System Design Principles for Intergenerational Knowledge Sharing

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Abstract. Up to four generations are potentially involved in education and workspaces. This means that people of different generations can increasingly learn together and share knowledge virtually in the digital age. Nevertheless, the principles for designing systems to support intergenerational knowledge sharing (IKS) are inconclusive. Our results demonstrate the value of applying design science research methodology to capture design principles for IKS systems. We articulate what design goals should be considered and bring more conceptual clarity to this phenomenon by presenting five design principles: a) positive personalization, b) progressive design ecosystem, c) effectual system design, d) iterative goal reflection, e) coopetitive intergenerational tasks. By reflecting on the design process and formalizing a class of design principles, we contribute to design-oriented IKS systems in the digital age.

Keywords: Intergenerational knowledge sharing · Intergenerational innovation · Design principles · Design science research

1 Introduction and Problem Awareness

This study explores the design principles (DPs) underlying digital technology to facilitate intergenerational knowledge sharing (IKS). IKS in this study is defined as knowledge sharing between younger adults and older adults with an age difference of at least 20 years who interact with each other via digital technology [17]. The content of knowledge sharing in this study relates to startup development, thus involving actors between older (experienced) adults and young (potential startup) innovators. Given the current state of the knowledge economy and the digital age, leveraging technology to facilitate such collaboration is becoming increasingly crucial for organizations, including startups [1, 11, 20, 21]. For example, video calls can be used to hold meetings, real-time collaborative ideation using digital whiteboards [3, 11, 21], and physical objects and digital spaces can be mixed to accommodate people with different technology backgrounds [7, 11].

On the one hand, research on IKS emphasizes the importance of identifying barriers to digital media use for both generations, such as technology selection, complexity, and user background [17, 21]. On the other hand, various strategies to facilitate digital knowledge sharing between generations, such as different forms of gamification and

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competency-based learning, have been vigorously promoted to provide meaningful positive experiences [1, 3, 13]. However, there is limited research on the phenomenon of digital platforms for IKS in the context of startup innovation [17, 20]. Existing IKS systems that could assist practitioners in designing IKS systems focus primarily on older adults and grandchildren [3, 13, 21] and do not consider the principle of meaningful experiences (and gamification) for diverse generations of adults or the principles of IKS about startup innovation in the digital space [17, 20]. As a result, there is a scarcity of consolidated normative theories on building an IKS system for learning startup development. This is a problem because it prevents the design inclusiveness of different actors [11, 21] in the startup ecosystem from combining and improving their knowledge. Therefore, we address the lack of general knowledge for digital systems that facilitate knowledge sharing in startup development between generations.

Outlining generic DPs as a set of proposed solutions to solve a (class of) problem is a widely endorsed and favored strategy for informing practitioners and researchers about technological meta-artifacts [10, 18]. In this regard, we contend that purpose-driven normative DPs for IKS systems could promote more vital co-innovation [13, 14], strengthen design for social inclusion [13, 17, 23], and assist practitioners and researchers in understanding and improving universal technology design for knowledge sharing. Hence, we formulate the following research question (RQ): How should knowledge-sharing systems be designed to support startup innovation learning in intergenerational ecosystems?

By proposing a set of design principles as meta-artifacts of study [8, 10, 16, 19], this study leverages Design Science Research (DSR) to improve the status quo in research and practice [19]. Meta-artifacts are human-made solutions to system design problem(s) and can be products or processes for the (class of) problem(s) [8, 10]. As a formalization for reflection(s) on the entire DSR, five principles are proposed in this study: positive personalization that goes beyond individualization; a progressive ecosystem for flow experiences; an effectual strategy in system design by optimizing the fit between available design resources and the competencies of different generations, iterative reflection on goals; and finally, coopetitive intergenerational tasks, or orchestrating the power of collaboration and competition. Five DPs are provided at a higher level of abstraction to assist practitioners and researchers in comprehending the means to build IKS systems for learning startup development. The following section describes the methodology in detail.

2 Research Methodology

The Design Science Research (DSR) methodology [19] was chosen for this study because it provides an iterative process for improving knowledge and meta-artifacts [10, 16, 19]. In DSR, the proposed meta-artifact is based on both scientific literature and expert/user studies, with a series of assessments, performed to ensure rigor. DSR allows different evaluations, both qualitative and quantitative methods [8, 16, 19] The results of each process in DSR can be cross-referenced with the previous procedure so that knowledge grows and is systematically refined in each cycle [19]. Moreover, the systematic approach facilitates validating and generating valid DPs as produced meta-artifacts [10, 18, 19]. Overall, DSR meets our requirements for a flexible and high-quality research methodology designed to deliver design-oriented knowledge.

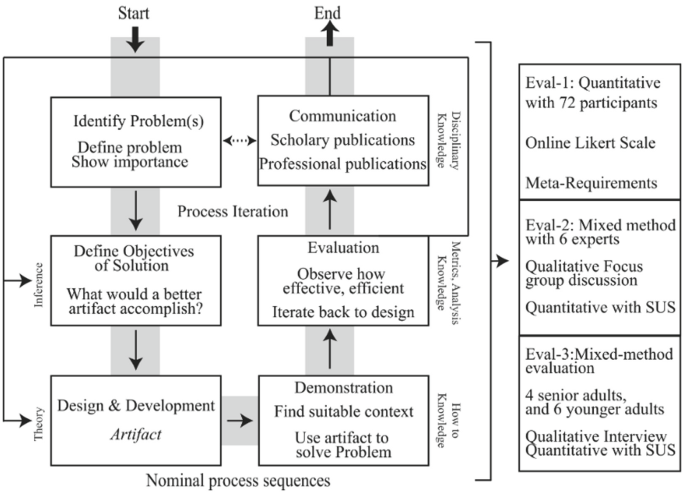

Fig. 1. Process-oriented design science research was applied in this study. Adopted from Peffers et al. [19]

Based on the DSR process, the initial problem for this study was identified and presented in the previous section. The class of problems and design solutions was elaborated through the reflection of a systematic literature review [22] in the objective definition. In previous studies [17], the systematic literature review process of 75 pieces of literature is explained in greater detail. The method was then combined with creative and abductive thinking (or the selection of the best possible solution(s) to solve the problem based on available information from literature and experience) during the design and development process. Overall, three validation processes were conducted. Eval-1 validated the class of problems quantitatively as meta-requirements based on the feedback of 72 participants (male: 48; female: 24; age range from 18 to >65 years). The number is based on feedback returned after the questionnaire is openly visible to an online crowd-working platform's targeted audience. The Eval-1 is a Likert-scale on importance (1–5: strongly agree) online questionnaire. The problem and positive expectations and various IKS design interventions were gathered from the literature [17]. Design and development were conducted based on identified relevant literature in the solution definition process and followed by the artifact's demonstration. The first demonstration of meta-design was a paper prototype. The initial paper prototype was evaluated with the help of three user experience experts, and the pre-evaluation results were used to develop a web-based app as a high-fidelity prototype. The derived meta-requirements and the gained design knowledge were compared with existing literature for the high-fidelity prototype.

The high-fidelity prototype was developed and evaluated. A two-stage process was used to support the previous assessment results for the evaluation. The first stage, known as Eval-2, consisted of an expert group discussion (N: 6; male: 3; female: 3;

expertise: digital learning, digital collaboration, intergenerational collaboration, global innovation, startup entrepreneurship). The number of participants was based on the available members of the invited group to participate in the study. This was followed by a quantitative survey using the System Usability Scale (SUS) [2]. For the second stage, called Eval-3, a set of questions based on the meta-requirements of the first iteration was created to help guide the interview. These questions were used to find out what users liked and didn't like.

Eval-3 included ten participants, five of whom were German and five Indonesian. The group was divided into younger and older adults. The number of participants is relatively small, but a good number [15] for a qualitative study that provides an almost perfect balance between younger and older adults and different cultural backgrounds. The younger ones were under 35 years old, and the older ones were over 55 years old. For the German group, two older and three younger participants were interviewed (three women and two men). The Indonesian group consisted of two older and three younger individuals (two women and three men). The evaluation took about 60–80 min per person and could be conducted face-to-face or via videoconference. Participants first rated the meta-requirements and meta-design to determine which requirements and design features were most or least important. Participants then chose the order in which they thought the meta-requirements and meta-design should be ranked.

Moreover, ten questions from the SUS [2] were asked of participants in Eval-2 and Eval-3. SUS scores were calculated to identify which usability aspects can be improved, combined with observations made during the demonstration, to identify further which design features need to be refined and support reflection on proposed DPs. The following section will present the meta-artifact of the study.

3 Result

Through the DSR process, this study generates prescriptive knowledge in the form of artifacts [8, 10, 18, 19]. Artifacts can be software, frameworks, and guidelines [18] representing DPs for developing research-based technologies and improving the status quo. The artifacts of the study can be summarized in Fig. 2. Figure 2 shows the DPs derived from meta-requirements appraisals and demonstrated meta-designs. Figure 2 depicts three rows of blocks related to different concepts: meta-requirements as a set of goals, meta-design as interventions to address or achieve the meta-requirements [10, 16], and the proposed DPs based on iterative reflection. The top block is the meta-requirements block, the middle block is the meta-design block, and the bottom shows the DPs. The arrows connecting the blocks illustrate how the DPs are derived from the meta-requirements.

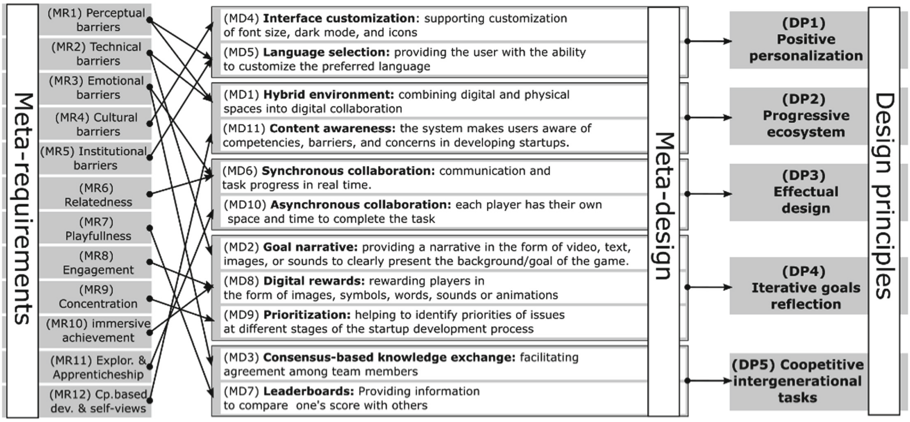

Fig. 2. Overview of design principles for IKS systems.

3.1 Elaboration on Meta-requirement

The meta-requirements derived from the design science research process are goals that encompass both the expectations of the different generations for the IKS system and the removal of barriers that (may) be encountered in IKS on specific topics (related to global startup innovation). The identified meta-requirements include twelve elements. The meta-requirements are higher-level abstractions of barrier dimensions that include perceptual barriers (MR1): different perceptions due to possible cognitive or physical limitations of particular generations [5, 7, 17]. The challenges of different styles and preferences in (digital) communication [11, 17] (Source: Eval-1: *"a different perspective on technology"*). (MR2) operational or technical challenges (Source: Eval-1: *"older people find it challenging to understand newer technology"*), (MR3) emotional barriers (MR4), cultural barriers (Source: Eval-1: *"cultural decisions are difficult"*), and (MR5) institutional barriers [1, 14, 17] (Source: Eval-3: *"it can be misunderstood as not to work by other colleges in the workplace if the knowledge exchange platform is not yet known and particularly conducted in a playful environment"*).

Meta-requirements also include positive expectations of well-being and the development of human potential as a goal of IKS [5, 6, 13, 17] These meta-requirements are as follows: (MR6) connectedness with others (MR7) and playfulness [5, 6, 13, 17] Motivation and engagement, and concentration (MR9). There is also a need for immersion (MR10) and achievement. Finally, (MR11) social interaction for apprenticeship and exploration (MR12), competency development, and self-assessment [3, 5, 7, 17, 20].

In Eval-1, although meta-requirements related to barriers on IKS had mean values of importance of 2.87–3.06, more than 90% of participants agreed with the presence of meta-requirements related to barriers. In addition, some comments on the comprehensiveness of barriers were as follows: "*I think most are included,*" "*all are listed above,*" "*there may be different approaches, but I think everything is included,*" and "*the list is comprehensive.*" Participants in Eval-2 and Eval-3 commented on a variety of goals and barriers, which provided insight into specific meta-requirements and how to fine-tune them. In Eval-2, expert panels agreed that several meta-requirements were critical, including the gamification component [4, 6, 13], technical and operational barriers, perceptual barriers, knowledge sharing and improvement, and social interaction [7, 14, 14, 17]. Some comments on specific meta-requirements are as follows: Technical-operational: "*can be overcome with a little practice,*" Knowledge sharing and improvement: "*I think this should be the main goal of collaboration in general,*" "*this requirement can help improve and enhance skills.*" In Eval-3, we discovered how important the game aspect is for knowledge sharing: "*it is crucial that people have fun with the system and experience positive emotions,*" and the usefulness of a consensus process for knowledge sharing: "*If you have a game, you can discuss it and learn from each other, which I think is beneficial.*" Unlike the experts on the panel, technical barriers seem to be an essential factor in Eval-3 for both generations: *"technical and operational barriers are critical if you do not know how to play,*" and *"understanding how to operate the system is critical."* The meta-requirements and associated evaluation criteria inform the importance of playfulness, positive emotions, and technical and operational barriers that should be prioritized for implementation.

3.2 Demonstration of Meta-design

The meta-design was developed by combining creativity with proposed interventions from the literature while thinking about meta-requirements. Creativity is essential in the design process that drives innovation to achieve meta-requirements [8, 10, 18]. Thus, design science research enables researchers to embrace creative risks and reflect knowledge through practical instantiation [9, 10, 19]. Based on the reflection on meta-requirements, the initial concept, which was based on previous studies [3–5, 7, 13], was to make a digital board game that could be played in the same room and allow for remote collaboration.

The board game was chosen because it can facilitate entertaining knowledge sharing, promotes playfulness (MR7), interaction, and social relationships (MR6, MR11), and more importantly, is accessible to a variety of age groups [3–5, 7, 13, 21]. A hybrid system was developed that incorporates digital and physical space into knowledge-sharing activities. A hybrid system was chosen to take advantage of physical objects in terms of control interaction from non-digital experiences, with the goal of overcoming technological and perceptual limitations and enabling immersive experiences [3, 7, 11]. Moreover, a hybrid system was used to combine the strengths of the tangible and intangible interface. The system provides a target narrative in the form of video, text, graphics, or audio to effectively communicate the story and purpose of the system to MR2 and MR1. Consensus-based knowledge sharing [12] is used to overcome perceptual and emotional barriers through customization of the user interface and language to overcome cultural, perceptual, and institutional barriers [4, 5, 17, 21].

The system incorporates game aspects such as leaderboards and digital incentives to further encourage playfulness and concentration [3–6, 13]. In addition, synchronous and asynchronous collaboration are used to facilitate communication and autonomous work between generations [14, 17]. The meta-design was demonstrated in two design cycles. A low-fidelity and a high-fidelity prototype demonstrate the meta-design to satisfy the meta-requirements. Figure 3 shows a low-fidelity prototype created by applying the meta-design to a paper prototype.

The content of the game relates to the competencies, obstacles, and challenges of entrepreneurship in digital startups to reflect the increase in topics related to entrepreneurial universities [12, 17, 20]. A collaboration narrative was developed in which each team had to collect one hundred points based on team members' consensus on the importance of a discussion topic related to competencies, obstacles, and challenges in specific innovation processes (four innovation processes: ideation, matching, design and development, and commercialization) [17]. This cumulative score is divided into four sections, each representing the four innovation activities. Consensus can be reached when the team draws an action card that presents three topics for discussion (each member gives a score, and after everyone is done scoring, the game displays all the answers and compares whether there is consensus or not). The more consensus is reached, the fewer action cards are removed, and the faster a team finishes the game, the fewer action cards determine the best team to finish the game.

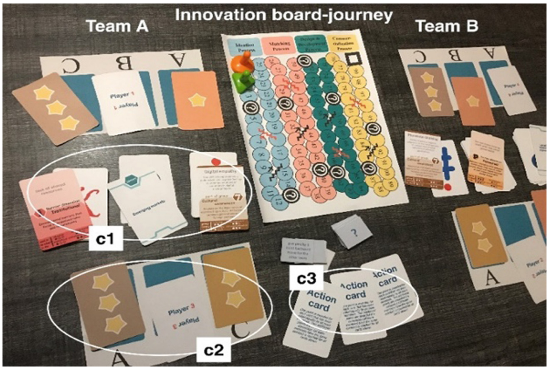

Fig. 3. Paper prototype meta-design for IKS system. C1: topic cards to achieve consensus; C2: rating cards by the player; C3: action-cards instruction for the player to pick a topic for discussion.

Based on an initial test of the paper prototype with three user experience experts, several improvements were suggested related to minimizing the process (or points to be collected) to complete the game (Fig. 3, Innovation Board Journey), providing a brief explanation of the topic of each discussion, and providing a visual overview of the points collected by the group. Overall, the consensus mechanism can stimulate discussion (on essential topics such as barriers, competencies, and competing interests of startups). The paper prototype was transformed into a web-based application as a high-fidelity prototype. The Meteorjs framework[1] was used to create a real-time application. A hybrid environment was created using webNFC[2]. Action cards (Fig. 3, C1) and rating cards (Fig. 3, C2) can be replaced with printed near field communication (NFC) cards. Figure 4 shows a general view of the high-fidelity prototype, with a description of meta-design written next to the picture. Each team has its own URL in the web app as a high-fidelity prototype. Each player registers their NFC card via a browser on a smartphone or can

[1] https://www.meteor.com/ (last access: 18.01.2022).
[2] https://w3c.github.io/web-nfc/ (last access: 18.01.2022).

play without an NFC card. Each player receives a short 3-min video that can be skipped. This video explains the purpose and process of the game. After logging in to the main dashboard, the consensus game scans the NFC action card. Communication is done via video chat through JITSI[3]. In the case of consensus, there is feedback on the accumulated points and animation in the form of a sound and fireworks celebrating the event. The number of action cards in each activity of the innovation process is played out at the end of the game as a reflection on which topics of discussion still have differences in perception and which the team has the same perception of an issue. A leaderboard shows the team's position and which team completed the game with the fewest action cards.

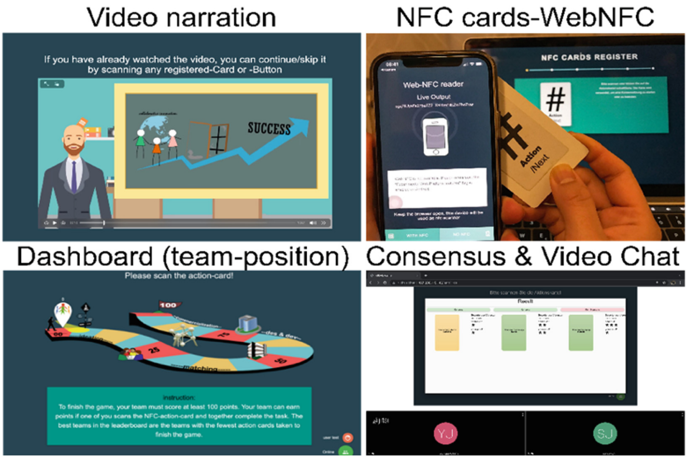

Fig. 4. Web-based prototype for an IKS system.

3.3 Reflection and Formalization of Proposed Design Principles

Based on the series of evaluation processes in design research, five DPs were identified as suggested system design interventions to support knowledge sharing in intergenerational contexts. Comments from study participants were also used to support the analysis. The suggested DPs, based on the overall process of DSR, are:

Positive Personalization: The IKS system should provide beyond customization and a more personal approach to software and hardware design to support positive emotions and wellbeing enhancement for a different generation. It personalizes the IKS system design to enhance positive emotions such as joy, exploration, empathy, and compassion, supporting embedded human potential and well-being. The meta-designs to fulfill this DP are MD1, MD4, MD5, and MD7. There is a need for personalization for digital safety, dialog, accessibility, language, visualization, appearance, and localization to support cultural differences between users and generations. Some of the competing

[3] https://jitsi.org/ (last access: 18.01.2022).

comments that go beyond customization and more about positive personalization are in Eval-2: "Customizing is a "nice to have featured," it does not impact the game's results*."* Furthermore, from Eval-3: *"I could not play this game in another language at all," "It is essential that people have fun with the game and have positive emotions. Otherwise, there is no motivation for future games."*

Progressive Ecosystem: The IKS systems should enable environmental adaptation gradually. The content, learning and adaptation process, challenges, and knowledge for exchange improved gradually for the quality and quantity of the content. Progressiveness aims Where the changes go unnoticed by the user until the content and process are finished or completely different. Progressive design in an intergenerational ecosystem can be provided by showing the position, time, or progress of the knowledge exchanged and the phase currently relevant to the knowledge exchange. Thus, the aim is to provide system feedback that is transparent, measurable, and (digitally) rewarding. Eval-2 contains some pertinent comments to the second DPs: *"…it is vital to understand the intention and phases of the game."* also due to time constrain in Eval-1:*" Time involved in learning about new strategies and redesigning courses."* Examples of meta-designs to fulfill this DP are MD1, MD5, MD8, and MD11.

Effectual System Design: The IKS systems should optimize the availability of technology resources, user experience, and user skills to interact with the system. Effectual interactive systems support interoperability and leverage current tools, available time, and space for both generations to engage in knowledge sharing. Examples of applied DPs for this system are MD3, MD6, and MD10. In meta-design, some features have also been applied to support the implementation of these DPs, such as web-based applications and WebNFC, which can be used on different devices without installing a native application. Some comments on these DPs are Eval-3: *"I think it will be difficult for older people to routinely use newer technologies," "..When something is so complicated, especially when you are older, it can really be a problem.."* and *"I think Synchronous collaboration is very important and the dial-in video option is also good."*

Iterative Goals Reflection: The IKS system should help both generations identify, evaluate, and re-evaluate common goals. The system should help manage shared goals that are transparent, iterative, and based on the common interests of both generations. The system should be developed based on reflections and goal narratives that are adaptable and clear through various forms of communication, such as text, images, and videos. Some meta-designs applied to support this DP are MD2, MD7, MD8, MD9, and MD11. Some comments that are relevant to this DP are Eval-2: *"The continues discussion supports the agreement between the team members," "the game was really fun and a new approach consensus about competencies, barriers and other aspects,"* and from the Eval-3: *"I think it is more important to find a consensus with your team to learn about each other…"*.

Coopetitive Intergenerational Tasks: The IKS system should engage both generations with simultaneous collaborative and competitive tasks. Developing design strategies that combine collaboration and competition in a playful environment can promote knowledge sharing. Game elements such as earning points and the leaderboard are two examples that can be used simultaneously to provide coopetitive activities for both generations. Some comments supporting the need for this DP come from Eval-3: *"It was fun to play together, but it was also motivating to do well because you can compare your results to the other teams," "Motivation to finish well/fast because there is a leaderboard, so you seriously want to make it to the end," "It is super handy to see where you agree. That also promotes the whole idea of the game"*. Some applied mate-designs for these DPs are MD3, MD7, MD8, and MD11.

While the SUS score for the web-based application with 16 participants from Eval-2 and Eval-3 was still not optimal at 46.7 (SUS-Eval-2 = 60.0; SUS-Eval-3 = 38.8), the goal of the apparent prototype in this study was to demonstrate the applicability of the DPs through meta-design and reflect user preferences to refine and gain a better understanding of the DPs [8–10, 19]. According to observations made during Eval-2 and Eval-3, one of the main problems was the implementation of webNFC for hybrid environments, where users spent most of their time trying to get the NFC card to work through the web browser. The complexity of setting and activating the webNFC function in the browser and the inconsistency of the content was the main technical challenges. Users can use the system without webNFC, but the inconsistent visual design instructions and clear instructions on how knowledge sharing works are also problematic. Overall, the initial high-fidelity prototype still has room for improvement, particularly concerning the SBS questions about usability (mean = 2.4 out of 5, the higher the better), instructions, i.e., whether users need help using the system (mean = 3.6 out of 5, the lower the better), and whether they need to learn a lot before they can get started with the system (mean = 3.3 out of 5, the lower the better). Therefore, basic usability features such as precise tasks or goals and ease of use are always important when designing IKS systems.

4 Discussion

In this study, five DPs were identified as salient design-oriented knowledge contributions in terms of theoretical contributions. These DPs were derived from meta-requirements and meta-design. Unlike previous studies [13, 14], this study diversified the content of the IKS system in startup development and context for IKS, which could help practitioners design IKS systems that focus on younger and older adults. Consistent with previous research [3, 5, 13], gamification strategies positively influence both generations. Compared to previous studies, this study adds to the system requirements for IKS in startup development [1, 13, 20, 21], which can be adopted in further studies on skill development in academic and entrepreneurial settings.

In general, the results of the mixed-methods evaluation in DSR show that the identified meta-artifact is a promising approach to help IKS understand startup development processes. Based on different contexts and design goals, some DPs should be prioritized for further study. There is room for improvement in meta-design, narrative content of questions, and selection of a more user-friendly hybrid technology. We demonstrated the meta-design as part of the DSR artifact for practical implementation. We evaluated the implementation of webNFC as a potential tool that can facilitate a hybrid environment for IKS. The high-fidelity prototype demonstrates the applicability of the proposed DPs.

On the one hand, the implementation of the meta-design serves to validate the relevance of the meta-design as a practical intervention of the DPs. On the other hand, it aims at a reflection process to better understand the relevance of the DPs to IKS. The use of webNFC also allows the user to interact directly with the NFC card through the web browser without installing a dedicated app (other technologies that could be used for hybrid environments in the future include web-based augmented reality). As far as we know, this study is one of the first studies to report on the use of webNFC.

Overall, some meta-design improvements are still needed to demonstrate the proposed DPs better. However, some features and analyses can provide a solid foundation for the further development of IKS systems. This research developed a more abstract level of DP capable of covering all meta-requirements and meta-design. Qualitative content analyses of experts, user preferences, and SUS also reflect the applicability and relevance of meta-requirements to the study context. The results of this study contribute to the provision of prescriptive knowledge based on problem-oriented research [19]. Implementing a hybrid environment using WebNFC leads to the application of new solution(s) to new problems [8, 9]. The study's domain-specific knowledge gained and demonstrated was shared with the scientific community, startup entrepreneurs, and students. As DSR emphasizes, effective research should consider applicable design [8–10, 19]. This study demonstrated that the DVs were appropriate for the study setting. The iterative evaluation process led to a deeper understanding of the IKS system design. To sum up, DSR was applied in this study to propose five DPs for the IKS system through a serial evaluation process. The DPs were fine-tuned based on the meta-requirements and meta-design.

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