KNOWLEDGE MANAGEMENT IN CUSTOMER INTEGRATION: A CUSTOMER INPUT ONTOLOGY

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Abstract

Exchanging and analyzing customer input across different departments and software tools in a company is a prerequisite to successfully implement the co-creation of innovations with customers. Ontologies pose helpful tools to support knowledge representation and retrieval in a company. Prior research has developed ontology-based frameworks to manage idea generation and assessment in the early phases of the innovation process. However, these approaches do not address the holistic management of customer input across all phases of the innovation process. Based on a review of existing ontologies as well as types and characteristics of customer input, we develop the customer input ontology. With competency questions we show how the ontology might be used to generate knowledge and value of obtained customer input in form of ideas, concepts, or feedback. The customer input ontology supports knowledge management in customer integration since it provides a common language and format to collect and save customer input in a structured manner. Further, the customer input ontology allows the tracking and reuse of customer input throughout different departments and innovation cycles.

Keywords: Open Innovation, Customer Input, knowledge management, Ontology

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1 INTRODUCTION

To gather customers' preferences and knowledge in order to develop new products in line with customer needs, many companies nowadays open up their innovation processes and integrate their current and potential customers. In this open innovation approach, customers can take an active role as a resource of information, co-creator, co-developer, or tester in the innovation process (Nambisan and Baron 2007). Based on these roles, customers can provide input to the different phases of the innovation process by providing information on their needs and preferences, creating and evaluating ideas or concepts, or testing prototypes (Chesbrough 2003, Nambisan and Baron 2007).
However, the management of these customer inputs poses a challenge for companies. Customer input is highly unstructured information as it is generated and collected in different form. For instance, an idea might reach the company in audio, text, as a picture, figure, or video. Further, an idea can be expressed by the customer in different levels of detail (e.g. idea described in two sentences or two pages of text). Therefore, customer input is often not machine-readable and must be manually analysed by employees. This approach for processing customer input is not only time-consuming but also inefficient and cost-intensive (Ziegler et al. 2008). Additionally, the proliferation of IT, such as the internet and software applications, allows companies to launch online platforms where customers can easily provide their input. With its "Innovation Jam" IBM received more than 46,000 ideas submitted by people from all over the world. This huge amount of customer input gets unmanageable (Jung et al. 2010). Therefore, co-creating innovations with customers is a knowledge-intensive process. However, solutions and languages for knowledge sharing, reuse, and integration across departments or stakeholders in innovation networks are missing (Song et al. 2013). Different guidelines and software tools used in different departments to manage customer information complicate communication and interoperability, and hinder the reuse of data (Franco et al. 2010).
Ontologies are helpful tools to support knowledge representation and retrieval. Thus, the co-creation of innovations with customers can be supported by ontologies that provide structure to unstructured data, making customer input machine-readable and automatically processable (Uschold and Gruninger 1996). Further benefits that can be expected from using ontologies include shared understanding of customer input, interdisciplinary communication, and reuse of customer input (Riedl et al. 2009). Reusing already created ideas, requirements, or concepts is viewed as a key factor to increase quality and productivity (Lim 1994, Orawski et al. 2013). Further, reusing customer input can decrease R&D costs in innovation projects, reduce time-to-market and market risks (Franco et al. 2010).
Previous research (Bullinger 2008, Riedl et al. 2009) has developed ontology-based frameworks to manage idea generation and evaluation in the early phases of the innovation process, but neither addresses the holistic management of customer inputs across all phases of the innovation process and departments in a company. To address this research gap, we develop a customer input ontology to support the collection, storage, management, and reuse of customer input. We chose the ontology development approach by Noy and McGuinness (2001) as it focuses on the reuse of existing ontologies which is a desirable attribute of ontology design. The customer input ontology poses a meta model which can be used as a basis for future research (e.g. implementation of a software platform).
The paper is structured as follows: First, we provide some theoretical background information on customer integration and ontologies. Second, we describe our research methodology to design the customer input ontology. Third, we present our findings and briefly illustrate the application of our ontology. Finally, the implications and limitations of the underlying research are discussed.

2 THEORETICAL BACKGROUND

2.1 Customer integration into innovation processes

Open innovation is a concept coined by Chesbrough (2003); defined as "a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology" (Chesbrough 2003). Due to consumption and usage of products and services, customers possess great product and service related knowledge which is of importance for companies when developing new products or services. Therefore, companies are increasingly opening up their innovation processes for external stakeholders such as customers. Basically, customers can provide three types of input into the innovation process: *decisions, information, and creation* (Reichwald et al. 2004). Customers can assist companies in *decision-making*

through the *evaluation of ideas, concepts, and prototypes* (e.g. rating product attributes according to their preferences). Further, customers are a source of information: *need information* covers customers' needs, demands, and preferences. This kind of information can be gathered by customer integration methods such as surveys or complaint analysis. Some customers also possess *solution information* on how to implement and realize a creative idea into a product or service. For instance, lead-user or focus group workshops can be applied to learn from customers about the solutions they encounter (Zogaj and Bretschneider 2012). In contrast, *feedback information* can be gathered by companies through complaint management or online consumer reviews (Mudambi and Schuff 2010). These types of input deliver post-purchase and consumption information and give directions for product improvements. Further, customers provide input by *creating* ideas, concepts, or prototypes. In this case, customers take the role of co-creators or co-designers in the innovation process (Reichwald et al. 2004).

2.2 Ontology

The term ontology is used with different meanings in different disciplines. In computer science, ontologies refer to an explicit formal specification of terms in a domain and relations among them (Gruber 1993). According to Borst (1997), an ontology is defined as a formal specification of a shared conceptualization. This definition implies that the conceptualization should express a shared view between actors rather than an individual view. Considering these definitions in the context of our research, the core of the customer input ontology is the representation of customer inputs and their interrelationships to support customer integration into innovation processes, including searching for, rating, tracking, grouping, or reusing customer input across departments or companies.
An ontology consists of a hierarchy of *classes*, *attributes*, allowed *values* which the attributes can take, and *instances*. *Classes* explicitly describe concepts in the domain of discourse (Noy and McGuinness 2001). Classes may have *(sub)classes* and can be arranged in an inheritance hierarchy. The (sub)classes of a class represent concepts that are more specific than the (super)class. As an example, Figure 1 illustrates the (sub)class "sales representative" which is derived from the (super)class "employee". *Instances* are concrete individuals of a class that adopt all structural and behavioural properties of a class. For instance, "Bob Miller" is an instance of the class "employee" (Bullinger 2008). *Attributes* are the properties or characteristics that classes can have. Attributes can take a set of allowed *values*. An example for an attribute of the class "employee" is "height". The attribute "height" of the class "employee" can have the value "185". *Relations* refer to associations or interactions between two or more classes. An "is employed relationship" indicates the relationship between the instance "Bob Miller" of the class "employee" and the class "company" (Bullinger 2008).

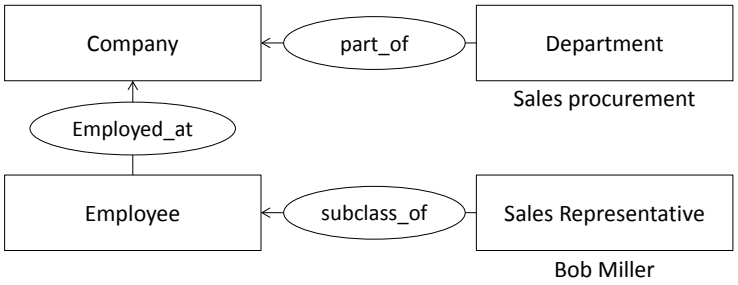

Figure 1. Illustration of example (Bullinger 2008)

3 METHODOLOGY

For the design of the customer input ontology we conducted the following three steps:

1. Since creating ontologies from scratch is a tedious and costly work, reusing existing ontologies or ontology components that already have been evaluated is a widely accepted approach (Lonsdale et al. 2010). Therefore, to identify relevant ontologies that can be used for the design of the customer input ontology, we conducted a structured review of literature on ontologies in the knowledge domain of innovation management (Webster and Watson 2002). The databases and keywords used for the literature search are described in section 3.1.
2. The design of an ontology includes the definition of classes and attributes. We conducted a second literature review (Webster and Watson 2002) to identify different types and

characteristics of customer input, which the customer input ontology needs to cover in its hierarchy of classes and sub-classes (see section 3.2).

3. Based on the steps 1 and 2 we designed the customer input ontology. The selected modelling language and followed guidelines for ontology design are described in section 3.3.

3.1 Literature review - Existing ontologies for innovation management

As ontologies, innovation management, and customer integration are of interdisciplinary nature, we selected databases that allow access to research in different discipline. Using AND as well as OR combination of the keywords "customer", "innovation", "ontology" we searched in titles, abstracts, and keywords to identify relevant papers (Webster and Watson 2002). The initial search yielded 138 results. In a first screening process we read title and abstract of all obtained articles to identify their relevance for the design of the customer input ontology. After removing duplicates and research papers that develop ontologies for purposes other than innovation management (e.g. ontology for fashion styling) we reduced the number of articles to 25. In order to reduce the set of articles to those that are actually relevant, we conducted a second screening process by reading the whole body of the paper. In this second screening process we excluded papers not capturing different types and characteristics of customer input in an ontology-based framework. Finally, we evaluated 8 papers as relevant for the underlying research. Presenting information about the databases used as well as the number of initially identified and finally included papers, Table 1 summarizes the literature search.

Table 1. Literature review – Existing ontologies for innovation management

	IEEE	**Google Book Library**	**SAGE Journals**	**Science Direct**
Initial search results	31	32900	11	93
After 1st screening	11	3	4	7
After 2nd screening	2	3	1	2
Total (relevant, without duplicates)				8

3.2 Literature review – Types and characteristics of customer input

To determine the types and characteristics of customer input needed along the different phases of the innovation process, we conducted a second literature review. We searched different databases (search fields: titles, abstracts, keywords) using the keyword combination "customer AND (input OR feedback OR idea OR, concept)" to identify types and characteristics of customer input (see Table 2).

Table 2. Literature review – Types and characteristics of customer input

	ACM	**IEEE**	**SAGE Journals**	**Science Direct**
Initial search results	823	1673	810	973
After 1st screening	288	180	234	195
After 2nd screening	41	53	56	56
Total (relevant, without duplicates)				206

3.3 Ontology design

For modelling the customer input ontology we selected Protégé, as Protégé can be adapted to build both simple and complex ontology-based applications. Further, Protégé fully supports the OWL and OWL 2 web ontology language and RDF specifications (Knublauch et al. 2004). The formal ontology design followed the ontology development approach by Noy and McGuinness (2001) as it focuses on the reuse of existing ontologies and provides an extensive guide for ontology design.

4 FINDINGS

In the following, we present our findings structured according to the steps of our methodology.

4.1 Existing ontologies for innovation management

In literature, there are many different ontologies that significantly differ according to their intended usage scenario, the formality of language, or the degree of generalizability. For instance, based on the intended application environment, an ontology can be classified on a continuum ranging from highly specific to most general representation (Bullinger 2008). Further, ontologies can be classified with respect to the degree of formality of a vocabulary and its meaning. An ontology can basically be highly informal (natural language, e.g. glossary), semi-informal (structured form of natural language, e.g. text version of coded ontology), semi-formal (ontology expressed in a formally defined language, e.g. Ontolingua), and formal (defined terms with formal semantics) (Uschold and Gruninger 1996).
Our customer input ontology aims to model diverse types and characteristics of input that customers can provide to the innovation process in formal language. Therefore, to determine whether the ontologies or ontology parts are reusable for the design of our customer input ontology, the 8 identified ontologies were analysed with regard to the customer input and knowledge domain that they cover (see Table 3, column "description"), their intended application/generality as well as their formality (see Table 3). Only ontologies that 1) model types and characteristics of customer input, 2) that are rather general than too specifically tailored for a particular application, and 3) are implemented in a rigorously formal language, can potentially be reused for the design of the customer input ontology. Based on these selection criteria, parts of the *OntoGate* (Bullinger 2008) and the *Idea Ontology* (Riedl et al. 2009) have been considered for our ontology design.

Table 3. Summary of existing ontologies for innovation management

Ontology	Description	Application	Formality	Reference
OntoGate	A generically valid ontology of idea assessment and selection.	General	Formal	Bullinger (2008)
Idea ontology	Represents ideas and covers further concepts to support collaborative idea development (e.g. rating ideas).	General	Formal	Riedl et al. (2009)
Preference ontology	Focuses on the elicitation of customer preferences regarding cell phones.	Specific	Formal	Cao et al. (2011)
Customer complaint ontology	An ontology-based approach for managing and maintaining multilingual online customer complaints.	General	Formal	Jarrar et al. (2003)
Knowledge ontology module	Focuses on knowledge sharing and reuse in innovation networks.	General	Formal	Song et al. (2013)
Ontology on customer needs	Presents an approach to automatically translate and represent customer needs.	Specific	Semi-formal	Chen et al. (2011)
Swarm ontology	Presents an approach to tap into customers' collective intelligence and creativity.	General	Formal	Baumoel et al. (2009)
Ontology for virtual innovation in construction	Presents an ontology for virtual innovation in construction powered by user driven innovation activities.	General	Semi-formal	Christiansson et al. (2008)

Some ontologies that we did not consider for the design of the customer input ontology rather model the process of co-creating innovations with external sources instead of types and characteristics of input. For instance, the ontology on complaint management (Jarrar et al. 2003) covers the entire customer complaint management process. Additionally, in our literature review on customer inputs (see Table 2 and 4) we found that complaints can be defined as positive or negative customer feedback. Therefore, we subsume customer complaints under feedback in our customer input ontology. Thus, we could not consider parts of the customer complaint ontology in the customer input ontology. Also, we did not consider the swarm-ontology that presents an approach to build a swarm

comprised of groups of customers so that the firm can benefit from customers' creativity and their contributions (Baumoel et al. 2009). With the knowledge module ontology, Song et al. (2013) aim to provide a technology solution for innovation networks to co-innovate with suppliers, customers, and other external partners. The proposed knowledge ontology module helps to integrate specific domain knowledge modules, such as design, manufacturing, or service knowledge. However, types and characteristics of input are not considered in this ontology and therefore it is not suitable for reuse in our customer input ontology. The ontologies on customer statements (Chen et al. 2011) and customer preferences (Cao et al. 2011) focus on a specific knowledge domain and therefore could not be reused.

4.2 Defining classes of the customer input ontology

We synthesized the findings of our second literature review to the following list of customer inputs and corresponding characteristics that our customer input ontology needs to model (see Table 4). According to our structured review of literature, customers can provide input in the different phases of the innovation process in form of information on their needs, preferences, and requirements. Further, customers can give feedback and create or evaluate ideas, concepts, and prototypes.

Table 4. Types and characteristics of customer inputs

Customer input	**Associated characteristics**
Customer need Customer preference Requirement	• Quantity: Frequency with which a certain need or requirement is mentioned by customers (Bailey and Horvitz 2010) • Quality: Overall evaluation of customer input, e.g. need description • Validity: Validity, reliability, and correctness of customer input (Galitsky et al. 2009)
Feedback: encompasses negative, positive, or neutral feedback, e.g. complaints.	• Quantity: Frequency with which a certain complaint is mentioned by customers • Validity: Validity, reliability, and correctness of customer input
Idea: An idea can be defined as an imagined product or service. Concept: A concept is an advancement of an idea. Not every idea evolves to a concept. A concept contains details of the innovation to be achieved, e.g. functional requirements, operation and revenue plans (Kasuga and Niwa 2006).	• Quantity: Frequency with which an idea is mentioned by customers (Bailey and Horvitz 2010) • Quality: A complex construct consisting of four distinct dimensions: novelty, feasibility, relevance and elaboration (Blohm et al. 2011) • Novelty: Extent to which the customer input is new and unexpected • Feasibility: Ease with which an idea can be realized • Relevance: Extent to which an idea or concept satisfies the company's goals • Elaboration: Extent to which an idea is worked out in detail The same attributes can be used to evaluate an idea or a concept. As a concept is a more detailed description of an idea, the attributes allow a more accurate evaluation compared to an idea.
Idea evaluation Concept evaluation	• Quantity: Number of idea assessments generated during idea evaluation • Validity: Results of cross validation check of idea assessment
Prototype	• Fidelity: The degree to which the virtual or physical prototype can accurately represent the utility and features of the real product (low/medium/high-fidelity) (Lim et al. 2006) • Completeness level: semi-finished, finished prototype
Prototype evaluation	• Quantity: Quantity of evaluation addressing the same prototype (Piller et al. 2004) • Validity: Results of cross validation check

4.3 Design of the customer input ontology

Figure 2 shows our formal ontology design. In our customer input ontology we reused the class "Participant" from Bullinger's (2008) *OntoGate* Ontology and its subclasses "Internal Participant" and "External Participant" as their attributes cover all critical elements to describe the internal or external origin of customer input. An internal participant (employee) selects and deploys a customer integration method to gather needed or desired customer input. Customers as external participants take part in this customer integration method. The class "Customer Integration Method" has been adapted from Bullinger's (2008) *OntoGate* Ontology. It encompasses the different methods and tools (e.g. idea competition, concept testing, or toolkits) that can be deployed by internal participants to generate and evaluate customer input. We adapted the attributes to our research by adding decision factors including duration and costs that allow internal participants to select appropriate customer integration methods (Füller et al. 2014). This also facilitates the analysis of the customer integration project's effectiveness and efficiency (e.g. costs and duration in relation to quality and quantity of customer input generated).

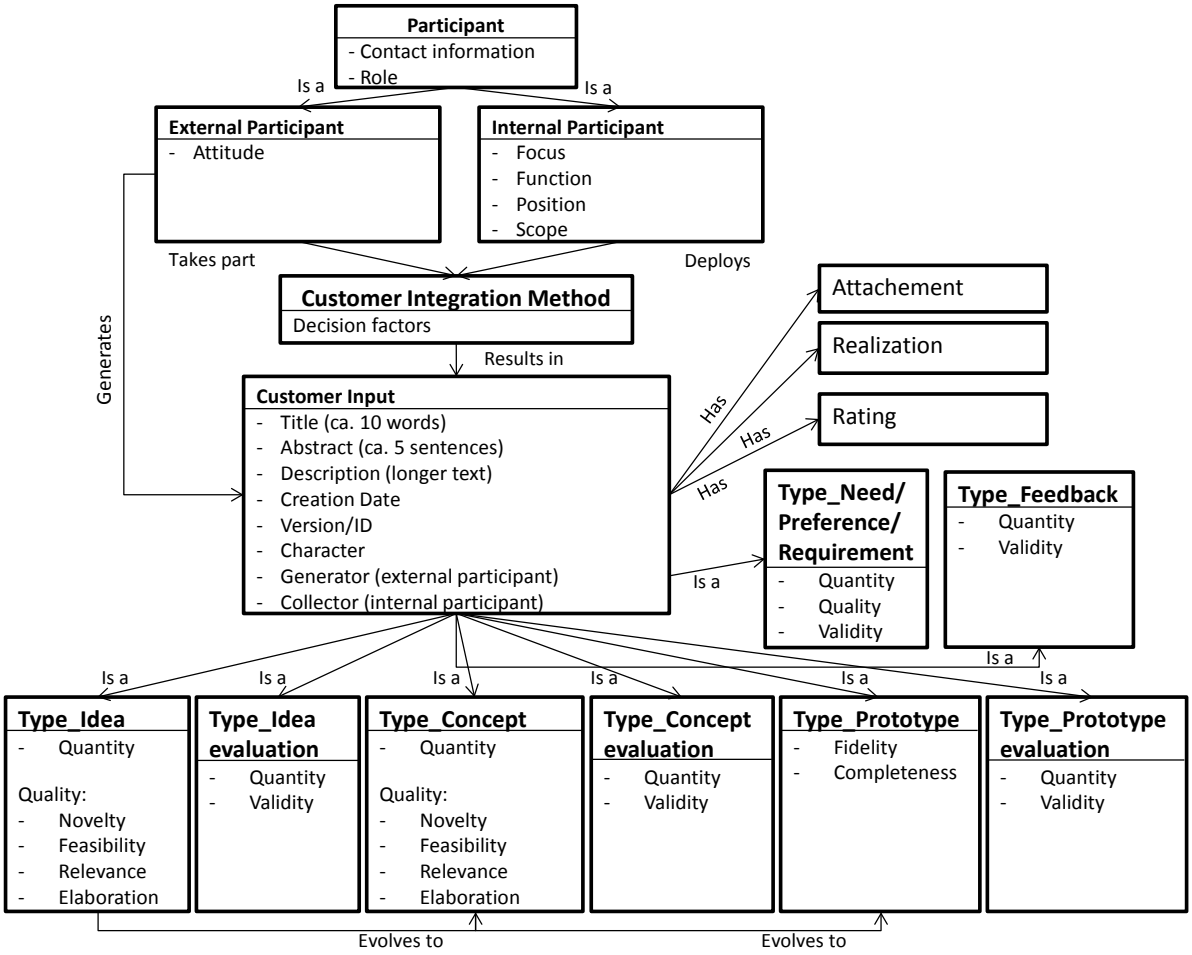

Figure 2. Customer input ontology

As an outcome of applying customer integration methods, the company receives different types and characteristics of customer input including ideas, idea evaluations, concepts, concept evaluations, or prototypes. These different types of customer input are modelled as sub-classes of the class "Customer Input". The different characteristics a customer input can have are modelled as attributes of the different customer input types (as identified in section 4.2, see Table 4). Since companies often receive a huge amount of customer input through online platforms, it is necessary to compare and evaluate customer inputs. The attributes respectively characteristics of customer input can serve as criteria to evaluate customer inputs (see class "Rating"). Further, for the class "Customer Input" we reuse the attributes title, abstract, description, creation date, and version as well as the relationships (has attachment, has realization) from Riedl et al. (2009). This allows the generation and management of customer input of different form, length, and descriptions. The "has Attachment" relationship allows

uploads of other resources (screenshots, audio files). Each customer input has a version number, which allows the different instances of the same idea to be tracked by the "is New Version Of" relationship. Further, we reuse the attribute character from the *OntoGate* Ontology (Bullinger 2008). The attribute character reveals the degree to which this input was expected: it can take the values continuous or discontinuous. Continuous input refers to inputs that are expected such as ideas originating from online brainstorming sessions or idea competitions, whereas discontinuous input is customer information received unexpectedly (e.g. reports on bugs, or complaints). Additionally, for the class "Customer Input" we defined the attributes generator and collector. Generator captures the origin of the customer input and can take the value external participant. The attribute collector refers to the internal participant(s) responsible for the customer integration project.

5 ILLUSTRATION OF ONTOLOGY APPLICATION

As proposed by Gruninger and Fox (1995), we derived a set of requirements in the form of competency questions that a knowledge base using the customer input ontology should be able to answer. The questions have been defined from the perspective of an innovation manager responsible for the co-creation of innovations with customers. The questions also serve as test cases to evaluate our customer input ontology. Similarly Riedl et al. (2009) used competency questions to evaluate their *Idea Ontology*. Based on the information (e.g. collector, generator, creation date) that the customer input ontology requires the users to provide for customer input, the following competency questions can be answered with the customer input ontology (see Table 5).

Table 5. Competency questions

Competency question	**Customer input ontology**
Which ideas have been realized?	Instances of the *customer input type idea* with a *"has realization"* relationship.
What are the last customer ideas generated and stored in the knowledge base?	Instances of the *customer input type idea* with the latest values for the attributes *creation date*.
What are the top 10 rated customer inputs?	Instances of the class *customer input* with a *"has rating"* relationship and the instances of *rating* having the ten highest values.
What is the customer feedback (e.g. complaints) obtained and stored in the knowledge base in the last two days?	Instances of *customer input type feedback* with *creation date* in the last two days.
Who are the five most valuable external participants as they provided highly rated (e.g. high quality) customer input in our customer integration initiatives?	Instances of the class *customer input* with a "*has rating"* relationship and the instances of the *rating* having a high value; viewing the value of the attribute *generator* of the customer input.
What are the most valuable internal participants responsible for customer integration initiatives resulting in a high amount of high quality customer input?	Viewing the value for the attribute *collector* of *customer inputs* with high values for the attributes *quality* and *quantity*.
What are the most successful customer integration methods?	Viewing the origin (*customer integration method*) of *customer inputs* rated with high *quality* and *quantity*.

The customer input ontology offers a template to systematically capture information related to customer input including title, abstract, description, creation date, generator and collector. Therefore, the customer input ontology allows innovation managers to structure unstructured customer inputs. This makes customer input computer-tractable.

6 CONCLUSION

Companies increasingly co-create innovations with external participants such as customers, acknowledging customers' product and service related knowledge and expertise. However, when integrating customers into innovation processes through the use of customer integration methods

companies receive a huge amount of customer input (Zogaj and Bretschneider 2012). Solutions and languages to systematically store this information, and to share, reuse, and integrate knowledge across departments or stakeholders in innovation networks are missing (Song et al., 2013). To address this research gap this paper proposes the customer input ontology.

Previous research basically differentiates customer input in need and solution information. By proposing a more detailed typology of types and characteristics of customer input, this paper contributes to open innovation research. This approach facilitates a more thorough investigation and usage of customer knowledge. The competency questions show how the ontology might be used to generate knowledge, use, and value of generated and received customer input in form of ideas, concepts, or feedback. To fully leverage the potentials of the customer input ontology, further research might implement this ontology-based framework in a software platform to manage customer input.

From a practical perspective, the customer input ontology provides practitioners with a shared and common understanding of the core concept of customer input. A common language is key to information sharing and to foster interoperability between tools (Riedl et al. 2009). By requiring the user to provide information on the input generator, collector, or creation date of the input in a unified manner across different departments of a company, the underlying research aims to solve the problems of cross-functional sharing and reusing of customer input. The stored information related to customer input allows companies to further analyse input and to identify success factors in customer integration. For instance, through automated analysis companies might identify creative external participants that provide high quality customer input, internal participants responsible for successful customer integration initiatives, customer integration methods that lead to invaluable customer input, or companies might track the life cycle and changes of customer input over time.

This research is subject to some limitations. The identified ontologies as well as types and characteristics of customer input in our literature review are obviously limited though the selection of the databases and keywords. Further, the customer input ontology presents a first meta model for the management of customer input. Future research can formalize the classes and properties of the customer input ontology and subsequently implement a prototype for a software platform to manage customer input across innovation cycles, departments, or companies.

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