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Towards the Development of a DSS Supporting the Integration of Crowdsourcing in Theory Testing: Conceptual Framework and Model

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Abstract

The information systems (IS) discipline has not accorded the same attention to theory testing as it has to theory building. Further, crowdsourcing presents rich opportunities for the theory testing process that have not been fully explored. This paper builds on previous work, employing a design science research (DSR) paradigm in order to develop a decision support system artefact that will help early career researchers identify viable theory testing approaches, and how crowdsourcing can help facilitate the testing process. As part of the DSR build/evaluate cycle, this paper presents a conceptual framework and model of theory testing in IS, and the problem frame in which they are situated is evaluated using Scho ̈n's theory of reflective practice and problem/solution framing. Data collected from PhD students revealed an incomplete level of knowledge of theory testing, and a lack of awareness of the possibilities provided by adopting a crowdsourcing strategy.

Keywords Theory building, theory testing, crowdsourcing, decision support.

1 Introduction

Theory testing is concerned with establishing or refuting the validity of a theory's core propositions, which are tested by determining to what degree they provide a close fit to empirical data (Colquitt and Zapata-Phelan 2007). The key foundations to advance scientific knowledge are testing and re-testing theory (Niederman and March 2015).

Often, the theory testing process involves human participation. People can play different roles in theory testing, such as collecting data on behalf of the researcher, checking data quality, mediating access to data, analysing data, etc. Although many robust methods have already been developed to test theories, including interviews, surveys, ethnography and many others, the adoption of crowdsourcing (CS) as a means to facilitate these methods has recently started to receive considerable attention (Lowry et al. 2016).

CS is an emerging strategy that fragments a single task into multiple tasks delivered to a large group of people in an open call (Howe 2006). Several reasons have lead researchers towards considering the adoption of CS in theory testing. For instance, Lowry et al. (2016) advocated CS as a way to increase the quality of data collection. In particular, the authors reviewed some criticisms raised against CS and concluded that most of these were also associated with other data collection methods. Steelman et al. (2014) also highlighted the advantages brought by CS concerning the demographics, psychometrics, and structural properties of data samples. Their research also provided initial empirical evidence that CS can tap into large samples of participants and reach a wide variety of demographics.

Especially in the psychology field, researchers have been open-minded on the use of CS (Lowry et al. 2016). Therefore, this field has been leading the way, particularly with the use of the Amazon Mechanical Turk (AMT) platform for data collection. In the information systems (IS) field, CS has also started to be seen as a valid medium for this purpose. For instance, Steelman et al. (2014) identified 20 quality IS publications that used CS.

Nevertheless, it is one thing to know that others have already successfully used CS in their research, and it is another to know *how* CS can actually be involved in the research process, especially because of the diversity of the IS field. We believe there is a need for helping researchers to understand and make decisions on how to integrate CS into theory testing. This is especially true with PhD students, because often they are engaged for the first time in theory testing, and theory testing is typically on the critical path to conclude their PhD.

This type of support is usually associated with a category of tools designated as Decision Support Systems (DSSs) (Arnott and Pervan 2005; Hosack et al. 2012). Therefore, we undertake the *development of a DSS that helps IS researchers making decisions about how to integrate CS into the process of testing IS theory*. To this end, we adopted the design science paradigm and Schön's (1983) theory of practice. They both emphasize a developmental viewpoint where the goal is to iterate problem and solution frames. Given space limitations, we only report on two problem frames necessary to build the DSS: the development of a *conceptual framework* and a *model*. This would be followed by the development of a DSS artefact, in the form of a DSS tool for theory testing, possibly in the form of a simple spreadsheet or a more complex decision tool (Thuan et al., 2015).

The remainder of this paper is organized as follows. Section two describes the adopted research method. Section three describes the conceptual framework and model. In Section four, we assess our problem frames using the card sorting method. Finally, Section five highlights the research contributions and draws implications for the DSS development.

2 Approach

The design science paradigm was adopted for this research. Design science is a problem-solving paradigm that seeks to create innovative IS artefacts that solve practical problems (Gregor and Hevner 2013). Design science involves building and evaluating artefacts while making significant research contributions (Peffers et al. 2007). By artefacts we mean anything that can be transformed into a material existence as an artificially made object or process (Gregor and Hevner 2013). Artefacts may also include social innovations (Aken 2004), or new properties of technical, social, or informational resources (Järvinen 2007). In essence, any innovative artefact providing a solution to a research problem can be seen as design science (Peffers et al. 2007). We adopted this paradigm because: 1) It reflects a developmental perspective over the identified challenge and proposed solution; 2) It is considered the most common approach to DSS development (Arnott and Pervan 2012); and 3) It has been accepted by the IS community as a mainstream research paradigm (Hevner and Chatterjee 2010).

Along with design science, we adopted the iterative problem/solution framing suggested by Schön (1983). According to Schön's theory of practice, design is a reflective conversation with the design situation (Schön 1992), where problem frames suggest solutions and experience with solutions suggest new problem frames. This iterative process leads to the development of primary and secondary artefacts, the former addressing the fundamental research challenge and the latter guiding and supporting the journey (Hevner and Chatterjee 2010; Von Alan et al. 2004). Secondary artefacts are relevant because they provide actionable knowledge (Argyris 1996), and in their own way they also frame the problem. In our case, the primary artefact is the DSS, while the secondary artefacts consist of a conceptual framework and model.

Design science research (DSR) involves two primary research activities: build and evaluate (March and Smith 1995). The build activity involves developing an artefact based on a problem frame. The build activity is followed by an evaluation activity, which confronts the artefact with the problem frame and suggests new problem frames, until a satisficing solution is obtained (Sein et al. 2011). Considering the particular nature of our research challenge and its specific context, we can then delineate a more detailed research method, which is described next.

2.1 Development Method

The adopted method was based on a detailed analysis of two methods previously described in the related literature and specifically used to develop DSSs. One such method has been suggested by Arnott and Pervan (2012). The other method was developed by Thuan et al. (2016). The method developed by Thuan et al. (2016), named SCOA, regards design as a verb (activities) and considers the following steps: 1) scope the knowledge sources; 2) develop a conceptual model; 3) develop an ontology; and 4) develop a DSS that supports users in exploring the ontology. To ensure rigour, SCOA scaffolds the development within existing knowledge sources. It also ensures that the researcher adequately frames both the problem and solution using a conceptual model and ontology, from which the DSS then logically emerges.

The method discussed by Arnott and Pervan (2012) is more centred on design as a noun (artefacts). It suggests several categories of artefacts: 1) constructs; 2) models; 3) methods; and 4) instantiations. These categories directly reflect a categorization of design science artefacts proposed by March and Smith (1995). Arnott and Pervan (2012) further suggest that there are logical and purposeful relationships between constructs, models and instantiations, which define an iterative construction method. That is, constructs lead to models, which then lead to instantiations. We may therefore regard instantiations as primary artefacts, and constructs and models as secondary artefacts.

Our method defines four conceptual elements mixing verbs and nouns: 1) conceptual model; 2) scoping knowledge source; 3) model; and 4) DSS instantiation. These elements are graphically represented in Figure 1. The sequential linkage represents the development order, i.e. the conceptual model precedes the scoping knowledge source, which precedes the model. This method has similarities with SCOA, with a shift between the scoping of knowledge source and conceptual model. This change is necessary because our problem is framed by existing theory and epistemology on theory building and theory testing. Regarding differences to the method discussed by Arnott and Pervan (2012), we essentially bring a verb (scoping knowledge source) in between the collection of nouns. The similarities and differences between these methods are summarized in Figure 1. Next, we provide additional details about these steps.

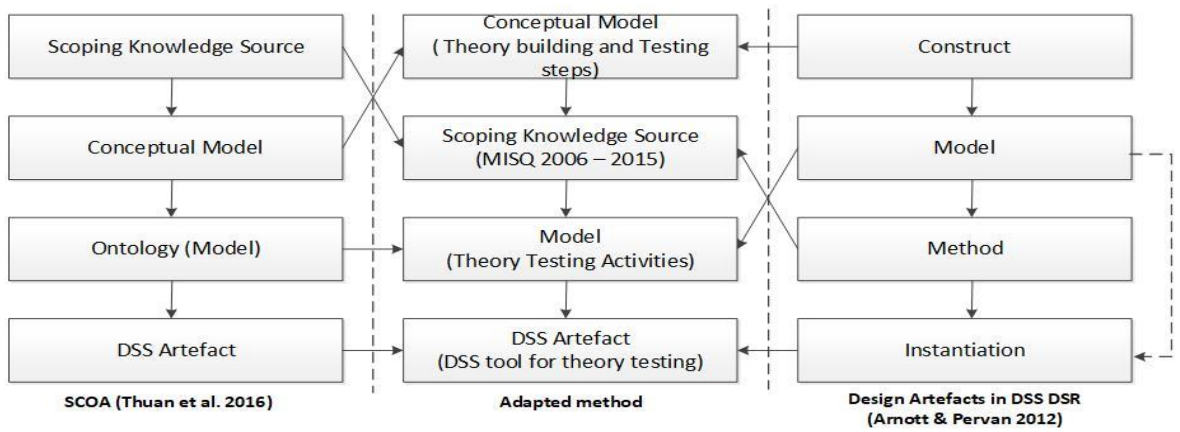

Figure 1: The adapted method, based on SCOA and DSS DSR

Step 1 – Build a conceptual framework. This step aims to identify the main concepts and constructs of the application domain, thus providing a holistic problem frame (Sonnenberg and vom Brocke 2011). As there are multiple ways in which a problem can be framed, an attempt to solve a problem should start with a particular viewpoint (Holmström et al. 2009). In our particular case, the conceptual framework highlights theory testing as a distinct component of theory building.

Step 2 - Scope the knowledge sources. Scoping the knowledge sources seeks to extract and articulate the existing knowledge related to the DSS that one seeks to develop (Thuan et al. 2016). It establishes a relationship between the DSS and the state-of-the-art. This is considered important for design science because it contributes to rigour, which should be on par with relevance (Gregor and Hevner 2013; Peffers et al. 2007).

The descriptive literature review method was adopted to identify the different ways in which theory has been tested in the IS field. This method was selected because it helps to determine the extent to which a body of empirical knowledge supports or reveals any interpretable trends or patterns with respect to pre-existing findings (Paré et al. 2015). This was done by collecting, codifying and analysing data that reflects the frequency of relevant topics found in the literature (Paré et al. 2015).

A systematic approach to data collection was adopted to increase rigor and transparency (Kitchenham et al. 2009; Paré et al. 2016). We also followed the data collection guidelines suggested by Kitchenham et al. (2009): 1) select articles; 2) filter articles; 3) data extraction; and 4) data synthesis. These steps are explained in detail in a prior paper [ref omitted for blind review] and will not be repeated here.

Step 3 – Build the model. The developed model represents the theory testing patterns and activities identified in the previous step. This is essentially the result of an analytic process. Our interest was not so much on the conceptual parts of theory testing, but more on the activities and patterns involved in the theory testing process, as presented by researchers to the community through published articles. Questions like what types of participants were used, what types of resources or instruments were used, what types of research methods and techniques were used, data collection methods, procedures followed during testing, and what were the outcomes of theory testing, were our concern when building the model. The model also highlights where CS can be used within the patterned activities.

Step 4 – Build the DSS. This step concerns the development of a solution addressing the framed problem. This can be realized in a variety of ways and can also be iterative (Thuan et al. 2015). For instance, the solution may go through conceptual design, prototyping and instantiation. As previously noted, in this paper, we do not detail this step.

2.2 Evaluation Method

Evaluation is a primary consideration in DSR, as it determines the utility of the developed artefacts (Von Alan et al. 2004). Since design science is still a relatively young paradigm, there has been some ongoing discussion regarding the breadth, depth and scheduling of evaluation in DSR (Sonnenberg and vom Brocke 2011). In particular, should the evaluation be centred on the last stage of the research, or done multiple times during the project? Should it concern the primary artefact or also consider secondary artefacts, and in the latter case, what is the purpose of evaluating secondary artefacts? Furthermore, what is the appropriate balance between rigour and utility?

In fact, DSR evaluation does not have to be limited to a single, summative evaluation of the primary artefact. Evaluation actions can be conducted along with the development of secondary artefacts. Furthermore, since secondary artefacts essentially serve to iteratively frame the problem, the evaluation actions may assume a more formative purpose, generating justificative knowledge (Sonnenberg and vom Brocke 2011). This justificative knowledge serves to either consolidate or adjust the problem frame. For these reasons, and to avoid misconceptions in understanding the purpose and target of the evaluation, we will use the term problem frame assessment (PFA). In this paper, we report on PFA regarding the conceptual framework and model.

3 Development Steps

3.1 Conceptual Framework

The conceptual framework is based on literature concerning both theory building and theory testing. We adopted the propositions by De Vaus (2013) and Bitektine (2007), which focus on the abstract set of activities necessary to build a theory, and then isolated the activities that specifically concern theory testing. Theory testing can then be characterised as two consecutive activities: operationalization and validation.

Considering operationalization, one has to restate the conceptual propositions as testable propositions. This involves translating abstract concepts into concrete, observable and measurable variables (De Vaus 2013). Then, one has to decide what data are relevant or appropriate to test the propositions. Regarding validation, one has to collect relevant data and analyse it. Data are analysed to see: a) how much support there is for the testable propositions; b) how much support there is for the conceptual propositions; and c) how much support there is for the whole theory. The framework is shown in Figure 2.

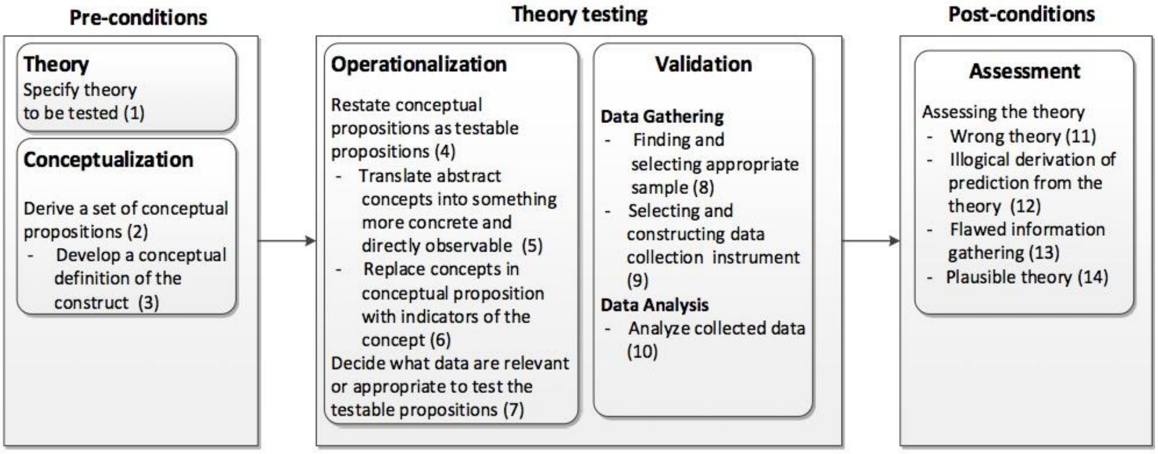

Figure 2: Conceptual framework, adapted from (Bitektine 2007; De Vaus 2013; MacKenzie et al. 2011; Niederman and March 2015)

Though addressing theory testing independently from theory building seems a reasonable way to frame the problem, we should nevertheless recognise that there is a level of dependence on theory building. Therefore, we define pre- and post-conditions to highlight the dependencies on theory testing. Furthermore, since many theories in social sciences are qualitatively tested, especially using the case study method, we integrate the recommendations from Bitektine (2007) into the conceptual framework, which specifically concern pre- and post-conditions related to case studies.

As pre-conditions, we consider: 1) briefly state what the theory is and what it intends to achieve; 2) provide a set of conceptual propositions (statements that show relationships between factors); and 3) when the research involves a case study, identify the case(s), unit of analysis and subjects.

As post-conditions, we consider: 1) state an assessment of the whole theory; and 2) when the research involves a case study, analyse the internal and/or external validity, realising that single-case studies tend to generate type-1 errors (accept false hypotheses) while cross-case studies tend to generate type-2 errors (reject true hypotheses) (Gerring 2006).

3.2 Model

The model is based on a scoping literature review conducted to understand the diversity of theory testing activities reported in the literature. The review uses a set of 248 papers published in a ten-year period in MISQ, which is considered the leading journal in the IS field and has a particular editorial focus on theory building.

The model organises the identified activities in a pattern system (Figure 3). A pattern is a sequence of regular and intelligible ways in which something is done. It can also be seen as a generalized solution to recurrent problems (Penker 2000).

Some vital elements associated to patterns are *intent* and *structure* (Penker 2000). Intent summarizes the general purpose of a study, taking a theory testing perspective, which does not concern the specific problem under investigation (Penker 2000). Structure considers how researchers put together some activities to reach their research intents. An intent may have one or more patterns, each one defining a particular sequence that allows fulfilling the intent. These patterns do not originate from a theoretical perspective but from practice, based on what researchers have reported in the literature. The whole collection of intents, activities and links then defines a complex, comprehensive pattern system, which suggests different ways of doing.

From the data gathered in the scoping literature review, we identified a large number of intents, activities and patterns. We found five intents: case study, records, experiment, survey, and Delphi study. We also found 53 different activities, which have been divided into two groups: data gathering and data analysis. The activities were then linked together, with the intents, to show the patterned characteristics of theory testing (Figure 3).

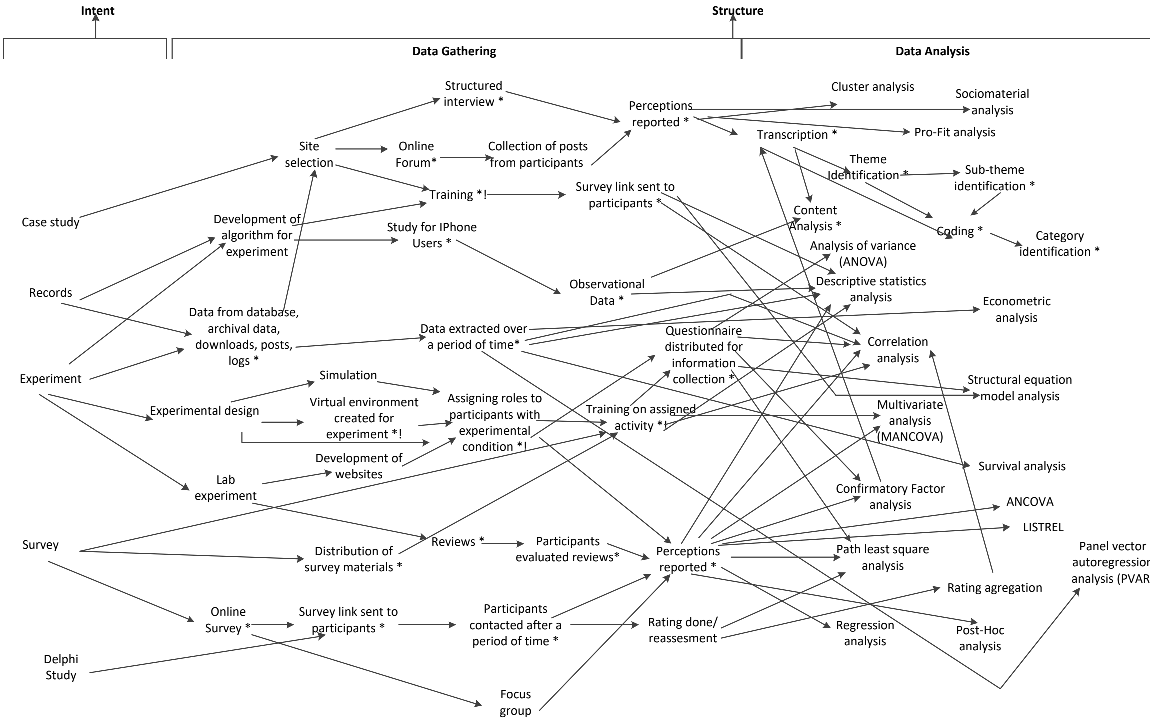

Figure 3: model showing theory testing patterns and activities (means the activity can be crowdsourced)*

The model emphasises the diversity of ways in that a theory can be tested. For instance, the survey intent can start in three different ways: training on assigned activity, distribution of survey material, and online survey. Then, it can take many different pathways. For instance, the survey can be followed by a survey link sent to participants or a focus group.

A final step in model building concerned analysing which activities can be CS. The analysis was based on a set of rules: 1) the activity should be decomposable in a number of simple CS tasks; 2) the CS tasks should be executed in a one-off event; 3) the CS tasks should be simple to understand; 4) the CS tasks should have clear inputs and outputs; 4) limited interaction with the crowd should be required; 5) the CS task should be remotely executed; and 6) the CS task should be completed in a bounded period of time. The activities that can be crowdsourced are identified in Figure 3 using an asterisk (*).

4 Problem Frame Assessment

Card sorting is an inexpensive and reliable method that has been widely used in various fields such as psychology, knowledge engineering, and software engineering (Barrett and Edwards 1995). The method helps understanding the people we are designing for (Spencer 2009), considering in particular how they structure information and action (Spencer and Warfel 2004). For instance, it can be used to assess the users' needs and priorities, how they deal with information, and how they react to tool features. Finally, it can offer more insights into the users' view about a problem and a solution. All in all, card sorting seems adequate to assess if our problem frame relates to what exists in the participants' minds and if our solution would be useful to them.

We structured PFA using four card sorting exercises followed by interviews. The exercises were conceived to acquire justificatory knowledge regarding:

E1: How familiar the participants are with theory testing activities. By allowing the participants to externalise their own conceptual frameworks, we can assess if they are close to best practices reported in the literature. A negative result suggests the DSS could help better planning theory testing.

E2: How familiar the participants are with theory testing intents and patterns. Once again, by allowing the participants to externalise their own views, we can assess if they are closer to what others have reported in the literature. A negative result suggests the DSS could help selecting theory testing patterns.

E3: What activities the participants think could be CS. This data may again suggest if the DSS could help integrating CS in theory testing.

E4: Which difficulties the participants face during theory testing and how a DSS could be more beneficial to their research. This exercise contributes a list of requirements for DSS development.

Setting and participants. The card sorting exercises were conducted in a meeting room, which had a large table for space and convenience. The participants were PhD students conducting their research in the IS field. PhD students were selected because they represent the main target audience for the DSS. The participants were selected by convenience.

Card sorting materials. The card sorting materials involved sets of 90 cards with words on them and a unique identifier number for recording purposes. Blank cards were also provided with pen to write if needed.

Card sorting procedure. The exercises were done in one-on-one sessions moderated by one of the authors (Figure 4). One-on-one sessions were adopted to promote personal opinions, to get detailed feedback, and also to cater for the diversity of research problems and methods that are typical in the IS field. The method was operationalised according to the following steps.

Figure 4: Participants sorting cards

A brief explanation about card sorting and verbal instructions were given to participants and the beginning. The purpose of each exercise was explained before handing over a deck of cards to the participants. The participants were given some time to read through the cards for familiarization of contents before the exercises began. The first exercise (E1) contained 14 cards with theory testing steps, which the participants should group in five categories. Both the categories and steps were taken from the conceptual framework (Figure 2).

The second exercise (E2) showed five theory testing intents (Figure 3) and required the participants to, for each intent, delineate how theory testing activities should be organised. In the third exercise (E3), we gave the participants a deck of cards with all activities and asked them to select which ones they thought could be CS. In the last exercise (E4), we gave the participants two decks of cards, one with potential problems faced during theory testing and another with possible features supported by the DSS. The participants had to organise the cards by order of importance. Blank cards were given to include any problems and features that were not in the decks.

After all exercises were completed, a brief interview was conducted to gather the participant's views regarding the exercise and how beneficial a DSS would be to help in making decisions on how to integrate CS in theory testing, and also to know what other features the participant might want the DSS to have that were not mentioned. The interviews were recorded and transcribed. All participants completed the entire procedure and each session took an average of 40 minutes, even though some exceeded 60 minutes.

4.1 Results

4.1.1 Familiarity with theory testing (E1)

To recap, the participants were offered a deck of 14 activities and were requested to place them in the five categories defined by the conceptual framework (theory, conceptualisation, operationalisation, validation, and assessment) and an additional category named other. The "optimal" distribution of activities by categories, as defined by the conceptual framework, is shown at the top of Table 1. Below, we show the participants' distributions. This approach allows measuring the deviations between the participants' sorts and the conceptual framework. Category deviations were calculated by measuring the distance between the categories where an activity belongs and where it was placed by the participant. For instance, placing activity #1 in the theory category has a distance of 0, if placed in the conceptualisation has a distance of 1, if placed in the operationalisation category has a distance of 2, and so forth. These results were then averaged.

As shown at the bottom of Table 1, the best approximation was obtained for the assessment category, and the worst was obtained for the validation category. These results suggest the participants are not sufficiently familiarised with the logical progression of theory testing activities, especially regarding the early stages. These results support the goal to develop the DSS as a way to improve knowledge about the structure of theory testing activities.

'Optimal' distribution (suggested by conceptual framework)						
Categories	Theory	Conceptual.	Operational.	Validation	Assessment	
Activities	1	2,3	4,5,6,7	8,9,10	11,12,13,14	
Participants' distributions						
Categories	Theory	Conceptual.	Operational.	Validation	Assessment	Other
P1	1	3,5	2,6,4,9	8,10,13,7	12,11,14	
P2	1	2,3,5		8,9,7,10,6,4,13	14,11,12	
P3	1,2	3,5,6,4,		8,9,7,10	11,13,12,14	
P4	1,14	2,5,3		7,9,8,10	11,13,12	4,6
P5	1	2,3	5,6,4	9,8,7,10,13	11,14,12	
P6	9,13	10,4,3	2,7,8	5,1,	12,6,11,14	
P7	1	3,2,4	6,5	8,9,7,13,10	14,11,12	
P8	1	2,12,4,3,6	5,7,8,9	13,10,	14,11	
P9	2,5	3,4,	1,12	8,7,9,13,10	6,14,11	
P10	1	2, 3	4,7	8,9,6,5,10	13,11,14,12	
Deviation	**1.5**	**1.6**	**1**	**1.9**	**0.4**	

Table 1. Familiarity with theory testing

4.1.2 Familiarity with model constructs (E2)

We adopted a contents analysis approach to evaluate the outcomes of this exercise. The ways in which the participants arranged the theory testing activities for each intent were then analysed and contrasted with the model shown in Figure 3. The results indicate that the participants had clear understanding of the different nature of the intents. However, we observed that the participants' arrangements were less diverse than the patterns suggested by the model. For instance, one participant characterised the case study intent as: site/case selection, interview, participants contacted after a period of time, and collection of posts from participants. This corresponds to one of eight possible patterns identified in the model. These results suggest the DSS may bring a more diverse view over theory testing.

4.1.3 Selection of activities that could be crowdsourced (E3)

We adopted frequency distribution to identify what activities the participants considered able to CS. The top selected activities are listed in Table 2.

Collection of posts from participants	8
Questionnaires distributed for information collection	7
Online forum, transcription	5
Coding, collection of data over time, develop website, study for iPhone	4
Virtual environment created for experiment, site selection, survey link sent to participants	3

Table 2. Top activities identified by the participants as able to CS

4.1.4 Problems and features (E4)

We adopted frequency distribution to analyse the problems and features reported by the participants. Figure 5 shows the obtained distribution of problems. Most of the identified problems are issues that CS can address, notably, recruiting participants and collecting data, which took the top of the list. With CS, one can recruit a large number of subjects, and they can contribute to data collection. The subjects may even be willing to give out private information, because CS allows for anonymity.

We also adopted frequency distribution to analyse which DSS features were most well-regarded by the participants. As shown in Figure 6, the highest priority was given to the capability to show different patterns to theory testing and the different pathways that can be adopted by a research project.

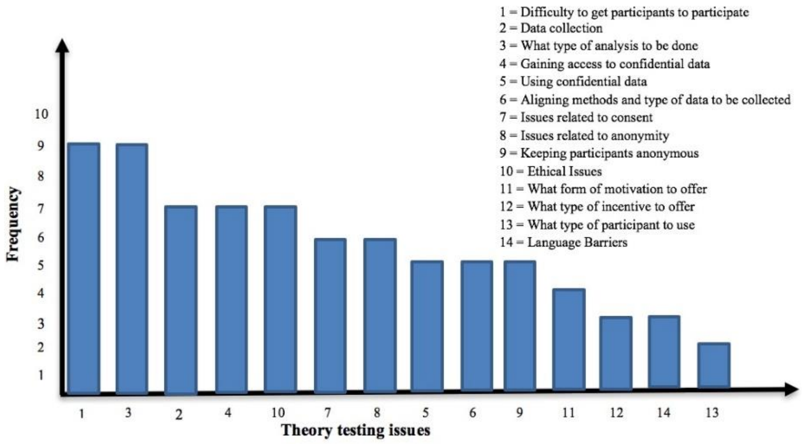

Figure 5: Frequency distribution of problems with theory testing identified by participants

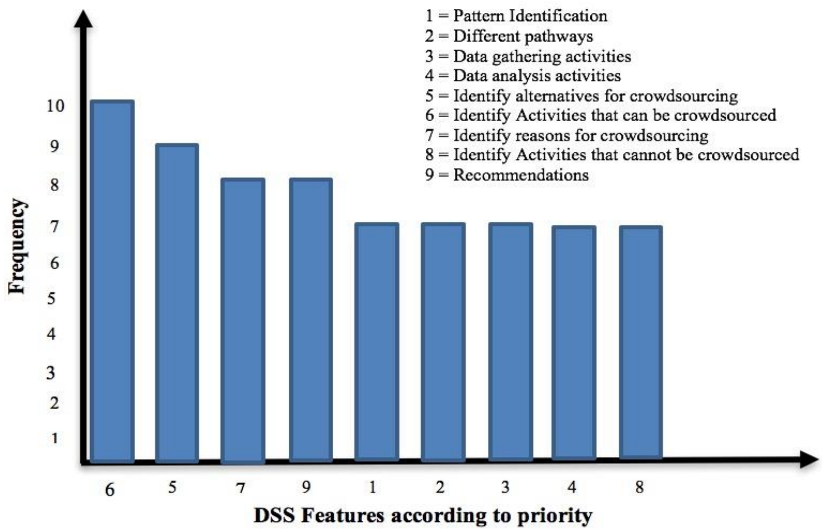

Figure 6: Frequency distribution of DSS features prioritized by the participants

4.1.5 Feedback from the interviews

The participants responded positively to the card sorting exercises. The first exercise in particular was an eye opener to some as they were not so familiar with the theory testing steps. Most of the participants said they have been overly exposed to theory building concepts, both in the literature they have read and the classes that have taken during their Ph.D. studies. However, theory testing has not been that prominent, even though they realised that it is important. In that context, the participants perceived that a tool illustrating how different theory testing activities could be related to a particular intent would be useful.

A lot of positive feedback was received from the participants about the card sorting exercises. They particularly liked the way of prioritising features they would like to see in the DSS. The card sorting exercises were also found to be effective to compare their thoughts with the conceptual framework.

5 Discussion and Conclusions

To the best of our knowledge, no DSS is currently available to help Ph.D. students making decisions about their theory testing endeavours, especially considering how to integrate the CS strategy in the process. This paper describes first steps in that direction and therefore represents a true innovation.

This paper also describes and justifies with significant detail the steps leading to the DSS. Our method uses the design science paradigm and Schön's (1983) problem/solution framing. We believe the two perspectives are very synergetic. On the one hand, design science emphasises the combination of rigour and relevance in the development of IS artefacts. On the other hand, Schön's viewpoint integrates design decisions into IS artefacts. Bringing them together, we completely scaffold the development of the conceptual framework and model. The framework is very important, as it provides a solid frame for the DSS: the framework is based on relevant literature about theory building, which integrates aspects of theory testing. The model not only builds upon the conceptual framework, but it also integrates elements from a comprehensive scoping literature review. Seen together, the two artefacts are logically related and solidly established in the related literature.

Our integration of the DSR build/evaluate cycle and Schön's problem/solution framing, has also been extended to evaluation, through problem frame assessment. Instead of evaluating the IS artefact against its users, we evaluated our problem frame against the users. This approach seems very adequate to evaluate secondary artefacts, as it provides justificative knowledge necessary to later on develop the DSS. This approach does not preclude adopting a more summative approach to evaluate the DSS. Instead, it contributes to support the DSS development on a realistic foundation, which takes both users and designers into consideration.

The problem frame assessment revealed that, even though PhD students were knowledgeable about theory building, they were not familiar with theory testing. The PFA also showed that PhD students were not aware of the variety of patterns that can be used to test theory. They also seemed to be unaware of the diversity of theory testing activities that can be CS. All in all, these results suggest the conceptual framework and model constitute a solid foundation for developing the DSS in the future.

Regarding the present, we note this research already brings some interesting contributions. One is highlighting that PhD students may be currently underexposed to theory testing, when compared to theory building. Another important contribution is the identification of a variety of patterns that can be used for theory testing, along with the identification of a set of activities that can be CS. Both the conceptual framework and model developed by this research may contribute to increase the attention to theory testing as a phenomenon of interest. The integration of theory testing with CS may increase attention to this strategy in research design.

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