Concept Maps: Theory, Methodology, Technology
Proc. of the Fifth Int. Conference on Concept Mapping
Valletta, Malta 2012

BRIDGING THE GAP BETWEEN QUALITATIVE, EMPIRICAL WORK AND SOFTWARE DESIGN

Georg Weichhart, Johannes Kepler University, Linz, Austria
Email: Georg.Weichhart@jku.at

Abstract. Research in Business Information Systems includes empirical as well as design related activities. For gaining access to domain knowledge for building an Information System, we have developed a method guiding researchers from qualitative, empirical research to the identification of requirements for Software features. The method builds on expert interviews, communicative validation, concept mapping, and the method for constructing description systems. This article motivates the usage of the individual methods, and discusses its application in two projects. In the first project a (web based) information system in the domain of progressive education and e-learning is developed. In the second project a navigation concept for a website is developed.

1 Introduction

A research project, which aims at the provision of software functionality for end-users requires insight in the application domain. It is required to structure the domain around the elements supported by the system. This is particularly true in Business Information Systems research, where the overall goal, immanent present in this area, is to research a technical system and its impact on the overall social system (cf. Wührer et al., 2010).

The application domain of the project, which triggered the development of this method, is e-learning support for progressive education. In this domain only limited theoretical and existing work exists. That lead to the need for a method which serves the purpose of deriving a layer of abstraction, supporting the design of useful software features. The method discussed in the following has been designed to serve the need to identify empirically grounded functionality.

The paper is structured as follows. First the selection of a method for each step along the research process is motivated, and the selected method is described briefly. These methods are expert interviews, mapping, communicative evaluation, construction of descriptive systems. This is followed by describing the application of the described approach in two research project.

2 Combining Research Methods

In this section the use of certain methods is motivated, and the selected methods themselves are briefly described.

2.1 Expert Interviews

Sociology provides methods to get insight into a social system. In general approaches can be clustered in quantitative and qualitative methods. Quantitative methods need an initial understanding of the domain. In this case questionnaires are designed around concepts which try to classify empirical data along these concepts. Qualitative methods do not have this restriction, but provide researchers with more open approaches.

Within the research project which triggered the development of the given method, an initial literature analysis lead to the conclusion that scientific research in the domain of progressive education and e-learning is limited. That is particularly true when searching for literature about e-learning support for the “Dalton Plan” (Parkhurst 1923 2010). We where not able to identify concepts for classification, needed by quantitative approaches. Hence a concrete qualitative approach is needed to gain insight into e-learning and education using the Dalton Plan. Expert interviews allow to explore existing conceptualizations in a new field (Bogner and Menz 2002). In particular, expert interviews aim at making concepts and their structural relationships transparent, and allow to analyze these (Meuser and Nagel 2002).

When doing expert interviews it is necessary to guide and structure the interviews, but still allow experts to detail matters along their own mental models. It is necessary to create an interview guideline which allows the researcher to to set the focus of the interviews to match the research question (Bogner and Menz 2002).

2.2 Mapping Techniques

Qualitative methods in general aim at providing abstract descriptions for gaining more general insight into the researched domain. For deriving software functionality additional requirements need to be fulfilled. A clear abstraction and systemic overview of the domain, centered around research goals, is required in order to be able to derive a set features that support users in this domain.

The above-discussed empirical method, is used to elicitate knowledge about the domain as communicated by experts. For building a common, consistent model based on diverse world views (or mental models), a higher level of abstraction is needed. An understanding of the individual knowledge needs to be gained and transferred into a single model. For both, graphical representations are particularly helpful (Bortz and Döring 2002). Models with graphical representations convey important concepts and their relationships in an accessible manner. Such models are more easily to follow than written descriptions (Davies 2010). Additionally the very explicit structure of knowledge facilitates the communication between researcher and expert. This is of importance for the validation of the documented knowledge by the expert her/himself.

To be able to select the most appropriate graphical representation we defined the following properties to evaluate individual approaches (see table below). However, as the overall goal is to make use of one of these methods, and not find objective strengths and weaknesses for the general case, the level of detail of the method's properties is limited. The evaluated methods and the evaluation results are also given in the table below. For evaluation we considered Unified Modeling Language "Use Case" Diagrams (cf. Génova et al 2005), Argument Maps (cf. Davies 2010), Mind Maps (cf. Davies 2010), Knowledge Maps (cf. O'Donnell et al., 2002), Concept Maps (cf. Novak und Cañas, 2008).

Graphical Representation: Graphical models facilitate knowledge transfers.				
UML Use Case	Argument Maps	Mind Maps	Knowledge Maps	Concept Maps
on a high, abstract level	Relationships between arguments are graphically shown	yes	yes	yes
Concise Representation of Knowledge: To facilitate the transformation process of putting knowledge structures into software, the approach needs to enable modeling of knowledge in a semi-formal way.				
UML Use Case	Argument Maps	Mind Maps	Knowledge Maps	Concept Maps
No: Use Case Diagrams are often vague	Yes: Mental models are represented as arguments	No: Its not possible to name relationships between Ideas	Yes/No: Restricted to given relationship types	Yes: It allows to depict individual knowledge structures
Representation of Complexity: To facilitate understanding by the researcher the approach needs to facilitate knowledge transfer about complex systems from the research subject to the researcher.				
UML Use Case	Argument Maps	Mind Maps	Knowledge Maps	Concept Maps
No: No possibility to model complex relationships	No: generic relationships are not modeled	No: The hierarchical nature does not allow to show complex relationships	No: constrained by the types of relationships	Yes: Concepts and Propositions allow representation of complexity
Simple use (and tool support): To allow domain experts to participate in the process and support understanding and validation of models, created by the researcher, it is necessary to find a method that requires no prior knowledge by the domain experts. Furthermore, for efficiency reasons, tool support is desirable.				
UML Use Case	Argument Maps	Mind Maps	Knowledge Maps	Concept Maps
yes	No: Its not possible to model generic knowledge	yes	Yes/No: Types of relationships are restricted	Yes: In general Concept Maps are easy to read. Its not always easy to model propositions

Table 1. Evaluation of graphical methods for transferring knowledge

Having analyzed the different approaches "Concept Maps" following Novak et al. (2008) are most suited for the intended use of a graphical representation in the overall researched approach.

2.3 Communicative Validation

The major criteria for understanding the quality of qualitative, empirical research are the validity of the results (Bortz and Döring 2002, Mayring 2002). Interpersonal consensus building is an important approach for determining the validity of research results. One concrete approach for this is the communicative validation method, which supports consensus building between researcher and research subject (the experts).

The communicate validation approach highlights the importance of the experts in the overall process as active agents (Mayring 2002). This method will be used to validate the documented results of each individual interview with the expert that took part in that interview.

2.4 Construction of Descriptive Systems

The validated Concept Maps show individual, subjective views. To be able to implement Software based on these views, concepts and propositions need to grouped and clustered to create an overall model. These clusters combine the context and requirements from each expert's point of view. For doing this a qualitative content analysis approach is needed. Here a method called “constructing descriptive systems” (Mayring 2002) is applied. It is a qualitative method on the border between analysis and interpretation.

Content to be analyzed (Concept Maps in this particular case), is arranged within a classification system. Guided by theory, researchers determine a research object's relevant dimensions and categories along these dimensions. The content is analyzed if its elements can be assigned distinctly to a unique category. If this is not possible, the dimensions and categories need to be redesigned. The category system is then applied again on the content. This method establishes a circle with categories determined by theory and emerging from the content.

3 Application of the method

The above-described method has been used within two research projects. In both cases it has been necessary to gather and structure knowledge from experts in order to understand the requirements on the information system.

3.1 E-learning support based on the dalton plan

Research about the implementation of the “Dalton Plan” (Parkhurst 1924) educational approach in e-learning is limited. The above described method has been applied in a research project to understand the requirements and implement e-learning support this setting and results exemplify its usability and usefulness for researching requirements for an e-learning environment supporting the Dalton Plan approach.

For the expert interviews guidelines along the overall research questions have been created. The interviews have been audio recorded and using these records, we have created concept maps following the approach of Novak and Cañas (2008). In order to validate each map, it has been send to the expert and changes to the map have been discussed. The maps have been then been updated to reflect these changes. At this point validated individual views on the research topic are documented.

In the following step the individual maps are aggregated and merged using the “construction of descriptive systems” method (Mayring 2002). This method requires first the determination of the research object and then deriving from literature relevant categories along multiple dimensions. This has happened on beforehand during the initial project phase where the research goals have been created. The same goals have been used to guide the design of the interview guideline. Hence a lot of the concepts and propositions could be assigned to the theoretically established categories. However, during an initial analysis of the content, more categories have emerged from the analysis. In this step concept maps are the content analyzed, but did not help to guide the overall process. The clustering of propositions along multiple categories, established a sound basis for requirements engineering. For each category a separate concept map was created with all concepts and propositions assigned to that category. For the software developer this established a view with all propositions for each software functionality. For determining the context in which a functionality is used, the original interview maps may be used.

A quantitative analysis of concepts assigned to a concrete cluster revealed which expert has contributed to that category to which extend. The different number of contributions was easily explained when looking at the background of the experts.

3.2 Navigation Structure for a web site

In the second project, a navigation structure for a website was researched. The experts in this case, have been typical users of that site. In the initial phase the maintainer of the site provided research goals. Different web sites with similar content have been analyzed for deriving details for the creation of the interview guidelines and the theory driven clusters for the "construction of descriptive systems" method. In this project the maps have been constructed on the spot by the researcher and the expert using paper cards on a brown paper. On that paper links have been drawn. As the experts participated directly in the creation of the maps, no validation was necessary. The research goals (as categories) have been applied to the maps. Again new categories emerged from the maps. After a few rounds it was possible to assign each concept and also propositions to a unique category. The documented work provided the requirements for the overall structure of the web-site. It clearly showed links between categories of pages to other categories of pages. For the developer, the concept maps provide an easily accessible documentation of the user's requirements.

4 Conclusions

In this article we described a method, combining existing methods, in order to provide transparent research process. Concept Mapping has been valuable for documenting individual steps and transfer knowledge gathered from experts to software engineers. Starting with research goals, interview guidelines have been created. The interviews have been documented as concept maps. The maps provide a higher level of abstraction helpful which showed to be helpful. Based on individual views, an overall model and requirements for software functionality implementing the research goals has been created using the method form the domain of qualitative content analysis. The resulting concept maps enable software design, by making the context of a SW module transparent.

Training independent researchers for using the above-described method was easy, even if no prior knowledge on the individual methods existed. The intermediate results where transparent and an easily to follow knowledge flow was established by the method.

5 References

Bogner, A. & Menz, W. (2002). Das theoriegenerierende Experteninterview - Erkenntnisinteresse, Wissensformen, Interaktion. In *Das Experteninterview - Theorie, Methode, Anwendung*, Leske + Budrich, 33 - 70

Bortz, J. & Döring, N. (2002). F*orschungsmethoden und Evaluation: für Human- und Sozialwissenschaftler. Springer-Verlag*, Berlin, Heidelberg, 3, 830

Davies, M. (2010). Concept mapping, mind mapping and argument mapping: what are the differences and do they matter? *Higher Education*, Springer Netherlands, 1-23

Génova, G.; Llorens, J.; Metz, P.; Prieto-Díaz, R. & Astudillo, H. Nunes, N.; Selic, B.; Rodrigues da Silva, A. & Toval Alvarez, A. (Eds.) (2005). *Open Issues in Industrial Use Case Modeling UML Modeling Languages and Applications.* Springer Berlin / Heidelberg, 3297, 52-61

Mayring, P. (2002). *Einführung in die Qualitative Sozialforschung*. Beltz Studium, 170

Meuser, M. & Nagel, U. (2002). ExpertInneninterviews - vielfach erpropt, wenig bedacht - Ein Beitrag zur qualitativen Methodendiskussion. In *Das Experteninterview - Theorie, Methode, Anwendung.* Leske + Budrich, 71 - 93

Novak, J. D. & Cañas, A. J. (2008). The Theory Underlying Concept Maps and How to Construct and Use Them. Florida Institute for Human and Machine Cognition (IHMC)

O'Donnell, A. M.; Dansereau, D. F. & Hall, R. H. (2002). Knowledge Maps as Scaffolds for Cognitive Processing. *Educational Psychology Review*, 14, 71-86

Parkhurst, H. (1923, 2010). *Education On The Dalton Plan.* Nabu Press

Wührer, G. A.; Schrefl, M.; Pomberger, G.; Roithmayr, F. & Stary, C. (2010). Antrag des Fachbereichs Wirtschaftsinformatik der Johannes Kepler Universität Linz auf Akkreditierung der Studienrichtungen 'Bachelor Wirtschaftsinformatik' und 'Master Wirtschaftsinformatik'