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Fostering knowledge sharing: Design principles for persuasive digital technologies in open innovation projects

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Integrating knowledge is crucial for open innovation, and digital technologies can play a central role because they support knowledge sharing. In open innovation projects, in particular, little is known about the role of technology. Here, the individual behaviour of users is taken into account concerning the extent to which knowledge is shared. Therefore, persuasive technologies offer the potential to foster sharing. In particular, to facilitate the construction of future digital technologies, this study applies a design science research approach to create and analyse artefacts as a research contribution and develop design principles as a step towards a nascent design theory. We present insights from the design and application of three artefacts in different stages of open innovation processes. Results show that digital technologies can be used for various purposes: to build a common understanding, support design phases, communicate ideas and simplify the application of the technology for the user. Our research provides insights into the role of digital technologies for knowledge sharing in open innovation projects, and four design principles are found to facilitate the construction of future persuasive digital technologies for open innovation projects.

KEYWORDS
design principles, design science research, digital technologies, knowledge sharing, open innovation, persuasive technology

1 | INTRODUCTION

Technologies have been playing an important role in supporting open innovation (OI) processes for many years now, whether in the form of OI platforms (Chasanidou et al., 2018; Ikävalko & Lempiälä, 2019), innovative technologies (Barlatier et al., 2020; Möslein & Fritzsche, 2017; Urbinati, Chiaroni, et al., 2020), social media (Ooms et al., 2015; Trabucchi et al., 2018) or collaboration technologies (Aloini et al., 2020; Ollila & Yström, 2016). Something that all these approaches have in common is that knowledge plays an important role (Chesbrough & Bogers, 2014). Therefore, digital technologies can be used to support knowledge sharing (Barlatier et al., 2020; Trabucchi et al., 2018). Here, the individual behaviour of the users plays a role in the extent to which knowledge is shared (Bogers et al., 2017). Behaviour-changing technologies have great potential for supporting users in innovation processes (Jalowski et al., 2020) or for knowledge sharing (Wiafe et al., 2020). Persuasive technology as a research field considers how technologies can be designed to influence the behaviour of users without coercion or deception (Fogg, 2003). In this research stream, only a few studies have investigated the impact of such technologies on collaboration, interaction and engagement (e.g., Stibe et al., 2013; Stibe & Oinas-Kukkonen, 2014).

Digital technologies in OI have so far been considered either from the perspective of specific technologies (Barlatier et al., 2020; Trabucchi et al., 2018) or from a process perspective, such as the influence of digital technology on inbound processes (Urbinati, Chiaroni, et al., 2020) or the use of technologies in outbound

processes (Aloini et al., 2020). However, an integrated and overarching approach that also derives design principles for the development of future technologies is lacking. Existing research has focused little on the use of digital technologies in OI projects (Bogers et al., 2017), and studies that look at the management of OI projects (Du et al., 2014; Marullo et al., 2020) do not focus explicitly on technologies. As one of the few current studies dealing with stakeholder integration and collaboration at the OI project level, Urbinati, Landoni, et al. (2020) identify relationships between stakeholders and derive project management aspects but do not consider the role that technologies can play in this context. Especially given the influence of persuasive technologies in collaborative settings (e.g., Stibe et al., 2013; Stibe & Oinas-Kukkonen, 2014), new research objects also arise at an OI project level, particularly at the individual or group level (Bogers et al., 2017) which this study aims to address. The various interactions and roles in OI projects (cf. Urbinati, Landoni, et al., 2020) create interesting application scenarios for persuasive digital technologies that require more detailed investigation.

From a practical point of view, there are likewise gaps on the role of digital technologies in OI, especially with regard to the integration of digital technologies in OI projects and how such technologies can be designed and developed for OI. So far, there is a limited knowledge base on digital technologies for OI (cf. Bogers et al., 2017; Urbinati, Chiaroni, et al., 2020), often focusing on innovation and collaboration platforms and in online contexts. The influence of technologies on an individual level, and specifically the influence on knowledge sharing, has been neglected. Thus, there is a lack of concrete recommendations for action and design principles that also facilitates the management of digital technologies for OI.

To fill these gaps, we propose a combination of different concepts from the existing literature. Based on knowledge flows in OI processes, we consider the use of digital technologies in intra-organizational and individual levels process steps. We view these technologies from a persuasive technology and boundary object perspective to support knowledge sharing and to foster collaboration. In order to facilitate the transfer into practice and to promote the design and development of future persuasive digital technologies, we adopt a design-oriented perspective for the present study. Therefore, we apply a design science research (DSR) approach to create and analyse artefacts as a research contribution and develop design principles as a step towards a nascent design theory (Deng & Ji, 2018; Gregor & Hevner, 2013; Hevner et al., 2004). Thus, the research question is as follows: *How can digital technologies be designed and applied to foster knowledge sharing in OI projects?*

2 | THEORETICAL BACKGROUND

2.1 | OI and knowledge

OI describes the commercialization of ideas that emerge inside or outside a company (Chesbrough, 2003, 2006). This can be seen as a distributed innovation process in which knowledge flows across company boundaries are controlled in a targeted manner (Chesbrough & Bogers, 2014). These activities may lead to challenges, for example, regarding the integration of externals in the innovation process and motivating externals to share their knowledge (West & Gallagher, 2006). To facilitate this step, various tool classes are described in existing literature: innovation contests, innovation markets, innovation communities, innovation toolkits and innovation technologies (Möslein & Fritzsche, 2017).

Regarding knowledge flows, the current literature often refers to three different modes of OI: outside-in, inside-out and coupled (Gassmann & Enkel, 2004; West & Bogers, 2014). In addition to different directions of openness, different degrees of openness also exist. Lazzarotti and Manzini (2009) name four different modes, depending on the openness of the funnel and the variety of partners: closed innovators, specialized collaborators, integrated collaborators and the OI model. There are various process perspectives for describing and implementing OI, which on the one hand facilitate implementation and, on the other, provide various units of analysis. For inbound OI in particular, West and Bogers (2014) describe a process consisting of obtaining, integrating and commercializing external innovations. In the same sense, Urbinati, Chiaroni, et al. (2020) use a process consisting of idea generation, product or service development, and commercialization for their analyses. Grönlund et al. (2010) describe a process consisting of defining, designing and validating steps for both inbound and outbound activities. The defining step is characterized, among others, by the identification of customer needs, the creation of concepts and the spin-in and spin-out of ideas and knowledge. In the design phase, the product design is finalized and tested. The validation phase is used for testing and reviews and also for evaluating different commercialization strategies (Grönlund et al., 2010). As possible levels of analysis in OI, intra-organizational, organizational, extra-organizational and inter-organizational and innovation systems have emerged (Bogers et al., 2017). At the project level, Marullo et al. (2020) propose a three stage process of OI: initializing, processing and reconfiguring. Each of these stages offers potential for joint value creation through, for examples, the estimation of sources, knowledge exchange or the refinement of business models (Marullo et al., 2020, p. 212). In this study, the focus is on the intra-organizational or project level, which also integrates external knowledge at certain stages.

2.2 | Digital and persuasive technologies

The advancement of digitization also has an impact on innovation processes. The use of digital technologies in innovation processes is researched under the term *digital innovation* (Yoo et al., 2010; Yoo et al., 2012). It is characterized by new products, services or platforms as outcomes being supported by the use of digital technologies (Nambisan et al., 2017). For example, Barlatier et al. (2020) examine the influence of digital technologies, such as artificial intelligence (AI), big data and social media, on OI processes. Other studies examine the use of storytelling applications for knowledge sharing (Park et al., 2020) or the influence of digital technologies on inbound

processes in general (Urbinati, Chiaroni, et al., 2020). Aloini et al. (2020) describe the use of technologies in inside-out processes and focus in particular on collaboration and content management tools as well as business analytics.

Design-oriented research is relevant to developing principles and theories regarding digital innovation artefacts (Hevner et al., 2019). Existing work in this area outlines two design principles for innovation artefacts: They 'should help persuade relevant stakeholders through proof-of-value and proof-of-concept' (Ciriello et al., 2014, p. 11), and they 'should help fuel collaboration by acting as boundary object and activity object' (Ciriello et al., 2014, p. 12).

In this study, digital technologies are considered from a persuasive technology perspective. Research on persuasive technology combines backgrounds from psychology, such as persuasion, with human-computer interaction (Fogg, 1998). Including behaviour change-related theories (Oinas-Kukkonen, 2013), technologies that influence attitudes and behaviours of users are examined (Fogg, 1998). This is always based on the premise that the change in behaviour occurs without coercion and deception (Fogg, 2003). Behind persuasive technology, there is always a person who wants to influence behaviour via information technology (Fogg, 1998; Oinas-Kukkonen & Harjumaa, 2009). It is the responsibility of the technology designer to ensure that the influence is ethically correct (Verbeek, 2017).

According to the *Fogg behaviour model* (Fogg, 2009), three factors are necessary for a behaviour change to occur: motivation, ability and a trigger. A user must therefore be motivated to perform the desired behaviour, possess the necessary ability and be triggered to perform the behaviour (Fogg, 2009). This can be achieved or supported by appropriate design principles. Building on preliminary work by Fogg (2003), Oinas-Kukkonen and Harjumaa (2009) describe 28 persuasive system features. These are organized into four categories: primary task support, dialogue support, system credibility support and social support. Table 1 presents all the system features.

So far, persuasive technology applications have focused primarily on health and well-being and ecological consumption or behaviour (Hamari et al., 2014; Orji & Moffatt, 2018). In the field of teaching and learning, the first applications of persuasive technology for knowledge acquisition or recommendations already exist (Mintz & Aagaard, 2012). Persuasive technology has also been applied for knowledge sharing (Brodie et al., 2007; Wiafe et al., 2020), consensus seeking in virtual collaboration (Peng et al., 2019) and for improving collaboration, interaction and engagement (Stibe et al., 2013; Stibe & Oinas-Kukkonen, 2014). Persuasive technologies also offer potential applications in workshops and design processes (Jalowski, 2020; Jalowski et al., 2020). In general, such technologies help to increase engagement, encouragement, motivation, awareness, enjoyment and fun (Hamari et al., 2014). These aspects also play an important role in OI approaches (cf. Algashami et al., 2017; Antikainen et al., 2010; de Vreede et al., 2013).

2.3 | Boundary objects

Technologies can also act as boundary objects. In OI processes in particular, they can offer further added value in terms of collaboration between different stakeholders along with the transfer of knowledge and the establishment of a common understanding. The concept of boundary objects introduced by Star and Griesemer (1989) describes constructs and artefacts that serve to span a frame of reference and enable actors from different social worlds to engage and work formatively on specific topics and subjects. Boundary objects enable this because they are, on the one hand, structured enough to create a working framework in homogeneous groups, and on the other hand, elastic enough to be recognized as a unified representation across the boundaries of heterogeneous groups (Fox, 2011). They can manifest themselves in a variety of forms, including both physical objects and intangible entities. Therefore, they provide a central reference for interaction with topics and subjects and for interactions among actors themselves (Moultrie, 2015). The application fields of boundary objects include system development, information systems (Doolin & McLeod, 2012), the general management context and in affecting the acceptance and adoption of new technologies (Fox, 2011). Star and Griesemer (1989) distinguish four types of boundary objects: repositories, the ideal type, coincident boundaries and standardized forms.

In design processes and OI activities, such objects are utilized for moderation, mediation, evaluation and alignment among stakeholder groups. They can be used at different stages and for different activities within the innovation process. In early phases, they are suitable for creating a common understanding among the actors involved and for addressing semantic and ontological inquiries. In later phases, they lend themselves to structuring collaborative work as well as to developing consensus among stakeholder groups. This is especially relevant if there are conflicting expectations and attitudes regarding concepts, technologies, etc. (Bechky, 2003). In summary, it can be stated that boundary objects are well suited to objectives that require stakeholder integration

TABLE 1 Persuasive system features from Oinas-Kukkonen and Harjumaa (2009)

Primary task support	Dialogue support	System credibility support	Social support
Reduction	Praise	Trustworthiness	Social learning
Tunnelling	Rewards	Expertise	Social comparison
Tailoring	Reminders	Surface credibility	Normative influence
Personalization	Suggestion	Real-world feel	Social facilitation
Self-monitoring	Similarity	Authority	Cooperation
Simulation	Liking	Third-party endorsements	Competition
Rehearsal	Social role	Verifiability	Recognition

(Bergman et al., 2007). In addition, technologies can also adopt the role of a boundary object in OI. For example, they can promote collaboration (Ciriello et al., 2014) or contribute in the form of prototypes as identity markers in innovation processes (Dosi et al., 2020).

3 | RESEARCH DESIGN

3.1 | Research approach

To answer the research question, a pragmatic DSR approach was selected to first create and analyse artefacts that emerged from previous research activities as research contributions based on research demands in the literature and to then derive principles as a step towards a nascent design theory (cf. Deng & Ji, 2018; Gregor & Hevner, 2013; Hevner et al., 2004). According to Hevner (2007), DSR is by default pragmatically oriented because it always aims to contribute to the application domain. In principle, two camps can be distinguished in DSR: a design-theory camp and a pragmatic-design camp. While the former primarily aims at developing design theories, the latter focuses on artefacts as the result of a design science study (Deng & Ji, 2018; Gregor & Hevner, 2013). However, Gregor and Hevner (2013) argue for a harmonization of both views, as they can also be seen as complementary. Furthermore, the integration of existing knowledge and the generation of new knowledge play an important role in DSR (Drechsler & Hevner, 2018; Gregor & Hevner, 2013). DSR should focus on synergies of contributions between relevance and rigour (Hevner, 2007). In order to ensure these synergies, Hevner et al. (2004) propose seven guidelines. Table 2 describes and summarizes these guidelines as applied in this work.

TABLE 2 Applied DSR guidelines from Hevner et al. (2004)

Guideline	Description
1. Design as an artefact	Three different instantiations addressing different problems in OI projects: Artefact 1: Cybersecurity City Artefact 2: QR-Toolbox and PID4CPS Artefact 3: CharAIBM
2. Problem relevance	Integrating knowledge is crucial for OI (Chesbrough & Bogers, 2014), and digital technologies can facilitate knowledge sharing in inbound and outbound processes (Barlatier et al., 2020; Trabucchi et al., 2018). There, persuasive technologies offer the potential to facilitate knowledge sharing (Jalowski et al., 2020; Wiafe et al., 2020), and knowledge work and collaboration are described as challenging fields for persuasive technology (Torning & Oinas-Kukkonen, 2009) (cf. Section 3.2).
3. Design evaluation	The three artefacts were each demonstrated and evaluated in a case study (cf. Section 4).
4. Research contributions	The study provides new insights into the role of persuasive digital technologies in OI in the form of four design principles.
5. Research rigour	Application of the DSR methodology (Peffers et al., 2007), persuasive system design models (Oinas-Kukkonen, 2013), design principles for innovation artefacts (Ciriello et al., 2014) and established evaluation frameworks (Peffers et al., 2012; Sonnenberg & vom Brocke, 2012; Venable et al., 2016).
6. Design as a search process	All artefacts were iteratively tested and refined (cf. Section 4).
7. Communication of research	Research and practice oriented communication of interim results at conferences, in presentations and discussions.

3.2 | Research methodology

To ensure research rigour, the DSR methodology from Peffers et al. (2007) was applied. It consists of six activities, which are shown in Figure 1.

The first step is to specify the problem and the added value of the solution. This forms the basis for the following steps (Peffers et al., 2007). The problem and motivation were already described in Section 1 and in Table 2. This study therefore explores persuasive technology with the lens of boundary objects to examine its impact on knowledge sharing in different OI projects and processes.

In the second step, specific objectives are defined based on the problem statement, either quantitatively or qualitatively by means of a description of how the artefacts specifically address the problem (Peffers et al., 2007). The six objectives are refined to 20 concrete features, which are connected to the three artefacts (cf. Figure 2).

In Step 3, the artefacts are developed; these can be, for example, constructs, models or instantiations. An artefact must provide a research contribution embedded in its design (Peffers et al., 2007). In project meetings, the requirements were regularly aligned and adjusted with the relevant stakeholders. The artefacts are described in more detail in Sections 4.1, 4.2 and 4.3.

The fourth step involves describing the application of the artefact and to showing how the artefact can contribute to addressing the problem (Peffers et al., 2007). The demonstration of the artefacts is carried out as part of Sections 4.1, 4.2 and 4.3.

In Step 5, the artefacts are evaluated to determine whether they contribute to solving the problem. A wide variety of evaluation methods can be used for this purpose. Depending on the evaluation result, it is necessary to iterate back to the design phase to adapt the design of the artefact (Peffers et al., 2012, 2007). Naturalistic evaluation strategies were conducted with real users in real settings (Venable et al., 2016). For this purpose, a case study was conducted for each artefact, which is particularly suitable for evaluating artefacts and their effect in real-world situations (Peffers et al., 2012). The description of the evaluation and the respective case studies can be found in Sections 4.1.2, 4.2.2 and 4.3.2.

The final step is to communicate the results to researchers and practitioners. This should also ensure the rigour and effectiveness of the artefacts (Peffers et al., 2007). The preliminary results regarding

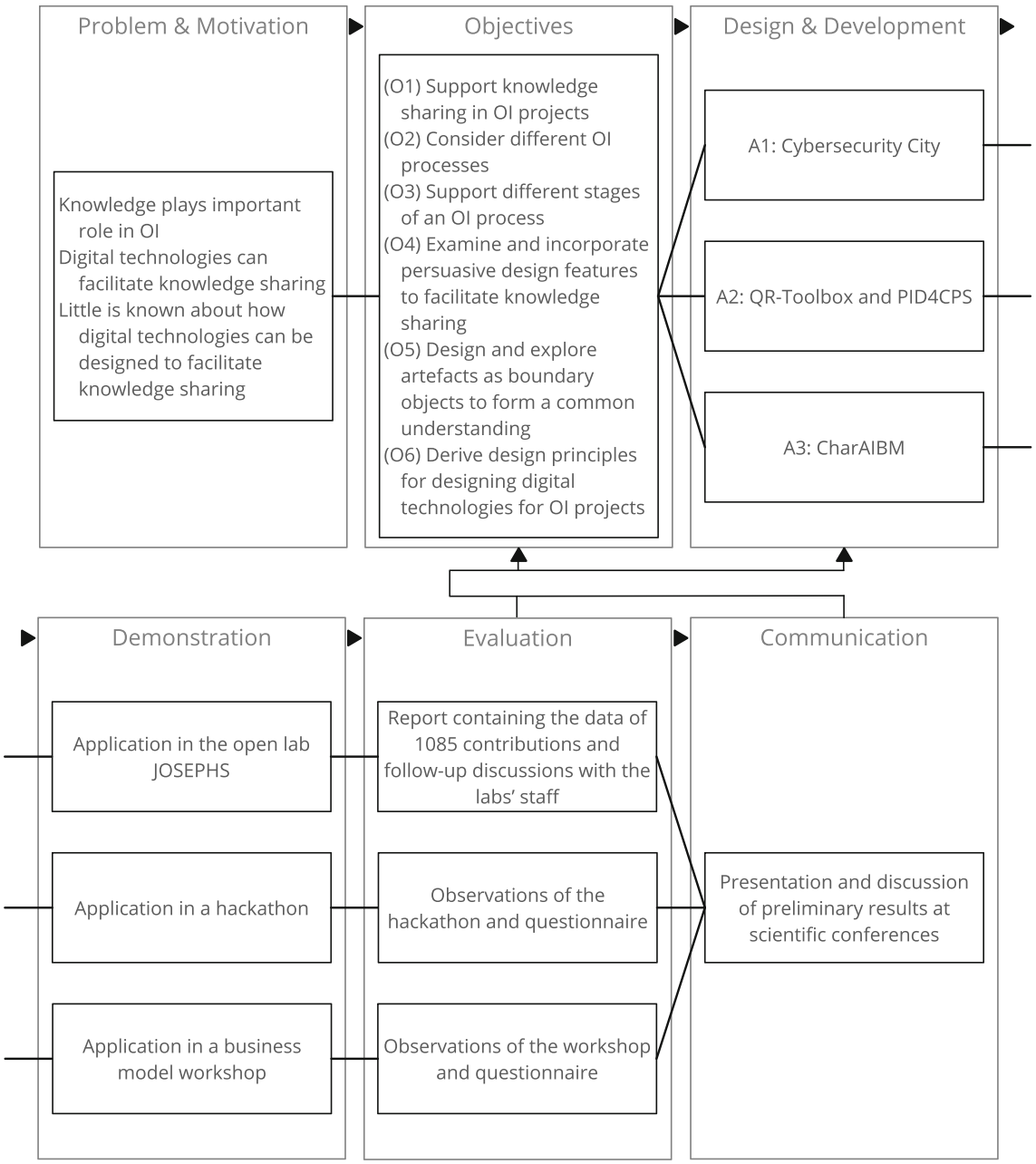

FIGURE 1 DSR approach used in this study based on Peffers et al. (2007)

the three artefacts have been communicated and discussed with researchers and practitioners at conferences and in scientific and practitioner-oriented publications. This study thus serves to communicate the findings of the described DSR approach.

Finally, design principles were derived to address *O6*. From a DSR point of view, these are the steps required to move towards a nascent design theory and contribute to the formation of a more comprehensive body of knowledge (Gregor & Hevner, 2013). Design principles ensure that knowledge from the application of instantiations is made more broadly usable (Chandra et al., 2015). To formulate design principles, Chandra et al. (2015) suggest describing the material property in terms of form and function, then naming the action provided to users, and finally explaining boundary conditions in terms of settings or special characteristics (p. 4045). Section 5 describes the derived design principles for persuasive digital technologies in OI projects.

4 | FINDINGS

In the following, the three artefacts and their evaluations are described in more detail. We present digital technologies from three OI projects. These incorporate different activities (cf. Gassmann & Enkel, 2004) and are related to the three steps of an OI process: define, design and validate (Grönlund et al., 2010). The first artefact

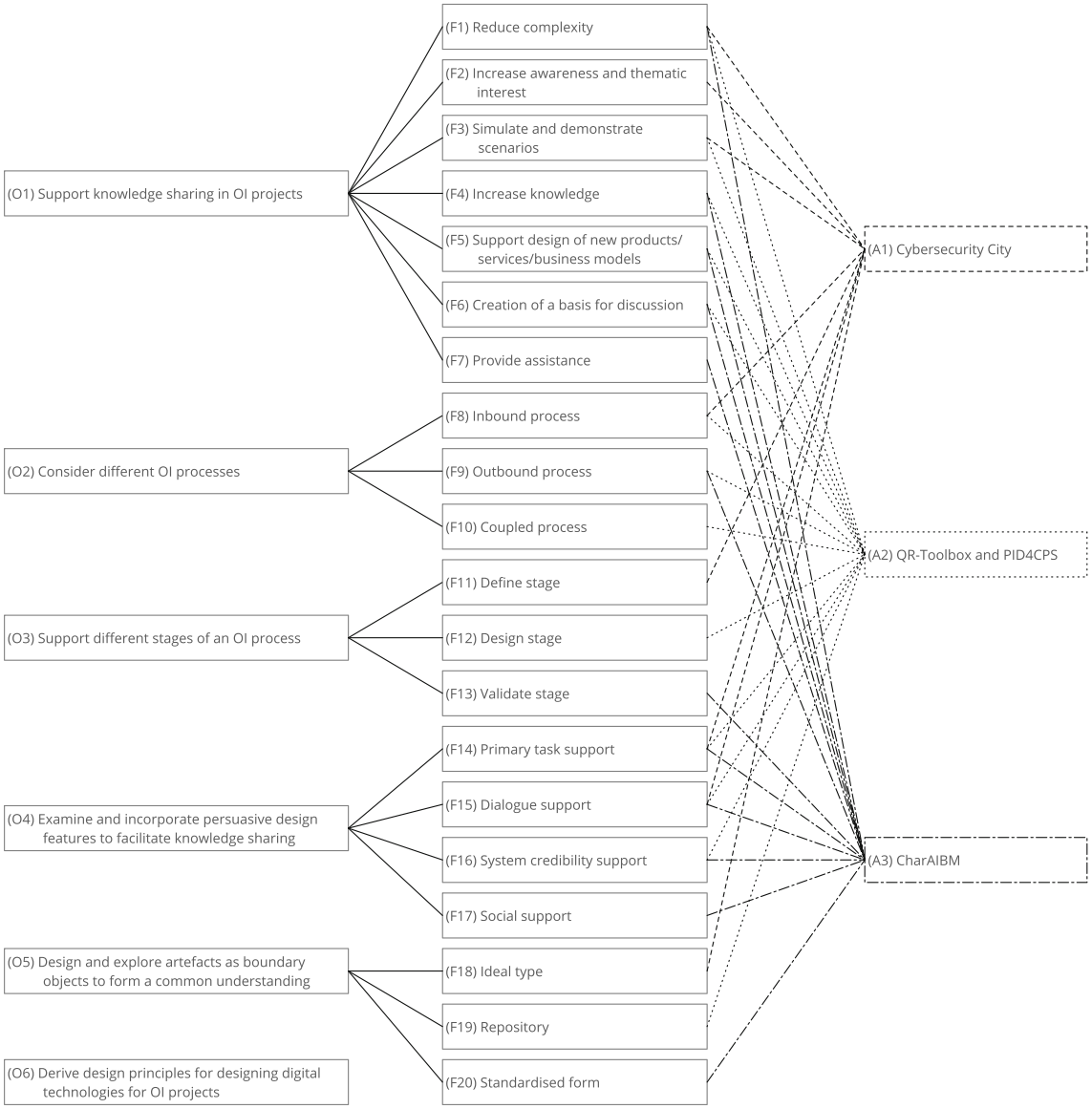

FIGURE 2 Connections between the objectives, features and artefacts

was used as part of an OI approach in an open lab to gather customer needs and define new possible products and services in the context of IT security. The second is a technology portfolio to design and develop new products and services in the context of Industry 4.0. The third artefact is a specific tool used to visualize and evaluate AI-based business models. Figure 3 presents a preview of the artefacts and their relation to the OI process. The following sections describe the design and development of the respective artefacts, as well as demonstration and evaluation by means of a case study in each case (cf. Peffers et al., 2012).

4.1 | Artefact 1: Cybersecurity City

Artefact 1 was developed as a thematic introduction to the topic of 'IT Security for Critical Infrastructures' as part of a co-creation approach in the open lab JOSEPHS in Nuremberg, Germany. The following sections describe the design of the artefact and its evaluation by means of a case study.

4.1.1 | Features and application: Co-creating cybersecurity

In the context of a research project on 'IT Security for Critical Infrastructures', various OI approaches were carried out. One part was a 3-month phase in an open lab. There, co-creators had various opportunities to test prototypes for improving IT security for critical infrastructures, to make a concrete contribution and to identify and prioritize focal and weak points. The open lab JOSEPHS is aimed at the general public, which means that not only experts in IT security or critical infrastructures are invited to work on the development of solutions.

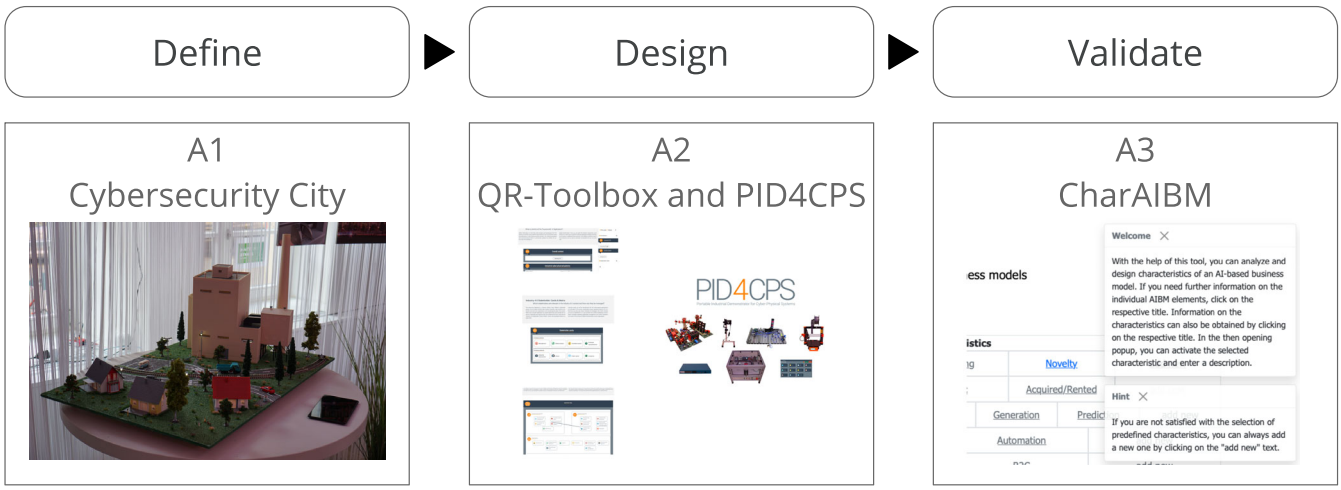

FIGURE 3 Overview of the artefacts and the OI process from Grönlund et al. (2010) [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 4 Cybersecurity City in the open lab and selected features for Artefact 1 [Colour figure can be viewed at wileyonlinelibrary.com]

To increase the awareness of the visitors and to familiarize them with the topic, a demonstrator was developed that simulates a cyber-attack on a power plant control system and a control centre. This *Cybersecurity City* consisted of two components: first, a scale model containing critical infrastructures, such as a power plant, a railroad line and security equipment, as well as a settlement and street lighting; and second, a tablet with an Android app that can be used to access the control centre remotely and switch various circuits on and off. Under instruction, co-creators were able to launch a brute force attack on the control centre to gain access to the control system. The control operations were visualized by switching lights in the houses, the street lighting, or the security equipment on or off. Figure 4 shows the set-up in the open lab, the Cybersecurity City and the incorporated features.

4.1.2 | Case study—Open lab

First, the artefact is analysed with regard to the objectives. Then, the findings from its application in the open lab are explained. As described, the aim of the artefact is to familiarize co-creators with terminology and to introduce them to the topic. This is intended to facilitate knowledge sharing and achieve a greater understanding of the topics among co-creators, ultimately also increasing the quality of the users' contributions. This is to be achieved by applying various persuasive system features (cf. Oinas-Kukkonen & Harjumaa, 2009). The artefact simplifies a complex topic, such as an attack on a control centre (*reduction*), by simulating a brute force attack (*simulation*). The tablet, including an app, guides the user through the process of the attack (*tunnelling*) and simulates remote access to a control room

TABLE 3 Overview of the characteristics of Artefact 1

Category	Characteristics
Purpose	Introduction and awareness was raised via a simulated cyber-attack on a power plant, which illustrated the range and consequences of a power plant outage.
Persuasive features	Reduction, tunnelling, simulation and suggestion
Boundary object role	Ideal type
OI process	Inbound
OI stage	Define

(*suggestion*). The Cybersecurity City can be seen as an *ideal type* boundary object (cf. Star & Griesemer, 1989) because it does not represent all the details of an attack and a control room but abstracts and simplifies them. However, characteristic steps, such as the attack and the ability to remotely control circuits, remain. From the OI process point of view, the presented project is an inbound process because different prototypes, questions and problems are presented for ideas and input. The artefact is especially suitable for the definition stage of an OI process, which includes customer needs, knowledge and concepts (cf. Grönlund et al., 2010). Table 3 summarizes the characteristics of Artefact 1.

The artefact was used in the open lab for 3 months. During this phase, 1633 co-creators visited the lab. They were accompanied by lab staff, who noted feedback and summarized it in a report, and 1085 contributions were recorded. In addition to the report (*R*), follow-up discussions (*D*) were conducted with the supervising staff. Data for the report came from visitor feedback on sticky notes, standardized staff notes and open staff observations.

The Cybersecurity City served as an eye-catcher that attracted the co-creators' interest and led to their involvement in other topics (*D*). In general, it became apparent that knowledge of IT security and critical infrastructures is not yet widespread among co-creators (*R*). Thus, the Cybersecurity City has contributed to introducing and raising awareness of the topic (*R*). Despite the simulation and instructions, some co-creators lacked an understanding of the brute force attack on the control centre (*R*). If a co-creator came up with it on their own, they were motivated and interested (*R*). It also showed that older co-creators were less interested in the introduction (*R*). A common problem for the visitors was the impact of IT security on critical infrastructures (*R*). It can be stated, that the Cybersecurity City provides a thematic introduction and supports the understanding of the co-creators. Equally, however, it also influences the direction of the co-creators' contributions.

4.2 | Artefact 2: PID4CPS and QR-Toolbox

Artefact 2 is a comprehensive toolbox and methods consisting of physical and digital tools to design Industry 4.0 systems. The following sections describe the design of the artefact and its evaluation by means of a hackathon case study.

4.2.1 | Features and application: Designing Industry 4.0 systems

Similar to IT security, Industry 4.0 is a topic that affects many organizations, but different understandings or perceptions prevail. Web-based tools (*QR-Toolbox*) and the demonstrator *PID4CPS* serve a wide variety of purposes in this context. For example, technologies can be simulated before being used in real systems, advantages and disadvantages of technologies can be demonstrated or application potentials of cyber-physical systems can be shown (Oks et al., 2019). The demonstrator is supplemented by the *QR-Toolbox*, including the *Industry 4.0 Compendium*, *Industry 4.0 Stakeholder Cards & Matrix* and *Industry 4.0 Application Map* (Oks et al., 2021).

The application of web-based tools is ideal if initial ideas have been defined beforehand and a concrete system is to be designed. First, the compendium is used to select relevant components and architectures from a set of over 250 concepts and technologies. Then, relevant stakeholders are identified, and their expectations are defined (Oks et al., 2018b). Finally, the application map serves to bring together the previously defined components and to transfer them to a concrete application scenario (Oks et al., 2018a). Figure 5 shows PID4CPS, screenshots of the QR-Toolbox and the incorporated features.

4.2.2 | Case study—Hackathon

First, the artefact is analysed with regard to the objectives. Then, the findings from its application in a hackathon are explained. The goal of the artefact is to support a common understanding of different topics related to Industry 4.0 and to support the design of new products or services related to cyber-physical systems. In each tool, the user can select relevant components, which are collected in a sidebar where comments and notes can be made regarding the individual components. The sidebar ensures that the selected components are available across all the tools. This serves as a basis for the design of the system in the Application Map. Persuasive system features are used to support user behaviour when using the tool (cf. Oinas-Kukkonen & Harjumaa, 2009). The tools described have an intended order, and the user is guided through the process by markers and hints (*tunnelling*). The visualization summarizes areas thematically, which is intended to reduce complexity and focus the user on one topic area (*reduction*). The knowledge conveyed by the tools is based on scientific publications and is communicated to the users (*expertise*). The underlying papers are linked, which facilitates the verification of the information (*verifiability*). The Industry 4.0 demonstrator also enables the simulation of the systems designed in the web tools (*simulation*). Suggestions and explanations are provided to increase understanding (*suggestion*). The artefact can be seen as a *repository* boundary object (cf. Star &

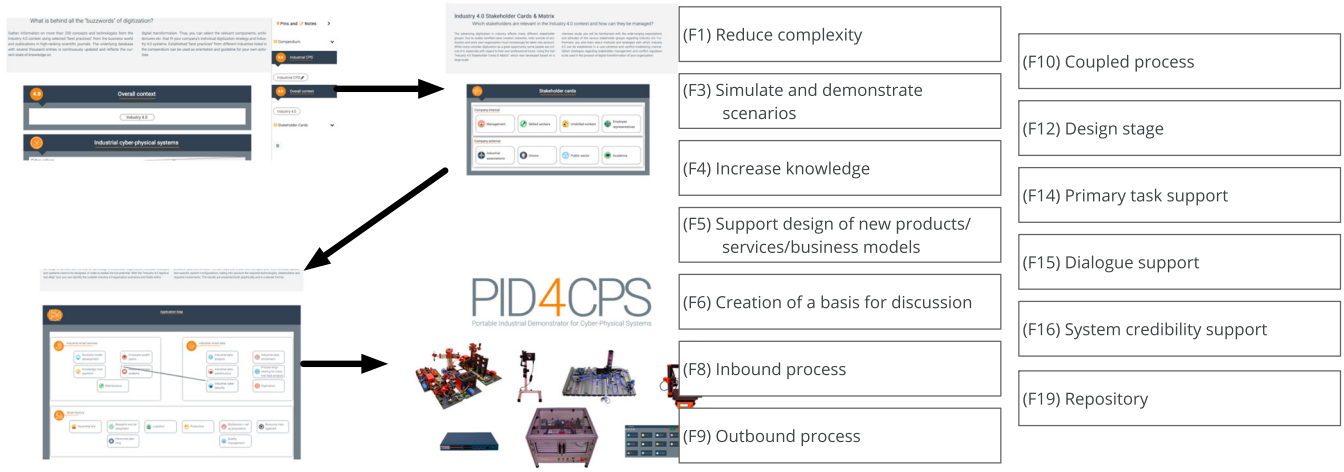

FIGURE 5 Connection between the QR-Toolbox, PID4CPS and selected features for Artefact 2 [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 Overview of the characteristics of Artefact 2

Category	Characteristics
Purpose	Industry 4.0 toolbox and methods to create a common understanding of different topics and the conception as well as the design of specific products or services related to cyber-physical systems.
Persuasive features	Reduction, tunnelling, simulation, suggestion, expertise and verifiability
Boundary object role	Repository
OI process	Inbound/outbound
OI stage	Design

Griesemer, 1989), as it provides different standardized methods and tools to address specific challenges when designing new Industry 4.0 systems. From a process perspective, it can be used in inbound and outbound projects for solving concrete problems or designing new commercialization modes. The artefact supports the design phase of an OI process, especially when developing new products or services (cf. Grönlund et al., 2010). Table 4 summarizes the characteristics of Artefact 2.

The artefact was used in a virtual 2-day hackathon with 15 participants. The participants' task was to work on improving industrial maintenance and repairs through the use of smart technologies. The participants had to design a prototype using the QR-Toolbox, and 12 of them completed a subsequent questionnaire and evaluated the applicability of the tools. The Industry 4.0 Compendium provides relevant information for the engineering and development process, thus contributing to a common understanding and inspiration; one participant (*P3*) would have appreciated better step-by-step support and more information about contexts. Regarding the tools, it is noted that they could be better tailored to specific tasks, for example, the specific industry sector (*P2*, *P3*). In general, it was noted that the 'tools are very understandable (…) and useful for developing ideas' (*P6*) and '(…) good for making you think about different aspects of the problem and solution domain' (*P10*). Structuring helps to give a good overview and increase general understanding (*P4*). In the hackathon, the tools were available for self-service use, but the participants could ask questions at any time. It was noted that more time was needed (*P4*, *P7*) and that explanatory videos or further information (*P8*, *P10*) would have been helpful: 'If one deals with it intensively, however, one can also understand the context oneself' (*P4*). So the QR-Toolbox enables the engineering and development of suitable Industry 4.0 system configurations. Regarding expertise and verifiability, all participants confirmed that the information provided was valid and helpful.

4.3 | Artefact 3: CharAIBM

Having described two more broadly applicable artefacts, we now present a specific tool for use in a business model development workshop. Artefact 3 is a digitized version of a tool for designing AI-based business models and was applied in a workshop with a startup company. The following sections describe the design of the artefact and an evaluation of it.

4.3.1 | Features and application: Refining AI-based business models

The advancing use of AI enables companies to develop new business models (Lee et al., 2019). Business models can be designed or innovated with specific tools or frameworks in workshops together with relevant stakeholders (Chesbrough, 2007; Osterwalder & Pigneur, 2010). First insights from a research project on AI-based business models reveal, especially in the area of business models for AI-based services, a lack of methodological and conceptual abilities to innovate them. However, the knowledge and abilities of participants

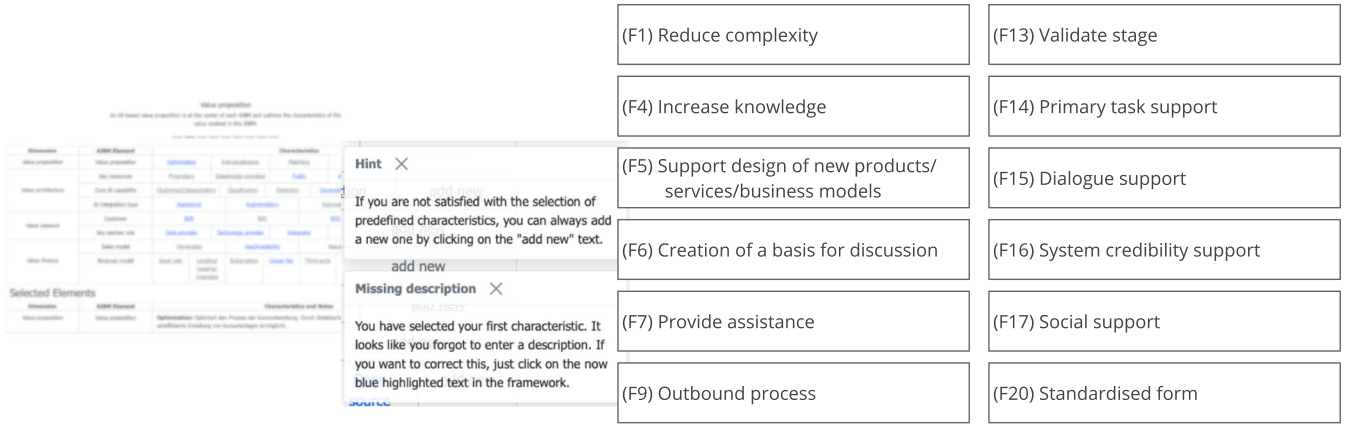

FIGURE 6 Screenshot of the tool, exemplary reminders, notifications and selected features for Artefact 3 [Colour figure can be viewed at wileyonlinelibrary.com]

in a workshop can be supported by suitable technologies (Jalowski et al., 2020).

Following these observations, a framework for the characterization of AI business models was converted into a web-based tool, which offers various support features (see Section 4.3.2). Against the background of the COVID-19 pandemic, the tool is embedded in a process that also allows virtual workshops. First, users individually select AI-specific characteristics of various business model elements and describe them from the perspective of the current or planned AI-based service. The results can be exported and then discussed and further developed in a joint discussion session with the other participants. Figure 6 shows screenshots of the web-based tool and the incorporated features.

4.3.2 | Case study—Business model workshop

First, the artefact is analysed with regard to the objectives. Then, the findings from its application in a business model design workshop are explained. The goal of the artefact is to facilitate knowledge sharing in a specialized context. Participants should be enabled to describe the components of an AI-based business model without the support of a moderator in order to facilitate subsequent discussion and elaboration within the group. Participants typically have extensive domain knowledge but limited knowledge of design methods. The artefact also supports increasing design knowledge to facilitate the sharing of domain knowledge. Again, persuasive system features are used to guide user behaviour regarding the tool (cf. Oinas-Kukkonen & Harjumaa, 2009). The tool provides step-by-step guidance through the individual elements, and those already processed are highlighted (*reduction*, *tunnelling*). The user sees pop-ups or notifications when making incomplete or unusual entries and receives suggestions for subsequent actions (*reminders*, *suggestion*). Furthermore, the artefact contains explanations of all the elements and characteristics to increase the user's understanding and knowledge (*expertise*). Finally, the filled framework serves as a basis for the subsequent discussion (*cooperation*). The

TABLE 5 Overview of the characteristics of Artefact 3

Category	Characteristics
Purpose	Web-based tool for the analysis or development of an AI-based business model. Users are supported by the tool via explanations, hints and guidelines.
Persuasive features	Reduction, tunnelling, reminders, suggestion, expertise and cooperation
Boundary object role	Standardized form
OI process	Outbound
OI stage	Validate

artefact can be seen as a *standardized form* boundary object (cf. Star & Griesemer, 1989) as it provides a predefined schema to describe an AI-based business model. From a process perspective, it is especially useful in outbound projects to develop a new business model. This integrates with the validation phase of an OI process to evaluate different commercialization modes (Grönlund et al., 2010). Table 5 summarizes the characteristics of Artefact 3.

The artefact was applied in a business model workshop with a startup that offers AI-based services in the teaching sector. Because it is new to the market, it is constantly trying to analyse its business models in order to develop them further. In doing so, it also relies on collaboration with partners. In the workshop, each participant used the artefact individually to get an overview of one of the startup's current business models. In a subsequent group discussion, the results were shared with all the participants, and ideas regarding adjustments to the business model were developed. The feedback, which was obtained via a questionnaire, shows that the artefact provides significant added value: 'I would use the tool to communicate our business models to teammates and potential investors' (*P1*) and 'I particularly liked the analytical categorization of complex relationships' (*P1*). This is especially true when it is used as preparation for a subsequent discussion. When all participants engage with it, it helps in assessing the status quo. The tool stimulates discussion and engagement and forms

the basis for the further development of the business model. One participant noted: 'The tool triggered my engagement and encouraged me to look at the individual elements (…) it provided me with further information that I need for strategic decisions regarding service enhancement', (*P1*) while recognizing that using the tool alone is useful but the conversation about the participants' findings is the most important contribution. It was critically noted that the *tunnelling* (i.e., the action of being led through the process) is not yet distinctive enough. In addition, a verification function was requested to check the selection and compare it with existing data and to ask about popular points that have not yet been selected by the participant.

5 | DESIGN PRINCIPLES FOR PERSUASIVE DIGITAL TECHNOLOGIES IN OI PROJECTS

The artefacts presented in the previous sections address objectives *O1* to *O5*. The last objective *O6* is the derivation of design principles. This forms the step towards developing a design theory (Gregor & Hevner, 2013) and helps in converting the findings of this study into future persuasive digital technologies for OI projects. Chandra et al. (2015) propose a three-level structure for the description of design principles, consisting of material property, actions and boundary conditions. Based on the findings of the artefacts and their evaluations in dedicated projects (*A1*, *A2*) or intra-organizational (*A3*) settings, overarching principles for OI projects can be derived. Figure 7 summarizes the four design principles and their properties.

The first principle is *apply technology to reduce complexity for clarification*. In particular, the findings of *A1* and *A2* show that complexity reduction can facilitate the introduction to a topic and thus also contribute to the building of a common understanding. At the same time, this can also support the sharing of knowledge, because there is a better understanding of the situation. In order for the principle to be applicable, the simplification must not appear too playful, so as not to lower the acceptance of experts. At the same time, the particular topic should be suitable for simplification. Besides a specific demonstrator

Apply technology to …	
reduce complexity for clarification (design principle 1)	
Material property	Use the digital technology to reduce complexity; provide illustrative cases and examples
Action	Build a common understanding
Boundary conditions	Participants are not experts in the field and may have different ideas, attitudes and expectations; topic can be simplified and presented as an illustrative case
integrate tailored methods and structures (design principle 2)	
Material property	Use the digital technology to augment methods and structures
Action	Support design phases
Boundary conditions	Design phase requires specialised concepts or structures; digital technology can cover a certain step in a method
facilitate the creation of prototypes (design principle 3)	
Material property	Use the digital technology to facilitate the creation of prototypes
Action	Support the communication of ideas
Boundary conditions	Sufficient knowledge available to develop a suitable digital technology; creation of a prototype can be supported by technology
consider the behaviour of users (design principle 4)	
Material property	Incorporate persuasive system features into the digital technology
Action	Simplify the application of the technology for the user
Boundary conditions	Knowledge sharing is prevented due to a lack of ability, motivation or triggers

FIGURE 7 Summary of the four design principles based on the structure suggested by Chandra et al. (2015)

as in *A1* or *A2*, this can also include the demonstration of a current technology, such as augmented or virtual reality (cf. Barlatier et al., 2020). This principle is also aligned with Principle 1 of Ciriello et al. (2014), because demonstrations of proof-of-value or proof-of-concept can also apply here.

The second principle is *apply technology to integrate tailored methods and structures*. The tools described in *A2* are part of a comprehensive portfolio of methods and can thus provide specialized support for the design phase in an OI process. *A3* also represents a specific technology for a particular task. The principle is applicable when, for example, the complexity of a topic requires specific support from a technology. This does not necessarily have to be a custom-developed tool. Structuring on a virtual whiteboard can also fulfil the principle. With the focus on knowledge sharing, this role can also be assumed by a playful application, as described by Park et al. (2020).

The third principle is *apply technology to facilitate the creation of prototypes*. Both the Compendium and Application Map in *A2* and *A3* provide overviews of system configurations and visualize business models, respectively. In both cases, this primarily supports the communication and discussion of ideas. A prototype can have different meanings here: physical objects and system configurations, other forms of representation or virtual prototypes. The basic condition for this principle, in particular, is that sufficient knowledge about the application context is available. The creation of a tool for the visualization of AI-based business models requires a deeper knowledge of this topic. This principle is related to the promotion of collaboration through a boundary object (cf. Ciriello et al., 2014).

The fourth principle is *apply technology to consider the behaviour of users* by incorporating persuasive system features. All artefacts were analysed and evaluated with regard to their persuasive system features (cf. Oinas-Kukkonen & Harjumaa, 2009). The results show that these principles can facilitate the application of a digital technology. In particular, the reduction of a task into substeps and the provision of reminders and other triggers, as well as the availability of explanations, as in *A1* and *A3*, contribute to making the task easier for the user. For persuasive technology to be effective, knowledge sharing must be prevented due to a lack of ability, motivation or triggers (cf. Fogg, 2009).

6 | DISCUSSION

6.1 | Theoretical implications

Our study makes several contributions especially with regard to the use of digital technologies in OI projects. So far, in the context of OI, digital technologies have been studied mainly from the perspective of one or more specific technologies (Barlatier et al., 2020; Trabucchi et al., 2018) or in terms of their impact on specific OI processes, such as inbound or outbound (Aloini et al., 2020; Urbinati, Chiaroni, et al., 2020). We have taken a generic OI process (cf. Grönlund et al., 2010) as a basis, presented an artefact for each step and derived design principles for the construction of new persuasive digital technologies based on it. In this way, we want to ensure that the findings are broadly applicable and can be utilized for specific use cases at the same time.

We build on the work of Ciriello et al. (2014) but extend it. They describe design principles for innovation artefacts that foster stakeholder collaboration. Our results incorporate the findings and provide more specific recommendations for action in the design of new technologies. The focus of our study was on OI projects, respectively, on the intra-organizational and individual levels (cf. Bogers et al., 2017). This leads to the need to consider very focused solutions thematically in order to be able to provide concrete support.

As described, there is still a limited number of research that explores the role of digital technologies for OI. For example, Urbinati, Chiaroni, et al. (2020) look at how companies implement digital technologies in OI processes or Barlatier et al. (2020) at how digital technologies can be used in different steps of the OI process. Building on these findings, our study provides another important component for the design and use of digital technologies in OI projects. Previous studies neglect the individual design characteristics of the technologies or consider only one specific technology. The design principles developed in this study will enable future research to consider the development of user-centred persuasive digital technology for OI.

Our approach disengages from concrete technologies and looks at the purpose and design of technologies. Depending on the selected focus, not every principle may be suitable for every technology. Principle 1, for example, focuses on a common understanding that different participants should develop before or at the beginning of an OI process in the defining (cf. Grönlund et al., 2010) or initializing (cf. Marullo et al., 2020) phases, in order to be prepared for knowledge exchange in a subsequent design (cf. Grönlund et al., 2010) or processing (cf. Marullo et al., 2020) phase. It can also facilitate the alignment of stakeholders on a common vision (Urbinati, Landoni, et al., 2020) by forming a common understanding between participants. Principle 2 can then directly support such a phase by providing appropriate methods and structures, such as in cases *A2* and *A3*, each of which provided support for a concrete method to structure knowledge or facilitate sharing. In a subsequent validation (cf. Grönlund et al., 2010) or reconfiguration (cf. Marullo et al., 2020) phase, Principle 3 provides guidance. The term prototype is defined broadly here; it can be a technical prototype but also, for example, the visualization of a business model, as in *A3*. In particular, when we focus on a project or individual level, the behaviour of the participants plays an important role (Bogers et al., 2017; Jalowski et al., 2020). Here, Principle 4 is taken into account and, therefore, also the integration of persuasive system features. These are particularly useful for reminding users of behaviours, simplifying tasks, or guiding users through a process (Fogg, 2003; Oinas-Kukkonen & Harjumaa, 2009). Also, all this has an influence on how well knowledge sharing is achieved, and all the principles are related to boundary objects (cf. Star & Griesemer, 1989). Simultaneously, digital technologies based on the principles are also suitable to support and monitor stakeholder engagement in OI projects, as described by Urbinati, Landoni, et al. (2020).

By looking at the persuasive features of the artefacts, our study provides insights for research on persuasive technology. In 2009,

knowledge work and collaboration was already described as a challenging field (Torning & Oinas-Kukkonen, 2009). The few studies on the topic of knowledge sharing (cf. Brodie et al., 2007; Wiafe et al., 2020) do not examine OI and do not provide recommendations in the form of design principles. The chosen design-oriented approach of our study, first considering the artefacts as a research contribution and then deriving design principles towards developing a nascent design theory (Deng & Ji, 2018; Gregor & Hevner, 2013) should help to better convey the emerging design knowledge (Chandra et al., 2015) and promote the future design of persuasive digital technologies for OI projects.

The study thus provides new insights into the role of digital technologies in OI. The results should increase the discourse on the use of persuasive technologies in the OI community and at the same time open up a new field of application for persuasive technologies.

6.2 | Managerial implications

The results of our study also provide added value for practitioners. Technologies offer great potential in OI projects that is not yet fully exploited. The results support findings from previous studies that technologies can foster knowledge sharing in OI processes. Thus, specific digital technologies offer a high potential to increase the potential output of OI projects. Therefore, our results are of interest to innovation managers who want to design their OI projects in a technology-supported way and not only rely on innovation and collaboration platforms in online contexts. The artefacts presented in this study address specific problems and help users to increase their knowledge about certain topics or to build a common understanding. This in turn contributes to form the basis for successful OI projects.

The design principles support both innovation managers and technology designers and developers. They summarize the findings of the application of the three artefacts and form a guideline for the design and development process of persuasive digital technologies. Practitioners may also be interested in incorporating the persuasive design of the technology. This results in a user-centred technology that facilitates its use and thus ultimately better supports the user. The application of such technologies in OI projects has not yet been widely researched and applied in practice. However, we have looked at OI projects of small and medium-sized enterprises and in the context of research projects. Nevertheless, we provide first insights and concrete recommendations for action that should also be suitable for large and established enterprises.

7 | CONCLUSION

The goal of this DSR study is to provide principles that support the design and use of digital technologies for OI projects. By examining the design and use of three artefacts in different steps of OI processes, four design principles are derived: (1) *apply technology to reduce complexity for clarification*, (2) *apply technology to integrate tailored methods and structures*, (3) *apply technology to facilitate the creation of prototypes* and (4) *apply technology to consider the behaviour of users*. These are intended to support and facilitate the design and application of future persuasive digital technologies in OI projects.

The limitations of this study lie, in particular, in the selection and analysis of the three artefacts. For each step of an OI process, only one artefact was presented, analysed and evaluated. In each case, the artefact was developed by the authors for a specific part of an OI project. Furthermore, the results are limited by the projects examined. In particular, OI projects of smaller companies or within the scope of a research project, and here also with the participation of established firms, were considered. Different organizational cultures and R&D structures may result in different requirements and potentials for persuasive digital technologies. The results of this study could be verified, for example, by means of a literature review of other applications of technologies in OI projects. Future work should also focus on validating the design principles and applying them to the design of new persuasive digital technologies in OI projects, also in larger or more established firms.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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