advice the user receives, which promotes the user to improve his or her innovation ability. For weighted outdegree, the more users pay attention to other users, the more the user's energy is distracted, which reduces the user's own innovation ability. For betweenness centrality, the more centrally located the user is in the network, the more convenient it is for the user to access innovation resources, which promotes the user to improve its own innovation ability.

Third, the results confirm that idea authors' innovation ability has a positive effect on idea recognition. The OIP's idea page provides an entry point to the idea author's homepage, and the number of ideas posted by idea authors and the quality of their ideas convey their own innovation ability to idea readers. The higher the number and quality of ideas posted by idea authors, the more their ideas are usually recognized.

Fourth, the results confirm that the characteristics of idea content have an impact on idea recognition. For the number of pictures and text length, pictures and text can help idea readers form a clearer and more accurate understanding of the idea and promote idea readers' recognition of the idea. For richness, richer ideas can attract more idea readers' attention and thus be recognized by more users. For emotional polarity, ideas with large emotional polarity are more likely to cause emotional resonance of idea readers and promote the recognition of the ideas.

6.2 Theoretical Implications

The findings of this paper have multiple implications for the literature. First, this paper enriches the research on OIP idea quality by exploring a new perspective of idea recognition. Compared to idea adoption, idea recognition focuses more on users' attitudes toward ideas, represents a broader range of adoption, and helps to understand the acceptance of ideas by product users.

Second, this paper extends the research on OIP users' social network. Previous studies usually focus only on whether there is an interactive relationship between users, and the established social network is an undirected and unweighted network, ignoring the directionality and strength of the interactive relationship. This paper establishes a directed weighted network of OIP based on the follow and comment behaviors among users, and through the analysis of the network, we find that the weighted indegree and weighted outdegree have different impacts on users' innovation ability, with the former positively affecting users' innovation ability and the latter negatively affecting innovation ability.

Third, this paper enriches the research on signal theory to a certain extent. Based on signal theory, this paper examines the influencing factors of idea recognition from the dimensions of idea authors and idea content, and proposes a research model by analyzing data from a representative platform. On the one hand, this paper finds some interesting factors of idea recognition (e.g., richness and popularity). On the other hand, while previous studies have mainly examined the influencing factors of user innovation ability or creativity recognition individually, this study further investigates the influence of such ability as well as idea content characteristics on idea recognition on the basis of the model of influencing factors of users' innovation ability.

6.3 Managerial Implications

This study has practical implications. For idea authors of OIP, this paper suggests that idea authors should participate in some challenging platform modules, which can help to improve their innovation ability. Meanwhile, idea authors should focus on other users' follows and comments about themselves and extract useful suggestions from them. What's more, idea authors need to avoid paying too much attention to the ideas of other authors and should put more energy into their own ideas. In addition, when describing the idea, idea authors can appropriately increase the number of pictures and text length of the idea, which will help readers understand the idea. Idea authors can also choose the types of ideas that are popular on the platform and include rich elements and emotions in their ideas, which helps to attract readers' attention and thus increase the recognition of the ideas.

This study also provides suggestions for improving the platform design and operation mechanism of OIP. At present, OIP has gradually become an important channel for enterprises to carry out open innovation. At the same time, enterprises are eager to utilize OIP to absorb external innovative ideas to improve their innovation performance. Therefore, this paper suggests that the platform can design some functions to enhance users' innovation ability. For example, the platform can open more challenging modules and remind idea authors to check other users' comments in time. In addition, the large number of users flocking to OIP increases the pressure for the platform to screen high-quality ideas. Therefore, this paper suggests that the platform can analyze the innovation ability of idea authors and the characteristics of idea content (e.g., richness and popularity, etc.) from the dimensions of idea authors and creative content to evaluate the idea and reduce the pressure of screening idea.

6.4 Limitations and Future Directions

This study still has some limitations that can be used as a direction for future research. First, although this paper selected a representative LEGO Ideas platform for the empirical analysis, it did not consider multiple platforms in different industries to validate the model of this paper. Therefore, future research can be conducted in OIP in different industry contexts to explore the influencing factors of OIP idea recognition and to generalize the findings. Second, the data used in this study are cross-sectional, and future research could use panel data to explore the dynamic effects of user social learning and social network on user innovation ability.

Finally, this paper chooses the number of times a user participates in a platform module as a measure of user social learning, which is not deep enough to explore user social learning; in the future, we can explore user social learning in scenarios other than OIP by means of questionnaires, etc., so as to deepen the understanding of user social learning.

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