Exploring the effects of problem- and solution-related knowledge sharing in internal crowdsourcing

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Abstract

Purpose – *Firms increasingly rely on both external and internal crowdsourcing to capture ideas more broadly and enhance innovative problem-solving. Especially in internal crowdsourcing, knowledge sharing that contributes to develop or further the understanding of the problem the idea is focused on solving can take place between critical employees, and in that way improve ideas generated by others. This far, most crowdsourcing practices have focused on identifying solutions to proposed problems, whereas much less is known about how crowds can be used to share problem-related knowledge. There is thus an untapped potential in leveraging crowds not just to generate solution-oriented ideas but also to share knowledge to improve ideas and even to reframe problems. This paper aims to explore the effect of problem- and solution-related knowledge sharing in internal crowdsourcing for idea development.*

Design/methodology/approach – *Data on ideas and comments were collected from an idea management system in a Swedish multinational company. The investigation captures the influences of the problem- and solution-related knowledge sharing on ideas based on content analysis and logistic regression analysis.*

Findings – *The results from this study show that sharing knowledge related to solutions in idea development impacts idea acceptance positively, whereas sharing knowledge related to problems in idea development has a negative effect on the likelihood of idea acceptance and these effects of knowledge sharing are moderated by the active author responses.*

Practical implications – *This research provides managerial implications for firms to deliberately manage knowledge sharing in peer communities in internal crowdsourcing, especially by providing suggestions on problem reframing and solution refining for ideas.*

Originality/value – *The results contribute to existing theory in terms of extending the view of crowdsourcing in ideation to include how crowds contribute to the development of the problem and the solution during the development of ideas and providing new insights on knowledge sharing in internal crowdsourcing based on problem-solving theory.*

Keywords *Development, Knowledge sharing, Internal crowdsourcing, Problem-related knowledge, Solution-related knowledge*

Paper type *Research paper*

1. Introduction

Crowdsourcing is a method to search for innovative solutions by collecting knowledge from crowds in diverse areas on internet-based platforms (Afuah and Tucci, 2012; Majchrzak and Malhotra, 2020) and has been shown to be of great value in solving complex innovation problems (Acar, 2019; Blohm *et al.*, 2013; Han *et al.*, 2020). In this search for new knowledge to fuel innovation, many firms have primarily relied on external crowds (Ruiz and Beretta, 2021). Recognizing that internal employees also constitute a crucial source of innovation, an increasing number of firms are embracing the use of internal crowdsourcing to motivate employees to participate in innovation (Beretta and Søndergaard, 2021; Greineder and Blohm, 2020). Internal crowdsourcing, defined as 'an IT-enabled group

activity based on an open call for participation in an enterprise' (Zuchowski *et al.*, 2016, p. 168) has been demonstrated to be a way for firms to purposefully leverage the knowledge of their employees for innovation (Pohlisch, 2020). Nevertheless, previous studies have, so far, mostly focused on external crowdsourcing and an improved understanding of internal crowdsourcing has recently been called for (Beretta and Søndergaard, 2021).

Given the creative potential of leveraging the knowledge of crowds to solve innovation problems (Acar, 2019; Chen *et al.*, 2020; Pohlisch, 2020), understanding the role of knowledge sharing based on problem-solving theory is essential in crowdsourcing (Majchrzak and Malhotra, 2016; Pollok *et al.*, 2019). Although it seems somewhat obvious to argue for the importance of knowledge sharing for all types of crowdsourcing, it is necessary to be careful when generalizing across internal and external crowdsourcing because of a number of substantial differences. In internal crowdsourcing, employees tend to be less diverse in knowledge sharing in comparison with external crowds (Beretta and Søndergaard, 2021; Malhotra *et al.*, 2017). However, employees possess an in-depth understanding of the organizational context that external crowds rarely do. In the knowledge-sharing process employees can therefore be more critical and also generate more feasible and strategically relevant ideas that better align with the firm's needs (Beretta and Søndergaard, 2021; Galeazzo and Furlan, 2019;von Hippel and von Krogh, 2016; Zuchowski *et al.*, 2016) and can be developed into comprehensive solutions to solve the problem (Malhotra *et al.*, 2017). This difference highlights that knowledge sharing in internal crowdsourcing provides access to exchanging the problem-related knowledge of the entire, often dispersed employees in addition to the solution-related knowledge to develop ideas (Hober *et al.*, 2021).

On an overall level, crowdsourcing appears to have primarily focused on identifying ideas as solutions, namely solution-oriented ideas, to proposed problems. Much less is known about how crowds can be used to create, share and exchange both problem- and solution- related knowledge to improve ideas having clear and well-defined problems and appropriate solutions. Enabling crowd members to make explicit and share their solution-oriented ideas to solve established innovation problems has been an initial desired outcome of crowd-based innovation (Afuah and Tucci, 2012; Sun *et al.*, 2020), where the very term "problem-solving" seems to contain an implicit assumption that one starts with a well-formulated problem (von Hippel and von Krogh, 2016). Majchrzak and Malhotra (2020) argued that in doing so the potential wisdom and value of the crowd is greatly limited, particularly when there is a need to solve poorly defined or wicked problems. To better leverage the full potential of the crowd, there is a need to reconsider previous "problem-solving" process through freeing the crowd to not only generate solution-oriented ideas (Armanios and Zhang, 2021) but also freely share any kind of knowledge in idea development, especially regarding problems that ideas are intended to solve (Von Hippel and Kaulartz, 2021).

This study focuses on internal crowdsourcing that enables employees to share both problem- and solution-related knowledge to fruitfully generate and develop innovative ideas. Unlike the solution-oriented ideas in the "problem-solving" process starting with a well-formulated problem, the basic perspective on ideas for innovation applied in this study is that they are composed of combinations of problems and solutions rather than just solutions (Bayus, 2013; Magnusson *et al.*, 2016). This combination view of ideas is in line with a new trend problem-solving process without the need of well-structured problem formulation (Von Hippel and Kaulartz, 2021; von Hippel and von Krogh, 2016), acting as an initial driver knowledge sharing of problem- and solution-related knowledge to improve the appropriateness of solutions to problems described in ideas. It happens in some crowdsourcing platforms such as AlphaCorp, where the problem/need description and solution information covering the technics and possible implementations to solve the problem should be provided (Blohm *et al.*, 2013). However, there is different description

levels of problems (i.e. ill-/well-structured) which need different knowledge sharing (i.e. commenting related to problem or solution information of ideas) to enhance the appropriation of ideas (Nickerson and Zenger, 2004; Natalicchio *et al.*, 2017). By adding additional problem- and solution-related knowledge (i.e. complementing or correcting the problem or solution information in ideas, adding new problem or alternative solutions) to ideas, employees' comments potentially improve these ideas. Thus, employees are encouraged to share their knowledge in idea development by offering comments, especially related to problem statements and solutions of ideas. Unfortunately, however, the limited extant knowledge about what really happens to ideas in internal crowdsourcing idea development makes it difficult to understand whether, and if so how, value is potentially created when employees are freed up to share problem- and solution-related knowledge on their peers' ideas. To address these identified limitations of existing theory, this study aims to explore the effect of problem- and solution-related knowledge sharing in internal crowdsourcing for idea development. More specifically, the first research question is:

RQ1. What are the effects of problem- and solution-related knowledge sharing, respectively, on the development of ideas in internal crowdsourcing?

Furthermore, because knowledge sharing in and across organizations has shown that knowledge exchange primarily blossoms if it is bidirectional (Dahlander and Piezunka, 2014), we argue that responses from idea creators, namely author responses, could influence the effect of problem- and solution-related knowledge sharing. Consequently, the second research question is:

RQ2. How do author responses affect the relationship between problem- and solution-related knowledge sharing and the development of ideas in internal crowdsourcing?

Data for the empirical investigation were collected from an internal idea management system in a Swedish multinational company. During the empirical study, the shared comments on ideas in idea development were classified into problem- and solution-related knowledge sharing based on content analysis and regression analysis was employed to test the influence of problem- and solution-related knowledge sharing on idea acceptance. The results reveal that solution-related knowledge sharing in idea development tends to influence idea acceptance positively, whereas problem-related knowledge sharing in idea development is negative for idea acceptance and these significant effects of knowledge sharing are moderated by the active response from idea creators. The theoretical contribution of this research primarily lies in the development of new insights on crowdsourcing for ideas based on problem-solving theory. In particular, this is one of the first studies to explore the effects of knowledge sharing in idea development, specifically highlighting issues related to the problem and solution sides of innovation ideas. Moreover, in terms of management contributions, this study provides not only guidance for the management of peer-help behaviors but also implications for inducing and sustaining different types of knowledge sharing in crowd-based innovative communities.

2. Knowledge sharing in internal crowdsourcing

2.1 Idea development in internal crowdsourcing

In the last decades, we have seen many examples of applying crowd-like approaches to ideation inside firms through the use of firm-internal online communities, e.g. Innovation Jam at IBM (Bjelland and Wood, 2008) and IdeaBoxes at Ericsson (Björk *et al.*, 2014), to mention just a couple of specific examples. In comparison with external crowdsourcing, internal crowds are expected to be more active and reliable in generating ideas, as the participants are employees who are more qualified and trusted than what is the case for participants in external crowds (Simula and Vuori, 2012). Firm-internal use of crowdsourcing turns the

internal ideation process into a truly collective ideation process, as internal crowds can not only freely submit ideas but also voluntarily comment on others' ideas, thereby sharing potentially valuable knowledge for innovation (Beretta and Søndergaard, 2021; Zhu *et al.*, 2019).

As a sub-process of idea management, idea development in internal crowdsourcing follows the generation of an idea, but precedes its evaluation/selection (Beretta *et al.*, 2019; Chen *et al.*, 2020; Zhu *et al.*, 2019). Compared to the traditional approaches to the management of ideas in the early stage of innovation, the differences brought by the usage of internal crowdsourcing are pronounced and dominated by a collective and transparent idea-development process. With shared knowledge input during this phase, weak points of ideas might be discovered or new directions for idea revision might be provided for the improvement of ideas (Brem and Voigt, 2009), something which to some extent helps ideas better fit current practice and needs (Kijkuit and van den Ende, 2007; Zhu *et al.*, 2017). In this respect, the development of ideas is an essential phase where the initially generated ideas can be enhanced with the help of shared knowledge input from internal crowds, eventually leading to a higher probability of idea acceptance and innovation success (Deichmann and van den Ende, 2014).

2.2 From sequential to mutual knowledge sharing in idea development

Problem-solving forms a critical theoretical base for understanding the knowledge processing to investigate problems and identify proper solutions (Galeazzo and Furlan, 2019). Regarding the internal and external crowdsourcing types and the different types of shared knowledge for problem-solving, crowdsourcing in previous studies can be mainly categorized into four types (Table 1), including Type I/Type II: internal/external crowdsourcing for the sharing of solution-related knowledge only and Type III/Type IV: internal/external crowdsourcing for the sharing of both problem- and solution-related knowledge. For Types I and II without open calls for problem-related knowledge sharing, one common and popular activity is to search for solutions through internal and/or external crowd contests (Afuah and Tucci, 2012; Malhotra *et al.*, 2017). Different from the traditional view on ideas as only solutions, a new proposed term called problem–solution design pair (von Hippel and Kaulartz, 2021) can be used for Type III and Type IV, which encourages an understanding of both problem- and solution-related knowledge sharing. One specific difference is that customer needs are considered together with solutions as a drive for matching problem–solution design pairs and the problem-related knowledge is discussed particularly in idea development in crowdsourcing (Majchrzak and Malhotra, 2016).

With respect to these four different aspects of idea development, the knowledge sharing types of idea development today have been mainly configured in two ways regarding the

Table 1 Four types of crowdsourcing and related literature

Crowdsourcing *Shared knowledge*	*Internal crowdsourcing excluding external crowds*	*Crowdsourcing including external crowds*
Solution-related knowledge only	Type I: Haas *et al.* (2014); Malhotra *et al.* (2017); Zuchowski *et al.* (2016)	Type II: Acar (2019), Afuah and Tucci (2012); Armanios and Zhang (2021); Brabham (2008); Campos-Blázquez *et al.* (2020); Chan (2018); Jeppesen and Lakhani (2010); Schemmann *et al.* (2016)
Problem- and solution-related knowledge	Type III: Deichmann *et al.* (2021); Hober *et al.* (2021)	Type IV: Bayus (2013); Beretta and Søndergaard, (2021); Blohm *et al.* (2013), Majchrzak and Malhotra (2016); Majchrzak and Malhotra (2020), Malhotra and Majchrzak (2019); Pollok *et al.* (2019), Sun *et al.* (2020)

two different shared knowledge types and the similar problem-solving mechanisms in internal and external crowdsourcing. For crowdsourcing that supports the sharing of only solution-related knowledge (Types I and II in Table 1), the first way (Figure 1) assumes that problems are predefined and then alternative solutions are sequentially sought with iterative adjustments to the predefined problems (Jeppesen and Lakhani, 2010). This approach is in accordance with the sequential problem-solving model (Basadur, *et al.*, 2013) as well as the iterative lean startup proposed for innovation (Ries, 2011). Hence, this configuration of knowledge sharing in idea development can be regarded as a sequential but iterative type of solution search.

By contrast, the second knowledge-sharing type in idea development (Type III and Type IV in Table 1), typically extended from the new logic of problem-solving processes proposed by von Hippel and von Krogh (2016) and Nambisan *et al.* (2017), assumes that problems can be identified through peer communication (Majchrzak and Malhotra, 2016). Thus, crowds have opportunities to share both their problem- and solution-related knowledge on ideas to define and match the problem with its solution through their conversations. Following this logic, we consider idea development as a collaborative problem–solution co-evolution process in creative design (Wiltschnig *et al.*, 2013), in which problems and solutions are mutually developed over time, constituting a second type of knowledge sharing in idea development (see Figure 2). The shared knowledge related to solutions might motivate a discussion on the problems and the shared knowledge related to problems might create a need to seek new solutions with the recognition of

Figure 1 Sequential and iterative knowledge sharing in internal-crowdsourcing idea development

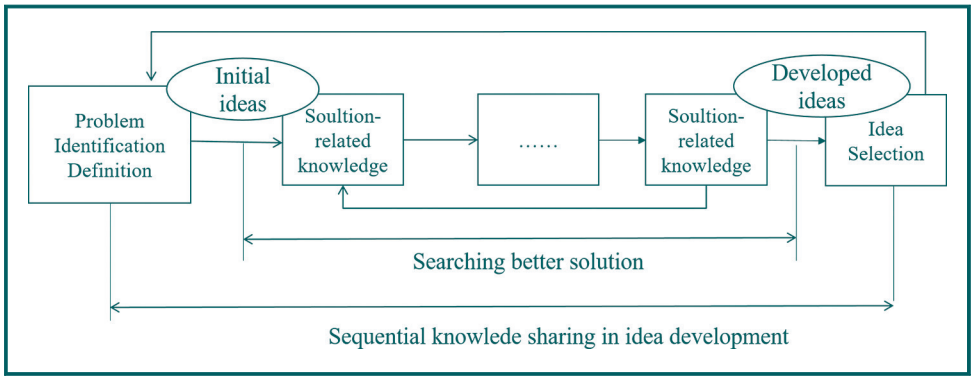
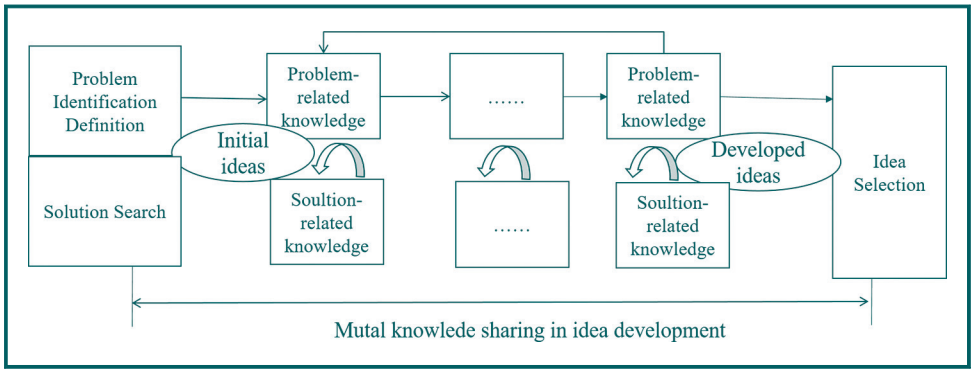


Figure 2 Mutual knowledge sharing in internal-crowdsourcing idea development



problem-solution design pairs, aiming to improve the appropriateness of solutions to the problems (Natalicchio *et al.*, 2017; Nickerson and Zenger, 2004; von Hippel and von Krogh, 2016). Therefore, there is no clear start and end during mutual idea development, but only the back-and-forth problem- or solution-related knowledge addition to ideas for the matching of problem-solution design pairs.

In terms of the above two types of knowledge sharing in crowdsourcing, Majchrzak and Malhotra (2020) argued that the potential wisdom and value of the crowd are greatly limited in the sequential problem-solving-oriented knowledge-sharing process. To better unleash the inherent potential of the crowd, there is a need to free the crowd from only generating solution-oriented ideas and move instead toward the free and mutual sharing of any kind of knowledge, especially knowledge related to the problems that ideas are intended to solve (Armanios and Zhang, 2021). Therefore, the mutual knowledge sharing in idea development, where problem- and solution-related knowledge is moving and changing over time, is likely to be of high theoretical interest for innovation (Stock *et al.*, 2018).

However, questions about whether the support of problem-related knowledge sharing should be open to crowds (Majchrzak and Malhotra, 2016) are theoretically argued, while empirical studies are lacking. In what follows, the role of problem- and solution-related knowledge sharing in idea development is confused, particularly in internal crowdsourcing where the occurrence of problem-related knowledge sharing has only been mentioned by few authors such as Deichmann *et al.* (2021) and Hober *et al.* (2021) and with a lack of theoretical support (see Table 1). Therefore, it is unclear whether the value is potentially created when employees mutually share knowledge related to both problems and solutions in idea development, something which calls for research based on empirical studies on the role of problem- and solution-related knowledge sharing in internal crowdsourcing for idea development.

3. Hypotheses development

Driven by the missing-knowledge part of presented ideas in idea generation, related knowledge is mutually shared in idea development through a reciprocal communication process, which includes comments given and comment responses (Wooten and Ulrich, 2017; Zhu *et al.*, 2019). In this case, individuals who obtain related knowledge are likely to elaborate on ideas to seize and exploit more opportunities (Perry-Smith and Mannucci, 2017), thereby helping ideas rise to the top (van den Ende and Kijkuit, 2009).

Given that ideas are the combinations of problem and solution (Bayus, 2013; Magnusson *et al.*, 2016), peers have the opportunity not only to optimize solutions but also to actually match the problem–solution pair and even reframe the problem. In this context, the shared knowledge is in the form of various knowledge types of comments given by peers in idea development, related to both problems and solutions (Malhotra and Majchrzak, 2019), while the author response is in the form of feedback given by an idea creator (Zhu *et al.*, 2019).

3.1 Problem- and solution-related knowledge sharing in idea development

Even in crowdsourcing where ill-structured problems cannot be avoided (Majchrzak and Malhotra, 2016), problem- and solution-related knowledge sharing are both needed and the sequential problem-first method is challenged (Posen *et al.*, 2018; von Hippel and von Krogh, 2016). On the one hand, the possible problem–solution design pairs without prior problem identification would remove the normally considerable costs of specific problem formulation. On the other hand, the constraint of a traditional sequential solution discussion to match the prior identified problem would be eliminated and more creative solution-related knowledge sharing would be warranted (Stock *et al.*, 2018).

Previous studies about the role of problem-related knowledge include arguments concerning:

- the uncertainty of ill-structured problems; and
- the ability of crowds to share knowledge on ill-structured problems.

First of all, because the uncertainty of problems is sometimes regarded as a negative factor that should be avoided, problems should first be well-structured by idea creators (Afuah and Tucci, 2012; Brabham, 2008) and then the solution-related knowledge sequentially added by peers sharing knowledge to match the problems in idea development. Furthermore, concerning the ability of crowds to discuss ill-structured problems, Afuah and Tucci (2012) argued that ill-structured problems, which need further discussion and reframing, should not be crowdsourced because they could not be solved by crowds or communities. One possible explanation for this is that the ill-structured problem might easily lead to a misunderstanding of ideas and result in the low probability of further investment in ideas. Therefore, in this case, we argue that increased problem-related knowledge sharing might have a negative effect on the development of a specific idea, resulting in a decrease in idea acceptance. This could be further argued from perspectives of both emotional and informational support. In terms of emotional support, too much effort placed on further discussion to understand the problem-side of ideas may frustrate creators and discourage them from continuing to work on the ideas until acceptance. From an informational support perspective, the value of current ideas might be unclear if contributors proceed in various directions by adding much problem-related knowledge. Furthermore, it would be hard for peers to find the matching solution when knowledge related to ill-structured problems is communicated (Afuah and Tucci, 2012). Furthermore, the line of diagnostic inquiry within the increased problem-related knowledge sharing is likely to lead the further needs of a totally different set of solution options, having to do with alternate ideas to solve the new discovered problems (von Hippel and von Krogh, 2016). In particular, in internal crowdsourcing where employees who possess deep knowledge of the organizational context might criticize that the ideas do not align with the needs of the firm (Beretta and Søndergaard, 2021), the increased problem-related knowledge sharing to some extent shows that the ideas are more criticized and the need for the ideas is questioned. This criticism is likely to lead a low probability of further investment in an idea if the added problems are not solved properly in the further improvement process.

By contrast, more solution input could not only increase the motivation of creators to keep ideas to find suitable solutions to the problem, which in the end might increase the probability of successful innovation, but could also potentially increase the feasibility of idea implementation through more efforts focused on its specific technology requirements. Particularly in the context of internal crowdsourcing, where criticized problem-related knowledge on an idea is mutually shared, the effort of problem-solution recognition with the more added solution-related knowledge sharing in idea development potentially results in a higher perceived novelty and creativity of ideas (Stock-Homburg *et al.*, 2021) and thus a high probability of idea acceptance. Hence, the following are hypothesized:

H1. Increased sharing of problem-related knowledge in internal crowdsourcing decreases the likelihood of idea acceptance.

H2. Increased sharing of solution-related knowledge in internal crowdsourcing increases the likelihood of idea acceptance.

3.2 Moderation of author response

Author response, in the form of feedback given by an idea creator, has been argued to be one of the most important factors for idea survival (Chen *et al.*, 2020; Di Vincenzo *et al.*, 2021). Furthermore, research on knowledge sharing on ideas shows that knowledge

exchange primarily blossoms if it is bidirectional with author responses (Dahlander and Piezunka, 2014; Zhu *et al.*, 2019). In the context of internal crowdsourcing, one-sided knowledge sharing in idea development by employees can be beneficial for improving the potential value of an idea. However, this potential improvement can be even stronger when an idea author joins in a discussion and creates a shared understanding (Zhu *et al.*, 2019). Therefore, the author response in idea development is regarded as a moderator that could influence the effects of problem- and solution-related knowledge sharing on ideas.

On the one hand, idea authors can be presumed to have continuous passion for their ideas when they respond to the knowledge shared by peers in idea development. This continuous passion can keep the opportunity for idea improvement alive and further attract peers' attention to idea improvement and knowledge sharing in idea development (Bono and Ilies, 2006; Zhu *et al.*, 2019). In particular, when the increased problem-related knowledge sharing happens on ideas in internal crowdsourcing, the increased author responses to some extent show the passion of idea authors to reframe the problem align with the firm's needs. Thereafter, there is a possible shift of the communication from the discussion on problem to the discussion on the alternative solutions to improve the appropriateness of their ideas (Natalicchio *et al.*, 2017; Zhu *et al.*, 2019). This shifting of problem-related knowledge sharing to solution search is in line with the problem-solving process via identifying problem-solution pairs (von Hippel and von Krogh, 2016), potentially decreases the negative effects of problem-knowledge sharing in idea development. In a similar vein, the increased author responses to solution-related knowledge sharing is likely to link to the authors' activities of working back to the previous discussed problems to discover what was eventually regarded as problem-solution pair (von Hippel and von Krogh, 2016). This shifting within the increased author responses possible acquires the efforts of identifying the problems where the problem-related knowledge sharing might take the domain role in idea development, decreasing the positive effects of solution-related knowledge sharing.

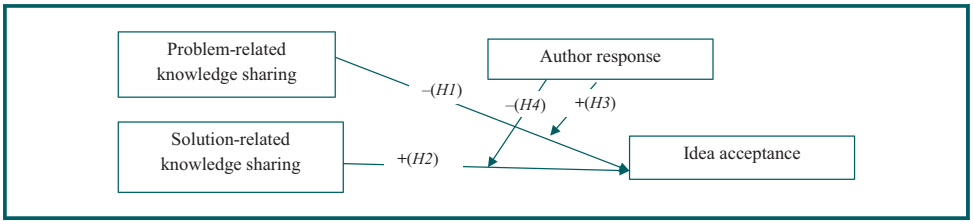
On the other hand, the number author responses reflect the strength of interactions with commenters. This interaction in a community contributes to the amplification and development of new knowledge (Nonaka, 1994) and thus influences idea quality (Zhu *et al.*, 2019). Furthermore, active author response could to some extent maintain the author's ownership of ideas and prevent the ideas from being killed or changed to other ideas, because the dynamics of online knowledge sharing could partly break the rules of social conventions and ownership with the lack of social interaction (Faraj *et al.*, 2011; Zhu *et al.*, 2019). In particular, when the increased problem-related knowledge sharing happens on ideas in internal crowdsourcing, this knowledge might be misused, thus increasing the misunderstanding of ideas and increasing the risk of ideas' ownership changing. In this case, author response with an explanation of the author's opinions on ideas and the understanding of problem-related comments could prevent this risk. Therefore, idea authors have opportunities to keep their ideas alive for further improvement to solve the problem described in ideas. However, when the increased solution-related knowledge sharing happens on ideas internal crowdsourcing, this strength of interaction to maintain their ownership might motivate authors to defend on their own solutions, which signals the weakness and limitation of authors' openness to absorb the shared new alternative solutions and adopt the correction of their proposed solutions to improve ideas. Consequencely, the benefits of the shared solution related knowledge on ideas could be limited regarding the defending on their solutions through author response. Hence, the followings are hypothesized:

H3. The negative effect of problem-related knowledge sharing in internal crowdsourcing is decreased by active responses of idea creators.

H4. The positive effect of solution-related knowledge sharing in internal crowdsourcing is decreased by active responses of idea creators.

Based on the above three hypotheses, the following research model is proposed (Figure 3).

Figure 3 Research model



4. Research methodology

4.1 Research setting and data collection

This empirical study was conducted based on data from an internal online idea management system in a Swedish multinational telecom company. The system was set up based on crowdsourcing principles in 2008 to capture and collectively develop ideas globally from employees in terms of process improvement, technological innovation, business innovation and service innovation. Different functions of the system are performed through the use of idea boxes for different specific problems, managed by one or more voluntary innovation managers. For the different boxes, dispersed and diverse employees have opportunities to share and learn from each other's knowledge and experience by searching for information, creating ideas and (reciprocal) commenting. During idea development, knowledge related to problems and solutions can be interactively added to ideas through comments. Idea acceptance is a measurement of idea quality in this system, here denoting that an idea has been claimed by managers for interest, action or implementation, which signals that further resources can be assigned for further idea implementation. Today, this system has more than 650 idea boxes, 14,000 users, 70,000 ideas and around 100,000 comments throughout the global organization, which brings both opportunities and challenges for the firms to manage the system and users to turn ideas into innovations.

In this study, a specific idea box focusing on general research and development in Hungary was selected for detailed analysis, as the unit in Hungary was one of the most effective boxes of a favorable size, containing 238 ideas and 1,022 comments. This particular idea box was set up in 2009 and closed in 2014. Furthermore, as attention to the idea box changed over the course of time, the average interval of idea acceptance was considered. It is interesting to note that the last 37 ideas created in the system were not accepted, while prior to that, the average interval between accepted ideas was three ideas. This phenomenon shows that ideas that have enough time to be improved might be high quality in average and thus more likely to be accepted. Therefore, it was imperative for our study to exclude the ideas submitted at the time near to the data collection as they arguably did not have enough time to get comments. During the sample selection, we noted that the last accepted idea for further investment was idea number 201. We therefore included all the 201 first-created ideas in our sample. Thereafter, to compensate for a limited time to comment on later-created ideas, we also included idea numbers 202–204, as the average interval between accepted ideas among the first selected ideas amounted to three ideas. Consequently, we ended up selecting 204 out of the total 238 ideas. After having selected these 204 ideas, 916 comments referring to these ideas were also eventually included in the final sample.

4.2 Variables and measurement

4.2.1 Dependent variable. With respect to the research question in this study, whether or not the idea was accepted for further consideration was regarded as the dependent

variable. The value of 1 represents that the idea had been accepted, while the value of 0 means that the idea had not been claimed and selected for further consideration. The way this dependent variable is operationalized follows studies in the field of crowdsourcing ideas conducted by Chan *et al.* (2018) and Chen *et al.* (2020).

4.2.2 Independent variables and a moderator. Problem- and solution-related knowledge sharing in this study refers to the number of comments related to the problem and/or solution per idea. It is measured based on the categorization of the problem- and solution-related comments through coding. If a comment related to the problem side of an idea, it would be categorized as a problem comment. By contrast, if a comment related to the solution side of an idea, it would be categorized as a solution problem. Furthermore, if a comment related to both the problem and solution sides of an idea, it would be categorized in the groups of both problem-related knowledge and solution-related knowledge.

Problem-related knowledge sharing refers to the number of comments for a specific idea that provides any additional information that improves the framing of the problem addressed in the idea. Specifically, the shared problem-related knowledge could be the interpretation of problem mentioned in idea, complementation of problem considering the users' need, addition of a new problem that the ideas might can solve, correction of a misconception in idea content related to a problem (Hannesson, 2015). These different types of knowledge related to problem are used for the coding in this study .

Solution-related knowledge sharing refers to the number of comments for a specific idea that provides additional information regarding how to solve the problem defined in the idea (Hannesson, 2015). Specifically, the shared solution-related knowledge could be the complementation or correction of existed solutions in ideas or adding new alterative solution when there is no solution mentioned in ideas. These different types of solution-related knowledge are used for the coding in this study.

Author response is measured by the number of comments contributed by idea authors in relation to each idea. This measurement followed the studies of Chen *et al.* (2020), Di Vincenzo *et al.* (2021) and Zhu *et al.* (2019). This variable therefore reflects the degree to which idea authors were involved in the discussion about their ideas (Zhu *et al.*, 2019) and the shared knowledge in idea development.

4.2.3 Control variables

4.2.3.1 Control variables about the idea itself. As idea characteristics such as their sentiment, scope and length have been found to be critical factors in idea development (Chen *et al.*, 2020), they are regarded as control variables at the idea level in this study.

Idea sentiment: Sentiment of ideas to some degree reflects the characteristics of creators' moods, signaling creators' inferior participation quantity and quality in the future (Coussement *et al.*, 2017) and has a potential impact on innovation (O'Leary, 2016). It is thus necessary to include it as a control variable. Sentiment analysis at present has been well recognized through nature language processing (NLP) (Nasukawa and Yi, 2003), in particular in R software. Most related sentiment analysis packages in R software are based on polarity with the counting of positive and negative words. One package, called 'sentiment' package in R and proposed by Jurka (2012), can calculate the sentiment based on the value of classified polarity [see Formula (1)]. The higher the sentiment value received from the package after running the text of a comment, the more positive this comment is:

$$IS = \frac{Sum(P)}{Sum(N) + 1} \tag{1}$$

Where *IS* is the sentiment of feedback to each idea, something which is calculated by the number of positive and negative words, *Sum(P)* is the total number of positive words of feedback to each idea and *Sum(N)* is the number of negative words to each idea.

Idea scope: Idea scope, referring to the breadth of topics related to the idea, to some extent impacts the commenting behavior in idea development. To measure the idea scope, we use tags of ideas (e.g. Windows platform, Simulator, Android) because these are used to categorize the knowledge areas of ideas in the database used. Thus, scope is measured by the number of different tags on the idea in this study.

Idea length: Idea length to some extent can indicate its elaborateness, which might impact the final idea's success (Chen *et al.*, 2020). Here, we add it as a control variable through the same measurement of number of words in a specific idea description.

Control variables about comments

For the control variables about comments, the number of comment providers, the number of author responses and the degrees of comment diversity and comment sentiment are considered. The detailed measurements on comment diversity and sentiment are presented as follows.

Comment providers: The variable about comment providers in this study is the number of commenters surrounding a specific idea, something which might, according to previous works on social networks and innovation management, influence the idea acceptance (Beretta, 2019; Björk and Magnusson, 2009). Commenters here are individuals who give information input for idea development through commenting on the idea, excluding those commenting on its comments.

Comment timeliness (Time to feedback): Comment timeliness, representing the speed of feedback given, has an impact on the idea acceptance (Chen *et al.*, 2020). The calculation is based on the second unit, measured by the average time distance of feedback given after an idea is submitted. Because the dates and times of feedback given and ideas created are labeled in the database, the average time distance can be calculated by the second unit by Formula (2):

$$T_{timeliness} = \frac{t_1 + t_2 + \cdots t_i + \cdots + t_n}{n} \tag{2}$$

$T_{timeliness}$ is the average time to feedback, $t_i (i = 1,2,3,\cdots, n)$ denoting the time distance between when the i_{th} comment is given and idea created, n represents the number of comments on an idea and $t_1 + t_2 + \cdots t_i + \cdots + t_n$ is the sum of time to feedback measured based on the time distance between all comments are given and idea created.

Comment diversity: Comment diversity here represents the diversity of content in comments to ideas, measured based on Sharon entropy (Hu and Xu, 2021), something, which indicates the diversity and uncertainty degree (Jost, 2006; Masisi *et al.*, 2008) and potentially influences the idea acceptance (Bayus, 2013). To capture the Sharon entropy of comments, the 'topicmodels' package in R based on word frequency is used (Hornik and Grün, 2011). The diversity measured by the entropy in this method indicates how the topics are distributed among comments submitted to each idea. On this basis, the topic entropy of each comment is first calculated by Formula (3):

$$En(C) = -\sum_{i=1}^{k} w_i \log(w_i), \tag{3}$$

where $En(C)$ is the topic entropy of comment C, w_i denotes the normalized weight on the i_{th} topic for comment C and k is the number of topics. With the usage of a 'topicmodels' package in R, 50 topics were selected according to the work of Hornik and Grün (2011). Therefore, $k = 50$. 'log' is the natural logarithm. Comment diversity on each idea was then calculated by Formula (4):

$$En(U) = \frac{1}{m}\sum_{j=1}^{m} En(C)_j, \tag{4}$$

where $En(U)$ is comment entropy on idea U, and m is the number of comments contributed to idea U during the selected one-year period.

Comment sentiment: The sentiments expressed by the commenters in the comment description may influence its likelihood of selection (Beretta, 2019). The same 'sentiment' package in R used to measure idea sentiment was also used here.

Comment amount: Comment amount refers to the overall attention that idea has created around itself (Di Vincenzo *et al.*, 2021; Schemmann *et al.*, 2016). It has been argued as a factor that affects the acceptance of ideas (Chen *et al.*, 2020; Di Vincenzo *et al.*, 2021). Thus, the number of comments per idea is added as a control variable.

5. Results

5.1 Data description

The statistical information based on the content analysis is presented in Tables 2 and 3. In terms of the categorization of problem- and solution-related comments in Step 1, Table 2 shows the coding examples for classifying comments into problems and solutions.

For the overall statistical information of problem- and solution-related knowledge sharing to ideas in terms of the independent variables in Step 2, Table 3 shows that 86 of 204 ideas received problem-related comments and 22 of 115 ideas got claimed for further investment, whereas 125 ideas received solution-related comments and 37 of 134 ideas got claimed.

The correlation matrix for all variables was also tested, where the interaction terms were also included according to the suggestion of Vatcheva *et al.* (2016) (Table 4). Although several

Table 2 Description of problem- and solution-related comments through coding

Comment types	*No. comment*	*Examples of comment text excluding personal names (replaced by**) and sensitive information (replaced by . . .. . .)*	*Coding analysis*
Problem-related comments	1	"The idea solves a real problem . . .. . . [here follows an explanation what the problem is]. The idea can be solved at a reasonable cost . . .. . ."	Interpretation of the problem that the idea can solve
	2	"Very nice idea. If there is a way to . . .. . .[here follows an explanation of the problem that could be solved] then this may be a very good solution"	
	3	"With ** technology we can . . .. . .[here follows an explanation of what issues can be avoided]"	
	4	"This is a very interesting idea. However, based on your description, the idea will only work if . . .. . .[here follows a description that narrows the scope of the problem that can be solved]. What if . . .. . .?"	Correction of a misconception in idea content related to a problem
	5	"Hi, I know of a something similar (sic!) problem . . .. . .[here follows an explanation of what the similar problem is]"	Adding a similar problem that idea might solve
	6	"Hello, I like this idea. Maybe it is also possible to address the following problem: . . .. . .[here follows an explanation of what the added problem is]"	Adding a new problem that idea might solve
Solution-related comments	7	"Hi **, we have had a first chat on the idea within the Innovation Board. The solution you are suggesting is technically feasible, and might not require too much implementation effort . . .. There is, however, an alternative solution . . .. . . [here follows a description of what the alternative solution is]"	Adding new alterative solution when there is solution mentioned in ideas
	8	"Good work. One of the use case (sic!) mentioned, ... [here the information about the solution is described] has very good proposition in our products"	Completing the existed solution part
	9	"Also it would be good if . . .. . . [here follows a description of the added solution]. This . . .. . . would help . . .. . . [here follows an explanation of what value the added solution has]"	Adding new alterative solution when there is no solution mentioned in ideas
	10	"Hi I think your proposal is very useful so I totally support it. Actually I kind of have a solution for the main problem : 1. Create a . . .. 2. Create a . . .. . .[here follows a description of the solution in detail]	

Table 3 Statistical information based on the categorization of comment as problem or solution

Items	*Problem-related comment*	*Solution-related comment*
Number of ideas	86	125
Number of claimed ideas	22	37

correlation coefficient is higher than 0.7, a threshold of high correlation (Dormann *et al.*, 2013), we analyzed the regression results by adding rather than omitting the potentially relevant collinear variables according to suggestion of Lindner *et al.* (2020) in all but extreme cases of collinearity (e.g. 0.8 and above, see Allison, 1999, p. 64).

5.2 Probit regression results

To test the effects of independent variables on dichotomous dependent variables, a binary choice model was first selected. Logit and probit models are similar in their treatment of binary variables. Because the AIC (Akaike information criterion) of the probit model is smaller than that of the logistic model in this study, probit regression was selected to perform the analyses. The probit regression model was constructed and carried out as shown in Table 5. In Table 5, it can be seen that seven models were built. Model 1, the basic model used for all the other models, includes all control variables at both idea and comment level. Model 2 and Model 3 are the separate regression models of two independent variables built according to the suggestion of Kalnins (2018). In Model 4, a variable tested as moderator about author response was added. Two independent variables¬—problem- and solution-related knowledge sharing – were added in Model 5 and Model 6. Model 7 is a model with the full set of variables including the test of moderation effects of author responses.

Because we have some variables are correlated more than >0.7, we built these regression models carefully step by step to check whether there is a concern of multi-collinearity influencing on the regression results (Lindner *et al.*, 2020). In the model building process, we checked that all VIFs (Variance inflation factors) of a regression model including all investigated variables is less than 5, which ruled out one of possibilities of high multi-collinearity (Cohen *et al.*, 2013). However, because VIFs less than 5 (VIF < 5) does not always indicate low multi-collinearity, there is a need to exam the changes in the coefficient sign along with the changes in their standard errors and even the changes in VIF (Vatcheva *et al.*, 2016). For those changes, the stability of plus and minus sign of two independent variables in TableV and the minor changes especially for problem-related knowledge sharing of standard errors (from 14% to 24%) and VIFs (from 1.05 to 2.3) in Table 6 indicate that the results in Table 5 are not distorted by the multi-collinearity (Kalnins, 2018; Vatcheva *et al.*, 2016). Furthermore, the effect of problem-related knowledge sharing become more stable after Model 6, indicating that one of the tested effect will become unstable if another important variable is missing (Lindner *et al.*, 2020). For this reason, the solution-related knowledge sharing variable is an important variable in this study, which needs to be considered together with the problem-related knowledge sharing.

Therefore, it is necessary to include all investigated variables in the regression model and the absolute pair correlation does not distort the regression results. The regression results show that the role of solution-related comments is significantly positive (β = 4.05e-1, $p < 0.01$) in Model 7, while the influence of problem-related comments is negative (β = −3.2e-01, $p < 0.05$) and this negative effect depends on the active level of author response (β = 2.02e-01, $p < 0.1$) (Figure 4). Figure 4 shows that the effects of problem-related knowledge sharing can turn to be positive when the author response is increased. However, the moderation of author response on the solution-related comments is significantly negative (β = −1.74e-01, $p < 0.1$) (Figure 5).

Table 4 Descriptive statistics and correlation matrix

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1 Idea sentiment	1.00													
2. Idea scope	−0.14*	1.00												
3. Idea length	−0.05	−0.04	1.00											
4. Comment providers	0.13*	−0.08	−0.10	1.00										
5. Comment timeliness	−0.10	0.13	0.13*	−0.25***	1.00									
6. Comment diversity	−0.15**	0.17**	0.00	−0.09	0.04	1.00								
7. Comment sentiment	0.39***	0.07	0.04	0.13*	−0.01	0.01	1.00							
8. Comment amount	−0.06	0.08	0.05	0.12**	−0.05	0.03	0.08	1.00						
9. Author response	−0.11	0.20***	0.10	−0.23***	0.19**	0.02	−0.06	0.16**	1.00					
10. PRK	−0.06	0.02	−0.05	0.13**	−0.08	−0.09	0.06	0.75***	0.05	1.00				
11. SRK	0.06	0.03	0.01	0.16*	−0.12*	−0.06	0.10.	0.78***	0.09	0.66***	1.00			
12. PRK: Author response	−0.08	0.01	0.02	−0.03	−0.01	−0.02	0.03	0.42***	0.50***	0.47***	0.32***	1.00		
13 .SRK: Author response	−0.05	0.02	0.08	−0.02	−0.02	−0.04	0.01	0.43***	0−65***	0.29***	0.51***	0.73***	1.00	
14. Idea acceptance	0.23***	−0.09	−0.07	0.04	0.07	0.02	0.15*	0.07***	0.71	−0.01	0.23***	0.05	0.12*	1.00
Mean	10.9	1	57.16	3.03	1.8 + 7E	0.13	16.14	3.8	0.7	1.01	1.32	0.53	3.7	0.26
SD	31.52	0.41	29.95	2.49	1.6 + 7E	0.08	18.41	2.87	1.01	1.17	1.69	1.59	2.43	0.44
Min	0.53	0	8	0	0	0	0	0	0	6	0	0	0	0
Max	200	4	139	18	9.3 + 7E	155.5	156	22	6	10	10	12	12	1

Notes: a: Number of observations: 204. b: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. c:PRK = Problem-related knowledge sharing, SRK = Solution-related knowledge sharing

Table 5 Probit regression result

Variables	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*
Control variables							
Idea sentiment	7.7e-03**			7.87e-03**	7.67 e-03**	6.01e-03**	5.54e-03
Idea scope	−4.96e-01*			−5.79e-01*	−6.1e-01*	−6.77e-01*	−7.93e-01**
Idea length	−4.40e -03			−4.76e -03	−5.5e-03	−5.75e-03*	−5.73e-03
Comment providers	5.26e-02			1.76e-02	1.87e-02	1.12e-02	2.01e-02
Comment timeliness	1.85e-08*			1.73e-08*	1.55e-08	2.15e-08**	2.12e-08*
Comment diversity	1.18e-00			1.31e-00	1.10e-00	1.67e-0	1.67e-00
Comment sentiment	5.92e-03**			6.40e-03	6.6e-03	7.11e-03	6.90e-03
Comment amount	5.05e-02			4.23e-02	9.5e-02*	−4.78e-02	−6.37e-03
Moderator							
Author response				1.51e-01*	1.44e-03	1.57e-01	2.0e-01*
Independent variable							
PRK		−4.3e-03			−1.67e-1	−2.75e-01*	−3.2e-01**
SRK			0.27***			3.67e-01***	4.05e-01***
Moderation effects							
PRK: Author response							2.02e-01*
SRK: Author response							−1.74e-01*
Constant	−6.8e-01***	−1.1***	−1.5***	−6.8e-01***	−6.9e-01***	−7.2e-01***	−7.3e-01***
AIC	235.95	230.22	230.22	235.62	235.95	223.07	223
Number of observations	204	204	204	204	204	204	204
Nagelkerke R^2	0.12	1.9e−05	0.07	0.137	0.15	0.24	0.27

Notes: a: Standard errors in parentheses; *p <0.1; **p < 0.05; ***p < 0.01 b:PRK = Problem-related knowledge sharing, SRK = Solution-related knowledge sharing, AIC = Akaike information criterion

6. Analysis and discussion

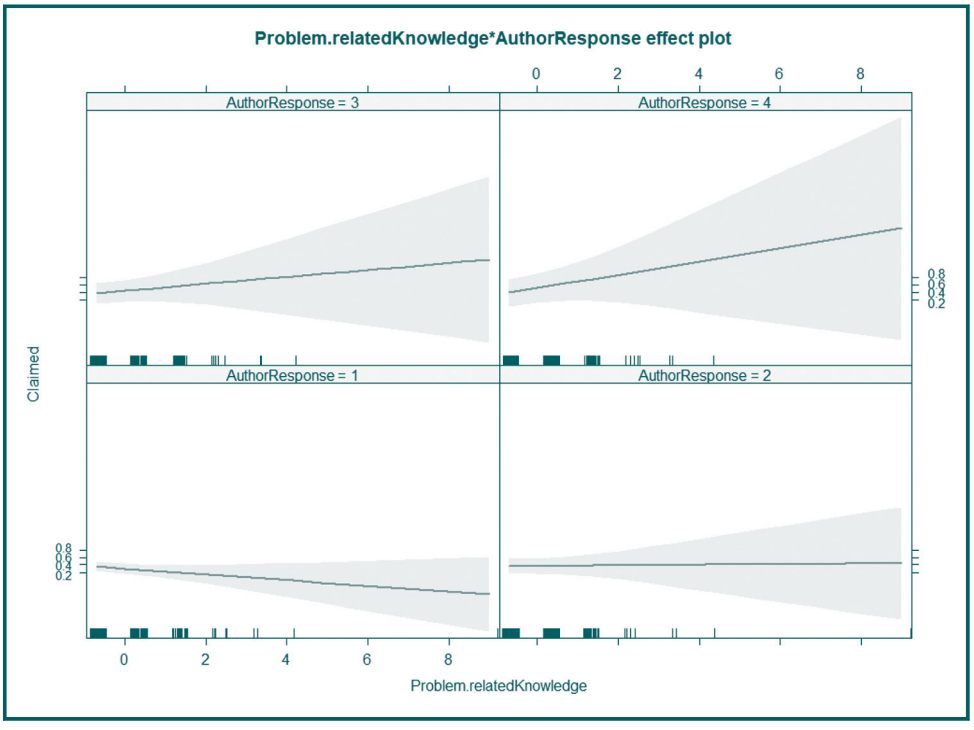
Because little is known about whether value is potentially created when employees contribute to their peers' ideas in idea development, particularly when both the problem and solution sides of ideas and the mutual knowledge-sharing process are taken into account, the primary objective of this article was to investigate the roles of problem- and solution-related knowledge in crowdsourcing idea development. To this aim, an empirical study of a firm-internal crowdsourcing venture in a Swedish multinational company was conducted to pursue the following two research questions: What are the effects of problem- and solution-related knowledge sharing, respectively, on the development of ideas in internal crowdsourcing? and How do author responses affect the relationship between problem- and solution-related knowledge sharing and the development of ideas in internal crowdsourcing? Briefly put, the results show that knowledge related to solutions in idea development impacts idea acceptance positively, whereas sharing knowledge related to problems in idea development has a negative effect on the likelihood of idea acceptance and these effects of knowledge sharing are moderated by the active author responses.

Table 6 VIFs and Standard errors of PRK and SRK in different regression models

Models including different variables	*Comment amount*		*PRK*		*SRK*	
	VIFs	*SD*	*VIFs*	*SD*	*VIFs*	*SD*
CVs + PRK			1.05	0.14		
CVs + PRK + SRK			1.8	0.21	1.9	0.14
CVs+Comment Amount + PRK + SRK	3.4	0.11	2.3	0.24	2.7	0.16

Notes: a:SD = Standard errors, VIFs = Variance inflation factors b: CVs = all control variables excluding comment amount, PRK = Problem-related knowledge sharing, SRK = Solution-related knowledge sharing

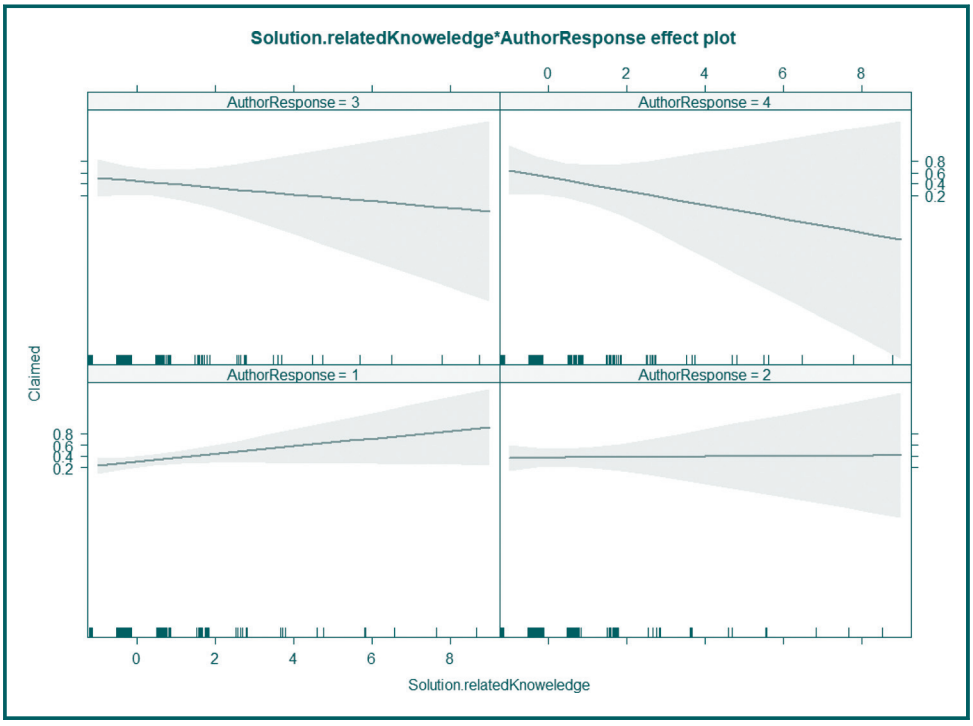
Figure 4 Moderation plot of author response on the effects of problem-related knowledge sharing



Thus *H1–H4* are all supported (see Table 5). To the best of the authors' knowledge, this is the first study that investigates how idea development is influenced by shared knowledge and author responses based on theories related to knowledge sharing and problem-solving.

Regarding the first research question, the significant role of problem- and solution-related knowledge sharing supports the necessity to argue the role of problem framing (Afuah and Tucci, 2012; Beretta and Søndergaard, 2021; Majchrzak and Malhotra, 2016) and highlights the need to refine the solution side of ideas (Afuah and Tucci, 2012; Brabham, 2008), especially in internal crowdsourcing. Because of the 'fringe of consciousness' (Dasgupta, 1994, p. 34) in the online problem-solving communities in internal crowdsourcing, problem identification, problem framing and solution structuring are not always explicit in ideas (Kijkuit and van den Ende, 2007), resulting in ideas with an initial problem state and solution state that attract peers to share knowledge to reframe the problem side of these ideas as well as to refine their solution sides. The empirical results in this research show that the sharing of knowledge to the problem side of ideas negatively impacts the probability of idea acceptance, whereas the sharing of knowledge to the solution side of ideas instead has a positive impact. The negative effect of problem-related knowledge sharing can be explained from both emotional and informational support perspectives, as argued in the section above on hypotheses development. In terms of emotional support, it may frustrate creators and discourage them from continuing to work on the ideas until acceptance. From an informational support perspective, the value of current ideas might be unclear if contributors proceed in various directions by adding too much problem information. This result to some extent supports an argument that a disadvantage of knowledge sharing in online communities is that discussions on ideas can decontextualize the ideas' content, resulting in an idea that differs from that which was originally intended (Faraj *et al.*, 2011). This disadvantage might lead to the low acceptance of ideas because of the risk of

Figure 5 Moderation plot of author response on the effects of solution-related knowledge sharing



changes in ideas' ownership. Furthermore, consistent with the opinion of von Hippel and von Krogh (2016) on problem-solution pairs, this result also indicates the risk of improving ideas derived from the further needs of a totally different set of solution options to solve the new discovered problems. By contrast, the significant and positive role of solution-related knowledge sharing supports a demand for solution searches in area of crowdsourcing (Afuah and Tucci, 2012).

To sum up, the significant role of problem-related knowledge sharing supports the necessity to argue the role of problem framing (Afuah and Tucci, 2012; von Hippel and von Krogh, 2016; Majchrzak and Malhotra, 2016). On the one hand, problem-reframing efforts might have a negative effect on idea development because of the resulting decrease in idea acceptance. On the other, if open problem reframing is purposefully used for solution refining with interactive peer communication and discussion, this might have a positive effect on the idea development. This argument also provides support for results regarding the second research question. The empirical results reveal that the increased author responses can influence effects of problem-related knowledge sharing in idea development in different ways. With the increased author responses, the ideas and the problem-related knowledge can be better understood and the need for ideas can be clearer and better approved by crowds, thus increasing the probability of idea acceptance. In this case, this finding supports the benefits of problem reframing in idea development (Haas *et al.*, 2014; Eriksson *et al.*, 2016) such as reducing the risk of solving the wrong problems (Schrader *et al.*, 1993). For example, the novelty and usefulness of ideas might be increased by collective and open efforts to discuss customer needs (Schweisfurth and Raasch, 2018) and losses connected with solving the wrong problems would thereby be eliminated as incorrectly focused problems might be corrected in time by mutually matching them with feasible solutions before implementation. Furthermore, this finding can imply that decontextualization of the idea in idea development led by knowledge sharing can be

avoided through the involvement of the idea's author in discussions and idea development (Zhu *et al.*, 2019).

Besides the findings about the role of problem-related knowledge sharing supporting *H1* and *H3*, the finding about the significant role of solution-related knowledge sharing for *H2* supports the need to refine the solution side of ideas in crowdsourcing (Afuah and Tucci, 2012; Brabham, 2008). However, there is a negative significant moderation of author response on solution-related knowledge sharing supporting *H4*. The significant moderation effect supports the opinion on the possible shifting of knowledge sharing and problem/solution search landscape in the problem-solving process proposed by von Hippel and von Krogh (2016) where the matching of problem-solution pair was considered. During the identification of problem-solution pairs, the increased author responses with the increased solution-related knowledge sharing might show that there is a matching gap between the problems and solutions, which needs further discussion, increasing the needs to find new problems and calling for a change of the idea(s). In this case, contributors might prefer to give up on the underlying ideas and shift their efforts to a new idea for another problem.

7. Implications and future research

7.1 Theoretical implications

This research entails several theoretical implications. First, we investigate knowledge sharing in idea development as an important antecedent for idea acceptance, contributing to the literature on both crowdsourcing and peer communication. Although much research has been conducted on contribution behaviors, the research contexts studied are predominantly teams, groups, organizations or external crowdsourcing and there is limited knowledge on the recently emerging peer-to-peer communication by employees in internal crowdsourcing. Findings here would subsequently benefit ongoing research on the nature and form of internal crowdsourcing and the factors that shape its innovation success (Schemmann *et al.*, 2016).

Second, deviating from most prior research on ideas in crowdsourcing, defined merely as solutions, we adopt the emerging concept of problem–solution design pairs (Nambisan *et al.*, 2017; von Hippel and Kaulartz, 2021). As ideas are here regarded as the combination of problem and solution states, the shared knowledge in idea development is likely to be classified into problem- and solution-related knowledge, respectively. Therefore, the role of both problem- and solution-related knowledge sharing is discussed, extending the application of problem-framing and problem-solving theory in crowdsourcing, where most previous work has excluded problem reframing based on the assumption that crowdsourcing is primarily aimed at searching for a solution (Posen *et al.*, 2018; Schweisfurth and Raasch, 2018). This study thus contributes to the recent research on the second type of knowledge sharing in idea development where mutual problem (need)- and solution-related knowledge sharing is highlighted (Nambisan *et al.*, 2017; von Hippel and Kaulartz, 2021; von Hippel and von Krogh, 2016). Furthermore, following the recent proposal of problem-solving without problem definition (von Hippel and von Krogh, 2016), one critical argument from a joint perspective on problem- and solution-related knowledge sharing, is whether reframing and refining ideas in idea development should be jointly focused upon or if they actually benefit from being handled separately. This study caters to the existing contradictions between the works of Afuah and Tucci (2012) and Majchrzak and Malhotra, (2016), respectively and then especially about the ability of crowds to discuss ill-structured problems: should a problem be well-structured by idea creators first or could it be better to use the crowd also for its reframing? However, these conflicting standpoints seem to be reasonable when the role of problem-related knowledge sharing and the moderation effects of author responses are taken into account.

Third, this study contributes to research on idea crowdsourcing, which is predominantly focused on the factors in idea generation such as idea author characteristics and idea characteristics (Zhu *et al.*, 2019), by showing how knowledge sharing in the form of problem- and solution-related comments influence the ideas. Furthermore, with the consideration of three important dimensions of comments, including commenters, comment diversity and comment timeliness, our results not only extend the understanding of crowdsourcing ideas, including idea development, but also construct an overall overview of knowledge sharing and problem-solving literature in crowdsourcing. This is a significant contribution because the value of knowledge sharing in crowdsourcing is attracting increasing attention by scholars (Sun *et al.*, 2020).

Last but not least, this study offers new insight into how online knowledge sharing and exchange take place in firm-internal crowdsourcing to promote an organization's knowledge base. It enhances the understanding of knowledge management in the front end of innovation by showing the interaction effects between problem- and solution-related knowledge sharing and author responses in internal crowdsourcing, which has thus far mainly examined the value of one-side knowledge sharing (Beretta, 2019). This study identifies the different value of author responses on different types of knowledge sharing and knowledge exchange. These findings are in agreement with literature about the front end of innovation, which emphasizes the importance of social interaction (Björk and Magnusson, 2009), especially interactive feedback in internal crowdsourcing idea development (Chen *et al.*, 2020; Di Vincenzo *et al.*, 2021; Zhu *et al.*, 2019).

7.2 Managerial implications

This study also provides implications for management, especially when firms try to motivate large parts of their employees to share knowledge and experience for innovation. For these firms, it is important to realize the necessity of knowledge management in idea development, although crowdsourcing tends to push firms to elicit large volumes of new product suggestions, improvements, innovation ideas and potential solutions. This could be supported by the significant effect of knowledge sharing on idea acceptance in empirical studies. More specifically, it should be noted that knowledge sharing in idea development, in terms of problem and solution sides of ideas, should be open and flexible under different goals and contexts. For example, if the aim of the communities or organizations is to improve the probability of idea acceptance, problem-related knowledge sharing by crowds in idea development needs to be avoided because of the observed negative influence of problem-related comments on idea acceptance. This highlights the importance of thorough problem definition in idea generation. Furthermore, the moderation effects of author responses suggest that the author should be active in discussions, especially when the commenters are sharing knowledge related to the problem statement of ideas. By contrast, the positive role of solution comments to ideas suggests that the attempts to share knowledge-related solutions should be encouraged during idea development until problems and solutions are matched.

7.3 Limitations and future research

Although this work presents significant results about the role of problem- and solution-related knowledge sharing in internal crowdsourcing, it still bears limitations that may condition the results in certain ways. First of all, as the data were extracted from only one specific idea box in a specific company, the generalizability of this research is limited. Further studies should extend the data collection to allow for better comparisons of the investigation results between idea boxes and other internal crowdsourcing systems. Secondly, although our results show that there is not multi-collinearity distortion mainly supported by a stable negative sign of problem-related knowledge sharing, we can see that the significant of this sign become stable until the solution-related knowledge sharing is

added in the regression model. This flip of significant might be the result of 'micronumerosity', a problem of two few observations possibly influenced by outliers on regression results (Lindner *et al.*, 2020). Thus, bigger sample is needed to be conducted in the future study. The third limitation is that basic individual information like age, nationality and gender is not considered. In terms of this shortcoming at the individual level, experimental studies allowing for the use of personal data as control variables would be a viable way forward. Last but not least, it would be desirable to have more complete information to better define the success of ideas or idea quality, which is also a hot issue in the idea-evaluation process. In terms of the dependent variable in this study, the value of idea acceptance triggered by the uncertainty of idea evaluation and implementation is unclear. For example, people often reject creative ideas because of the subjective uncertainty of idea evaluation, even when espousing creativity as a desired goal (Lee *et al.*, 2017), resulting in the risk of value loss after rejection. Consequently, the criteria used for evaluating idea quality need to be further investigated in research on idea evaluation to reflect selection uncertainties. Nevertheless, the novelty and feasibility of ideas always conflict in idea evaluation, making it unclear what real value would be created by accepted ideas. In terms of idea implementation, uncertainty is more pronounced when the long-term value is taken into account. Therefore, knowledge sharing in idea development might be helpful or not helpful, depending on the perspective we are looking out from and which real context the discussion takes place in. This calls for further research on the clear definition of idea success regarding the value of idea evaluation and implementation.

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