VALIDATION CRITERIA FOR THE OUTCOMES OF DESIGN RESEARCH

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Abstract

Design research can be described as a form of research that involves the design of some human-creation or artefact. These artefacts are designed for some purpose, i.e., they aim at responding to some human necessity, either existing or foreseen. Although these artefacts are inescapable in design research, the actual outcome of design research is knowledge about the artefacts.

The knowledge resulting from design research is named knowledge-for-a-purpose. It is contrasted with knowledge-for-understanding, the knowledge resulting from other forms of research.

The article addresses the validity of knowledge-for-a-purpose. Four elements for such validity are presented, namely: success of the corresponding artefacts, generality, novelty and explanation capability.

In order to attempt to clarify the view underlying the article, design research and its outcomes are contrasted with several other concepts that are common in the design research discourse: design activity, design science, and design science research.

Keywords: Design research, Design science research, Scientific knowledge, Validity criteria of scientific knowledge.

1 Introduction

The information systems (IS) discipline encompasses a wide body of scientific knowledge that is used by professionals whose job is to put information technology (IT) at the service of work, processes, organizations, business, the economy or the society.

Two main types of scientific knowledge are considered in this article. The first type corresponds to existing understanding of human, group, organizational or social phenomena related to activities that involve some form of information processing and the use of IT in these activities. This knowledge – normally named as "theories" - can take the form of classifications, descriptions, explanations, or causal relationships. They provide IS professionals with sound work capabilities to deal with multiple work objects and events, to follow the progress of happenings, to make sense of an existing reality, and to anticipate future events. In any case, theories can be described as justified assertions about regularities (patterns) in the world phenomena – either physical, chemical, biological, human, or social. In the IS discipline relevant phenomena typically belong to the human and the social realms.

A second type ok knowledge corresponds to knowledge about human-designed *artefacts*. Examples of relevant artefacts to the IS discipline include *IT applications and platforms*, and *ways-of-working* applicable to the IS profession acts (such as those considered by (Topi, Valacich et al. 2010): improving organizational processes; exploiting opportunities created by IT innovations; understanding and addressing information requirements; designing and managing enterprise architecture; identifying and evaluating solution and sourcing alternatives; securing data and infrastructure; understanding, managing and controlling IT risks). The IS body of knowledge provides abundant recommendations on how to conduct these profession acts. Artefacts can be generally described as human-creations, designed for some purpose, i.e., they aim at responding to some human necessity, either already existing or foreseen.

These two types of scientific knowledge will be referred in this article, respectively, as *knowledge-for-understanding* and *knowledge-for-a-purpose*.

The production of these two types of scientific knowledge involves different types of research. Hevner, March and Park (Hevner, March et al. 2004) suggest the existence of two paradigms for knowledge acquisition, respectively: *behavioural science* and *design science*. In this article, the term "design research" is used to refer to their second paradigm. The article addresses several aspects related with the scientific knowledge that results from *design research*.

The reason for using "design research" instead "design science" is to avoid the use of the term "science". "Science" is sometimes used in the sense of *scientific knowledge* and, in other times, even in the same text, in the sense of *scientific research*. So, in this article the term "science" is used only in the sense of scientific knowledge. The term "research" will be used whenever what is a stake is the process of knowledge creation.

Also for clarity reasons the term "theory" won't be used to refer to the outcomes of design research. Such use is quite common in the IS area as in (Walls, Widmeyer et al. 1992), (Goldkuhl 2004), (Gregor and Jones 2007), (Kuechler and Vaishnavi 2008) (Kuechler, Park et al. 2009), (Sjöström 2010). However, an important intention in this article is to stress the differences of the outcome of *design research* from the outcome of other types of research. Therefore, and because there isn't a widely accepted alternative, the bulky expression "outcome of design research" will appear several times in the article.

This article addresses issues that are often brought up by doctoral students in a doctoral seminar the author runs in a school of engineering. Students are enrolled in different doctoral programs, including information systems, computer science, and diverse engineering areas (e.g., civil, mechanical, electronic, industrial, biotechnology). In most cases, doctoral research projects involve the design of some kind of artefact. Issues reflect difficulties related with the vocabulary of research narratives. Terminology used in the conventional science/research discourse (research that produces *knowledge-for-understanding*) is sometimes hard to adjust to research situations that involve the creation of scientific knowledge that is supposed to have utility for some purpose - *knowledge-for-a-purpose*. However, the discourse of the former is often viewed as the orthodoxy that must be followed to guarantee acceptance in the scientific community.

Those raised issues fit in two main groups: the validity criteria for knowledge and the knowledge creation process. In what concerns validity, four aspects are of major concern: success of the designed artefacts, generality, novelty, and explanation capability. The knowledge creation process raises questions related to the inclusion of a design step and, whenever the research project aims at contributing to engineering practices, the relationship between design and research.

2 Design research

Design research can be described as a form of research that involves the design of some human-creation or artefact. These artefacts are designed for some purpose, i.e., they aim at responding to some human necessity, either existing or foreseen.

The term "artefact" is used in this article to refer to the human-creations designed during *design research* projects. It should be clear that several types of artefacts might be considered.

A first distinction can be established between artefacts that are tangible and artefacts that are intangible. To the former, matter plays an important role in the realization of the artefact. To the latter, matter is accessory. Typical examples of intangible artefacts resulting from *design research* are ways-of-working, i.e., prescriptive models for how to carry out some human activity.

March and Smith (March and Smith 1995) call "methods" to these ways-of-working, while tangible artefacts correspond to their "instantiations". According to March and Smith, together with *constructs* and *models*, *methods* and *instantiations* are the outputs of *design science research*.

Another distinction to consider among artefacts leads to the classes of *tools*, *machines* and *automata* (Tondl 1974). In tools, "man himself constitutes the source of energy, the motive force and the source of information" ((Tondl 1974), pp. 10). The word "information", in Tondl's sentence, could be substituted by "control". Machines are a class of artefacts where man is no longer the source of energy, although he remains the source of control. Finally, in what concerns automata, artefacts are capable of some degree of self-control. These distinctions have their origin in the philosophy of technology, e.g., (Tondl 1974; Gasset 1983 (1941)) and are applied to *technology* or *technological devices*.

A correspondence between *technological devices* and *artefacts* is assumed in this article. This might imply an extension of the concept of *technological device* to encompass intangible artefacts – methods/ways-of-working. Considering that the intangible artefacts are to be used by humans, who are the source of energy and control of their application, intangible artefacts fit in the class of tools.

3 Outcome of design research

The outcome of research is new scientific knowledge. So, it should be in *design research*. A consequence of this assertion is that the actual relevant outcome of *design research* is not the designed artefacts, but knowledge about them. Surely design research involves the design of artefacts, but these artefacts shouldn't be considered as the major outcome of the research endeavour.

Knowledge about artefacts can be of different kinds, such as: representations of the artefacts' structure (architecture), applicable to tangible artefacts; descriptions of the way they work and are operated; representations of ways-of-working (including reasoning as a form of work). Gregor and Jones (Gregor and Jones 2007) propose a set of eight elements that should be present in a full description of an artefact (although the eighth element is an instantiation of the artefact it self).

The demarcation between artefacts and knowledge about the artefacts is not easy to establish, especially in the case of intangible artefacts. Buts, it is important for discussing the validity of the outcomes of design research, aspect to be addressed in next section.

The idea that the actual relevant outcome of *design research* is not the designed artefacts but knowledge about them seems to be in disagreement with March and Smith (March and Smith 1995) as they consider *instantiations* - the realization of an artefact in its environment, i.e., the actual artefacts – as a major outcome of research.

4 Validity of the outcomes of design research

The major outcome of *design research* is scientific *knowledge-for-a-purpose*. The validity criteria for this knowledge comprise several elements. The validity elements addressed bellow are different from their counterparts in scientific *knowledge-for-understanding*.

4.1 Artefact success

The first validity element is that the new artefacts should be *successful*. Success can be established in terms of measures such as:

- usefulness – the degree to which an artefact contributes to the achievement of a result, at a level broader than the artefact itself; this measure is applicable to tools (cf. section 2) and it takes into consideration that the artefacts, by themselves, might be insufficient to achieve the expected results; they have to be used or applied by humans or to co-operate with other artefacts;
- efficacy – the degree to which the artefacts achieve the expected results (in accordance to the reason for their creation); this measure can be applied to machines and automata (cf. section 2); these two types of artefacts can perform their role in an a manner that has a high degree of independence from other artefacts or from their human operators;
- efficiency – a combined measure of efficacy and paucity of resources involved in the operation or use of the artefacts;

Knowledge about unsuccessful artefacts might also have its value as it contributes to establish ways that aren't worth to pursue.

Although some differences can be established, artefact success is a concept close to *practical utility* and other forms of expressing the relevance and applicability expected for the results for design research (e.g., (Hevner, March et al. 2004), (Sjöström 2010), (Gill and Hevener 2011)).

Artefact *success* contrasts with *truth* as the main validity element of *knowledge-for-understanding*.

4.2 Generalization

A second validity element is related to an important characteristic of scientific knowledge - generality. Scientific knowledge is general in the sense that it is not situated. This means that its applicability is not restricted to specific situations. In some sciences (e.g., physics, chemistry), the applicability is expected to be universal. In other cases (e.g., social sciences), it is understood that the applicability of scientific knowledge is restricted in time, space, and circumstances.

Knowledge-for-a-purpose should be applicable to classes of situations. This means that knowledge – knowledge about designed purposeful artefacts – should be applicable to several instantiations (using the term chosen by (March and Smith 1995)). Therefore, instantiations shouldn't be considered as a possible outcome of design research. Instantiations are produced in order to demonstrate the feasibility of artefacts and/or to enable the assessment of their success (cf. section 4.1).

The architecture of a specific product corresponds to situated knowledge. Its generalization leads to architectural patterns for a class of products. Architectural patterns are not sensitive to the special needs of specific situations. They apply to all instances of the class. Similar considerations can be made to methods, as cases of ways-of-working, applicable to a variety of activities with similar purpose.

Generalization is widely addressed in the *design research* literature. Gregor (Gregor 2006; Gregor and Jones 2007) address generality as a crucial element in research outcomes (theories), including those related to design, namely her Theory Type V - theories for design and action. This theory type clearly fits within *design science* (as presented in section 5 of this paper). It can also fit within that part of design science that might result form design research. However, this distinction is not considered in Gregor's articles.

Sein and colleagues (Sein, Henfridsson et al. 2011) propose a design research method - *action design research* – and enunciate several "principles that encapsulate its underlying beliefs and values". Their 7th principle is about the generalization of research outcomes. It considers the need of generalizing both the problem and the solution.

4.3 Novelty

A third validity element considers *novelty*. Research produces *new* knowledge. In the case of *design research*, there is new knowledge if there is a new artefact that corresponds to a new class of artefacts, or it exhibits significant improvements in relation to existing artefacts of some class.

Design researchers are supposed to demonstrate that the knowledge they produce is new. However, novelty in design research is expressed differently from the way is it expressed in research that leads to *knowledge-for-understanding*.

To express the novelty of the outcome of a design research project, one can articulate sentences like: this didn´t exist before; this is better now. In the case of *knowledge-for-understanding*, novelty is typically expressed as something like: we didn't know this.

Novelty in *knowledge-for-a-purpose* is associated with *invention* while novelty in *knowledge-for-understanding* is associated to *discovery* (as presented in (Edgerton 2004)).

Although new *knowledge-for-a-purpose* might be closely related to innovation, *novelty* and *innovation* are quite different concepts that should be clearly separated. Innovation is a key concept in economics, related to the realization of benefits resulting from changing work practices. Such changes might be achieved thought the application of novel *knowledge-for-a-purpose*.

Discovery, invention, innovation, and the diffusion of innovations are present in several models that aim at explaining the progress of society from the perspective of economics (Edgerton 2004; Fleck 2004).

The distinction between novelty and innovation is assumed in this article. To be recognised as an innovation, the outcome of research has to be transferred to some economic activity and has to lead to benefits or advantages. Although recognizing that the ultimate expectation of design researchers is that their creations become recognized as innovations, from the point of view of research it is enough to demonstrate the novelty of the research outcome.

4.4 Explanation capability

A fourth and last element to consider in the validity of the outcomes of *design research* is that the reasons for the success of the designed objects should be explained. Just to design a new artefact that is successful in achieving its purpose is not enough. The researcher should be able of explaining why it is useful, efficacious, or more efficient than alternative artefacts. This implies that there should be an understanding of the phenomena that enable the realization and performance of an artefact and/or of the phenomena that encompass its use or operation.

So, it should be clear what is the *knowledge-for-understanding* that enables an artefact to be successful. Even before the design and realization (construction) of the artefact, it is reasonable to expect an explanation of the plausibility of the artefact's success, based on the existing understanding of the way the world functions (at the relevant realm, be it the physical, chemical, biological, human, or social).

Design research can therefore be viewed as a form of *applied research* (Feibleman 1961) (for the reasons mentioned in section 1, Feibleman's term "applied science" is herein substituted by the less ambiguous term "applied research"). According to Feibleman (with some adaptations) applied research can be described as the use of pure science – in the sense of *knowledge-for-understanding* obtained through a research process that aims at satisfying the need to know - for some practical human purpose.

Because *design research* involves application of *knowledge-for-understanding*, it doesn't mean that chance cannot be present in design research projects. However, even that some serendipitous event leads a researcher to the design of a successful artefact, a full comprehension of the reasons for its success (or failure) is necessary. In such case it might be necessary to combine a design research approach with a more conventional research approach that enables to understand the reasons for the success.

Explanation capability is achieved through referencing to *knowledge-for-understanding*. Therefore this validity element is relevant only for *design research* and the resulting scientific *knowledge-for-a-purpose*. It is not necessary in research that leads to *knowledge-for-understanding.*

Explanation capability is understood as a basic element in design research. Walls and colleagues (Walls, Widmeyer et al. 1992) mention that a design theory needs theoretical underpinnings. Gregor and Jones (Gregor and Jones 2007) or Sjöström (Sjöström 2010) refer to it as *justificatory knowledge*. Several authors (e.g., (Walls, Widmeyer et al. 1992; Markus, Majchrzak et al. 2002; Gregor and Jones 2007; IIvari 2010) use the term "kernel theory" to refer to the *knowledge-for-understanding* that explains the success of the outcomes of design research.

5 Design research, design, and design science research

Design research was presented as a form of research that involves the design of some human-creation or artefact and leads to *knowledge-for-a-purpose*. In this section *design research* is contrasted with *design activities*, and with *design science research*. To accomplish this, *design science* is also considered.

This explanation was felt necessary because of some terminological confusion and disagreement existing in the area and already mentioned in the introduction.

5.1 Design activities

Design activities involve the creation of artefacts or lead to some change in the world. Design activities are typical of several professions like engineering, medicine, management, or architecture.

Design activities use existing scientific knowledge (Figure 1) to produce some situated artefact or to produce some specific change in the state of affairs of some situation.

Design activities are not a form of research.

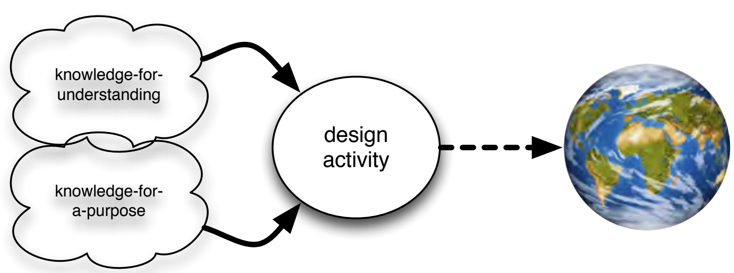

Figure 1 - Design activities –scientific knowledge (both knowledge-for-understanding and knowledge-for-a-prupose) is used to produce some change in the state of affairs of the world; in some cases the change involves the production of situated artefacts

5.2 Design science

Design science corresponds to knowledge about the design process – *knowledge-for-understanding* focusing the design process - or knowledge about design artefacts, i.e., artefacts used or applied to facilitate designing. The latter corresponds to *knowledge-for-a-purpose*.

Simon (Simon 1981) longs for a body of knowledge that is relevant for any design activity, irrespective of the knowledge domain it fits in (e.g., engineering, architecture, management, medicine). However, it is possible to envisage sub-sets of design science that are relevant to design activities specific to a knowledge domain. Mechanical engineering design surely has facets that, although they are present in any mechanical engineering problem, they don't exist in design situations in biological engineering, in management, in medicine, etc.

Figure 2 depicts design science. It includes part of the scientific knowledge used in the design process.

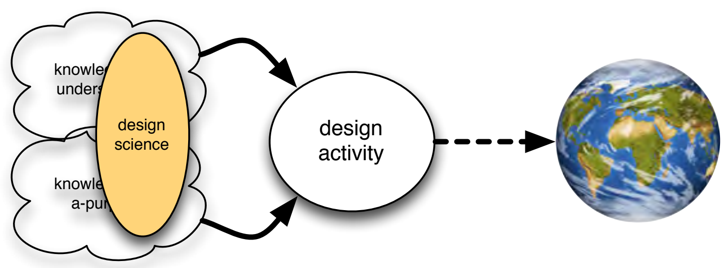

Figure 2 - Design sience – knowledge about the design process or knowledge about design artefacts

5.3 Design research

Design research is a form of research that creates knowledge about new artefacts. This research activity has been described in previous sections. In Figure 3, the dotted lined leaving design research aims at suggesting that the outcome of design research is *knowledge-for-a-purpose*.

Besides producing new scientific knowledge about artefacts, design research also involves the design and realization of situated artefacts. These realizations – instantiations – can serve a dual purpose: 1) to test the success of the novel artefacts 2) to solve an actual problem in the world.

If only the first case is present, design research is mainly an applied research endeavour. It may be carried out even without the collaboration of the entities that are potential beneficiaries of the artefacts or of the knowledge about them. The most interesting situation is when both cases are present.

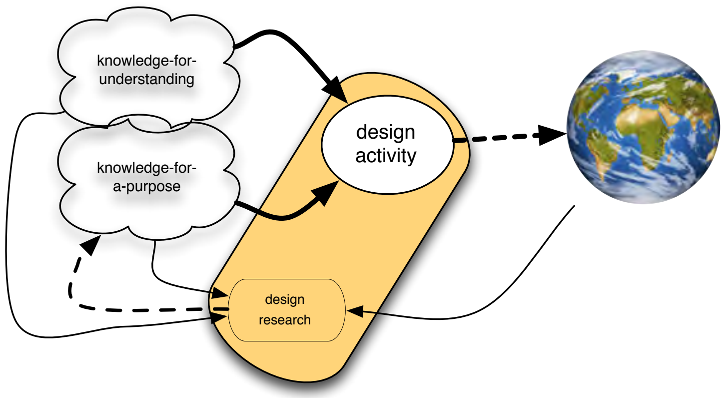

Figure 3 - Design research – reserch that leads to knowledge about new artefacts

5.4 Research leading to understanding how the world functions

Research that leads to new knowledge about how the world functions is the most common understanding of the term "research".

In the representation of this type of research, in Figure 4, the bubble representing the design activities has been removed because it is not necessary. The world is investigated in order to validate the tentative models of the world put forward by researchers during the research process.

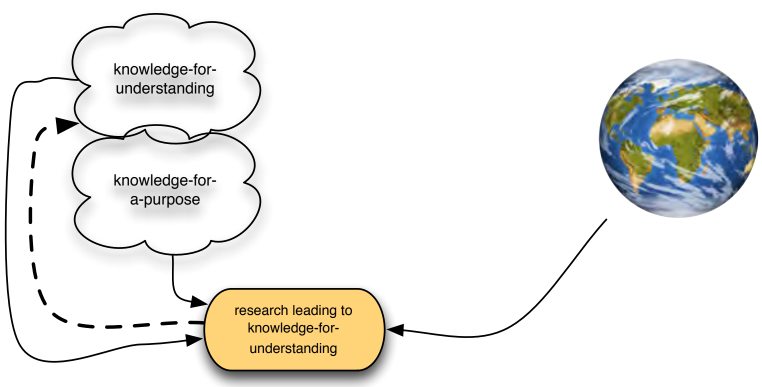

Figure 4 - Design research – research leading to understanding how the world functions

5.5 Design science research

Considering the ideas expressed so far, it is now important to distinguish between *design research* and *design science research*.

Design science has been presented as a body of knowledge about the design process. Therefore, *(design science) research* is a form of research that aims at enlarging such body of knowledge. *Design science research* can be either of the type described in section 5.3 (design research, leading to *knowledge-for-a-purpose*) or of the type described in section 5.4 (research leading to *knowledge-for-understanding*). In Figure 5, the dotted lined leaving design research aims at suggesting that the outcome of design research enriches the body of knowledge that constitutes design science.

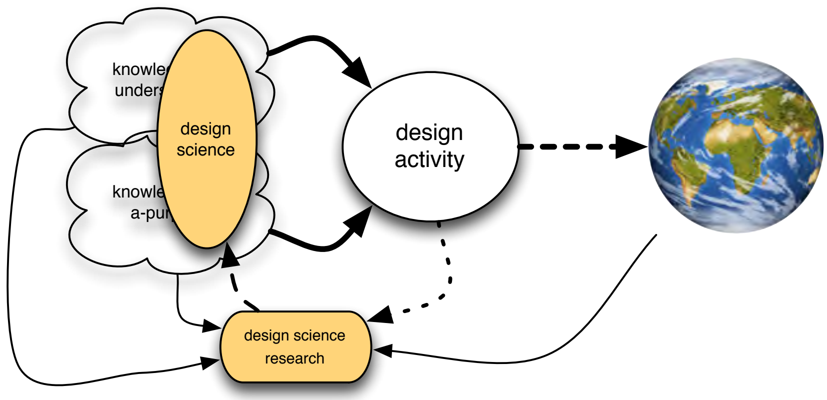

Figure 5 - Design science research – research that aims at enlarging the body of knowledge of design science

5.6 Synthesis and discussion

The different activities and knowledge realms considered in the previous section are now put together in Figure 6. The figure helps to convey that the scope of *design research* and of *design science research* are different, although they overlap.

Knowledge			Research	
knowledge-for-a-purpose	not to be used in design activities			design research
	to be used in design activities	design science	design science research	
knowledge-for-understanding	addressing the design process			other than design research (research that doesn't involve the design of an artefact)
	addressing phenomena other than the design process			

Figure 6 - Design research, design science and design science research; shadowed boxes highlight the concepts central to this article

These distinctions differ from other attempts to describe the knowledge and the knowledge creation processes that involve design activities.

In his "framework for design-related research areas in IS", Iivari (IIvari 2010) (Figure 7) considers as *IS practice*, both the world where IT applications/artefacts exist and are used, and their development. This way, there is no strong separation between the design activity (*Development of IT products*) and its outcomes (both the *IT artifacts* and the *Utilization of IT products*). On the other hand, Iivari focuses on the *Development of IT products* but he seems to disregard other design activities also central in the IS profession. Examples of such activities include organizational change activities motivated by the adoption of IT artefacts and several activities normally presented under the label of IS/IT management.

On the other hand, Iivari's framework makes no distinction between *design research* and *design science research*, the latter encompassing the former.

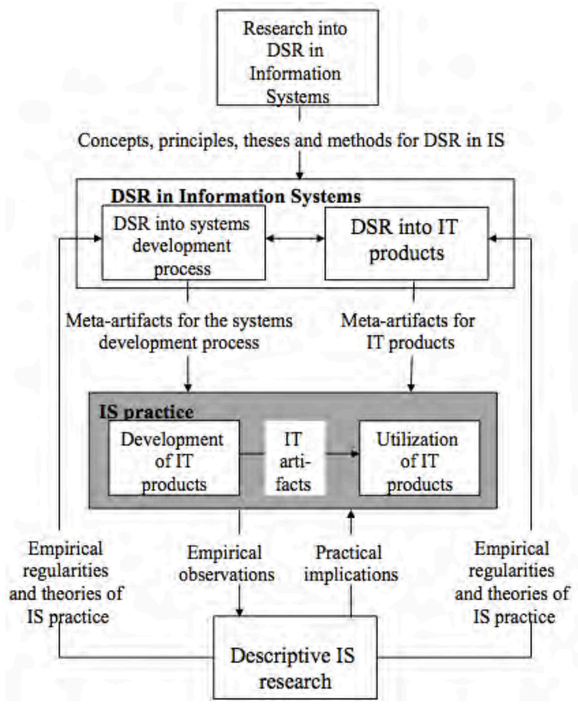

Figure 7 – A Framework for design-related research areas in IS (from (IIvari 2010))

Baskerville and colleagues (Baskerville, Kaul et al. 2011) also consider the distinctions addressed in this article. However, they start from a different meaning for "design science research" that seems close to what is being called *design research* in this article. They distinguish among three types of knowledge: general knowledge; domain knowledge; and design process knowledge. General and domain knowledge are not addressed in this article. In what concerns design process knowledge, this article goes further distinguishing between two types of such knowledge, as represented in Figure 1.

6 Conclusion

The article addressed several issues in the discourse of *design research*. It started by presenting a view on the validity of the outcomes of *design research – knowledge-for-a-purpose*. Four elements for such validity were presented, namely: success of the corresponding artefacts, generality, novelty and explanation. Later, design research and its outcomes were contrasted with other concepts.

The article doesn't suggest a name for the outcomes of *design research*. Bulky expressions such as "outcomes of design research" and "knowledge-for-a-purpose" were used throughout the text. This omission results from a hesitation related to the risk of neologisms for ideas that aren't yet mature. The author has been influenced by readings in philosophy of technology and has been using the term "technological knowledge" to refer to the outcomes of design research. However, a final decision has been made in order to avoid its application.

It is not claimed that scientific knowledge should be classified only in two categories: *knowledge-for-understanding* and *knowledge-for-a-purpose*. Formal knowledge, for instance, is omitted in the article just because it wasn't necessary to explain the concepts that were considered as central to the objective of the article.

The article is an attempt to contribute to clarify different types of research and different types of knowledge present in the IS discipline. And to help those that do research that address new IT applications and platforms or new ways of intervening in organizations (or society) in order to take the most of existing IT.

It is the author's believe that a clear differentiation between *design research* and other types of research is being hindered by attempts of design researchers to abide by the orthodox discourse of conventional research. Although this might help to exhibit a scientific look, it hides important differences that could be highlighted through the use of alternative vocabulary.

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