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Development of a Method for the Engineering of Digital Innovation Using Design Science Research

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Abstract: This paper outlines the path towards a method focusing on a process model for the integrated engineering of Digital Innovation (DI) and Design Science Research (DSR). The use of the DSR methodology allows for achieving both scientific rigor and practical relevance, while integrating the concept of innovation strategies into the proposed method enables a conscious approach to classify different Information Systems (IS) artifacts, and provides a way to create, transfer, and generalize their design. The resulting approach allows for the systematic creation of innovative IS artifacts. On top of that, cumulative DSR knowledge can be systematically built up, facilitating description, comparability, and reuse of the artifacts. We evaluate this newly completed approach in a case study for an automated conversational call center interface leveraging the identification of the caller's age and gender for dialog optimization, based on machine learning models trained on the SpeechDat spoken-language resource database. Moreover, we validate innovation strategies by analyzing additional innovative projects.

Keywords: digital innovation engineering; information systems; process management; innovation management; design science research; method engineering; speech data analytics; machine learning

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1. Introduction

Ideas are important, they are the core fundaments of innovation, and that is why they matter to a great extent. Process models, on the other hand, are simplifications of business processes, which help transfer experiences and knowledge by summarizing complex matters; therefore, they are extremely useful not just for the generalization of universal solutions to certain problems, but also for deriving knowledge from and transferring it to a variety of complex cases and scenarios.

1.1. Motivation

While the origins of a technical invention and the subsequent innovation management or business modeling have been subject to the sciences of engineering and business administration, respectively, the issue of moving from invention to innovation remains a problem that has afflicted the scholarly and industrial research fields for decades. This particular difficulty is known as the "problem of translation" [1], and it is even more relevant in the field of Information Systems (IS), due to its fast-pacedness and ever-expanding variety. This issue often results in a long time spanning between the instantiation of an invention and the realization of its full potential (societal impact) as an innovative product, and the latter is what drives the most value into the business. Thus, it is important for research to introduce tools, in the form of constructs, models, or methods, to help innovative teams build innovation consistently and efficiently, by allowing them to gain scientific knowledge on the value and consistency of the intended innovation, throughout its development.

The contribution of this article to science is to introduce a complete method for the engineering of innovation based on IS that addresses this issue, by clearly guiding teams and stakeholders through a novel focus-oriented process. This process takes care of the two main phases of an innovation effort, both pre- and post-Kick-Off, and each phase defines stages and milestones that are gated for evaluation. We argue that having stage gates for evaluation allows us to pragmatically extract, accumulate and track the evolution in time of Design Knowledge [2], which may aid the same or different teams in successive innovation efforts, shortening the "translation" time from invention to innovation. Hence, our motivation for proposing DSR as a Digital Innovation strategy: it brings a scientific approach to innovation since it promotes tools that can result in practical implementations with scientific rigor, while also ensuring knowledge generalization and transfer.

As will be discussed later, the innovation that was built through this new method resulted in drastic financial savings for the notable telecommunication company in which the project was conducted. This achievement is in line with our motivation: R&D teams in the company certainly tried to solve the problem on earlier occasions, and inventions described in scientific publications had existed that could be potential solutions, but identifying the feasibility of implementation within the company (even just considering compatibility with preexisting systems or use cases) had arguably not been possible. This is where our method was meant to bring a contribution, not only by leading the research for an invention, but also bridging the gap to transform it into implemented innovation that would bring benefit.

As shown in [3], this kind of difficulty does not affect only technical innovation, as it is felt quite strongly also in the business domain. Based on the results of a large survey, the authors argue that innovating business strategies can be a slow process because it mostly depends on the experiences collected within the company. While there is a lot of research on business innovation, often the results of such research are seen as either too complex to implement in a real industrial scenario, or the business stakeholders in the company feel from the results that the research (and the experience of those who conducted it) is not mature enough. While [3] proposes several ideas to address this problem, we argue that our method could serve the interests of business stakeholders as well.

1.2. Design Science Research in Information Systems

Design Science Research has its roots in engineering and the sciences of the artificial as described by [4]. In this seminal work, Herbert A. Simon states that historically and traditionally, it has been the task of the natural science disciplines to teach about natural things: how they are and how they work. On the other hand, it has been the task of engineering disciplines to teach about artificial things: how to make artifacts that have desired properties and how to design them. Consequently, engineering is a science of the artificial that is, however, mainly taught and scientifically exploited through mathematics and natural sciences [4]. While the application of many useful exact scientific methodologies from natural sciences and mathematics is desirable, the decisive and inherent contributions in an engineering and innovation process have been overlooked, in scientific terms, without applying a design science approach, especially in complex innovation tasks. In other words, it is not easy to elicit scientific knowledge from an engineering process if such a process has not been designed/actuated using a DSR approach. Devising a design science approach toward the engineering of digital innovation helps to overcome limitations in knowledge transfer and adoption.

Benbasat and Zmud [5,6] have reflected on the limited empirical relevance of research in IS artifacts, which often yields little practical utility, i.e., compared to research in natural sciences. In an aggregation of answers to this deficit, Hevner, March, Park, and Ram [7] introduced guidelines for bringing the design of artifacts into the focus of science while ensuring scientific rigor and practical relevance at the same time.

The epistemological approach of design science differs from natural science in that it does not seek (only) truth, but rather utility. Our present work reflects on how to increase utility in design artifacts.

In order to contribute systematically to the body of knowledge of Information Systems the term "theory" has been explained by [8], which describes it as follows: "Theory is [...]

a generalized body of knowledge, with a set of connected statements expressing general relationships among constructs that refer to entities of different types, both real-world and theoretical". This view is based on [9] where it is stated that the purpose of a theory is "prediction and/or explanation of a phenomenon". The trustworthiness of theories can be assessed through certain criteria, which differ depending on the epistemological foundation [10]. Ref. [11] supports a broad view on a *design theory*, stating that an appropriate form of a design theory is a so-called utility theory that "makes an assertion that a particular type or class of technology [. . .] has [. . .] utility in solving or improving a problematic situation". Thus, the epistemological question is not primarily the search for truth as in natural sciences, but for utility. We want to add that the evaluation of the resulting artifact should, of course, show that utility proves also true, but the primary goal of design is the search for utility. The presented design work aims at the fulfillment of utility statements and to systematically contribute to the body of knowledge of IS by adding to IS Design Theories (ISDT).

This paper does not position both the empirical and design science approaches as a contradiction but aims at combining both. The goal is to make tacit knowledge during the design process explicit and comparable, thus refining the two approaches and bringing them to a new level of quality. Problems are not limited to research, but we also aim at solving practical problems, e.g., from industry: it remains unclear under which circumstances a design artifact can be used and which artifact yields the highest utility for a given problem, reducing acceptance. So, the DSR that is applied in this paper searches simultaneously for both scientific rigor and practical relevance, while creating IS artifacts of which the utility shall be empirically evaluated when useful, applying accepted methodologies from Information Systems as aggregated, e.g., in [7,12].

1.3. Engineering of Innovation

Sourcing innovation is a key task for future-oriented enterprises. There is evidence that those companies in which efficient ways to absorb innovation exist perform better than those which do not have dedicated approaches to do so. A seamless framework compatible with Information Systems would facilitate IS tool support and integration of IS artifacts into existing vertical industries during digitalization.

Corporate innovation can be provided by a stand-alone innovation center or by an intra-company research and development or innovation department. Innovation artifacts can be delivered by operational businesses parallelly to daily tasks as well. However, ref. [13] has shown that separate competence centers are often chosen as decoupled from operational business competence centers for reasons among which the most important are rooted in location, processes, and culture. Our approach focuses on organizational innovation units of this kind, even more so because innovation following the Open Innovation paradigm [14] is often coming from outside of the boundaries of business units.

This paper newly combines previous scientific work modules to propose a method for delivering innovative IS artifacts. The necessary features of this overarching method are:

- A process model for the engineering of innovation service systems by the combination of a practitioners' innovation process with a dedicated Design Science Research (DSR) process [15];
- A systematic design of innovative IS artifacts as method output and systematic contribution to DSR by identifying and applying distinct strategies for the reuse, creation, generalization, and transferability of these IS artifacts [16–19].

In this paper, we design a complete methodical approach from these features, present it together with an extended case study for evaluation, and describe various related uses for it. Ref. [20] has stated an "alarming paucity of follow-up research" building on existing Information Systems Design Theories. The presented approach allows for the systematic creation and reuse of cumulative DSR knowledge such as in a "factory" [21] while contributing to ISDTs, and thus overcomes this deficit.

2. Related Work

Innovation Management (without connection to DSR) is a well-analyzed scientific field starting as early as the 1930s [22]. Considerable research on innovation processes and their organizational management has been carried out in the related field of innovation management of which [14,23,24] give an overview and examples of project-oriented innovation processes. These findings are integrated into the innovation engineering method as state-of-the-art. However, none of them integrates the design of IS artifacts by scientific standards from the field of Information Systems. Ref. [13] acknowledges these shortcomings and provides a framework for strategic positioning of intracompany research organizations, but does not focus on methods or engineering to be applied by these. Ref. [25] has described scientifically an approach where multiple industry partners find consensus in a moderated academic platform about joint research projects that are then carried out in a consortium. However, the created artifacts are not linked inherently to the innovation processes of the respective companies.

Innovation processes have been implemented in corporate environments over past decades where especially stage-gate oriented idea-to-launch processes, as proposed by [23], are well established and continue to persist with modifications also for Digital Innovation [26,27].

DI has become an area that is researched in various application domains. One of the most focused areas is business management and researchers interested in this field are investigating general innovation processes in the organization. They also concentrate on novel innovative services and product research, fostering the organization's improvement. Business models, processes, and product innovations are also in focus when it comes to research in DI, so it has been further investigated how digital technologies can contribute to these areas for improving the capability and quality of innovation processes [28,29]. Ref. [30] takes into account the digitalization of the financial sector and assesses emerging business models and technologies. Ref. [31] explores supporting tools, namely data analytics, for innovation processes and states that it is a must for firms to utilize big data analytics to stay innovative. Ref. [32] develops a process model which eases analyzing the impact of potential digital innovations on existing business models and helps generate a new one (the authors also follow a DSR approach as research methodology). Furthermore, numerous researchers, including [33–38], have assessed the digital innovation capability of organizations by focusing on how organizations can produce innovations using digital resources, considering the organizational focus on businesses. Notable studies by [39–45] have proposed a framework for digital innovation management which emphasizes the need for management of actual process innovation using digital technologies. The works of [26,46] further elaborate on IT artifacts that can increasingly facilitate the implementation process of digital innovation frameworks.

Although these studies have been conducted with respect to DI, the vast majority of them do not include DSR concepts to synthesize their findings in terms of DI.

On the other hand, regarding the joint synergies of DSR and DI, recent studies have been cordially conducted to identify the commonalities and cooperation of these fields in recent years. DSR is generally accepted as a contributor to DI from a research and practical perspective since it is mainly concerned with the design and development of innovative artifacts. However, we can see that there is still a scarcity of research regarding DSR/DI synergies, and this limitation is also related to the general realization of how digital innovation may be supported by DSR. Reference [47] sees the possibility of inclusion of design science into digital innovation research; however, it also suggests some open-ended questions regarding whether to keep these research streams separate or joint. The authors of [48], Ref. [15] have combined these areas into a framework for getting the maximum benefit with practical and theoretical means, by conducting studies regarding the combination of DI and DSR concepts and building conceptualized frameworks. Ref. [48] in their paper state that "DSR in the IS field is, at its essence, about DI". They further introduce a matrix approach to DI based on DSR and consider innovation and entrepreneurship theories while building it. The paper defines a DI-DSR matrix-based approach that relies on the Knowledge Innovation Matrix, which in turn expands on the four strategies "Invention; Advancement; Exaptation; and Exploitation". The research here contributes to the DI–DSR relationship in a considerable way by delivering an understandable process model, allowing people with various entrepreneurial backgrounds to perceive the concept as well.

Digital Innovation in the context of IS comprises both the use of IS to support (or even trigger) innovation processes and also the design of IS as an outcome of the innovation process. For example, Ref. [26] have focused on the importance of Digital Technologies as a change agent for the discipline of Innovation Management. For DSR in the area of DI, this means that both the innovation method and process and also the innovation outcomes are IS artifacts. In a recent approach, Ref. [33] have structured the field of DI into six roles. The roles that are important for our approach are Role 1 (*Design of a DI Technical Artifact*), Role 2 (*Design of an Artifact for Deployment and Use of a DI Artifact*), Role 4 (*Development of Design Theories Surrounding a DI Artifact*), and Role 5 (*Use of a DI Artifact as a Creativity Tool in the DSR Solution Process*). As a whole, this paper primarily describes how the central method artifact is composed (Role 5). We devise a method with a process model for the DSR solution process and the resulting method artifact fulfills this role. However, the artifact itself produces an output of Roles 1 through 3, as we will also document during the case study and lessons learned for the example of an automatic speech recognition system.

Ref. [15] has introduced a combination of state-of-the-art, practice-driven stage-gate-innovation processes such as [23] with Design Science Research Processes. This combination provides an elegant way of combining practical relevance and scientific rigor as demanded, e.g., by [7] – provided that the degree of innovation allows for research. We will build on this work.

Information Systems is not the only field where design is relevant. The sciences of the artificial as described, e.g., in [4] have influenced science in a great number of seemingly different disciplines: from the already introduced engineering and Information Systems domains to social sciences, medicine, architecture, design thinking, industrial design, and many more. It might seem far-fetched to compare the design science research approach in this paper to the design approaches of these heterogeneous domains. However, specifically, Design Thinking Research [49] and Design Research stemming from—but not limited to—industrial design [50,51] offer some interesting parallelisms and also differences that are noteworthy for the discussion as they are often related to creativity in innovation, but this work has not been primarily created for Information Systems. A Unified Innovation Process Model for Design Thinking has been introduced by [52]. While our method—including the process model—covers the whole life cycle of an innovation project and also the systematic contribution to science, the Unified Innovation Process Model focuses specifically on the creative phases of the design of an artifact.

3. Methodology

As pointed out in the introduction, our work is rooted in Design Science Research (DSR) and Information Systems Design Theories (ISDT). Among the possible design theory types, more specifically, ISDTs are theories for design and action [8]. Based on this point of view, [53] has identified eight components that describe an ISDT: *Purpose and Scope*, *Constructs*, *Principles of Form and Function*, *Artifact Mutability*, *Testable Propositions*, *Justificatory Knowledge*, *Principles of Implementation*, and *Expository Instantiation*.

The central artifact of our work is a method and our scientific approach to constructing it is DSR, with some elements of Method Engineering (for the evaluation and tailoring in situationally defined contexts) as introduced by [54]: "the engineering discipline to design, construct and adapt methods, techniques, and tools for the development of information systems". The creation of the method artifact is complemented by the understanding of [55,56] that a method is a solution that exists and is composed of design activities that are executed by roles in a specific order, applying specific techniques, and producing design outcomes as results. A process model poses these design activities in a specific order.

Consequently, the process model is part of the method (importantly contributing to the constructs of the method besides the meta-model).

A particularity of this work is that to build our proposed method we relied on the same scientific constructs that we propose being part of it. We based our approach on the three stages of DSR, namely Problem Identification, Solution Design, and Evaluation as defined in [57]. For the first stage, the identification of the problem is expressed in the motivation for this work: the problem of transporting an innovation birthed from academic research into industry, to make innovation, is a sensitive issue, and it does not affect only IS engineering. For the solution design, we follow the Combine Design strategy described in [16]. This strategy specifies work that produces artifacts from the constructive combination of pre-existing scientific/technological artifacts. A concrete example illustrating the usage of such a strategy can be found in Section 4.2. Finally, the third stage, Evaluation, is discussed throughout Section 6. In summary, the evaluation of our method is performed in industrial and academic settings, both for the innovation that was through this work, and through the study of preexisting projects to evaluate the extraction of design knowledge.

The designed method fulfills all the seven guidelines for Design Science Research as formulated by [7].

4. Foundational Elements for the Proposed Method

This section shall provide a description of the artifacts (Figure 1) we used to build the proposed method, and answers to the search for features described by bullet points in the tasks from Section 1.3. In Section 4.1, we introduce the deployed innovation and Design Science Research processes (Sections 4.1.1 and 4.1.2, respectively) and in Section 4.1.3, we integrate these processes with synchronization points at *Gates*. The result is a process model expressed as a composition of the introduced innovation and design science research (DSR) processes, which we augment with the Integrated Innovation Strategies Framework described in Section 4.2.

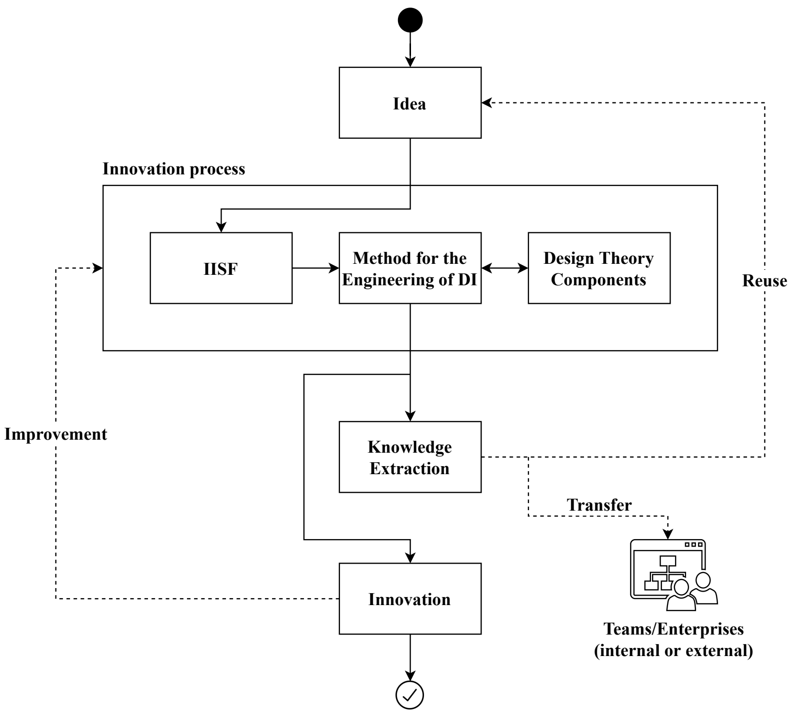

Figure 1. Solution overview: proposed aggregation of DSR artifacts for DI.

4.1. Integrated Innovation and Design Science Research Processes

The underlying idea for the integrated process model is a combination of an innovation process and a Design Science Research (DSR) process. In the lab setting that was described in [15], interviews were carried out with lab management and stakeholders. The group of interviewees and the setting is similar to the ones published in [58]. The main requirements were sorted out from these interviews and design decisions were taken accordingly. This showed that it is necessary that the seamless transfer of the results of the process is ensured by stakeholders that come from related business units (which are responsible for the transfer to production or "productization"). Consequently, the opinion of these stakeholders is necessary to be prominently integrated, which leads to requirement R1. It was considered crucial that all lab activities take place in the form of projects with defined starting and ending points to ensure controllability and transparent resource allocation (requirement R2). At the same time, the lab is realized as a university–industry collaboration, where it is necessary that scientific staff such as Ph.D. students can pursue their research while accompanying the innovation projects, which leads to the requirement R3. At the same time, the process should give room for agile elements to combine the need for control with the necessity to introduce agile elements, leading to requirement R4. Finally, the practical relevance of the resulting process should fulfill and document the achievement of commercial KPIs for productization in business units, to secure the market impact inherent to innovations. This results in requirement R5. The summary of these main requirements is exhibited in Table 1.

Table 1. Main Requirements for the Integrated Method.

R1	Rigid synchronization points with stakeholders
R2	All activities take place in the form of projects
R3	Pursuit of research accompanying innovation projects (e.g., PhD students)
R4	Support of agile elements
R5	Fulfill commercial KPIs jointly with business units

4.1.1. Practice-Driven Innovation Process

Evidence of success has been documented specifically when innovation in enterprises can be brought forward in a project format, i.e., as innovation projects, following a dedicated idea-to-launch process with roles and responsibilities that systematically involve key experts in the domain and decision makers in the firm at so-called "gates" [23]. We use the initial dimensioning in the context of a setting at a telecommunication company's innovation center [59] with an experience of more than 50 innovation projects previously piped through at the time of initiating the method. The innovation process is intended to act as an innovation proposal funnel as described, e.g., by [14]: the gates act as filters, sorting out ideas that are not considered to be viable to make it to production, whereas the stages serve as phases of refinement and detailing of the proposal, utilizing feedback from the stakeholder groups present at the gates. The underlying concept is "to fail often and to fail early" at little cost, whereas admission to further progress of the proposal at the gates is carried out with a higher probability of success, which makes it so that higher preparation costs during the higher stages are better justifiable. The gates are also used for filtering and transformation based on stakeholder input as required by R1. The stakeholders are generalized to the role of decision makers further on.

In the used version there are three gates after which the innovation project is formally kicked off. Then, the project is executed and if the milestones are met as planned it will finish at a fourth gate after which the created artifacts are handed over for productization by product units acting on the market, or to technology and IT organizations outside of the innovation lab. It is common to start a joint transfer project carrying out the necessary transition from a prototype to a full product. Generalized and aggregated remarks about the implementation of an innovation funnel can be found, e.g., in [24,60]. The roles necessary for the innovation research process are *innovation project manager*, *expert* (for passable simplicity the expert will also be the product manager with domain-specific expertise whom the artifact is handed over to), and *decision maker*. Thus, the innovation process ensures practical relevance to a high degree, fulfilling also R5. However, it does not enforce scientific rigor and the systematic creation of design knowledge and contribution to design theories. Hence, R3 is not yet fulfilled. This will be overcome by means of an embedded DSR process.

4.1.2. Design Science Research (DSR) Process

In the past, a number of DSR processes were introduced, among which [61] can be arguably named as one of the most widely used ones. Ref. [57] has compared five processes including [61] and mapped them into the common three stages *Problem Identification*, *Solution Design*, and *Evaluation*. Furthermore, the authors in Ref. [57] have introduced their own process as a sixth one, based on insights from the presented processes. These processes have in common that they are stage-gate oriented as well, with the notable features of separate definition, design, and evaluation phases. Ref. [57] foresees iterative cycles of these three phases with subsequent refinements of the design, meaning that if a process is defined so that it can be mapped unto these three phases (basically through DSR), then it can also be tailored. The necessary additional role for the DSR process is the design science researcher. Applying the DSR process in the combined model fulfills requirement R3.

For our initial method design, we propose following the DSR process laid out in [57], which we consider most suitable for synchronization with the practice-driven innovation process because the three phases and the transitions between them are carved out explicitly. The phases and their transitions are depicted in Figure 2. The dashed lines indicate possible transitions for iterations that must be chosen situationally, according to the specific design that is pursued. We foresee cycles of three phases with subsequent iterative refinements of the design. This is consistent with the statement that design science is inherently a search problem [7].

In the first phase of the research process, the problem is identified. It must be ensured that the problem has (or might be of) practical relevance once solved. Criteria for problem relevance are reviewed, e.g., in [6], and will be ensured by a combination with the practice-driven innovation process from the previous section. The research question may arise from a current business problem or opportunities offered by new technology. The phase is divided into the following steps: *identify problem*, *literature research*, *expert interviews*, and *pre-evaluate relevance*. It specifies a research question and verifies its practical relevance. As a result of this phase, an IS research question is defined and its relevance is validated by experts. The state of the art in research in the observed area is analyzed. Thus, this phase offers a solid and important foundation for the following research process.

In the second phase, the solution is designed. It is divided into the steps *artifact design* and *supporting literature research*. After identifying a problem and pre-evaluating its relevance, a solution has to be developed in the form of an artifact. Within this phase, research rigor must be ensured by using all the available related work. The artifact design is a creative engineering process and not much guidance is provided in the literature. On the one hand, there exist general creativity methods as described in the Introduction, which offer little structure to match the complexity of a typical engineering problem in IS. These methods pursue goals that are often contradictory to a controlled process that is necessary for such tasks [49], and where contribution to science can usually only be determined in a rigorous evaluation of the created artifacts (as a phenomenon in the following phase). In this paper, we argue for the documentation of scientific progress both in the design and the evaluation of the artifacts.

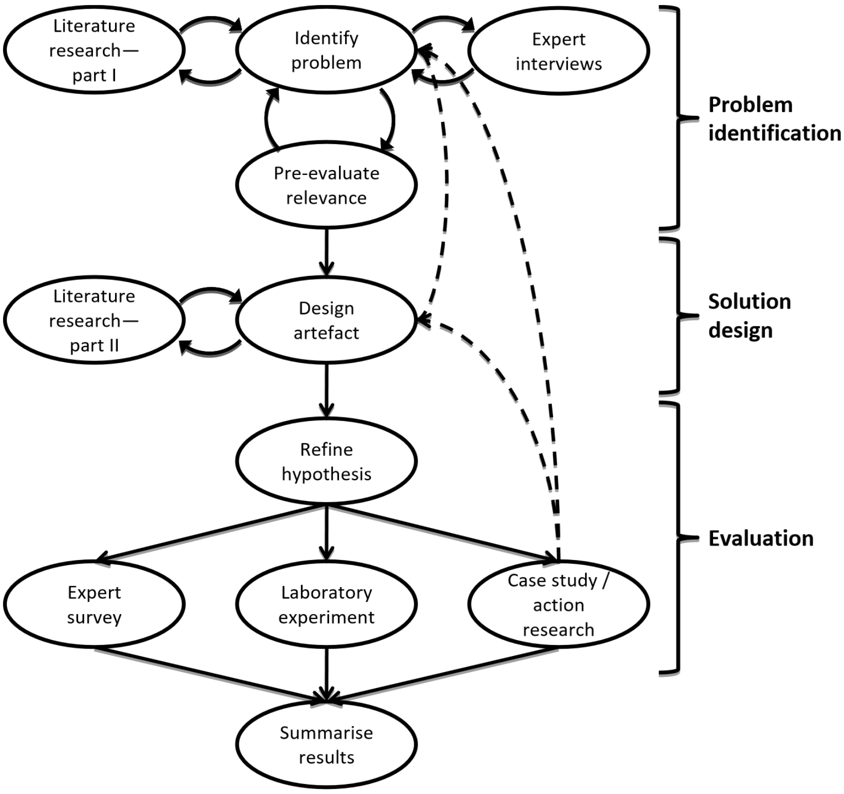

Figure 2. Design Science Research Process from [57].

Once the solution reaches a sufficiently stable state, its evaluation can be started (third phase). It is possible to iterate back to "design artifact" or even "identify problem" stages, if necessary for further iterations. Evaluation is to be achieved by the means of a case study or action research, by arranging a broad expert survey, laboratory experiments, simulations, or other methods described, e.g., by [12]. The expert interaction of the innovation process in Section 4.1.1 again provides a favorable situation for the evaluation of the artifact. Although we emphasize the design phase, we believe that empirical evaluations are best suited for ex-post [62] evaluation and to generate accurate insight. Assumptions should be verified empirically and presented to the observed practitioner to keep in touch with current developments. This is empirical grounding according to the classification from [63].

4.1.3. Initial Method Design: Combination into an Integrated Process Model

Because of the comparable modeling, these stage-gate oriented processes can be easily integrated into the presented *innovation stage-gate process*. Although the DSR process goes through iterations more frequently, the gates act as synchronization points as depicted in Table 2. For researchers, an immediate advantage of this integration is that the experts and decision makers at every gate can be sourced for the expert interviews to ensure practical relevance and the testing of hypotheses. Agile elements can be integrated into the process between the gates (R4). Thus, the integrated process fulfills all main requirements from Table 1.

Table 2. The Synchronization Points between Innovation Process and Design Science Research (DSR) Process.

Synchronization Point	Role in Innovation Process	Role in Design Science Research Process
Gate 1	Stable First innovation idea, filter for "go" vs. "no go" decision	Stable Research problem formulation, Stable utility statement
Gate 2	Project scheme available, filter for "go" vs. "no go" decision	Stable Innovation strategy, design outputs named
Gate 3	Full project plan with business case available, filter for "go" vs. "no go" decision, project kick-off after passing Gate 3	Preliminary evaluation of research hypotheses, practical relevance ensured in alignment with innovation process
Milestone	Project fulfillment is actualized and compared to the project plan	Progressing status of individual design components presented, pre-evaluated, and commented
Gate 4	Fully functional prototype ready, handover project kicked off	Suggestion regarding behavior in a summary of research/publication

The character of the stage-gate process largely depends on the selection criteria and on the staffing of the decision makers at the gates ("who is the gatekeeper"). An interesting insight is shared by [52] with this discussion: the established gates carry the danger of early censorship of ideas by the decision makers. While it is noteworthy not to censor an idea before a phase of experimentation and execution, the authors also stress the necessity of censorship in some cases. Examples are given, of how only wise decision makers can gauge the right balance between giving room for experimentation or censorship of an idea. They cite prominent examples where either way (censorship or support) can be beneficial to innovation when applied wisely.

Based on these parameters, the stage-gate process may have either a filtering function or a coaching and feedback purpose.

4.2. Integrated Innovation Strategies Framework

We generate cumulative knowledge for the body of knowledge of Information Systems by incrementally adding to Information Systems Design Theories in the sense of [8].

It is the goal of the method to contribute systematically to the creation of design knowledge that goes beyond individual solutions to individual problems. The authors in [64] reflect that generalizability of a theory means that the theory itself can be confirmed in a setting different from the one where it was empirically tested. Other concepts include transferability [10], which was introduced in reflections about natural sciences and contrasts with the concept of generalizability. This paper follows up on the reflections of [16] about the generalizability and transferability of design science knowledge, identifying strategies for the creation and reuse of design knowledge and their specific roles in design research. Here, generalizability suggests diverse levels of knowledge, and transferability is a lateral movement between settings.

The value of these strategies lies in consciously documenting, communicating, and educating about scientific design, as well as in evaluating critical parts in a new or unfamiliar design. They make the creative steps of the designer explicit and document them in a common structure. Moreover, they help researchers in identifying and performing design science and engineering research projects as they offer criteria to categorize their design. These strategies help to make the reuse of design knowledge more efficient. The "producer" of knowledge has a reference against which the work can be described, and the "consumer" of knowledge can describe the information needed in a more standardized way. These strategies enhance transparency and maturity of the design process and its subsequent communication—be it for scientific publications, project documentation, strategic reflection, or educational purposes.

Furthermore, [18] proposes a novel integrative tool – the Knowledge Innovation Matrix (KIM) for strategic innovation management by considering diverse stakeholders in the industry, government, and academia. KIM defines innovation in four categories, namely (1) Invention, (2) Improvement/Advancement [48], (3) Exaptation, and (4) Exploitation. This way, it intends to assist researchers and industry professionals in categorizing innovations and setting potential expectations about appropriate value and results, depending on each category. The authors further explain value propositions related to stakeholders, as this guide is intended to be understandable and have a common language for all the related parties.

- The *Invention* quadrant includes innovations which are "new-to-the-world". Here the problem, and especially the knowledge required to solve it, have not been identified before.
- The *Advancement* quadrant encompasses innovations that are achieved by implementing superior (to the state-of-the-art) solutions to an existing problem.
- The *Exaptation* quadrant includes innovations by which existing solutions for a problem (in a different context) are used for a completely different purpose.
- The *Exploitation* quadrant includes innovations where known solutions are applied to known problems, so the setting is not "new-to-the-world", but rather "new-to-us".

Based on these highlighted works [16,18,48], in ref. [19] we developed the Integrated Innovation Strategies Framework (IISF) to further encompass innovation categories to understand the creation, transfer, and generalization of digital innovation ideas. We add this work on top of the process model to be utilized in the ideation stage. We believe that this will be a conscious tool for the reuse and transfer of Design Knowledge [2].

In the *Invention* quadrant, the "*Explore new problem*" strategy is identified, where the focus is on finding breakthrough innovative solutions to unfamiliar problems. The strategies "*Improve*" and "*Synthesize*" fall under the *Advancement* quadrant, as in both strategies the problem is known, and the new solution is designed specifically for that problem. The *Exaptation* quadrant includes the "*Validate*", "*Apply out of scope*", and "*Derive from*" strategies since they focus on those innovations where solutions are known, but they can be utilized on diverse causes. Finally, the *Exploitation* quadrant includes the "*Generalize*", "*Combine*", and "*Increase scope*" strategies, by which both solutions and problems are known, and they can come from different contexts. For instance, in the case of *Combine*, two different solutions can be combined to solve a more generic problem.

The main ideas of the two frameworks are the same; however, one framework explains the other and we combine both to address the known scope of the problem in terms of design science and innovation. Basically, it is interesting to note that the *Combine* strategy has been used to achieve an integrated framework. As part of the method we introduce here, the IISF plays an important role: after the ideation process, the main quadrant shall be identified first, and afterward, the right innovation strategies could be determined. This allows us to figure out what the innovation process aims to achieve and what its contribution could be. Furthermore, this categorization is also helpful in determining the Design Knowledge [2] that the teams/stakeholders can utilize and/or generate while going through the innovation process. Defining the scope of the design helps focus the efforts, and identify the risks/benefits of approaches, right from the initial planning stages. Thus, the IISF can provide a decisive contribution when trying to solve the issue of transforming ideas into innovation.

5. Result: A Method for the Engineering of Digital Innovation

5.1. Scientific Artifact "Method"

A method consists of design activities that are executed by roles in a certain order using specific techniques, and deliver a defined design output. Process models are part of a method and they order the design activities and their output in a dedicated sequence. Situational methods are an expansion of the concept of method artifacts. Ref. [56] introduced an enhanced meta-model for situational method engineering on the basis of [55], who had first identified the five constituent elements of a method: design activities, design results, roles, techniques, and information model. Gutzwiller's meta-model [55] has been expanded with the elements *context type* and *project type* that define a development *situation* which influences the applicability of "*method fragments*" [56]. Additionally, the framework proposed by [65] suggests ways in which method fragments can be easily adopted by researchers and development teams after a situational context has been properly identified.

In order to perform a method-specific specialization of design theory structures as proposed by [53], Ref. [66] considered each of the eight components *Purpose and Scope*, *Constructs*, *Principles of Form and Function*, *Artifact Mutability*, *Testable Propositions*, *Justificatory Knowledge*, *Principles of Implementation*, and *Expository Instantiation* in turn and discussed what constitutes a specialization specific to methods. Based on individual pre-understanding regarding design theories and methods, they identified what would qualify as a method-specific specialization of the theory elements by [53]. They then discussed how each element supports the criteria for theory evaluation, including criteria derived from method-specific specializations. Finally, they illustrated good specifications for each component by citing examples fulfilling these evaluation criteria and provided guidelines on how to represent methods as Information Systems Design Theories (ISDT) and how to evaluate a given method description, whether it fulfills the requirements of being a method ISDT according to the structure of [53]. We use this structure to describe our to-be-constructed method for the engineering of digital innovation.

5.2. Method Description

We now have all the necessary components for constructing the method in place as required in Section 1. The formalization of the combined innovation and research process is exhibited in Figure 3, where the dark-shaded phases are under the focus of the DSR process during each stage.

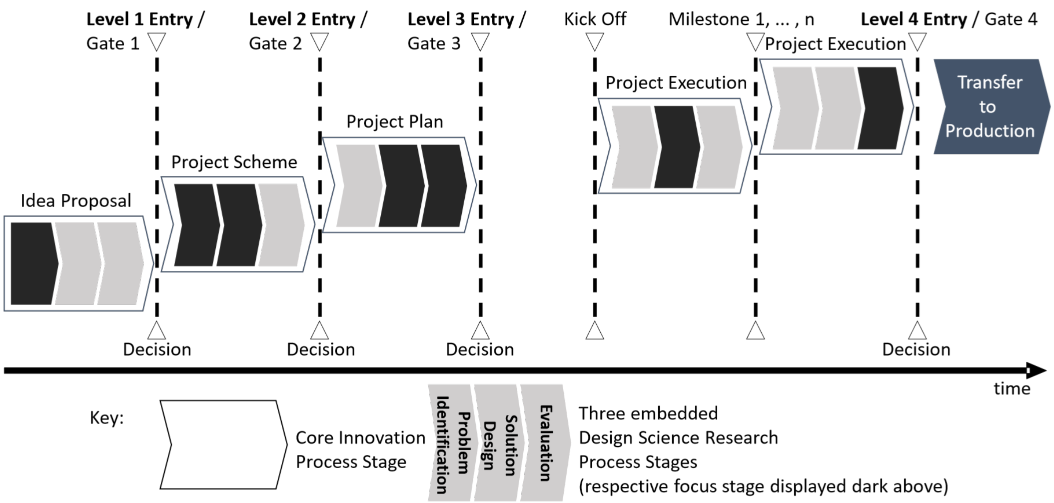

Figure 3. Combined Innovation and Research Process

As Design is considered a search process, usually several iterations are necessary involving optionally all other phases in a less pronounced way.

In order to add knowledge to method design theories, we present the designed method guided by the components of design theories as proposed by [53] with the method-specific refinements as proposed by [66] and answers to the related evaluation criteria formulated there.

The output of this method is an artifact. Ref. [67] discusses four artifact types: *constructs, models, methods, and instantiations*, which were stated, however, without a reference to the grounding and quality of this classification. Further, for our approach, a more detailed granularity of artifacts is targeted. Ref. [68] has carried out an empirical literature review on 102 papers from DESRIST 2006–2009 and 4 papers from the international journal MIS Quarterly from the special issue vol. 32 (4) on design science and have clustered the described IS design artifacts into eight distinct types. The identified artifact types are *system design, method, language/notation, algorithm, guideline, requirements, pattern, and metric*. This list of artifacts is considered to be the output of our method. It is important to note that in this schema list "*instantiation*" and "*implementations*" are not listed. This is due to the understanding that all these artifact types have instantiations as validation of the more general artifact type. In the presented concept *implementation* is considered an instantiation of *system design*. That means that the most important output of our method for digital innovation engineering, i.e., a fully functional prototype, is also presented here as an instantiation of the artifact type *system design*.

6. Evaluation by a Case Study: Tailored Call Center Process

We will demonstrate the applicability of the approach in a case study. The evaluation is structured as proposed by [69] in the following paragraphs: Situation Faced, Action Taken, Results Achieved, and Lessons Learned.

Situation Faced

Innovation Process. An incumbent telecommunications company faced the problem of having excessive operational costs in the call center when compared to the competition. The decision was taken to set up an innovation project to introduce cost savings by automating part of the work of call center agents by means of Automatic Speech Recognition (ASR), resulting in an Interactive Voice Response system (IVR) and chatbot. The company used commercial off-the-shelf modules but also had the ability to differentiate itself from the competition by developing new own modules. A project team was set up, led by the innovation process manager of the company's internal innovation lab and business stakeholders. Stakeholders were experts from the unit that runs the call centers and the business owners within this company. The innovation process manager from the innovation lab had been continuously in contact with the stakeholders. Tools for interaction and creativity stem from Design Thinking and (industrial product) Design Research. Part of the core team were also Research Engineers, Information System Developers, and End Customers (i.e., lead users of the call centers). During the workshop, it turned out that a major pain for the stakeholders was the high costs per call due to the tedious manual interaction of live call center agents. As a matter of fact, the automation of manual process steps would have yielded a high benefit (a business case for efficiency). Likewise, new value-added services for target groups (gender and age-dependent) would have offered additional marketing and business opportunities at the call center customer front end.

Research Process. Recognition of non-verbal features such as age and gender beyond speech-to-text from a speech signal has been a topic that had only recently emerged at the time of the project, with no commercial-of-the-shelf recognizers available. It was a goal of this project to perform a classification of such non-verbal features in parallel to recognizers that convert speech to text in a call center, to make skill-based routing and market analyses in call centers possible. These features were not commercially available.

Action Taken

Innovation Process. According to the process description proposed in [15] a Gate 1 proposal was put together with stakeholders. At this phase, Design Thinking workshops based on iterative user-centric and participatory design with a multi-disciplinary team were carried out. Researchers of ASR knew about new research on non-verbal speech recognition. Thus, the practical relevance of the project was ensured when passing the four gates. In this context emerged the idea to tailor the IVR call process flow according to the age and gender of the caller. This would enable the call center agents to save time by pre-classifying the caller and automating part of the dialog script. This would then result in saving effort, thus reducing the cost per call as human interaction is the most cost-intensive.

Subsequently, a Gate 2 proposal was prepared by submitting the required documentation, the Project Scheme. For the Gate 3 proposal, a full project plan (work packages, Gantt chart, effort calculation) and a Business Case were finalized. After Gate 3 the project was successfully carried out and a prototype was presented. At Gate 4, decisions were taken by the stakeholders after evaluating the prototype along with the corresponding artifacts, and the decision was made to transfer the prototype to production, which required further project work with respect to the scalability, reliability, and resilience of the system. The project was finally put into production and met all of the planned goals, including higher efficiency in the call center.

Research Process. Before the Gate 1 presentation, the researchers identified the research design problem of age and gender recognition in the domain of speech recognition. Knowledge of the literature yielded several approaches, but none of them were ready for immediate use on the problem. The second research question was how to best tailor the IVR dialog, given knowledge of age and gender, in order to achieve the desired goals. The practical relevance of the project was formally approved by the Gate 1 meeting.

Thus, the research design strategy followed two steps. First, the team contributed to science with the design and comparison of four different approaches for age and gender recognition and the subsequent comparative empirical evaluation in a laboratory experiment [70] on the same speech database "SpeechDat" [71]. SpeechDat is a spoken language resources database of labeled audio files of multilingual telephone speech. It contains phonetically balanced sentences uttered by speakers of different ages and genders. The recognition task was to differentiate seven groups by age and gender: children of 13 years and younger, young people between 14 and 19 years (male/female), adults between 20 and 64 years (male/female), and seniors.

The best-performing method was an adapted design based on an existing Parallel Phone Recognizer (PPR) [72]. For easy tasks, its precision is comparable to human performance [70]. PPR was originally developed to recognize languages (such as English, German, Hungarian, etc.), not gender and age. For the adoption of the task, seven different phone models were trained using exclusively those parts of the audio files that had been labeled as belonging to one of the seven distinct speaker groups (differing by age and gender as described above), respectively. Instead of using PPR with different phone models for languages, the researchers adopted its principles for phone models of the seven different age and gender groups. According to the classification from Figure 4 the design adhered to the strategy *Increase Scope* as the scope of PPR was increased from language identification by recognition of the age and gender of the speakers. For more details of the recognizer, please refer to System A in [70].

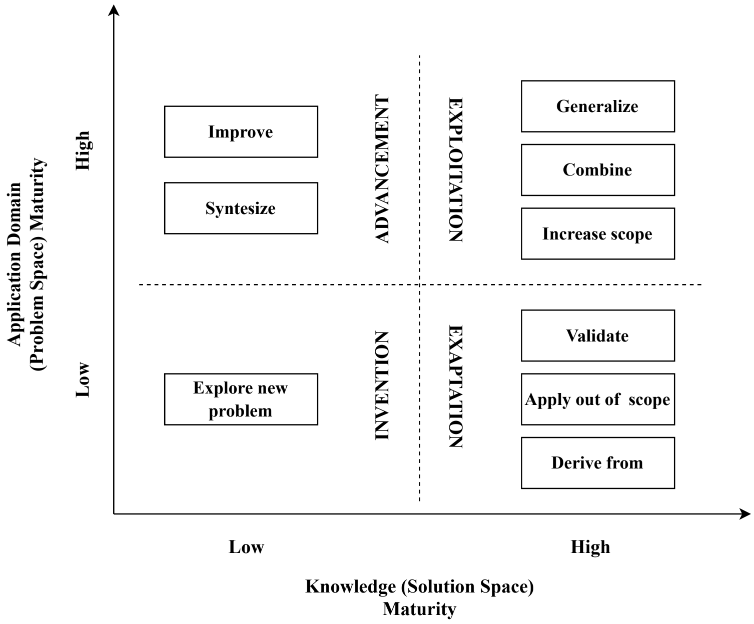

Figure 4. The Integrated Innovation Strategies Framework [19].

In the second design step, the team combined commercially available recognizers that are used for speech-to-text tasks with our own PPR classifier for non-verbal speech used in parallel on the same speech signal. By the classification exhibited in Figure 4 the chosen innovation strategy is *Combine* because the innovation is based on a novel combination of existing designs.

For the presentation held at Gate 2, the design strategy was stable according to Table 3.

Table 3. Research Design for Case Study, applying the IISF strategies from Figure 4.

Design Contributions	Applied Innovation Strategy	Description of Implementation
Design Step 1: Create innovative module for recognition of age and gender	Exploitation: Increase Scope	Use PPR recognizers from Language ID scope and increase their scope to age and gender recognition task.
Design Step 2: Create new tailored IVR dialog	Exploitation: Combine	Use existing COTS recognizers/IVR tools and combine them with a new module for age and gender recognition

The corresponding abstract templates form [73] are employed accordingly, as visible in Table 4:

Table 4. Adjusted abstracts for the chosen IISF Strategies (Figure 4).

Applied Innovation Strategy	Adopted Abstract of Design Strategy
Exploitation: Increase Scope	In the field of Automatic Speech Recognition, the PPR (Parallel Phoneme Recognizer) is meant to be used to recognize languages for language identification in ASR systems. In this paper, we propose extensions to the design so it can also be used for age and gender identification.
Exploitation: Combine	In the field of Interactive Voice Response Systems, the problems of Speech-to-Text and Age and Gender Recognition often occur together. The first problem can be solved by Commercial-of-the-Shelf recognizers, while the second problem by the increased scope of a PPR. We analyzed both designs and propose a combined design with an enlarged scope that addresses both problems at the same time.

For the Gate 3 presentation, initial scientific experiments were built, as well as a first sketch of the evaluation by empirical recognition rates, user interviews, and process simulation. Researchers also participated in preparing Gate 4 as their innovative artifact was built into a live system and they needed to evaluate it also scientifically. This evaluation is published in [74].

Refs. [70,74] answer the question of how to build a system, and are as a matter of fact eligible to describe it as an ISDT for design and action [8]. Many Engineering publications fulfill this criterion, which is not surprising as engineering is also classified as a science of the artificial by [4].

Results Achieved

The empirical evaluation by a laboratory experiment shows improvements in mean opinion scores of live users and average ratings of users when compared to a conventional routing [74]. Yearly efficiency gains could be quantified at 42 Million Euros.

Although the new artifact was originally not built using a "formal" DSR process, it was possible to align all its contributions in detail to the phases *Problem Identification*, *Solution Design*, and *Evaluation*, as well as our research process from Section 4.1.2. In fact, all the activities of the researchers could be mapped to the phases of the DSR process according to its embedding in Figure 2. The process and the results fulfill all seven guidelines of [7]: *Design as an Artifact*: method artifact; *Problem relevance*: ensured during the Gate process; *Design Evaluation*: both empirical and qualitative in a case study; *Research contributions*: contribution to IS Design Theories (ISDTs) as in Table 5, following the innovation strategies *Increase Scope* and *Combine*; *Research Rigor*: demonstrated by accepted peer-reviewed scientific publications; *Design as a Search Process*: search iteration during Gate-process, four age and gender solutions were identified and tested; *Communication of Research*: presentation to stakeholders, publication of results.

Table 5. Contribution to Method Design Theories.

Design Theory Components and Method-specific Elements
Purpose and scope
• Project type: situational method to carry out innovation projects that create novel IS artifacts and their prototypical implementation. The projects shall ensure novelty, and economic impact and systematically contribute cumulatively to the design science body of knowledge. The necessity is to cover Requirements R1 through R5 from Table 1. • Project context: innovation center that delivers innovation for transfer to enterprises with an existing business. • Lifecycle coverage: from sourcing of idea, from the start of a project to the delivery of a prototype and handover for further productization by the absorbing entity. • Role coverage: *innovation project manager, design science researcher, expert, decision maker*. • Activity coverage: *Project Identification, Solution Design, Evaluation, Idea Proposal, Project Scheme, Project Plan, Project Execution, Project Transfer* as depicted in Figure 3.
Constructs
• Enhanced meta-model for situational method engineering as described in [56]. • Stage-gate-oriented DSR process model as, e.g., in [61] or [57]. • Stage-gate-oriented idea-to-launch process model as, e.g., in [23]. • Combined process model as in Figure 3. • Test: Is the new business case viable? Does the utility statement fulfill the criteria of the gate process and contribute to DSR? Further Gate-criteria according to context type can be introduced and checked.
Principles of form and function
• As described in Sections 4 and 5. Define project type and context type. Perform situational adjustments depending on project type. Carry out design activities in the order defined by the process model in Figure 3. • The design activity “solution design” shall apply one of the nine strategies exposed in Figure 4.
Artifact mutability
• Situational tailoring for project types. • Number of gates for innovation processes can be adjusted to the specific needs of the respective enterprise. Staffing of decision makers can be adjusted depending on project type (e.g., incremental innovation vs. disruptive innovation, idea filtering vs. coaching). • Use other stage-gate-oriented design research processes, e.g., [61]. • Modular approach is encouraged when applicable to the domain, but not mandatory. • Disruptive projects should be carried out outside the formal process (out-of-scope).
Testable propositions
• Utility statement for method output: does the method deliver artifacts that are novel and come with a positive business case to deliver economic impact (innovation) and contribute to the body of knowledge in design science? • Truth statement for method output: does the delivered artifact at Gate 4 match its specification from previous gates? Is the new business case viable? Does the utility statement fulfill the criteria of the gate process and contribute to DSR? Further Gate-criteria according to context type can be introduced and checked.
Justificatory knowledge
• Method design theories as described in [66]. • Theories about the application context including innovation management (examples are [14,58,59]. • Theories about DSR as summarized in [57]. • To be used in innovation systems such as University-Industry-Collaborations. • Other aspects of interest: Innovation Process applied in 100 and more innovation projects.

Table 5. *Cont.*

Design Theory Components and Method-specific Elements
Principles of implementation • Not all components from Section 4 have to be rolled out in an implementation. For example, the DSR process can be left out if no research goal is pursued; likewise, the classification of artifacts or the pursuit of the design strategies can be left out. • It requires an already implemented idea-to-launch process or willingness to implement.
Expository instantiation • See case study from Section 6.

Lessons Learned

The Integrated Innovation Strategies Framework. The outcome of the case study is that the innovation strategies are very well applicable and they smoothly integrate into the combined process artifact. On the one hand, they perform well in classifying the actual design work and thus help teams to better document the actual innovation steps. The IISF could be used for the analysis of a wealth of past engineering projects, making their results available for the DSR body of knowledge (Table 6).

Table 6. Contribution to IS Design Theory following the structure of [53].

Component	Compliance
Purpose and scope	Automation of call center processes. Result of design strategies: *Increase Scope* of Parallel Phoneme Recognition (PPR) Age and Gender recognition; *Combine* this new module with IVR in a newly tailored dialog system, in order to automate and increase utility in call center applications.
Constructs	Hidden-Markov-Models for the acoustic models [70], tailored dialog engine of IVR System.
Principles of form and function	Automated skill-based routing depending on user groups, users prefer tailored dialogs, dedicated voice databases
Artifact mutability	The concept can be extended to other non-verbal features like emotion recognition
Testable propositions	Higher recognition rate for age and gender classification, higher user acceptance for age and gender adapted dialog
Justificatory knowledge	Kernel theories from ASR [70,74].
Principles of implementation	Integration project using Voice XML, etc.
Expository instantiation	Incumbent telecommunications IVR, Project "Speech Based Classifier"

Innovation Strategies Validation

We have performed interviews with researchers from the Institute of Industry-Academia Innovation at Eötvös Loránd University (ELTE), Budapest. Interviews were conducted with academic researchers to whom we asked questions regarding the projects they had been actively working on. After gathering empirical data, we selected four projects to validate three innovation strategies among the ones we point out in this paper. We will further validate the remaining innovation strategies in an upcoming research paper accordingly.

Mini-Link, developed by Ericsson, is a radio unit for microwave transmission in radio transport networks. In-network telemetry systems connected to this product require a vast number of configuration files, depending on the usage scenarios. Steps were taken to process these files into databases to help developers, testers, and customer support to focus their work on development and testing, and to be able to give advice to the customers about how to configure the nodes (e.g., Ericsson customers could obtain useful feedback when they were upgrading software on their nodes). Customers could more confidently upgrade their software because of the visualized data on the predictions based on logs. On the other hand, processing of this data in a relational database management system is very slow and can be hard to query; storing this data takes lots of disk space as well.

Hereby the authors [75] present a better way to store the data produced by these nodes in graph databases by using a NoSQL environment instead of a relational database. With this approach, it is possible to easily represent and visualize a network of machines in its bigger picture. As a result, these machines achieve much better efficiency in several aspects including time, storage, performance, etc., when evaluating insertions, querying time, and storage size. Technologies used in this task are Apache Spark for the processing of the data, HIVE for storing data, and Tableau for creating visualizations.

Here, the researchers improve the existing design for storing and querying vast amounts of data on relational databases and come up with an improved design that makes use of NoSQL databases within the organization. The design strategy here is *Improve* since, after identifying shortcomings in the standing design, the researchers have proposed an improved design that overcomes such shortcomings.

RefactorErl is a static source code analyzer and transformer tool, which has also been made open source. The aim of the project was to create a product to support Erlang developers in their daily code comprehension tasks. The usefulness of the product has been proven in industrial usage. The tool has an Erlang source code analyzer and transformer [76] which is able to handle real-world code. According to statistics, it was applied successfully on more than 1.5MM LoC. There are several helpful features which include support to analyze macro constructs, storage and fast retrieval of analysis results, source code layout improvement, and comment preservation during transformations. The results from various deep semantic analyses are expressed through a user-based semantic query language which can help Erlang developers in debugging, program comprehension, identifying relationships between parts of the program, and so on. It helps understand legacy code, aiding software restructuring, and checking code complexity and quality. The tool is capable of shortening the learning time of newcomers, increasing code quality by reducing faults, and facilitating effective teamwork in various ways.

Prior to the initiation of this project, there was no such tool for Erlang. That is the reason why researchers at Eotvos Lorand University, Budapest, started to build one (though, similar other tools did exist at that time for other programming languages). Moreover, elements such as the semantic analyzer framework and the incremental analyzer of the changes of the source code are still unique components of RefactorErl, if compared to other tools built for other scopes/languages/programming paradigms. Incremental analysis helps with source code that contains millions of lines of code, which are difficult to inspect and comprehend: if the analysis is incrementally applied, a few minutes are enough to obtain results. In addition to that, features such as variable binding and static analysis on data flow and control flow [77] are currently not provided by other alternatives as well.

As mentioned earlier, the idea of performing source code analysis is not new, and tools to achieve this task existed for other programming languages, but not for Erlang. Therefore, in this project, an *Increase Scope* strategy has been followed, since an existing design was already available for a different purpose and scope, and the researchers extended it to be used in a new one.

Internet of Eyes is an object detection system capable of detecting and recognizing moving objects and determining their three-dimensional spatial position through real-time processing of video streams from multiple cameras. Although the system moves large amounts of data over the network and uses high computing capacity, it does all this with very low latency thanks to a high-performance "Edge" server placed at the edge of the network. The system is used in a simulation environment in which the goal is to detect and avoid possible collisions with vehicles. This project started as an Ericsson-supported project at ELTE, Budapest. The aim here was to simulate and illustrate possible scenarios in which the low latency and high reliability of 5G are fundamental. At the time of this project, there was already much positive talk/opinion on the benefits of 5G, but not many use cases that would effectively demonstrate why the technology and its properties would represent a breakthrough both in industry and in the daily lives of users. This project was meant to boost or create common ground to sell Edge Computing technology to telecom companies, and possibly their clients. Here, the design strategy is *Explore New* because the issue was not yet solved and the researchers proposed a solution to it.

CodeChecker is an open-source project developed in close collaboration with Ericsson. The tool applies static analysis to find potential software bugs in programs written using the C/C++ programming language. There are several issues that are likely not caught by compilers; herewith, to eventually increase software quality, static analysis tools are significantly important. CodeChecker does not run the program as in testing, it solely performs a static analysis. There are several known users of CodeChecker, which also include developers from companies such as Apple, Google, Sony, and Samsung. The tool provides command line C/C++ Analysis, web-based report storage, and incremental analysis which works by considering only the changed files and their dependencies, provides false positive suppression, and visualization of results in the command line or on a static HTML web application to allow viewing discovered code defects with a streamlined and easy experience. It has also been improved to become an ecosystem-independent, web-based multiplatform tool, and Cross Translation Unit Analysis was implemented [78], which helps to find more bugs. The followed design strategy is *Improve* because the proposed design brings improvements over the shortcomings of a previous one.

7. Discussion

We have used our concept in multiple ways in the areas of research, innovation, and education. Not all of the presented components from Section 4 have to be deployed at the same time. The original use is the setting in an innovation lab of the above case study (Section 6) where the combined process ensures both practical relevance for innovation and scientific rigor for research purposes. Not all the projects have been scientifically published like the one from the case study, however, the method has been applied and proven useful for at least 50 different projects in the context of an innovation lab, similarly to the presented case. While the conscious process helped also knowledge transfer through the systematic synchronization with the stakeholders at the gates, mapping it with innovation strategies also helped to facilitate discussion and to clarify the ideas for presentation. The abstract templates have been considered a great help for identifying the matching design strategy. The practical application usually takes three steps:

1. Use IISF strategies from Figure 4 and corresponding abstracts from [73];
    - Map an existing idea to the fitting IISF strategy;
    - Identify a solution design by trying out the four innovation and nine design strategies
2. Optional: Try out different scenarios by pivoting through the remaining three innovations and eight design strategies in order to come to new design ideas.

The method proved equally useful for educational purposes. In a two-semester M.Sc. course at ELTE on Innovation and Entrepreneurship for Computer Science students, the students have to develop an innovative IS artifact in a project themselves. To develop and test their ideas, the students must undergo the innovation part of the process model (Section 4.1.1), which allows them to obtain regular feedback during the gates to be passed.

The benefit of a "fail early, fail often" approach becomes immediately transparent to the students when they obtain early feedback on a project idea that will probably not “fly”, so they can pivot or stop the project early without too much effort and start with a pivoted idea or a completely new one. The advantage of saving time and energy is immediately felt by the students during the process, and during the second-semester effort can be put into tested ideas. In the same way, the archetypal strategies to build design knowledge help the students to classify and communicate their ideas better, and also to receive better feedback. Pivoting also gets more systematic by trying out the remaining other 11 strategies.

In one example, the innovation strategies were also successfully applied for innovation and business model design in the 2017 ELTE summer school on blockchain technologies. In this case, the three ranges were not related to research abstractions, but to the blockchain paradigm: the blockchain paradigm itself (long-range), smart contracts, cryptocurrencies, etc., as mid-range, and concrete solution implementations as short-range. Seven teams with an average of 5 people were built and they had to come up with an innovation design, including a business model in the blockchain market. This resulted in presentations of each group’s innovation proposal without knowledge of the concept of the design strategies. Subsequently, they were asked to map and streamline their pitches using the strategies and abstracts from [73]. All of them were able to map the core of their ideas to a design strategy [73] and the streamlined pitches helped them focus and were much clearer to the audience. In the second step, the teams were asked to pivot their idea using one of the other 11 strategies [73] which was also possible in all cases, with some considered as superior and more innovative. This laboratory experiment still has to be scientifically analyzed but shows the applicability and potential of these strategies.

The design strategies were equally useful in an educational application to a 2019 workshop on research design. Ph.D. students from four universities (University of St. Gallen, University of Neuchâtel, City University of Hong Kong, and Eötvös Loránd University of Budapest) were asked to describe their existing publications and future intentional publications by applying the abstract templates. The students were asked to classify their existing papers according to the strategies from Section 4.2. In the same way, they were asked to submit their ideas for future publications and their thesis outline in the format of the design strategies. All 19 participants were able to map their research according to the concept. After the submission of their strategies, a two-day workshop was conducted with peer coaching or by the present four professors of the four universities. In their feedback, the students acknowledged that the concept led to a well-prepared and intensive discussion with high outcome values. The different design ranges were especially good for modeling research designs, as mobility between these abstraction layers is inherent in research where generalization or validation plays an important role. The course was rated on average as “very good” in anonymous feedback forms, which is extraordinarily high.

8. Conclusions and Future Work

The proposed innovation engineering method presents a combination of DSR processes with innovation processes that are characterized by an innovation funnel and stage-gate-orientation. Inherent features from design science, such as the named application of strategies for the reuse and creation of design science knowledge (for module-based innovation strategies) contribute to the novelty of the approach. As such, the method can be used for digitalization projects that inherently build on existing infrastructure and organization. The innovation engineering method provides a solution to be applied to a class of problems that is domain-independent, especially embracing innovation based on a modular design. It is specifically well suited for incremental innovation. Agile modules can be integrated during the stages; however, results have to be realigned during the gates. The method can be situationally tailored to fit specifically the operations of university-industry innovation centers.

The approach has been proven in numerous projects and facilitates addressing different expectations from academia and industry. Thus, it helps to systematically collaborate. It is specifically well suited for long-running and complex tasks, combined with incremental innovation.

Future work will focus on the integration of different innovation processes (scrum, agile, etc.). Similarities between other neighboring design disciplines, such as Design Thinking or (Industrial) Design Research, are also to be considered, as well as specific tool support. Some grounding work in this regard has already been performed: we proved the utility of such a tool for the definition and the evaluation of methods that contribute to business processes in [79], together with the establishment of a framework to optimize situationally defined processes [65]. We plan to build a set of tools/artifacts that can be embedded into an enterprise management infrastructure, contributing to the construction of the *Method Factory* [21].

Additionally, a continuation of the process from Figure 3 with a dedicated Enterprise Architecture Approach for targeted transfer to production should be pursued in the future.

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