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# Conceptual Analysis of Interdisciplinary Scientific Work

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**Abstract.** The main advantage to interdisciplinary professional practice is that it can produce novel product designs and problem solutions. However, it requires knowledge sharing and integration to leverage this potential. This paper reports on a study with a method of conceptual analysis to elicit, analyse and compare conceptual models used by individual researchers, with the ultimate aim to facilitate researchers in sharing and integrating their conceptual notions. We build on an earlier study by extending an existing conceptual model with conceptual notions from two additional researchers from an interdisciplinary research project. The results of the present study suggest that the time costs of adding more information to the existing model diminish with each addition to the existing model, and that the method of conceptual analysis can validly represent researchers' conceptual notions. Furthermore, our results offer some indication that conceptual analysis can reduce transaction costs related to grounding.

**Keywords.** Conceptual analysis, interdisciplinary research, knowledge sharing, knowledge integration.

## 1 Introduction

The main advantage to interdisciplinary professional practice is that it can bring together multiple disciplinary and domain perspectives to produce novel product designs and problem solutions [1]. It requires knowledge sharing and integration to leverage this potential. Researchers and practitioners from different disciplines have therefore sought to facilitate such knowledge sharing and integration. In the social sciences, researchers have stressed the importance of knowledge being implicit, 'sticky', and difficult to formalise [2]. In this view, learning occurs through what is called "the legitimate peripheral participation of individuals in groups" [3], and knowledge is seen as situated and socially constructed [4]. In the information sciences, researchers have emphasised the potential of systems that make codified knowledge ubiquitously accessible as information with well-defined semantics [5]. In this view, people learn from each other by exchanging information, and knowledge takes the form of explicit, externally available information [6].

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Although these views seem to present a choice [7], we believe that the characteristics of interdisciplinary scientific practice call for an attempt at synthesis. First, scientific practice is a social endeavour and the resulting theories and paradigms have been shown to be social constructs [8], the meaning of which is negotiated [9]. Second, in science there are explicit rewards on knowledge sharing. For instance, scientists are increasingly judged by their yearly number of publications and their citation indices [10]. In fact, *not* sharing knowledge is frowned upon, and knowledge externalisation is explicitly rewarded [11]. Third, scientific knowledge is particularly formalised in comparison with other fields of profession [12]. Science uses definitions, theories, conceptual models and even formal models to capture knowledge, and the scientific method involves formal validity criteria, such as replicability of experiments and reproducibility of results [13].

Knowledge in scientific practice thus is socially constructed meaning, but also characterised by a high degree of explicitness (on account of rewards for sharing), and a high degree of formalisation (on account of generally accepted methodological principles). The method of conceptual analysis we put forward in this paper should therefore combines elements from both the social sciences perspective and the information sciences perspective. It focuses on the conceptual models underlying scientific work. It aims to uncover the concepts that are necessary to describe a researcher's disciplinary knowledge and how these concepts are related (cf. [14, 15]). This produces a highly explicit account of a researcher's knowledge that allows him/her to reflect on it and compare it with / relate it to the knowledge of other researchers, thus affording knowledge sharing and integration.

The method we propose, in particular the construction of an overarching conceptual model that it involves, may give the impression that we believe that disciplinary differences can be resolved by unification of knowledge in a single 'true' model of reality. This is not the point we want to make. The conceptual analysis should be seen as a hermeneutic activity in the spirit of Gadamer (see e.g. [16]), and the models it produces as a trigger for researchers to partake in such an activity and as a means to facilitate them in gaining an understanding of the languages other researchers use.

In a previous paper [17], we reported on an exploratory study in which we performed a first test of our method in the context of a multidisciplinary research project. In that study, the method was found to be effective in eliciting concepts, also those used implicitly. In addition, interview data revealed certain strategies and mechanisms by which researchers adopt new concepts and choose terms. However, the analysis costs were very high, while the benefits remained uncertain. In this paper we report on a follow-up study within the same research project, involving conceptual analysis of the work of two additional researchers. The aims of this follow-up study were (1) to extend the initial conceptual model derived in the previous study, (2) to fine-tune our procedure so as to make it less labour- and time-intensive, while preserving its validity, and (3) to reflect on the viability of the method.

We have structured our report as follows. We start by arguing why we believe that conceptual analysis has good potential to support interdisciplinary knowledge construction. We then describe our method in a formal way as well as on a more practical level. Next, we describe some selected results, permitting ourselves a few illustrative examples while focusing on those observations that reveal certain

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problems that seem inherent to the method. In the final section, we summarise our findings and draw some tentative conclusions.

## 2 Facilitating interdisciplinary knowledge construction

We realise that when writing about conceptual analysis, our own concepts must be clear. We define a '*multi*disciplinary research project' as a project in which at least two researchers *a* and *b*, with knowledge and skills particular to different disciplines A and B, participate with the objective of producing *new* scientific knowledge *k*. Assuming that *a* and *b* are individually capable of producing new knowledge $K_A$ and $K_B$, their project becomes *inter*disciplinary only when *k* is such that $k \notin K_A \cup K_B$, that is, that *k* could not have been produced within disciplines A or B alone.

New, interdisciplinary knowledge *k* comes about by induction from empirical observation when researchers *a* and *b* work on some empirical phenomenon that they cannot fully explain using concepts from A or B. It requires that both *a* and *b* (1) can meaningfully relate *k* to their respective disciplinary knowledge, (2) have sufficient understanding and awareness of each other's knowledge to be able to accept that *k* is related to both disciplines, and (3) agree that their understandings of *k* are similar enough for their current purposes of collaboration (cf. [18]). In other words, they need to negotiate some *common ground* as to the meaning of *k* and its relation to their respective disciplines.

Such 'grounding' processes have high transaction costs, that is, they require much time and effort from researchers, resources that can be allocated more efficiently to mono-disciplinary research. Empirical studies of interdisciplinary research [19, 20] show that the incentive structures in the present institutional context impede interdisciplinarity. While these structures remain, we should try to lower the transaction costs of 'grounding'. We believe that conceptual analysis may help to achieve this.

Conceptual analysis of domains A and B produces a set of definitions that affords researchers *a* and *b* more explicit knowledge about their own disciplinary knowledge and about how the concepts in A and B do (and do not) relate to each other. It enables them to exchange knowledge without the need for a "globally shared theory" [21]. To achieve common ground, *a* and *b* must each discover what they have in common (i.e., $A \cap B$) and extend their 'language' to A+C and B+C where C consists of the concepts needed to better understand the empirical phenomenon they investigate. We expect that conceptual analysis will lower

- the cost of discovering $A \cap B$ because the results of a conceptual analysis of A and B are explicit and can be re-used when other researchers from A and B engage in interdisciplinary research
- the cost of negotiating the concepts in C because the process of conceptual analysis provides focus and rigour to the grounding process, which leads to a concise and unambiguous set C that is easier to relate to the concepts in A and B, especially when these also have been rendered concise and unambiguous

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- the cost of mutual misunderstandings due to homonyms and synonyms in the discourses of *a* and *b* [22], which, when undetected at first, may pose much difficulty later [23].

Our aim is to offer researchers in interdisciplinary teams explicit information about the relation between their and others' knowledge by enabling meaningful conceptual comparisons while avoiding labour-intensive group negotiations. Our first study [17] showed that conceptual analysis is a valid means to this end, but also suggested that our method would be too time-consuming to be adequate. In the follow-up study we therefore wished to address these questions in particular:

1. Do the marginal costs of conceptual analysis diminish for every additional researcher included in the analysis?
2. Does the structure of scientific articles permit selective reading without loss of validity of the conceptual analysis?

## 3 Methodology

To be able to precisely describe our methodology for this follow-up study, we first define our method of conceptual analysis. We will then outline the empirical context and the more specific methods we used in our data collection and analysis.

### 3.1 Conceptual Analysis

A conceptual model is defined as a 3-tuple M = (C, R, Q) where C is a set of concept types, R a set of relation types between these concept types, and Q the set of question types that can be answered using M. The analysts aim to conceptually model the knowledge that is generated and/or used by the participants $P = (p_1, \ldots, p_n\}$. To that end they peruse the scientific articles produced by each person $p_i$ and codify the knowledge it contains in n separate conceptual models. Ideally, for each of these models $M_i = (C_i, R_i, Q_i)$,

- $C_i$ contains all concept types used (explicitly or implicitly) by researcher $p_i$
- $R_i$ contains all relation types between these concept types (i.e., of the type $r \subset C_i^j$ for some $j \geq 2$) used (explicitly or explicitly) by researcher $p_i$
- $Q_i$ contains the questions that researcher $p_i$ seeks to answer, expressed (insofar as possible) in terms of elements of $C_i$ and $R_i$

The analysts also construct a conceptual model $\mathbf{M} = (\mathbf{C}, \mathbf{R}, \mathbf{Q})$ that can be conceived of as the 'master model', because for all i, $C_i \subseteq \mathbf{C}$ and $R_i \subseteq \mathbf{R}$. The sets in $\mathbf{M}$ will necessarily be larger than the union of their respective subsets in the models $M_i$ because the 'master model' should answer questions that are typically not posed by the individual researchers, so the analysts will have to define additional relation types (notably to represent incompatibility) and possibly additional concept types as well

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(for example, to explicitly represent the researchers and their disciplinary perspective).

The analysis process involves a series of operations performed by analysts:

1. Select the set of researchers P
2. For each $p_i \in P$, select a set $A_{pi}$ of scientific articles (co-)authored by $p_i$ and relevant to the interdisciplinary research project under study
3. Initialise the 'master model' **M**. Note that this need not imply that **M** = (∅, ∅, ∅), because **C**, **R** and **Q** will at the onset contain the generic concepts, relations and questions that are used by analysts (notably the methodological concepts, such as 'researcher', 'concept', and 'relation')
4. Initialise the conceptual model for each researcher, which here does imply that $M_i = (\emptyset, \emptyset, \emptyset)$ for i = 1..n

Then iterate over the following five steps:

5. Select and peruse a scientific article $a \in A_{pi}$, searching for potential concepts
6. For each potential concept, determine whether there is a corresponding $c \in C_i$. If not, determine whether there is a corresponding c ∈ **C**. If not, add c to **C**. Add c to $C_i$
7. Peruse article a in search for relations involving c
8. For each relation, determine whether there is a corresponding $r \in R_i$. If not, determine whether there is a corresponding r ∈ **R**. If not, add r to **R**. Add r to $R_i$
9. Periodically check whether $M_i$ is coherent. If it is not, see if an explanation can be found (implicit concepts and relations? poor line of argument?)
10. Peruse article a in search for research questions q. If needed, rephrase q in terms of C and R. Determine whether there is a corresponding $q \in Q_i$. If not, determine whether there is a corresponding q ∈ **Q**. If not, add q to **Q**. Add q to $Q_i$

The main challenge for the analysts is to define the elements of **C** and **R**. The analysts must not only develop an adequate understanding of the concepts and relations used (explicitly or implicitly) by the researchers involved, but also resolve the problem of homonyms and synonyms, choosing words to define the elements of **C** and **R** in such a way that

- the elements of **C** and **R** allow valid representation of *all* concepts and relations used by the researchers involved (completeness);
- the definitions can be understood not only by the analysts, but also by the researchers $p_i$ and permit them to validate 'their' model $M_i$ (comprehensibility); and
- **C** and **R** do not contain more elements than necessary to achieve the previous two goals (parsimony).

### 3.2 Empirical context

**Project.** Our research is part of the Next Generation Infrastructures program (NGI, see http://www.nginfra.nl), an international, multi-university, interdisciplinary research effort that comprises projects in fields ranging from applied mathematics to philosophy of technology, and from information sciences to spatial planning. The NGI program focuses on infrastructures for energy supply, transport, telecom-

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munications, and water: large-scale socio-technical systems of high and increasing societal and economic importance.

**Participants.** The four junior researchers P1, ..., P4 that took part in our research all work on the Understanding Complex Networks theme of the NGI project. P1 investigates innovative methods for research, learning and intervention based on multi-actor simulation and gaming, P2 explores industrial ecology and agent-based simulation of infrastructure development, P3 studies the use of distributed energy generation with micro-combined-heat-and-power generators as an alternative to classic, centralised electricity generation in power plants, with the aim to increase energy efficiency, and P4 uses game-theoretical insights to mathematically analyse tolling strategies to alleviate traffic congestion.

**Articles used in the analysis.** We asked the participants for their recent writings pertaining to their NGI project. This yielded three conference papers for P1, four conference papers and a book chapter in preparation for P2, seven conference papers for P3, and six conference papers and an unsubmitted manuscript for P4. These writings of the participants served as data for our analysis.

**Models.** In our first study [17], we used the writings of P1 and P2 to construct 'their' conceptual models $M_1$ and $M_2$, and the encompassing master model M. In the follow-up study we report in this paper, we constructed the conceptual models $M_3$ and $M_4$ and updated the master model M.

### 3.3 Practical methods

The previous section covers operations 1 through 4 of our method of conceptual analysis. To perform operations 5 through 9 we qualitatively analysed the participants' writings using open coding (cf. [24, 25]). Rather than coding excerpts directly as concepts, relations or questions, we first classified them according to a small set of content type categories [17]:

1. Real-world Notions: Statements that refer to abstract and / or concrete aspects of what the researcher considers as the real world
2. Model-world Notions: Statements that refer to formal or informal representations of such real-world notions
3. Techniques: Statements about a modelling technique used by the researcher
4. Model: Statements about the model used and / or developed by the researcher
5. Real-world Questions and Aims: Research questions and aims pertaining to the real-world
6. Model-world Questions and Aims: Research questions and aims pertaining to scientific theory
7. Case: Statements about a research case or research client.

The excerpt categories were then analysed in search for concepts c, relations between concepts r, and / or research questions / aims q. The meaning inferred from the

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excerpts pertaining to a new element was recorded in one or more short phrases. Together, the summaries of all excerpts thus define the elements $C_i$, $R_i$ and $Q_i$.

To test the validity of these summaries, the first author conducted a semi-structured interview with each participant. The analyst informed the participant in general terms about the approach that had been taken for the content analysis, paying special attention to the categories that were used to structure the data. During the interview, the analyst read aloud the category summaries for the participant's research. Three questions were repeatedly asked throughout the interview:

1. Is there anything in the summary that is unclear to you?
2. To what extent does the summary match your research:
   a. Does the summary contain elements that are not part of your research? And if so, which?
   b. Does your research contain elements that are not part of the summary? And if so, which?
   c. Does the summary contain errors? And if so, which?
3. Do you have any further comments on the summaries?

The first question aimed to get any problems in understanding out of the way. The second question focused on whether the summaries (a) contained misinterpretations, (b) were complete, and/or (c) contained errors. The third question was aimed at improving the summaries.

### 3.4 Differences in Procedure between the Studies

In the original study, all articles were read and categorised in their entirety, and each category was analysed for the presence of new concepts. On the one hand, this procedure is very reliable in the sense that the chances of missing conceptual information are very low, and therefore it yielded valid results. However, it also required reading and analysing redundant material, and the associated time costs were high. In the present study, we did not categorise all writings, nor did we analyse all categories. Instead, we used a strategy of selective reading: we only categorised an excerpt if it did not contain redundant material, and we only analysed excerpts in the real-world notions and model-world notions categories, because we expected the other categories not to contain additional concepts. These alterations were expected to result in less time costs, but also to incur a risk of lower validity.

## 4 Results

The study reported is a small-scale test of our method of conceptual analysis. We carried out all the steps necessary to complete the analysis for researchers P3 and P4, and added this new data to the results obtained for P1 and P2. Reading the papers and summarising the data cost about one week, which amounts to one third of the time in the first study, for the same number of researchers. A detailed presentation and discussion of the resulting models $M_3$, $M_4$ and the extended master model $\mathbf{M}$ are beyond the scope of this paper. Instead, we wish to give the reader an idea of the type

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of results the analysis yields, and we present some aspects of the validity of the procedure

### 4.1 Extending the Master model

The most important difference between the present study and the previous one is that the initial model **M** was not empty, but instead already contained the concepts from the first analysis [17]. If indeed model convergence takes place, then concepts identified in the previous study should be usable in the present analysis. To show that this was the case we use a subset of the previous analysis, which contains definitions of a number of concepts regarding systems (see Table 1).

The analysis showed that, in total, about 35% of the concepts in $M_3$ and $M_4$ were already present in **M**. Using systems-related concepts as an example, P3 uses the concepts “system” “subsystem,” “system state,” “system change,” “technical system,” “social system” and “socio-technical system” in his work. In the specific case at hand, all those similar concepts already present in **M** can be used to fill $M_3$. Of the concepts in table 1, P4 only used “system”, so **M** was less useful for describing P4’s convictions related to systems. Nevertheless, the data show that concepts from earlier, related conceptual analysis efforts can be used to partially fill conceptual models of additional researchers. Thus, one is spared the effort of starting from scratch with every new topic that an additional researcher brings in.

**Table 1.** Excerpt from the Original Master Model

| Concept | Definition |
|---|---|
| System | A bounded, coherent part of reality consisting of elements within an external environment |
| System environment | The part of reality outside the system that can influence the system |
| Subsystem | S1 is a subsystem of S0 when the system elements of S1 are a subset of the system elements of S0 and they are structured the same way |
| System structure | The system elements and the (type of) relations that exist between them |
| System state | The system at some moment in time |
| System change | The difference between the state of system S at some moment in time t1 and the state of S at some previous moment in time t0 |
| Artefact | Some thing that is the product of human action, dividable into physical artefacts and social artefacts |
| Natural system | A system that does not contain any artefacts |
| Technical system | A system that contains at least one physical artefact |
| Social system | A system that contains at least one social artefact |
| Socio-technical system | System consisting of at least one technical system and one social system that are mutually influencing each other, i.e., their respective system boundaries have common elements |

The analysis of the writings of P3 enabled us to elaborate on the notion socio-technical systems, by introducing the notions of institutional domain and economic domain as aspects of the notion of social system. This means that an existing model

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**M** can be used as a source of conceptual definitions to begin describing the convictions of an additional researcher. Also, the model $M_3$ could next be used to extend and improve upon **M**. For instance, from $M_3$ additional concepts about systems were added to **M**. To name a few:

- "system level" – a subsystem that relates hierarchically to other subsystems;
- "system heterogeneity" – the extent to which a system consists of parts that are mutually different;
- "system organisation" – the way the various subsystems relate to each other; and
- "hierarchy" – example of system organisation in which decisions taken in one subsystem (higher level) can impose rules on another subsystem (lower level).

The analysis also yielded two homonyms that were present both in **M** and in $M_3$, but had different meanings. One example was "emergence", as the following dialogue between analyst (A) and participant (P3) shows:

> A: "Emergence means that system behaviour can not be directly deduced from the behaviour of the different parts of the system."
> P3: "That concept of emergent behaviour is not so clear in different stories. . . . . Some say that emergence is nothing more than a question of adding things; that is just deductivist, reductionist, . . . others bring in a lot of higher stuff, and in between those there are lots of other variants. . . . . You might say that the market price comes about through emergent behaviour of the economy, but it still follows logically from what everybody's doing. So it follows directly from local behaviour."

From the interview data it appears that the participant's conception differs from the definition offered by the analyst, in that the participant assumes that the total behaviour of a system can be understood from the behaviour of the system's parts, whereas according to the definition in **M** it can not. For **M**, this means that the present definition of emergence had to be altered, and another had to be added, so both "versions" of emergence could be expressed with concepts in **M**.

In sum, concepts from **M** could be used to initialise the participants' models $M_3$ and $M_4$. Furthermore, the analysis of P3 and P4 could be used to enrich **M**. In some cases the analysis explicated conceptual tensions between participants, for instance, when one word appeared in both **M** and a participant's model, while still referring to different concepts in each of the models, tensions that the analyst then resolved by adding more fine-grained definitions with terms that resolved the homonyms.

### 4.2 Issues of Validity

Neither participant P3 nor P4 found any part of our summary of their writings unclear. Furthermore, neither summary contained elements that the participants thought did not belong there. Both participants made many additions throughout the interviews. However, these additions did put validity at issue, because either they could not have been drawn from the data, or they did not pertain to conceptual notions, for instance when a participant added information about results. This finding suggests that it indeed is sufficient to analyse only those excerpts coded real-world notions and

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model-world notions. In some cases, however, the participants did make corrections to the summaries proposed by the analyst.

The interview data contained several statements that are important with regard to the validity of our approach. First, there were two examples in the interview data in which a participant expressed ambiguity regarding a certain concept. In both cases, the concepts were important to the paper in which they were mentioned, but not essential to the participant's work. The first example is the relation between "complexity" and "interactivity":

P3: "[Interactivity] also changes the complexity of a system. Or perhaps it is more of an enabler for complexity. I'm not sure whether it then would be an aspect of complexity."

A: "So it is an aspect and not an enabler?"

P3: "If I'd have to choose then I'd say yes. But maybe you could just as well make a case for an enabling role. . . . It hasn't yet been necessary for me to make such choices."

From the interview data it appears that the participant's model-world notions have not fully matured, whereas related concepts are already present in his writings.

The second example was a case in which the information in the papers actually differed from the participant's convictions. At first it appeared that the analyst had misinterpreted the participant's work with regard to the meaning of the concept of multi-level decision-making. In the case of multi-level decision-making, decisions are made at two levels that are hierarchically related to each other. The decisions made on one system level influence the decisions made on another level. The analyst's interpretation was that the higher level constrained the decision space of the lower level, and thus that the influence was unidirectional. However, in the interview it became clear that in the participant's conception, the constraints on the decision spaces were mutual, and therefore not the criterion by which the different decision-making levels were distinguished. The actual difference is in power and authority:

P3: "The higher level has more power, more authority. That's why you define it as the higher level. . . . . The thing that matters is the power to decide about certain parameter-settings."

A: "That very precise difference [between constraints and authority to make decisions]. Did I gloss over that while reading your paper?"

P3: "You didn't miss that. . . . In a number of publications . . . I have formulated it in this way, as it has been written down in these papers. But I didn't look in the more fundamental work to find . . . what the formal characteristics of a multi-level decision-making exercise are."

A: "So my interpretation would be justified on the basis of what I have read?"

P3: "Yes."

Another phenomenon affecting validity was the occurrence of interpretational differences between analyst and participant. In some cases, it was clear that there was a conceptual difference in understanding between analyst and participant, which could not be explained by the data. One such case was the concept of "full information":

A: "[In your research,] different actors have different information, so nobody has full information."

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P4: "No, in the deterministic models everybody is assumed to have full information, while in the stochastic models . . . there is some random component which they don't know. . . . The travellers always have less information than the road authority." . . . .
A: "So full information then really means that they have all information they need for their decision."
P4: "Yes."

From the interview data, the analyst appears to assume that "full information" means access to all information available to all actors in a system, whereas the participant uses it in the sense that an actor has access to all information it needs in order to make a decision. The difference is that there is information in the system that some actors do not need. Imagine the case where an actor has all the information it needs to make a decision, but not all information available within the model. Initially, the analyst would have concluded that the actor did not have full information, whereas the participant would have concluded that it did.

In sum, the interview data yielded two ways in which validity might be negatively influenced by the procedure. First, participants included concepts in their papers while not having made final decisions regarding their meaning. It may thus be the case that in the data one conceptual conviction may be present, whereas the participant him/herself holds a different, or an additional conviction. Second, the interview data revealed cases where the analyst's interpretation of the data differed from the participant's intended meanings. These cases could only be identified with use of the interviews, and could not be derived from the data alone.

## 5 Conclusion and Discussion

Interdisciplinary scientific practice requires scholars with different disciplinary backgrounds to share and integrate their knowledge. To that end it is important that they have a correct understanding of each others' contributions. In this paper we have introduced a method for conceptual analysis, built on the assumption that eliciting the participants' conceptual models $M_1, \ldots, M_n$ and constructing a master model $\mathbf{M}$ can enhance this process. The master model $\mathbf{M}$ is expected to reduce transaction costs of grounding by making it easier to identify the concepts that are shared between researchers, and identifying which are potentially different. In this paper, we addressed two questions regarding the effects, validity and viability of the method.

1. Do the marginal costs of conceptual analysis diminish for every additional researcher included in the analysis?

With regard to the goal of reducing transaction costs due to grounding, the results lend some credence to the conclusion that conceptual analysis provides such reduction. This conclusion can be drawn from the fact that we used the master model $\mathbf{M}$ to initialise the participants' models $M_3$ and $M_4$, which enabled identification of differences and similarities between all models. In other words, comparison of a new conceptual model $M_i$ with the master model $\mathbf{M}$ can give insight in differences and

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similarities between the new model $M_i$ and *all* models that are represented in **M**. Without the use of **M** this would have had to be done via comparisons of $M_i$ with all other models $M_j$.

2. Does the structure of scientific articles permit selective reading without loss of validity of the conceptual analysis?

Our results indicated that it indeed is sufficient to analyse only those excerpts coded Real-world Notions and Model-world Notions. Although the participants did add information to the analysis, such additions did invalidate the method, because either they could not have been drawn from the data, or they did not pertain to conceptual notions. It seems that our strategy of selective reading did not lead to an under-representation of conceptual content. However, the interview data did yield two ways in which validity might be negatively influenced by the procedure. Participants included concepts in their papers while not having made final decisions regarding their meaning, and there were cases where the analyst's interpretation of the data differed from the participant's intended meanings. These cases could only be identified with use of the interviews, and could not be derived from the data alone.

Thus, the results show that even when the procedure is made less rigorous and time-consuming, it can still produce valid conceptual models from researchers' writings. However, it has also become clear that doing interviews should not only be included for validation purposes, but also to allow for corrections on the analysis. The interview data have indicated that unwarranted differences in interpretation may occur if no interviews are conducted. Therefore they must be included in the procedure, which will have the unfortunate side-effect of making it more time-consuming.

In sum, the present study has indicated that conceptual analysis can be used to validly identify a researcher's conceptual notions. Furthermore, the results suggest that only a small part of the total amount of data is actually needed in the analysis. This results in a reduction in time costs compared to our first study of conceptual analysis. However, the results also indicated that validatory interviews should be used to check, and in case of problems, modify the analysis. Although conceptual analysis initially takes some effort, this effort appears to diminish with every new researcher who's work is added to the analysis. This appeared to be due to convergence of the master model **M**: concepts that already exist in **M** can be used for initialising conceptual models of additional researchers. This latter result also indicates that conceptual analysis can reduce transaction costs related to grounding.

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