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Co-Innovation Platform Affordances: Developing a Conceptual Model and Measurement Instrument

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Abstract

Purpose – The importance of co-innovation platforms has been well established, but a valid and reliable instrument to measure the affordances of these platforms for co-innovation behavior has not yet been reported in the literature. A robust, validated instrument to measure co-innovation platform affordances will facilitate the conduct of studies across different platforms and contribute to enhanced understanding of co-innovation behaviors, outcomes and platform design. This paper conceptualizes co-innovation platform affordances, develops a reliable measurement instrument capturing critical facets of co-innovation, namely ideation, collaboration, and communication, and validates the instrument.

Methodology – The construct of platform affordances was conceptualized based on our findings from two case studies of co-innovation networks and the key characteristics of social mediating technology affordances. The measurement items newly developed via a case study underwent a two-round exploratory analysis to ensure face validity and content validity. The resulting instrument was subjected to a pilot study and a field study to establish the necessary reliability and validity.

Findings – The findings of our study reveal that co-innovation platform affordances have three distinctive components, namely ideation, collaboration, and communication. Furthermore, the results of our study suggest that platform affordances are most appropriately operationalized as a second-order construct comprising all three components. The empirical results from our field study show a high degree of confidence in both translation validity and criterion-related validity.

Value – Drawing from co-innovation and affordances literature, this study develops and validates a general instrument to measure co-innovation platform affordances. The result is a reliable and parsimonious instrument with 12 items. We believe that the instrument can contribute significantly to future empirical investigations of co-innovation behavior on virtual platforms.

Keywords – Co-innovation, Collaborative innovation network, Co-innovation platform, Affordances.

1 Introduction

Widespread adoption of information and communications technologies (ICTs) has enabled businesses to innovate collaboratively with their customers and partners across geographies. These developments have coalesced into the phenomenon of open innovation (Chesbrough, 2012) and the study of co-innovation (Gloor, 2006; Leavy, 2012; Lee et al., 2012). Researchers and practitioners have highlighted the transformational potential of co-innovation in how businesses develop new ideas and bring them to market (Gemser and Perks, 2015). A recent and notable development with co-innovation models is the application of social technologies to engage actors through social mechanisms (Brown and Wyatt, 2010; Harrisson et al., 2011; Kahnert et al., 2012; Martini et al., 2012; Piller et al., 2012). In this paper, we use the term *actor* to emphasize the individual in an active role in relation to the co-innovation information system platform, an IT artifact.

Distinctive from early open innovation approaches such as open-source or virtual customer communities, the application of social mechanisms in co-innovation represents a new business model enabled by social media technology (Bertoni et al., 2012; Piller et al., 2012). This social model of open innovation extends open innovation beyond customer-involvement models to encompass socially-engaged individual actors who are fully involved in the ideation and development of new products (D'Andrea et al., 2015; Peterson and Schaefer, 2014; Wu et al., 2016). This new business model allows all members of a community to participate in a wide range of new product development activities. While researchers and practitioners have focused on business models and strategies, research is also needed to IT artifacts enable co-innovation, as the design of the co-innovation platform can affect the quality and sustainability of value co-creation across the co-innovation cycle.

In the social model of co-innovation, social technologies are incorporated into platforms to facilitate, or afford, critical innovation tasks. While collaborative technology affordances have been an area of growing Information Systems (IS) research interest (Fayard and Weeks, 2014; Grgecic et al., 2015; Leonardi, 2013; Majchrzak et al., 2013; Volkoff and Strong, 2013), much research on technology affordances has treated IT artifacts as 'black boxes' without adequate consideration of the context in which the technologies are embedded. Context-specific research efforts to date have led to mixed and inconclusive outcomes, due in large part to inconsistent definitions and measurement approaches, which result in measurement instruments that do not demonstrate adequate validity and reliability (Wang et al., 2015). A comprehensive instrument to measure the variety of technology affordances in the context of co-innovation, which would address these shortcomings and contribute to future empirical research efforts, has yet to be developed.

This paper reports on the development of an instrument designed to measure the various aspects of the affordances of co-innovation platforms affecting co-innovation processes. This instrument is intended as a tool for the study of the individual co-innovation behavior within co-innovation network organizations. Although the focus of this paper is on the affordances of co-innovation platforms, the measurement instrument developed is applicable more generally to a variety of open innovation networks. This study also demonstrates how quantitative measurements may be developed to investigate sociotechnical phenomena from the perspective of affordances in IS research.

To develop the measurement instrument, a framework of actor goals and platform tasks was identified through two case studies of collaborative innovation platforms, and platform affordances were conceptualized and refined with respect to social media technology affordances suggested by previous studies (Mesgari and Faraj, 2012; O'Riordan et al., 2012; Olapiriyakul and Widmeyer, 2009; Sutcliffe et al., 2011). The measurement items developed via case studies underwent a two-round exploratory analysis to ensure face validity and content validity. The resulting instrument was subjected to a pilot study and a field study. Following the final test, the instrument demonstrated acceptable levels of reliability as well as construct and criterion validity. The result is a parsimonious 12-item instrument comprising three subscales, providing a useful tool for the study of co-innovation platforms and their relationships with individual collaborative behaviors.

2 Literature and Theory

Gloor (2010) defined a co-innovation network as "a cyberteam of self-motivated people with a collective vision, enabled by the Web to collaborate in achieving a common goal by sharing ideas, information, and work." Stakeholders (actors) in a co-innovation platform typically come from diverse backgrounds to work collectively on problems presented to or proposed by members of the virtual network (Lee et al., 2012; Paulini et al., 2013; Raesfeld et al., 2012; Song et al., 2013). With rapid growth and diffusion of social technologies, the co-innovation model has expanded to encompass networks of diverse actors who collaborate in innovation activities primarily through a social media platform. Social product development platforms such as Edison Nation and Quirky are well-known examples of co-innovation communities enabled by social media. Co-innovation platforms enable value co-creation across the innovation cycle (e.g., collaborative idea submission, evaluation, and development of co-invention activities). This combination of social technologies with open innovation strategies offers the potential for business transformation in how new products and services are identified, developed, and marketed.

2.1 Co-Innovation Platform Functionalities

The business model of a particular co-innovation platform defines the scope of external actors' involvement in co-innovation, which then becomes the basis for designing the co-innovation platform technology. For instance, a co-innovation platform may invite external actors to participate in product launch or product support activities, whereas another network may limit actors to contributing or commenting on new products or service ideas. Subsuming variations in the scope of activities, Gloor proposed three general and fundamental dimensions of actor participation in collaborative communities: *creativity, collaboration, and communication* (Gloor, 2006). In socially-enabled co-innovation networks, creativity is often referred to as *ideation* or co-creation of new product ideas, a critical component of co-innovation processes (Romero et al., 2011). Collaboration and communication are essential to any socially-enabled co-innovation system (Nambisan, 2003). *Collaboration* involves interactions among internal and external actors to address problems and find or improve solutions (Piller et al., 2012). Because of the distributed nature of the coinnovation process, *communication* between actors such as networking and sharing knowledge is an inherent aspect throughout co-innovation processes and activities (Paulini et al., 2013). Co-innovation platforms typically provide a variety of social technology features and functions to enable ideation, collaboration, and communication, and these three high-level functionalities are applicable to a variety of co-innovation settings, as our case studies (described below) reveal.

2.2 Co-Innovation Platform Affordances

In Gibson's words, the affordance of an artifact arises from a combination of its properties that provide a specific type of user an "opportunity for action" (Gibson, 1986; Greeno, 1994; Hutchby, 2001). IS researchers have adopted the theoretical concept of affordances to understand the relationship between technology properties and technology users more generally (Faraj and Azad, 2012; Majchrzak et al., 2013; Majchrzak and Markus, 2013; Markus and Silver, 2008; Volkoff et al., 2007; Volkoff and Strong, 2013). In this stream of research, technology affordance is defined as "the mutuality of actor intentions and technology capabilities that provide the potential for a particular action" (Majchrzak et al., 2013, p. 39). That is, the concept of affordance specifies the possibilities for action that different sociotechnical features of virtual platforms offer to its users (Treem and Leonardi, 2012) (Nambisan and Baron, 2010) to achieve actor-specific goals. Whether an affordance —or invitation to action— triggers action depends not only on the technology properties but also on the actor's ability to perceive the action possibilities (Gaver, 1991; Norman, 1999). We discuss these two concepts – properties and perception – in the following paragraphs.

Some IS researchers conceptualized the designed properties of an IT artifact as "functional affordances" (e.g. Grgecic et al., 2015). From the perspective of an actor, a functional affordance of a designed object is a potential, an opportunity to perform a certain goal-oriented action (Hutchby, 2001).[1] Indeed, functional co-innovation affordances can be purposefully designed in the IT platform to assist or direct users to accomplish co-innovation tasks intended by the platform owner (Hartson, 2003), though the user may not choose to act on the affordance. More importantly, affordances are unique to the particular way and particular context in which the actor perceives them (Malhotra and Majchrzak, 2012). In other words, depending on an actor's perceptions, the same IT artifact may present different functional affordances, which do not exist without an actor's intentions or functional goals (Markus and Silver, 2008).

To summarize, the affordances of a co-innovation platform depend not only on the designed features but also on the multidimensional interactions between actors' perception of platform properties and their

[1] For instance, designers of a laptop computer include an "on" button. The functional affordance of the button allows users to turn the laptop on, if that is their goal, but little else. The functional affordances of other artifact features are more open to interpretation by specific users. For instance, a feature that allows the user to dim the screen has a specific technical outcome (reducing or increasing screen brightness), but the user might act on this feature to preserve battery power or to reduce eye strain. That is, users may perceive different affordances of the feature. The first example highlights the design of functional affordances, whereas the second example highlights how affordances are relational between the technology features, the user, the context, and the users' goals, and the functional affordances may be perceived differently by different users.

context-specific goals to achieve an action or outcome (Leonardi, 2013; Majchrzak and Markus, 2013; Strong et al., 2014; Volkoff and Strong, 2013). This theoretical perspective on affordances underlies our conceptualization of co-innovation platform affordance as a multidimensional, context-specific and goal oriented construct (Malhotra and Majchrzak, 2012; Mesgari and Faraj, 2012; Volkoff and Strong, 2013). It also informs development of a measurement instrument for co-innovation by relating the functional properties (designed features) of the actor-artifact system to the goal-oriented actions based on Gloor's framework.

2.3 Measuring Co-Innovation Platform Affordances

IS scholars have recently attempted to model the relationship between social technologies and user behavior using an affordance lens (Majchrzak et al., 2013; Strong et al., 2014; Treem and Leonardi, 2012; Volkoff and Strong, 2013). Modeling and measuring social technology affordances can potentially provide new insights to understand, explain, and predict the consequence of technology usages within and beyond organizational boundaries (Leonardi, 2013; Markus and Silver, 2008; Volkoff and Strong, 2013; Zammuto et al., 2007). As noted in the systematic literature review of affordance by Pozzi et al. (2014), the majority of previous studies focused on conceptual work or qualitative investigations exploring the mechanisms of affordance emergence and actualization. These studies have focused on explaining the nature of affordances rather than determining how the construct should be measured (Wang et al., 2015) so that quantitative methods are rare in prior affordance research (Pozzi et al., 2014; Wang et al., 2015). Measurement efforts are further challenged by various approaches to empirically assessing affordances, for instance as affordance existence, affordance perception, affordance actualization, and affordance effect (Bernhard et al., 2013; Pozzi et al., 2014). Because affordances of a co-innovation platform are not synonymous with features (Franssila et al., 2012) but arise from the perceived properties that enable co-innovation actions (Kaptelinin and Nardi, 2012), affordances cannot be measured solely in terms of features present in a platform or by participants' use of specific features (Pozzi et al., 2014; Wang et al., 2015).

Only a few empirical studies have explored the affordances of social technologies, and these have focused on communication and relational aspects of social networks (Harindranath et al., 2015; Majchrzak et al., 2013; Treem and Leonardi, 2012). Furthermore, the empirical methods used were specific to a particular firm, software, or business model (Mansour et al., 2013; Pozzi et al., 2014); therefore, the findings of prior studies have limited applicability to the broader context of collaborative co-innovation technologies and phenomena (van Osch and Mendelson, 2011). Further research is needed to provide a construct measurement model that it is not specific to any particular platform or business model while it is contextspecific to co-innovation on social platforms.

Our literature review has highlighted the importance of actors' perception of functional affordances to enable their actions. We therefore argue that the construct of *co-innovation platform affordance* should be defined and measured in relation to actors' perception of the platform properties to enable co-innovation tasks or functions (Hartson, 2003; Pozzi et al., 2014; Wang et al., 2015) and to achieve the actors' coinnovation goals, as outlined by Gloor (2006). This approach incorporates differences among individual actors in understanding and utilizing a co-innovation space with the functionalities designed into the platform to enable co-innovation tasks and activities. As summarized in Section 3.1, we propose that ideation, collaboration, and communication represent three general functionalities relevant to the context of co-innovation, which these platforms are designed to support. This measurement approach, which considers the different functional properties of co-innovation platforms (Heft, 2003; Michaels, 2003), is consistent with the focus on functions in the comprehensive framework for sociotechnical affordances of collaborative environments suggested by Sutcliffe (2011). It suggests a multidimensional construct that considers the different functional properties of co-innovation platforms (Gloor, 2006; Heft, 2003; Michaels, 2003). While our goal is to produce a general instrument, we acknowledge that technology affordances, per se, are context-specific (Faraj and Azad, 2012; Grgecic et al., 2015; Strong et al., 2014) and therefore the measurement of affordances (aided by a general instrument) would differ across empirical settings (Majchrzak and Markus, 2013; Wang et al., 2015).

3 Construct and Instrument Development Process

Wang et al. (2015) argued that measuring users' perceptions of affordance requires contextually situated qualitative research followed by quantitative processes to validate emergent measures. Accordingly, we developed our instrument in six phases, including case studies, item generation, item pre-test, questionnaire pre-test, pilot study, and field study (as illustrated in Figure 1). The first phase, construct development, was based on an exploratory case study. Item creation in the second phase was based on an in-depth single case study. Following the case studies, we validated our empirical findings by reconciling with the affordances literature and the definition of co-innovation by Gloor (2006) to select the sub-constructs and generate the measurement items. In the third and fourth phases, the measurement items were pre-tested for face validity and content validity. We had a panel of judges sort the items into separate affordance categories based on the similarities and differences among items. Then, based on their placement, the items were re-examined and ambiguous items were modified or eliminated. The sub-scales were then combined into an overall instrument for a second pre-test using two independent expert panels. The pre-tests helped ensure that the items of the new measures were valid in the context. In the fifth phase, the instrument was pilot tested to obtain an assessment of the scales' reliability. Items that did not contribute to the reliability were culled. Phase six was a full-scale test with a larger number of subjects to further evaluate instrument validity and reliability within the co-innovation context. Subscales were further refined and the instrument's predictive (nomological) validity was assessed.

Figure 1. Instrument development process

4 Case Study I

We conducted an initial case study of co-innovation platforms to identify the key functions afford by typical co-innovation platforms. Following Treem and Leonardi (2012), we used a theoretical sampling approach to select 22 publicly accessible co-innovation platforms[2], based on variation in the platform owner, business model, and subject area. The 22 platforms provide a diverse mix that was nonetheless centered on coinnovation activities (versus general social platforms or virtual communities). The method for collecting and analyzing the case study data included the following steps as advised by O'Riordan et al. (2012):

1. examine co-innovation platform documentation for intended functions, tasks, and feature lists;
2. code data for each platform according to feature/properties name, description, associated behavior/action/tasks, and comments;
3. extract relevant properties from coded data and categorized them for each platform;
4. compare properties and themes across selected platforms for a common language;
5. apply hierarchies to the properties by identifying the key categories and their sub-categories;
6. re-investigate the key feature categorization across all platforms to identify similarities and differences to verify the key categories;
7. identify and label each individual affordance category based on the empirical instances.

Table 1 provides examples of properties and action possibilities afforded by these co-innovation platforms. Our purpose was not to survey, or count, the occurrences of specific features or functions in

[2] Platforms that were studied during the first case study: 99design, Better Seattle, BRAINRACK, crowdSPRING, Eureka Medical, Hypios, IBM's JAM, iBridge, Idea Bounty, Idea CONNECTION, IdeasProject, InnoCentive, Innoget, Jovoto, Kraft Collaborative Kitchen, Ponoko, Presans, Quirky, Syndicom, TopCoder, Whinot, and ZOOPPA.

these platforms but to understand the typical functions these platforms are designed to support. The cases exhibited a variety of structural forms and relationships between the platform and actors, but they offered similar mechanisms to facilitate value co-creation across the innovation process. We accounted for existing literature by categorizing functions we identified in alignment with Gloor's (2006) general categories, using the terms *ideation*, *collaboration*, and *communication*. Following these steps allowed us to develop a measurement instrument with general applicability in the context of co-innovation platforms.

Table 1. Examples of properties and action possibilities afforded by co-innovation platforms

Ideation Affordances. The first possible action on co-innovation platforms is the ability to propose a new product or service idea. In all platforms we examined, co-innovation participants or actors have the opportunity to lead ideation or support the ideation process. Ideation affordances, which directly serve the main purpose of co-innovation networks (Gloor, 2006), include the broad range of possible actions from submitting a new solution for an organizational problem to suggesting a new product feature for already proposed products. The ideation affordance is enabled by a group of features such as idea submission, revision, and resubmission forms, and idea development tools.

This type of affordance has been observed by previous studies as well. Sutcliffe et al. (2011), for example, discussed a specific group of sociotechnical platform features allowing actors to perform tasks such as submitting new ideas or revising ideas. Mesgari and Faraj (2012) identified co-creation and direct contribution as one of the key affordances offered by social technologies such Wikis. In a B2B setting, Tan et al. (2016) observed co-creation affordances as action opportunities to participate in product innovation and design. Ideation affordances depend on actors' perception of features that help them initiate (e.g. submit a design) or manipulate objects (e.g. improve a design) (Mathiesen et al., 2013; Olapiriyakul and Widmeyer, 2009) .

Collaboration Affordances. The co-innovation platforms that we studied encourage collaboration between actors. Collaboration is different from ideation as the collaborator's role is to comment on or improve another actor's idea rather than proposing a new idea. Collaboration affordances relate to interdependent activities (Mesgari and Faraj, 2012) and may allow for a large range of collaborative tasks from enhancing other actors' new product ideas by helping to select colors, finishes, or materials to participating in commercialization activities such as market research and pricing. Collaboration affordances rely on platform features such evaluation and ranking forms, product improvement tools, and social survey tools.

Collaboration affordances are the cornerstone of all collaborative environments (Mesgari and Faraj, 2012) and relate to social and group support functions (Sutcliffe et al. 2011). For instance, Olapiriyakul and Widmeyer (2009) observed system properties supporting collaborative activities such as exchanging information. Mansour et al. (2013) studied collaborative properties of wikis such as commenting and validation. Collaboration affordances also rely on actors' abilities to identify collaboration opportunities, for instance by featuring new ideas, searching, linking/grouping new ideas (based on characteristics), social sharing, and recommendation systems (Cha, 2009). They are thus similar to social exchanges features on social networks (Cha, 2009; O'Riordan et al., 2012) that enable actors to reach different nodes in their network and acquire the knowledge necessary for innovation.

Communication Affordances. Communication is a common task in the co-innovation platforms we examined. All platforms support actor-to-actor communication in different forms such as discussions, knowledge sharing, and social networking. Although communication may lead to collaboration or ideation, it is different in terms of actor goals and process outcomes. Actors communicate to learn, network, selfpromote or share their understanding without necessarily teaming up with other actors to improve a specific new product or solution. They discuss opinions, share knowledge, ask for help or votes, or participate in general discussions on forums without being engaged in any particular innovation project. Communication affordances may also relate to creating and demonstrating the actors' socio-professional image and identity. Communication activities familiarize actors with one another and thus can facilitate ideation and collaboration activities. Communication affordances are related to technical features for social networking, such as profile creation and management pages, sharing and posting messages, and connecting and networking tools.

Previous studies have associated communication affordances with tasks such as messaging, chatting, developing and sharing personal profiles, and networking (Sutcliffe et al. 2011). These interactional properties facilitate co-innovation tasks through communal or social interactions in a relatively complex co-innovation network (Mathiesen et al., 2013; Mesgari and Faraj, 2012; Olapiriyakul and Widmeyer, 2009). The construct of social media affordances suggested by (O'Riordan et al., 2012) highlights social connectivity, social interactivity and profile management as the main dimensions of social affordances. This supports our conceptualization of communication affordances on co-innovation platforms, in which actors have a visible list of connections and a profile page that enables them to find and communicate with other actors while managing their public identity. Actors can also manage their social presence via this visible public space or private space (Kietzmann et al., 2011).

Case study I showed that ideation, collaboration and communication are the main functions afford by typical co-innovation platforms. Supported by the affordance literature, these three categories of affordances can help develop a measurement instrument with general applicability in the context of coinnovation platforms.

5 Case Study II

To move from the conceptual level of co-innovation functions to developing the measurement items, we conducted a second case study. Case selection was based on the 'information-oriented case selection' suggested by Flyvbjerg (2006) and the revelatory single case study approach supported by Yin (2009). While large-scale socially-enabled co-innovation platforms are relatively rare, Quirky.com has successfully implemented such a model using social media technology (Piller et al., 2012). Thus, case study data were collected from Quirky.com for the following reasons: (1) co-innovation in Quirky included a broad range of socially-enabled interactions and accordingly provided more opportunities for external actors to collaborate or to be engaged; (2) the numerous co-innovation opportunities in this network provided a rich phenomenon to study; and (3) different types of data (e.g., user profiles, product profiles, and forum discussions) were publicly available to study.

Founded in 2009, Quirky is a co-innovation platform based in New York City with about 100 employees at the time of this case study. Quirky's business model was founded on soliciting new product ideas for broad categories of consumer products and sharing a portion of the sales revenue with the community of innovators who contributed to product ideation as well as product selection, design, development, and promotion. Quirky has not only sold its products directly on its platform but also distributed them through America's top retailers, including Target, Bed Bath & Beyond, and Amazon.com. At the time of our case study, about 600,000 members had collaboratively developed and launched 150 consumer products. Quirky's mission is to 'make invention accessible'.

Different data sources were used in the case study. The first data source was online interviews with the active members of the Quirky community. Fifty active and successful Quirky members[3] were invited to participate in the interviews. The second source of data was discussions on member forums. The third source of data was the first author's participatory and non-participatory observations of actors' contribution, interactions, and relationships across the platform. The fourth resource was published materials by Quirky, including reports, blog posts, and press releases that directly or indirectly specified

[3] Actors who had one selected product idea, or who received credits for at least 30 collaborative projects (above network average).

the co-innovation processes facilitated by the Quirky platform. The last set of data was published case studies of Quirky in books, academic journals, and managerial reviews. Similar to the first case study, we coded all the platform properties and the associated action or behavior possibilities but went to a deeper level of detail on this platform. Our goal was to understand the features, functions, and processes potentially related to coinnovation platform affordances.

We initially coded all the platform features and the key functions this platform is designed to support. To consider platform actors' perception of affordances, we conducted the interviews and online discussion analysis to understand the goals these functions and features served as well as the actors' perception of these functions and features in different phases of co-innovation. As discussed below, the key concepts that emerged during the second case study were well-aligned with the general model of co-innovation platforms suggested by Gloor (2006) and the construct definition derived from our first case study.

Ideation Affordances. Quirky's co-innovation process starts with the ideation process, where all community members are invited to propose new product ideas using multi-step ideation tool. Ideation tools provide different functionalities for the verbal and visual presentation of the new idea. Other features include tools for adding sketches, 3D models, video pitches, and market research data. With ideation tools, community members can submit, review, vote, comment, and build upon others' ideas. For ideation, actors may use different features – not necessarily designed for ideation – to explore different invention profiles, other members' background information and contributions, new product proposal, market research data, and success stories. These features help Quirky's members to refine and resubmit their new product ideas.

Collaboration Affordances. Quirky's collaboration process includes collaborative product evaluation, development, and commercialization. Quirky's community use tools such as searching, sorting, filtering, commenting, social voting and ranking to collaboratively review, evaluate, and vote for different ideas. Other platform features for social networking allow actors to leave comments, find similar products, discuss preferences and potential use cases, and promote new ideas in collaboration efforts. If an idea is well received by the community and approved by Quirky, collaborative tools such comparing, selecting, commenting, and ranking products help actors co-specify design or refinement requirements. Collaborative commercialization is facilitated by tools for name and tagline selection, pricing game, and social sales.

Communication Affordances. The co-innovation activities discussed here are supported by Quirky's communication tools and features. These tools facilitate knowledge and experience sharing as well as network building in different phases of co-innovation. Communication tools such as social profile management, networking, messaging, blogging, online brainstorming, live discussion, and forums support community building and relationship development, which are essential in to facilitate ideation and collaboration in co-innovation processes.

In summary, our analysis of co-innovation processes on Quirky.com validated the construct definition and dimensions derived in our first case study and helped us develop measurement items for the three subscales of ideation, collaboration, and communication. Table 2 summarizes the measurement items generated based on the second case study. For *ideation*, we identified new idea submission, improvement, monitoring, and revision; for *collaboration*, identifying co-innovation tasks, contributing to product design, evaluation, development, and commercialization; and, for communication, messaging, sharing, and commenting, networking and profile management.

Table 2. Examples of items generated from the second case study

6 Initial Measurement Item Development

Studying the attributes of ideation, collaboration, and communication tools in a natural setting supported our measurement development by providing dependable sources of evidence (Blaikie, 2009; Creswell, 2013). The two case studies grounded our study of co-innovation platform affordances in this specific context and highlighted the platform properties and their relationships with actors' actions and goals. To create a well-supported general research instrument, and to follow best practice in measurement construction (Mackenzie et al., 2011), our next step was to generate a set of items that fully represents the conceptual domain of the ideation, collaboration, and communication. Acknowledging the context specificity of affordances (e.g. Wang et al. 2015), these items were mainly developed from the detailed results of the second case study to fully capture essential aspects of each subscale (see, Churchill, 1979; Nunnally and Bernstein, 1994). The measurement items were refined through two pretests, which helped ensure that the items of the new measures are valid in the context, and the resulting questionnaire is understandable by the target respondents. The first pretest helped investigate the face validity and identify problems in item selection, comprehension, and grouping. After the first pre-test, items were turned into a questionnaire for the second pretest to examine wording, scaling, and formatting.

6.1 Pre-test of Scale Items

Measurement items and their categorization were examined through two rounds of card-sorting in accordance with established guidelines (Moore and Benbasat, 1991). In each round, two sequential cardsorting exercises were conducted by 32 judges, drawn respectively from a research community at our University and from the Quirky community in accordance with established guidelines (Moore and Benbasat, 1991). The card-sorting process was repeated until the required level of inter-rater reliability was reached. This technique helped test initial classification of and relationships between different proposed items. It was also an initial attempt to test convergent and discriminant validity by grouping items into different categories, thus confirming the conceptualization of platform affordances as ideation, collaboration and communication affordances.

In both rounds of card-sorting exercises, the randomly listed items along with the names and definitions of the constructs were distributed to the judges. The judges individually (1) sorted each item to what they believed to be the most appropriate construct, or (2) marked it as “Does not fit any category”, or “Does not make sense or is confusing.” After the first card sorting practice, inter-rater reliabilities (Cohen's Kappa) were calculated. The Kappa scores met the acceptable level of 0.65. The misplaced items in this round of sorting were reworded based on the judges' feedback. After the refinement, the same procedure was repeated for the second card-sorting practice with the members of Quirky community. The judges were instructed to sort 20 items to three categories. This second phase of card-sorting indicated four items as confusing. These items were rephrased before the questionnaire pre-test.

6.2 Pre-test of Scales in Questionnaire

The refined measurement items were included in a comprehensive questionnaire that examined individual motivations and outcomes of co-innovation in addition to platform affordances. In accordance with the pretest guidelines suggested by Creswell (Creswell, 2013), we employed the ‘expert panel technique’ to identify possible weaknesses in the construction of the questions and pinpoint potential sources of bias (e.g., possible order effects). All items in the questionnaire were constructed as 7-point Likert-type scaled questions (Jamieson, 2004) to avoid collapsed variance and maintain the consistency of responses. The questions were ordered randomly. Ten research faculty members were asked to review the questionnaire and identify flaws associated with questionnaire construction, wording, and formatting. The questionnaire was evaluated in terms of respondent issues (e.g., comprehension, burden), as well as format issues (e.g., flow, typographical errors, and order effects).

After the first draft of the questionnaire was revised based on expert feedback, 20 members from four different co-innovation platforms were asked to complete the questionnaire and provide feedback on potential problems or desired improvement. Written and oral comments on the questionnaire were aggregately considered to improve the questionnaire. Five reviewers were also nominated from the Quirky community, who participated in the second case study for follow-up probes. Quirky members provided insights on the entire co-innovation process as well as the terminology used in the co-innovation community, facilitating further refinement.

7 Specify the Measurement Model

After assessing the content validity of the generated items, we formally specified the measurement model that captures the expected relationships between the items, the affordance construct and its dimensions (MacKenzie et al., 2011). We modeled platform affordances as a *second-order formative construct* (see Jarvis et al., 2004) comprising of three first-order reflective constructs: platform ideation affordances, platform collaboration affordances, and platform communication affordances (Figure 2). We used four criteria to determine the existence of a formative construct (Cenfetelli and Bassellier, 2009; Diamantopoulos and Winklhofer, 2001; Jarvis et al., 2004; Petter et al., 2007): (1) the predictability of the affordance construct by the proposed second order measures; (2) the sensitivity of the construct to the exclusion of any second-order measures; (3) the possibility of changing one measure without requiring a change in all other second-order measures of the construct; and (4) the existence of different antecedents and consequences for the second-order measures.

Figure 2. Reflective first-order, formative second-order platform affordances construct

Regarding the predictability of the affordance construct, we argued that the direction of causality is from the second-order measures to the affordance construct as ideation, collaboration, and communication affordances each can partially predict the level of platform affordances. Our case studies showed that ideation, collaboration, and communication are distinct processes of a co-innovation platform, with each process explaining part of the co-innovation process but only together providing a holistic understanding of co-innovation functions enabled by a co-innovation platform. Thus, measurements of ideation, collaboration or communication cannot be substituted for each other in the measurement of the coinnovation platform affordance, as each measures different aspects of the process. Omitting any one would alter the definition and comprehensiveness of the higher-order construct. There is also no empirical evidence or theoretical reason to expect the three second-order measures to be highly correlated and thus interchangeable. Lastly, if we assume users' goals and goal-directed behavior are antecedents and outcomes of platform affordances (e.g. Volkoff and Strong, 2013; Leonardi, 2013), the ideation, collaboration, and communication affordances can have different *antecedents* in terms of actors' goals, and *outcomes* in terms of actors' behavior.

8 Pilot Study

We conducted a pilot study to ensure that the scales demonstrated the appropriate levels of reliability and validity. We also examined the measurement model specification in two steps following the recommendations of Hair and his colleagues (Hair et al., 2011; Hair et al., 2013): (1) examination of firstorder reflective constructs and estimation of latent variables, and (2) assessment of formative second-order constructs. The sample for the pilot study was drawn from the Quirky community and data were collected online using Qualtrics online survey software. More than 650 Quirky users were randomly selected[4] and invited to participate in the pilot study. The respondents were also asked to provide feedback on the items, format, and scaling. The respondents were all active members of Quirky, contributing to the

[4] All active users had a unique six-digit user ID defining their profile URLs. We randomly selected user IDs to send the survey invitations via the associated user profile page.

platform on a weekly basis, with at least one-month experience with co-innovation. A total of 72 complete and usable questionnaires were returned. Since data were normally distributed, this sample size is a reasonable number for multivariate analysis with SEM-PLS (Hair and Anderson, 2010). The sample was relatively balanced according to all known demographic factors. We employed SmartPLS version 3.0 (Ringle et al., 2015) to assess the reliability and validity of the construct of co-innovation platform affordance and its sub-scales.

First-order constructs. Table 3 presents the overall quality of the measurement items for the three firstorder reflective constructs. Cronbach's alpha and composite reliability were calculated to test the reliability. At this stage, PIDA5 (with a factor loading less than 0.5) was the only indicator removed from the initial model. Its removal improved the reliability of PIDA from 0.867 to 0.909. The rest of measurements met the reliability criteria. PLS standardized loadings along with Cronbach's alpha with a minimum of 0.7 were used in determining acceptable items (Hair et al., 2011, 2013). Before any item elimination, we ensured that the domain coverage of the construct would not suffer.

Convergent validity of reflective constructs was tested by examining Average Variance Extracted (AVE). All constructs met the threshold of 0.5 (Table 3). Discriminant validity was tested by the Fornell–Larcker criterion and the examination of cross-loadings. Comparing the loadings indicated that an item's loadings in its own construct are in all cases higher than all of its cross loadings with other constructs. Moreover, the AVE of each reflective construct was higher than the construct's highest squared correlation with any other construct. These results of the tests indicated adequate discriminant validity. **Table 3.** Reflective measures reliability

Second-order construct. The second-order formative construct (i.e. co-innovation platform affordance) was assessed following the guidelines of Hair and his colleagues (Hair et al., 2011, 2013). The estimation of indicator validity, which refers to the importance of each indicator of the related formative construct was performed using the PLS algorithm method with a bootstrapping of samples to calculate item weights and loading of each formative indicator. Each item's weight (relative importance), loading (absolute importance), and associated t-value using bootstrapping were used to assess items' significance. The t-value determines whether the path from the indicator to the construct is significant. The results showed that all the second-order formative weights were significant except for Platform Collaboration Affordance (PCLA). Since PCLA had significant loading value (0.75, $p < 0.05$), there is an empirical support to retain the subconstruct with some consideration (e.g. theoretical relevancy) for the field study (Hair et al., 2011, 2013). Formative constructs must also be evaluated for multicollinearity in order to avoid the use of redundant items (Hair et al. 2013). Multicollinearity tests showed that each indicator's variance inflation factor (VIF) value was less than the recommended cut-off value of 5, indicating an absence of multicollinearity.

9 Field Study

The refined measurement instrument used in the field study is presented in Table 4. The data for the field survey were collected from a random sample of Quirky members. From 600,000 potential respondents, 1000 Quirky members were randomly invited to participate in an online survey on the platform affordances and their behavioral intention. Of the 320 Quirky members who responded, fifty-nine responses were removed due to the respondents' lack of co-innovation experience or incomplete data, leaving a final sample of 261 usable responses for analysis. The measurement models of different affordance constructs were tested as three different first-order reflective constructs. Then, the second-order construct of affordances was examined as a three-dimensional formative construct.

Table 4. Final measurement items used in the field study

First-order constructs. The evaluation of the reflective measurement model included the test of factorability, indicator reliability, internal consistency, convergent validity, and discrimination validity.

The dimensionality was initially examined by using principal component analysis with direct Oblimin rotation to preserve the unique variance of each measure and render a more accurate solution (Costello and Osborne, 2005; Petter et al., 2007). First, it was observed that the items correlated at least 0.3 with at least one other item, suggesting reasonable dimensionality. Secondly, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.86, above the commonly recommended value of 0.6, and Bartlett's test of sphericity was significant (χ^2 = 1940, p < 0.01). Given these overall indicators, component analysis was deemed to be suitable for all 12 items. Initial eigenvalues indicated that the first three components explained 51%, 15%, and 10% of the variance respectively. The fourth, fifth and sixth factors had eigenvalues less than 1 and only explained 15% of the variance in total. As we expected, the three-component solution, which explained 76% of the variance, was preferred because of (1) theoretical support, (2) the "leveling off" of eigenvalues on the screen plot after three factors, and (3) the insufficient number of primary loadings for the fourth factor and subsequent factors. The final pattern matrix is reported in Table 5 below. Although an Oblimin rotation was used, only weak-moderate correlations between each of the composite scores existed: 0.41 between PIDA and PCLA; 0.47 between PCLA and PCMA; and 0.54 between PCMA and PIDA. These correlations were sufficiently low for formative constructs. Overall, these analyses indicated that three distinct measures were underlying co-innovation affordances as we expected.

Table 5. Component pattern matrix after direct Oblimin rotation

In addition, the loadings of the reflective indicators were examined as a confirmatory analysis in order to assess the indicator reliability. As presented in Table 6, all constructs were found to have good to very good factor loading. Internal consistency reliability (construct reliability) was assessed by examining the Composite Reliability (CR) and Cronbach's alpha of the constructs. Table 6 shows acceptable CR values and Cronbach's alpha values for all the constructs, thus demonstrating acceptable internal consistency reliability for the first-order constructs.

Table 6. Factor loadings

Convergent validity of the model was again assessed using AVE. The acceptable standard is that the AVE of the constructs should exceed 0.5, which means the items share at least half of their variance with the construct. Table 7 shows that the AVE values of the reflective measurement model of the research are greater than 0.5 with values ranging from 0.683 to 0.784. These values provided evidence that the convergent validity was achieved, and indicates that the measures used were robust. The discriminant validity of the model was evaluated by examining the cross loading for each indicator. It was found that the loading of each indicator with its own construct is all higher than its loading for other constructs. Discriminant validity was also examined using the Fornell–Larcker criterion. The second evidence of discriminant validity, the AVE of each reflective construct, was higher than the construct's highest squared correlation with any other construct. Therefore, analysis of cross-loadings and Fornell–Larcker criterion showed that discriminant validity was perfectly established.

Table 7. Internal consistency reliability

Second-order construct. The evaluation of second-order construct of platform affordance as a formative construct included assessment of the formative indicators' validity, multicollinearity, and convergent validity. The estimation of indicator validity was performed using the PLS algorithm method with a bootstrapping of samples to calculate item weights and loading of each formative indicator. Each item's weight (relative importance), loading (absolute importance), and associated t-value using bootstrapping were used to assess each item's significance. The number of bootstrap samples was 5,000, and the number of cases was equal to the number of observations in the original sample. The weights and loadings of the formative indicators of the measurement model are given in Table 8. The indicators' weights represent the partialized effect of the subscales on the affordance construct, controlling for the effect of all other indicators (Cenfetelli and Bassellier, 2009). The significances of weights indicated the relevance of ideation, collaboration and communication affordances in measuring the platform affordances. The absolute contributions of the subscales indicated by the significant loadings confirmed the importance of subscale.

Table 8. Weights and loadings

Formative constructs were also evaluated for multicollinearity. Multicollinearity tests showed that each indicator's VIF value was less than the cut-off value of 5 (see, Table 9). Following the general guidelines of Hair et al. (2013), all formative indicators in this measurement model should be retained, as they were not highly correlated in the model.

Table 9. Formative indicator multicollinearity

To assess the likelihood of interpretational confounding, redundancy analysis was conducted by correlating each formative construct with a global measure for that construct (Mackenzie et al., 2011). A path coefficient for global platform affordance construct (PA) was above the threshold of 0.80 ($p < .001$), providing support for the construct portability to the different nomological contexts. The off-diagonal values in Table 10 are the squares of correlations between the latent constructs. As the evidence of independency, the AVE of each reflective construct was higher than the construct's highest squared correlation with any other construct.

Table 10: Latent variable squared correlation

Figure 3. Test of predictive validity

Lastly, we examined the nomological or predictive validity of the platform affordance construct by testing its relationship with its immediate consequence, actor intention to co-innovation (Kreijns, 2004; Vugt et al., 2006). Wang et al. (2015) noted that investigating the influence of actors' perception of affordance on the consequence of technology use is an essential step in validating context-specific measurements of affordances. We tested the significance of the direct effect using bootstrapping procedures computed for each of 5,000 bootstrapped samples. The results showed that the three subscales of platform affordances, PIDA, PCLA, and PCMA, were significantly related with intention to ideate ($b = 0.62$, $p < 0.001$), intention to collaborate ($b = 0.61$, $p < 0.001$), and intention to communicate ($b = 0.63$, $p < 0.001$), respectively. Our further test confirmed that the second-order construct of platform affordances also has significantly impact on intention to contribute to co-innovation ($b=0.73$, $p < 0.01$; see Figure 3). Therefore, the predictive validity of the proposed instrument for platform affordances was established.

10 Discussion and Implications

In this paper, we focus on co-innovation platform affordances that enable organizations to collaboratively innovate with social actors. In a series of studies (including two case studies, pre-tests, a pilot study, and a field study), we followed a rigorous scale development process to establish an instrument for the construct of co-innovation platform affordances. The results of our studies reveal three distinctive components—ideation, collaboration, and communication—of co-innovation platform affordances. In testing the measurement instrument developed for co-innovation platform affordances, we operationalized platform affordances as a second-order formative construct comprised of three second-order constructs and demonstrated satisfactory reliability and validity of the instrument. The final result is a reliable and parsimonious instrument with 12 items (see Table 4). The results of this study show that the predictive (nomological) validity of our model of platform affordances is promising. More generally, this study demonstrates how quantitative measurements may be developed to investigate sociotechnical phenomena from the perspective of affordances in research.

The instrument development study reported in this paper offers several contributions. The process for developing a general instrument helps clarify the theoretical meaning of co-innovation platform affordances. The findings of our study demonstrate the applicability of Gloor's (2006) conceptual model of co-innovation in modeling the affordances of co-innovation platform. One goal of the co-innovation platform is to provide a virtual environment in which external actors can, or believe they can, contribute new ideas or solutions. Assessing affordances as a measure of perceived possibilities can help platform owners evaluate whether the platform achieves this goal by conveying the kind of tasks actors can perform on the platform. The instrument developed in our study has advantages in terms of measurability and specificity by identifying functions and affordances relevant to co-innovation phenomena, rather than general functions of collaboration or knowledge management through social media. Thus the measurement instrument is better suited to evaluate platform affordances in the context of co-innovation business models and activities, for instance, to investigate actors' behaviors and motivations to participate in co-innovation. We also provide a resource for researchers to draw on in a variety of studies and thus lay the groundwork for building cumulative knowledge about affordances for co-innovation within the research community. For example, our findings would support additional research to examine the interaction between these three dimensions in driving co-innovation behavior, and the role platform affordances play in influencing the relationship between motivational factors and intention to contribute to co-innovation processes.

We developed this construct and measurement instrument to facilitate research on co-innovation platforms, which have been inspired by the open innovation movement and the availability of online social platform technologies. However, our instrument is not limited to specific social technology features present in these platforms and may also be applicable to other virtual collaboration contexts such as open source communities, as the three main affordances of co-innovation networks (ideation, collaboration, communication) are generalizable to other co-creation communities. Nonetheless, we acknowledge there may be additional affordances not included within our model that may be relevant in other contexts, for instance, information archiving and public dissemination in Wiki communities.

The findings of the research also have important practical implications for co-innovation network implementation and governance. The process for developing a general instrument helps clarify the meaning of co-innovation platform affordances in practice. For practitioners, the understanding of the three dimensions of co-innovation affordances established in this study could be a conceptual tool guiding coinnovation platform design and governance. This may help platform owners understand the actions certain technologies may afford and how and why actors (platform participants) may exploit platform features and functions in a way that affects co-innovation practices and outcomes. Through an enriched understanding of affordances, designers could do a better job of engaging actors and facilitating higher levels of value cocreation in their communities. The proposed instrument can also serve a useful diagnostic purpose by helping co-innovation organizations evaluate the affordances of their platforms, understand the factors that influence actors' intentions to co-innovate, and improve co-innovation platform functions and services.

11 Limitations

In recommending the instrument that we developed for co-innovation platform affordance, we note its limitations and the opportunities for further development. The instrument is developed to be generally applicable to co-innovation platforms, but it was tested with respect to a particular type of co-innovation platform. Based on the results of the first case study, we assume that most co-innovation platforms have the three functions of ideation, collaboration, and communication in some form. However, some coinnovation platforms, such as a customer virtual community, may limit actor participation to a single function such as communication. Although this instrument could be easily adapted for co-innovation platforms adopting different business models, additional checks for validity and reliability would be prudent if a sub-construct is removed. Moreover, cumulative and comparative research is needed on other coinnovation platforms to further assess the generalizability of the scales.

12 Conclusion

As businesses increasingly adopt open innovation models and collaborative innovation platforms, and with rising academic interest in these phenomena, we need to ensure the quality of measurement to instill confidence in research results among both academic and practitioner audiences. The proposed measurement scale contributes to the existing literature by establishing a basis for theoretical advances on platform affordances design. The development of a valid and general instrument to measure affordances of coinnovation platforms supports the research community and can also contribute to co-innovation platform design, development, and evaluation.

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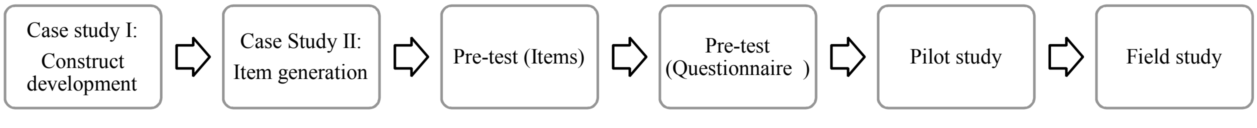


Figure 1. Instrument development process

Table 1. Examples of action possibilities afforded by co-innovation platforms (Case study 1)

Affordances	Features / Properties	Actions / Behavior
Ideation	▪ idea summation tools (e.g. form, direct upload) ▪ design tools (e.g. sketching) ▪ revision tools (e.g. idea editors) ▪ resubmission tools ▪ presentation tools ▪ compare/contrast tools ▪ new idea profiling tools ▪ add features/info tools ▪ profiling/archiving tools ▪ monitoring tools (ideas evaluation/improvement)	▪ develop new idea ▪ design new product/service ▪ submit new idea ▪ compete in problem-solving ▪ introduce/present new idea ▪ evaluate one's own idea ▪ improve one's own idea ▪ monitor the evaluation of one's own idea ▪ resubmit revised one's own idea
Collaboration	▪ search ideas/projects tools ▪ tagging/categorizing tools ▪ Addition/suggestion tools ▪ review/commenting tools ▪ vote/survey/poll tools ▪ select/rank/sort tools ▪ team building tools ▪ accessibility tools (e.g. openness/restrictions) ▪ contribution history tools ▪ notification systems ▪ activity streams	▪ find new project ▪ review new project ▪ join new projects ▪ contribute to new project development ▪ contribute to new project improvement ▪ contribute to new project commercialization ▪ share & exchange knowledge ▪ contribute to new project marketing/commercialization
Communication	▪ set/manage profile tools ▪ access/search/share profile tools ▪ networking/making contacts ▪ tools (e.g. follow) ▪ publicizing/promoting tools ▪ create/join group tools ▪ messaging/chat tools ▪ posting/social sharing tools ▪ invitation tools ▪ live discussion tools (e.g. brainstorming) ▪ public/private forum ▪ open Q&A/knowledge base tools ▪ discussion/communication history	▪ create and share profile ▪ self-presentation/promotion ▪ network internally ▪ network externally ▪ find/know collaborators ▪ learn about new ideas ▪ learn about process ▪ learn about new opportunities ▪ discuss new idea/project ▪ exchange knowledge ▪ exchange comments ▪ exchange votes

Table 2. Examples of items generated from the second case study

Affordances	Items

Ideation	Submit new idea
	Describe new idea
	Promote new idea
	Monitor new idea evaluation
	Revise new ideas
	Resubmit new ideas
Collaboration	Search new projects
	Review new projects
	Contribute to new project evaluation/selection
	Contribute to new project design
	Contribute to new project development/improvement
	Contribute to new project commercialization
Communication	Manage social profile
	Search social profiles
	Share new ideas/projects
	Share knowledge/experience
	Solicit contribution/support new ideas/projects
	Discuss new ideas/projects (e.g. directly via private message)
	Discuss new ideas/projects (e.g. indirectly via forum)
	Network with other actors (e.g. follow other actors)
	Team up with other actors (e.g. for join submission)

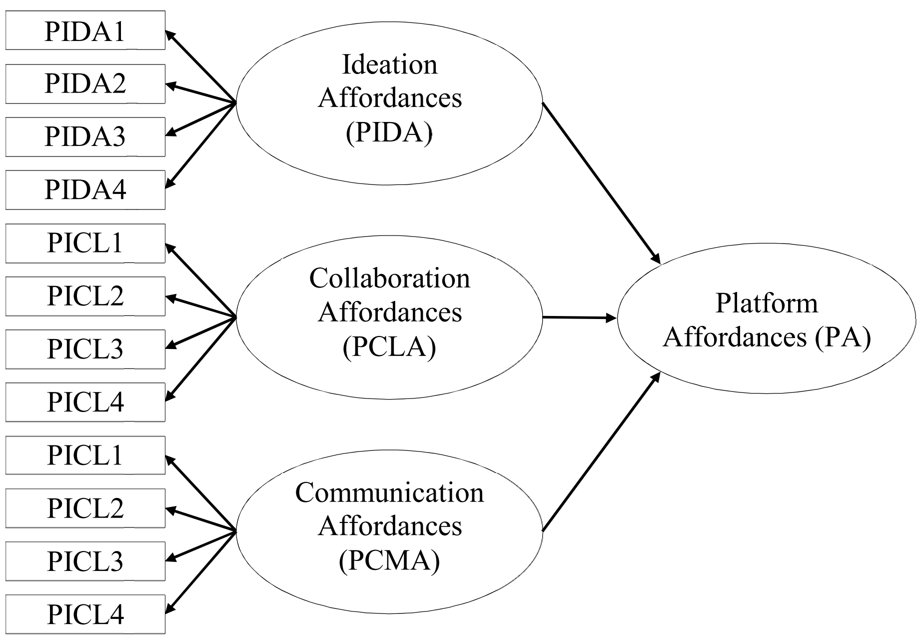


Figure 2. Reflective first-order, formative second-order platform affordances construct

Table 3. Reflective measures reliability

	AVE	Composite Reliability	Cronbach's Alpha
PIDA	0.786	0.936	0.909
PCLA	0.648	0.880	0.815
PCMA	0.670	0.890	0.832

Table 4. Final measurement items used in the field study

Second-order formative construct	First-order reflective dimensions	Items
Platform Affordances	Platform Ideation Affordances	The platform enables me to … PIDA1: submit new product ideas PIDA2: describe/present my product ideas PIDA3: monitor my idea evaluation process PIDA4: revise/resubmit my product ideas
	Platform Collaboration Affordances	The platform enables me to … PCLA1: review different product ideas PCLA2: vote for different product ideas PCLA3: contribute to product design/development PCLA4: contribute to product commercialization
	Platform Communication Affordances	The platform enables me to … PCMA1: share my knowledge PCMA2: solicit votes/support PCMA3: discuss new ideas with community PCMA4: network with community

Table 5. Component pattern matrix after direct Oblimin rotation

	Component 1	**Component 2**	**Component 3**
PCMA3	**.882**	.017	.029
PCMA4	**.909**	-.039	.050
PCMA2	**.782**	-.013	.079
PCMA1	**.852**	.080	-.055
PIDA2	.178	-.004	**.700**
PIDA1	-.018	.097	**.802**
PIDA4	.035	-.049	**.863**
PIDA3	-.032	.022	**.827**
PCLA3	-.105	**.835**	.186
PCLA4	-.061	**.867**	.085
PCLA2	.126	**.884**	-.084

PCLA1	.084	**.891**	-.090

Table 6. Factor loadings

	PIDA	PCLA	PLCMA
PIDA1	**0.898**	0.546	0.421
PIDA2	**0.913**	0.551	0.384
PIDA3	**0.829**	0.501	0.363
PIDA4	**0.856**	0.474	0.410
PCLA1	0.544	**0.818**	0.422
PCLA2	0.468	**0.842**	0.475
PCLA3	0.492	**0.845**	0.395
PCLA4	0.454	**0.800**	0.413
PCMA1	0.375	0.512	**0.883**
PCMA2	0.368	0.460	**0.881**
PCMA3	0.447	0.441	**0.897**
PCMA4	0.408	0.416	**0.879**

Table 7. Internal consistency reliability

	AVE	Composite Reliability	Cronbach's Alpha
PCLA	0.683	0.896	0.845
PIDA	0.765	0.929	0.897
PCMA	0.784	0.935	0.908

Table 8. Weights and loadings

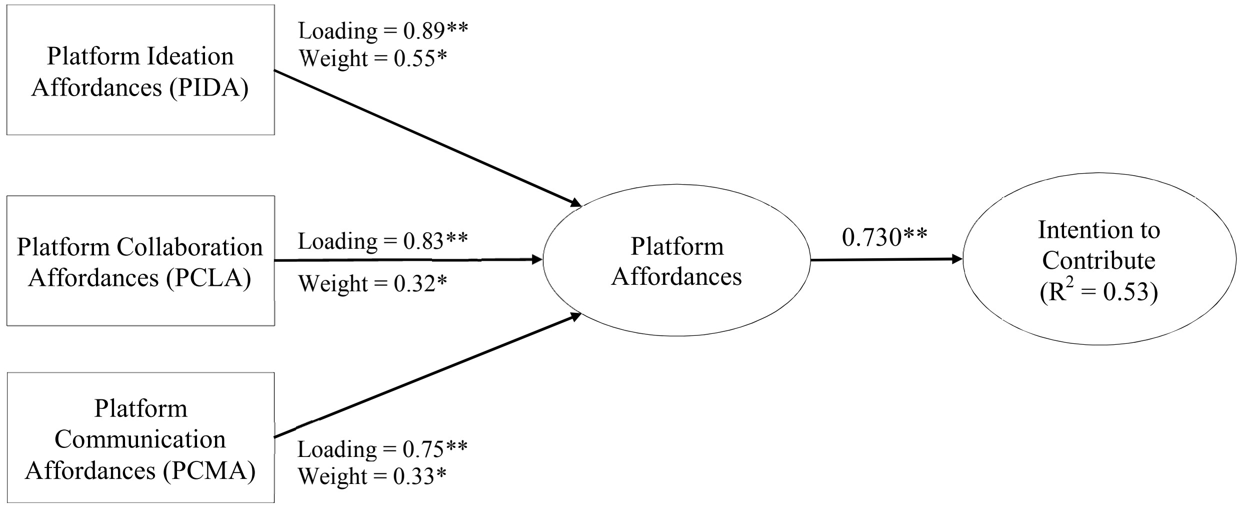
	Loading	t-value	Weight	t-value
PCLA → PA	0.828	16.440	0.316	2.908
PIDA → PA	0.893	27.814	0.545	6.804
PCMA → PA	0.749	12.584	0.327	3.525

Table 9. Formative indicator multicollinearity

	Tolerance	VIF
PCLA	0.609	1.642
PIDA	0.64	1.563
PCMA	0.748	1.338

Table 10: Latent variable squared correlation

	PCLA	PIDA	PCMA
PCLA	**0.683**		
PIDA	0.352	**0.765**	
PCMA	0.267	0.204	**0.784**



* p < 0.01; ** p < 0.001

Figure 3. Test of predictive validity