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MEASURING APPLICATION DOMAIN KNOWLEDGE: RESULTS FROM A PRELIMINARY EXPERIMENT

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Completed Research Paper

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Abstract

Conceptual models are used in IS development for capturing and specifying requirements. However, the mere understanding of the syntax or semantics of a modeling language is not the most crucial factor. More relevant is pragmatic knowledge about the application domain. The problem that this paper addresses is how one can verify that a shared understanding of the application domain exists. In our study we show that domain-specific languages are an indicator for separating novices from experts in a given application domain. Novices and experts can be distinguished based on the domain-specific language they use. We demonstrate that these different language communities can be observed empirically by employing latent semantic analysis (LSA) as an instrument and by measuring semantic similarity. The separation of groups using LSA is also possible if the terminology, the application domain, or the expert-layperson-status of the examined group are unknown. Therefore the separation based on domain-specific languages is independent of the domain under consideration or the prior knowledge of the researcher. This provides a useful measurement instrument for studying the role of application domain knowledge in future research.

Keywords: Domain knowledge, Communication, Conceptual modeling, Language, Laboratory experiment

Introduction

Information systems development is a social process involving users, systems analysts, and developers, carried out in an organizational setting (Hirschheim et al. 1995; Newman and Robey 1992; Newman and Robey 1996; Truex et al. 1999). Information systems (IS) research and related fields provide a vast body of knowledge on structuring and specifying different aspects of the IS development (ISD) process (Hirschheim et al. 1995; Iivari et al. 2004). Besides, the literatures on software and requirements engineering propose many methods and approaches for analyzing, specifying, and designing IS (e. g., Davis 1990; Dreiling et al. 2006; Fichman and Kemerer 1993; Galliers and Swan 2000; Kavakli and Loucopoulos 2005; Morrison and George 1995). In this context *conceptual models* are widely used for different purposes, including the development, acquisition, adoption, standardization and integration of IS (Maier 1999). Diagrams and (semi-) formal graphical models, for example, are intensively used by software engineers, system analysts or business process engineers for specifying requirements of new or changing applications and business processes (Davies et al. 2006).

Conceptual modelling is commonly considered to be an important instrument for analyzing and solving several technical and organizational design issues at the level of IS, enterprises, or industries (Falkenberg et al. 1998; Moody 2005). Conceptual models are used to describe the problems of users or stakeholders with concepts that are commonly used by them. The development of conceptual modeling was driven by the need to represent conceptual knowledge in a form that is adequate to the task at hand, comprehensible for all parties involved in the development of an IS and use of these representations, and independent from the eventual technical realization of the representation (Wyssusek 2006). Accordingly Wand and Weber (2002) claim that conceptual models are designed for at least three different purposes:

(1) *Supporting communication between developers and users*: if the stakeholders involved from both business and IT staff can work collaboratively on specifications of IS, using the same conceptual modelling method for communication, it is a reasonable assumption that the requirements engineering during ISD can be simplified (Gemino and Wand 2004). It has been argued that the use of conceptual models facilitates communication between stakeholders (Falkenberg et al. 1998; Wand and Weber 1995; Wieringa 1989).

(2) *Helping analysts to understand a domain*: a shared domain knowledge between business and IT staff positively influences an improved alignment of business and IT objectives, and thus enhances the quality of IS (Reich and Benbasat 2000; Tan 1994). It is generally assumed that graphical presentation improves comprehension (Card et al. 1999; Nassi and Shneiderman 1973). However, it has also been shown that graphic displays are not always easily understood and require learning and expertise (Nordbotten and Crosby 1999; Petre 1995).

(3) *Providing input to system design*: in order to develop and to control high quality applications, business requirements need to be identified and modelled from a business perspective (Jarke et al. 2009; Sommerville and Sawyer 2003). Afterwards, an application system can subsequently be implemented according to these specifications or even, as some authors in the field of model-driven development claim, an application system can be build mostly automatically based on the models (Arlow and Neustadt 2004; Dreiling et al. 2008; Frankel 2003).

For example, all three purposes are visible in business process modelling, where a process model is typically a graphical depiction of the activities, events/states and control flow logic (Curtis et al. 1992). Firstly, these conceptual models are used to increase awareness and knowledge of business processes (e. g., Kettinger and Teng 1997; Laguna and Marklund 2005). Secondly, the models are applied for capturing requirements and for discussing business processes with all relevant stakeholders by using graphical languages such as the Business Process Modelling Notation (BPMN, OMG 2009). Thirdly, the models are used as workflow specifications for process automation, for example, using more formal modelling notations such as Petri nets for capturing the process logic (e. g., Dreiling et al. 2006; van der Aalst and van Hee 2004).

There are some empirical studies that have already addressed and examined the role of conceptual modeling in ISD. Most of these explore and investigate the effects of modeling techniques, especially with regard to grammar, syntax and semantics of modeling notations (e. g., Bandara et al. 2005; Burton-Jones et al. 2009; Recker 2010; Recker et al. 2009; zur Muehlen and Recker 2008). Similarly, other research evaluates the ability of conceptual models to communicate meaning about a domain to analysts (e. g., Burton-Jones and Meso 2006; Gemino and Wand 2005; Khatri et al. 2006). Some approaches have been proposed for aiding modelers and supporting the modeling process (e. g., Bögl et al. 2008; Born et al. 2007; Delfmann et al. 2009; Ehrig et al. 2007; Greco et al. 2004; Höfferer 2007).

However, the mere understanding of the syntax, or even the specific semantics, of a specialised modelling language or grammar is not the most crucial factor in ISD. Khatri et al. (2006) found that schema-based problem-solving tasks performed better when *application domain knowledge* was present. Similarly, in a study by Burton-Jones and Weber (1999), individuals who knew the domain very well were not troubled by unclear conceptual models because they could use their prior knowledge to understand what the model was intended to show (see also Aguirre-Urreta and Marakas 2008). Consequently, more relevant are the unstated assumptions that reflect the shared ("common sense") knowledge of people familiar with the social, business and technical contexts within which the proposed system will operate (McDavid 1996; Ryan 1993).

Research should address these problems that are mostly related to pragmatics and knowledge about the application domain. For example, how can actors establish a common language that allows them to communicate in the first place, and how can a group of actors come to have "common knowledge"; that is, "they all know something and they also all know that they all know it" (Malone and Crowston 1994, pp. 99-100)? Ambiguities in language are clarified, not by logical analysis of syntax and semantics, but by looking at how the words or phrases in question are used in our daily activities and practices (Blair 2005; Blair 2006). Without addressing pragmatics, conceptual modelling is bound to fail to create the effects it strives for (Ågerfalk and Eriksson 2002; Ågerfalk and Eriksson 2004). The core of the problem is that the modeler or the modeling team needs to be both an expert in the modeling technique *and* the application domain. The remaining open question and the problem that we begin to address in this paper therefore are: *how we can verify that a shared understanding of the application domain exists? How can we create it where required?* So far, what has been missing is an empirical means to measure shared understanding or knowledge of the application domain. Therefore, as a first step, we report the results of an experiment that we carried out for addressing this issue.

The remainder of this paper is structured as follows. First we analyze related work on conceptual modeling and discuss the research gap concerning issues of pragmatics that led to the study we present in this paper. Afterwards we outline our research methodology. We suggest leveraging latent semantic analysis, a well-known approach from text analysis, for measuring application domain knowledge. The feasibility of our approach is shown exemplarily within a detailed experiment. After discussing the implications of our findings we finish the paper in a "Conclusions and Outlook" section and motivate further research.

Related Work

Following the authors of the FRISCO report (Falkenberg et al. 1998), the context of conceptual modelling can be expressed by a tetrahedron as a projection in the plane of the classical semiotic triangle and the different aspects of signs and their relationships (see Figure 1). Using this, we can visualize the semiotic categories involved in conceptual modelling (Hesse et al. 2008). The three corners of the triangle in Figure 1 stand for the *domain* of a sign (its *reference* or *pragmatic* aspect), the *conception* of a sign (its *meaning* or *semantic* aspect), and the *representation* of a sign (its *syntactic* aspect). However, the FRISCO authors have extended the triangle by a fourth point in the centre, forming a tetrahedron. This central point – the actor, interpreter and representer – emphasizes the essential role of humans which are responsible for forming, communicating, interpreting and using signs in conceptual modelling.

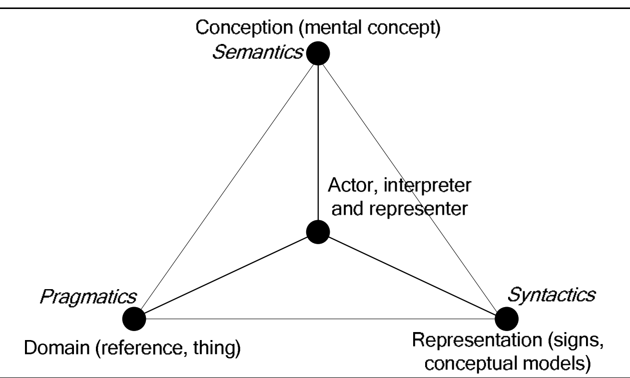

Figure 1. Semiotic Tetrahedron (Falkenberg et al. 1998; Hesse et al. 2008)

Human actors have a central role within the tetrahedron. Specifically, representations (syntactical signs) are not objectively related to referenced objects: their relationship is established by – and may vary with – a particular actor who gives a perceived (or imagined) object its meaning (semantics) by subjective conception and interpretation. The role of pragmatics is to provide the domain reference – an inter-subjective *joint attention frame* (Tomasello 1995) – for any kind of conceptions that helps in the constitution of the world and its objects as objectively existing objects (Hesse et al. 2008). An actor either represents something to someone else or interprets what resulted from perception (observation) of some data in relation to her or his domain of reference.

Figure 2 illustrates the communication process that creates *interacted understanding* between a sender and a receiver according to Hesse et al. (2008). On the left side, whenever a sender passes a representation in form of a message to a receiver, s/he chooses a representation – for example, a conceptual model – according to her or his conception and doing so s/he presumes an (initially subjective) domain reference. On the other side, the receiver interprets the received message and creates his own conception of the conceptual model which again leads to an (initially subjective) domain reference. It can only be clarified in an adjoining feedback process by additional communication loops whether or not the interpretation – the referenced domain – corresponds with the one intended by the sender. To put it simply, we can mean the same thing with different words (Lorenzen 1987, pp. 115-118).

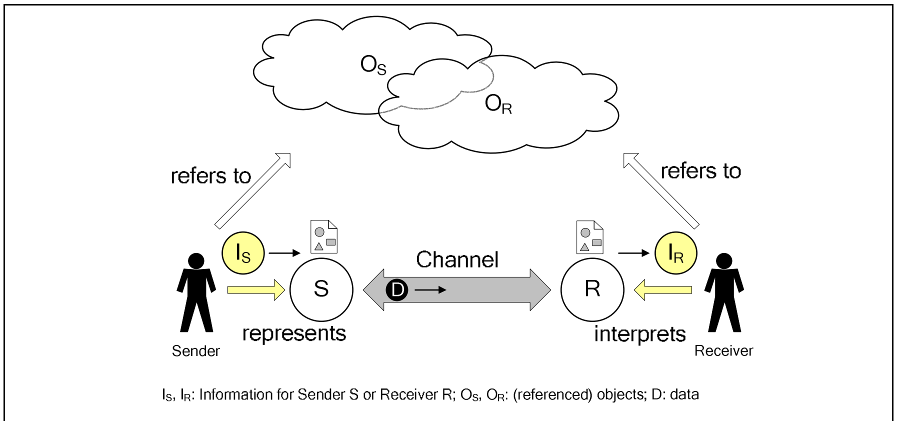

Figure 2. Communication and Information Transmission (Hesse et al. 2008)

Following this and in accordance with the authors of the FRISCO report (Falkenberg et al. 1998), we define conceptual models as *a – more or less – precise and unambiguous (inter-subjective) representation of a (subjective) mental conception in some appropriate formal or semi-formal language*.

Some empirical studies address the role of conceptual modeling in ISD processes. For example, Bandara et al. (2005) identify process modeling success factors and measures empirically evidenced in case studies. An analysis by zur Muehlen and Recker (2008) suggests that a minimal set of BPMN constructs actually is used in practice so far, and that modelers, and organizations, use BPMN for purposes similar to flowcharting. Recker et al. (2009) comparatively assesses representational analyses of 12 popular process modeling techniques, uncovering causes for a number of shortcomings that remain in process modeling practice. Similarly, Recker (2010) shows that the high interest in BPMN has created a massive demand for education and training, but suggests that BPMN is over-engineered and that more insights into practical usage are needed for future development. In other areas than process modeling, Burton-Jones et al. (2009) provide guidelines on how to empirically investigate modeling grammars. Burton-Jones and Meso (2006) evaluate the ability of conceptual UML models to communicate meaning about a domain to analysts. Similarly, Khatri et al. (2006) examine the effects of both IS and application domain knowledge on different types of schema understanding tasks, concluding that IS domain knowledge is important in the solution of all types of conceptual schema understanding tasks in both familiar and unfamiliar application domains. Gemino and Wand (2005) compare two versions of the entity-relationship model (ERM) in an experiment, suggesting clarity within the model may be more important than the apparent complexity of the model when a model is used for developing domain understanding.

All of these studies empirically demonstrate problems related to syntactical and semantic correctness of modeling notations. To address these issues, Delfmann et al. (2009) show how syntactic correctness and semantic comparability can be ensured by introducing an approach that avoids naming differences in conceptual models already during modeling. Therefore they propose to formalize naming conventions combining domain thesauri and phrase structures based on a linguistic grammar. This allows for guiding modelers automatically during the modeling process using standardized labels for model elements, thus assuring unified enterprise knowledge representation. Similar, related approaches are suggested by various researchers (e. g., Bögl et al. 2008; Born et al. 2007; Ehrig et al. 2007; Greco et al. 2004; Höfferer 2007).

Almost next to nothing in the literature of conceptual modeling investigates why different people construct different models given the same domain (Soffer and Hadar 2007) or addresses concerns of pragmatics in general. As Recker et al. (2009) conclude for process modeling, at present, little is known about modeling practice and modeling technique usage overall. A notable exception are Ågerfalk (2004) and Ågerfalk and Eriksson (2004). They show how speech act theory can be used as a theoretical foundation for conceptual modeling and for analyzing the communication acts performed by use of the system within its business context. They apply the language/action perspective (LAP) that conceives IS as tools for social action and communication in specific business contexts (Ågerfalk 2004). However, measuring shared understanding or application domain knowledge are not in the focus of their work or that of other related research (e. g., Burton-Jones and Weber 1999 where participants answered questions that asked them about their knowledge of the domain in the case; or Khatri et al. 2006 who selected "sales" and "hydrology" as domains for participants drawn from a business school). Providing a general or applicable (a posteriori) measure that is independent of the researchers' influence or knowledge itself remains an open question.

To conclude, we are interested in questions regarding the pragmatic effects of

(1) modeling techniques and notations (expertise or level of experience of a modeler or reader as regards modeling) – investigating the pragmatic knowledge of modeling notations, grammars, and techniques ("How well is a model/modeling grammar understood and used?"). Some research in this area has been done by Recker (2008) and zur Muehlen and Recker (2008).

(2) application domain knowledge (expertise or level of experience of a modeler or reader as regards the modeled domain) – investigating the pragmatic knowledge of the modeled domain ("How well is a modeled domain understood?"). To the best of our knowledge, no study that we know of tries to (a posteriori) measure application domain knowledge, independent of the researcher's (a priori) set-up or participants' subjective perception.

In accordance with Ågerfalk and Eriksson (2004) we argue that traditional conceptual modeling research has focused on the syntactic and semantic aspects and that there is a need for development in understanding pragmatics in conceptual modeling. Pragmatics deals with action oriented linguistic activities. As Weick states: "situations, organizations, environments, and their meaning for actors are "talked into existence" (Weick et al. 2005, p. 409).

To the best of our knowledge, only the LAP (e. g., Flores et al. 1988; Winograd 1988) until today has made language and communication the cornerstone of an IS theory in the area of IS development and modeling. But pragmatics has not been in the focus of research in the LAP (Ågerfalk and Eriksson 2002; Ågerfalk and Eriksson 2004). This may be due to the difficulty to make pragmatic communicative concepts such as "shared understanding", "meaning" and "knowledge" empirically observable and inter-subjectively examinable (e. g., Boisot and Canals 2004; Deacon 2007; Langefors 1995, p. 144; Mingers 2004, p. 387; Rouse and Morris 1986).

To provide a theoretical basis for our work we turn to *Language Critique*. In the tradition of Wittgenstein's (1953) language games and his focus on pragmatics, *Language Critique*, a branch of constructive philosophy of language known as the "Erlangen School" (Kamlah and Lorenzen 1984; Lorenzen 1987; Lorenzen 2000), argues that language is used to disclose the world (Kamlah and Lorenzen 1984, p. 33). Language Critique offers the construct "*language community*" to explain why and how a group of persons is able to understand each other: *a language community is a group of persons that shares the relation of concept and term as the knowledge of using this term* (Kamlah and Lorenzen 1984, p. 45). Consequently, the construct "language community" tries to answer how the conventions are formed that align syntax, semantics, and pragmatics of signs in order to provide meaning in communication (see Figure 1 and Figure 2). Kamlah and Lorenzen (1984) argue that language as a system of signs promotes mutual understanding as "a 'know-how' held in common, the possession of a 'language community'" (p. 47). A new term (a sign plus its meaning or concept) is introduced by *agreements* between language users with respect to its usage (*first agreement*) and meaning (*second agreement*) (Kamlah and Lorenzen 1984, p. 57). These agreements leads to a relation of concept and term, and are shared by a language community as the knowledge of using this term. Accordingly, if members of a group of people communicate, and each has an aligned semantic and pragmatic dimension of a sign (or term) in mind, then this group of people forms a language community.

We propose that these constructs from linguistic theory can be applied for studying application domain knowledge and the role of pragmatics in conceptual modelling. In this manner, conceptual models can be used as a formalized way of stating the inter-subjective consensus – *a representation of the domain-specific knowledge* – of a language community. Conceptual models provide a starting point for communication as the written expression of the shared understanding of the language community that is part of every IS as a socio-technical system (e. g., business users, experts, managers, IT experts, programmers and so forth). New concepts and problems that every changing organization constantly encounters need to be introduced, discussed, negotiated and agreed upon by this language community. To recap:

(1) A shared understanding of a group of people as a language community should become observable in language use and communication.

(2) Groups that have a shared understanding and corresponding knowledge of an application domain and that understand each other should be distinguishable by their linguistic communication from groups that do not understand each other.

Based on this we propose the following two research questions:

RQ1: *Is there a difference in groups' linguistic communication? In particular: is there a difference in linguistic communication if a group has created a shared understanding of an application domain in contrast to another group (expert versus layperson)?*

RQ2: *Is a group's linguistic communication characterized by a group's domain-specific language (terminology)? That is, can membership to the group be anticipated by examining linguistic communication if the domain-specific language (terminology) is given?*

Research Methodology

Method

We chose a *quasi-experimental design* (Campbell and Stanley 1963, pp. 34-64) for our study. We wanted to test if degrees of shared understanding of an application domain in the sense of a "language community" can be empirically observed in linguistic communication. We selected (1) first-year students (*control group*) and advanced students (*treatment group*) from the Department of Social Sciences, Economics and Business Administration at the University of Bamberg, Germany. The advanced students are all enrolled for more than four semesters and take courses in "logistics" and "operations management" as their main area of study. All participants in the experiment had a chance of winning gift vouchers in a raffle. There were no incentives awarded for good task completion. All in all, 62 first-year students and 64 advanced students participated in the experiment. From this participant pool, we randomly built 31 two-party teams for the control group (first-year students) and 32 two-party teams for the treatment group (advanced students) respectively. While the average age of the control group is approx. 21.7 years, the age in the treatment group averages approx. 24.5 years. Likewise, students of the control group visited 0.5 courses on average in the application domain while the treatment group visited 4.8 courses on average (out of eight relevant courses).

Set-up and Materials

The participants of both groups had to work on a task (divided into seven parts) from the domain of logistics and operations management, each in randomly arranged teams of two persons (for details of the task see Appendix A). The essential design element for the experiment is based on the fact that the advanced students (treatment group) were close to graduation and had attended up to eight different specialized courses within the domain of logistics and operations management. In comparison to the first-year students (control group) advanced students had much more time and spent much more effort to learn the domain-specific terminology in the field of logistics and operations management. We therefore presume a noticeably higher degree of mutual understanding of domain-specific terminology for the treatment group in comparison to the control group.

We consider the attendance of courses in the domain of logistics and operations management as the experimental factor that provides a basis for empractically learning the application domain knowledge of logistics and operations management and for the development of a language community. We assume that by attending the courses and accompanying exams and exercises, the advanced students learnt the terminology and the domain-specific language of logistics and operations management. We expected that the developed domain-specific language, created by attending the courses, would have an effect on the processing of the task; the two-party teams of the control group should use more natural, colloquial language in discourse compared to the treatment group.

Since the treatment group had accompanied exams and exercises we presume that these students did invest the effort to learn the domain-specific logistics terminology. We therefore expect that the treatment group has a higher degree of mutual understanding than the control group, and that the treatment group therefore forms a "language community" to a higher degree than the control group. Our main hypothesis to be tested therefore is:

> *H: Experts with application domain knowledge use a different terminology in linguistic communication than laypersons or novices.*

Procedure

The experiment was conducted for each group (control group and treatment group) in a separate session in February 2009 in the PC laboratory at the University of Bamberg. On both dates, for a run of one hour each, participants had to answer a survey in written form for gathering control variables (gender, age, courses taken and so forth) and afterwards jointly process the task in randomly assigned two-party teams. Figure 3 illustrates the total experimental set-up and procedure (two group posttest design).

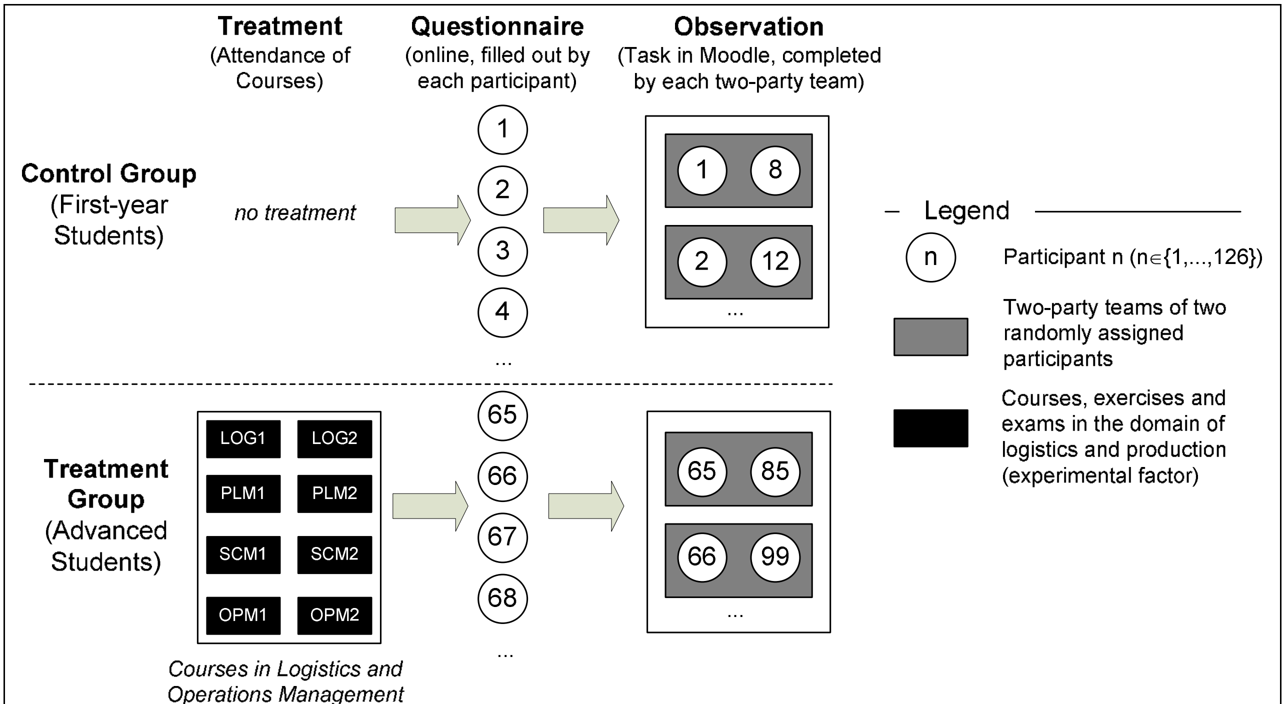

Figure 3. Illustration of Experimental Set-up

For each two-party team, the communication between two teammates proceeded via synchronous, text-based chat, using the chat module of the university-wide e-learning system Moodle[1]. This allowed us to leverage the recorded chat protocols for measuring data. Since the experiment was conducted in a laboratory environment (PC laboratory), we were able to control most confounding variables. For example, the random group assignments and the seating arrangements prevented any direct, verbal communication; therefore all communication proceeded via electronic chat. Furthermore, all intergroup communication was prohibited by the investigator who attended each session. We cannot completely rule out the usage of the Internet for solving the tasks. However, this is not an issue because we are primarily interested in the communication patterns and not in the correctness or quality of answers.

We presumed that different languages (e. g., words and signs) are used by control group (laypersons, first-year students) and treatment group (experts, advanced students). Especially we expected (1) that advanced students are semantically more similar, have a higher degree of both application domain knowledge and mutual understanding, and therefore use *terminology* and terms more often in discourse if compared to the control group, and (2) that advanced

[1] http://www.moodle.de/.

students would be semantically closer to a domain-specific terminology of "logistics" and "operations management" in comparison to first-year students. Examples indicating differences between control group and treatment group dialogues concerning part 2 of the task (Appendix A) are shown in Table 1.

Table 1. Examples of Dialogues concerning Part 2 (see Appendix A)

Two-party Team ID	*Chat Protocol Excerpts* [a]
0-A-868 (control group, first-year students)	A: I belief that one concept is OOS rating; thus I would say stock-keeping and ordering early enough. B: What does that mean? A: OOS rating is a permanent control of stock movements; this way bottlenecks can be detected early. And then I would mention the concept of identification. B: Ok, this sounds very good. Take this and stock-keeping? A: It includes application of bar codes and RFID and stuff; additionally it enables better inventory management. B: Wow, ok. This does not mean anything to me; but it seems you know the ropes. A: Then let's take OOS rating and the concept of identification.
1-BX-943 (treatment group, advanced students)	C: By stock-keeping and just in time delivery? D: I would say kanban and JIT. C: Ok, sounds even better; let's take yours. D: Thus we agree on kanban and JIT?

[a] The reported excerpts have been translated from German by the authors.

During pre-analytical, qualitative coding, we marked those passages which were related to the factual, content-wise communication and mutual coordination. Meta communication, emoticons, corrections and other comments were filtered. Afterwards, we counted the used signs and words of those passages per part of the task and team. The control group (first-year students) experienced technical performance problems with the e-learning system (i. e., time lags); therefore not all two-party teams could (completely) solve all sub-tasks. As a result, the number of valid data sets decreases in the later parts of the task due to the performance problems. Therefore we had to eliminate three of the seven parts of the task because they yielded not enough data for a subsequent analysis. Moreover, we had to discard some teams due to the severe performance problems as well. Overall, this resulted in a data pool of 30 teams for the control group and 26 teams for the treatment group, each working on the first four parts of the task.

The recorded chat protocols were used as empirical data. For analyzing the data we used *latent semantic analysis* (LSA) (Deerwester et al. 1990; Landauer et al. 1998; Landauer et al. 2007). LSA is a mathematical technique for computer modeling and simulation of the meaning of words and passages by analysis of representative corpora of natural text (Landauer and Dumais 2008). It is often applied in the context of information retrieval (Lemnitzer and Zinsmeister 2006, pp. 34-36). What makes LSA especially interesting for our purpose is its main ability to show latent *semantic similarity* between text documents. LSA computes the similarity between documents, words, and document-word combinations, representing both documents and words as vectors and calculating the cosine distance between vectors or other metrics, such as Euclidean or city-block distances, as the measure of their similarity (Wild 2007, pp. 29-30). Therefore, LSA does not simply compute a measure of the overlap of words between the two documents as many text-analytical methods do.

We examined two characteristics of our data set using LSA. First, we compared semantic similarity between and within groups. Second, we examined the semantic coherence of both groups with regard to so-called *corpus congruence*. Corpus congruence indicates the semantic similarity between the chat protocols and a self-constructed logistics and operations management corpus which is based on the course materials. We developed the logistics and operations management corpus as a "reference corpus", representing a terminology for the application domain.

Analysis & Results

Basically, we wanted to test whether the attendance of logistics and operations management courses (i. e., acquisition of application domain knowledge) is reflected in the linguistic communication behavior, that is, whether the participants of the treatment group show a significantly measurable different language than the participants of the control group, measured by semantic similarity (using cosine distance).

For the following three tests, we employed the open source software R and its LSA package developed by Wild (2007; 2009).[2] Prior to using LSA, we applied different pre-processing techniques. On the one hand, we used a stop-list for filtering words, including the 1,000 most frequent words of a corpus-based monolingual dictionary of the German language ("Leipziger Wortschatz").[3] On the other hand, we conducted stemming, for example, the type "Produkt" with an absolute frequency of 408 is composed of the words "Produkt" (frequency of 209), "Produkte" (frequency of 154), "Produkten" (frequency of 22) and "Produkts" (frequency of 23).

First Test: Semantic Similarity of Documents between and within Groups (without Corpus)

As a first test, we conducted a run of LSA without incorporating the corpus of the application domain as a document in our sample of documents. Therefore we created a term-document matrix based on the chat protocols only and applied LSA to this matrix. Then, we conducted the following t-test[4] for both the treatment group and the control group:

> H_0: *The mean values of semantic similarity within the groups (treatment and control group) are not higher than between the groups.*
>
> H_1: *The mean values of semantic similarity within the groups (treatment and control group) are higher than between the groups.*

Semantic similarity was computed by LSA using cosine distance between documents . The comparison of means (see Table 2) shows that documents within the control group (first-year students) on average are semantically similar with a cosine distance of 0.33. Likewise, documents of the treatment group show on average a semantic similarity with a cosine distance of 0.40. By contrast, documents of the control group and documents of the treatment group (advanced students) are only semantically similar with an average cosine distance value of 0.2540 and documents of the treatment group and documents of the control group are only semantically similar with an average cosine distance of 0.2546 (see Table 2). These average cosine distances indicate that documents of the control group and treatment group respectively are semantically more similar to each other than compared to documents of the respective other group.

Table 2. Descriptive Statistics for Semantic Similarity (Cosine Distance)

	Group	N	Mean	Standard deviation	Mean standard error
Semantic similarity with documents of control group (first-year students)	control group	30	.3293	.08967	.0164
	treatment group	26	.2540	.09145	.0167
Semantic similarity with documents of treatment group (advanced students)	control group	30	.2546	.05301	.0104
	treatment group	26	.4031	.10687	.0210

Figure 4 illustrates position and distribution of the cosine distances for all four comparisons as boxplots. The shaded area represents the values margin that starts at the bottom at the 25 % percentile and ranges to the 75 % percentile at the top. The black line in the shaded area represents the 50 % percentile (median). The lower (upper) bar (below and above the shaded area) represent the lowest (highest) value that is no outlier. Both boxplots show outliers with values that are 1.5-times higher or lower than the mean range. The two boxplots indicate that semantic similarity is higher within groups than between groups in both cases.

The results for both t-tests (one t-test for the control group and one for the treatment group) regarding semantic similarity (cosine distance) are given in Figure 5. The t-tests show that the observed differences in semantic similarity are significant ($p = 0.01$, probability of error for control group 0.000001, probability of error for treatment group 0.000346). Accordingly, we can reject the null hypothesis in both cases. Documents within the two groups (treat-

[2] http://www.r-project.org/.

[3] The stop word list is available at http://www.wortschatz.uni-leipzig.de/Papers/top1000de.txt.

[4] For a test of normality, we applied Kolmogorov-Smirnov (Sig. .086). Since the significance is above .000 and the data performed very well on visual inspection using histogram and quantile-quantile plots, we assume a normal distribution.

ment and control group) are more semantically similar than documents between groups. This means that both advanced students and first-year students on average are more semantically similar to their peers than to members of the other group.

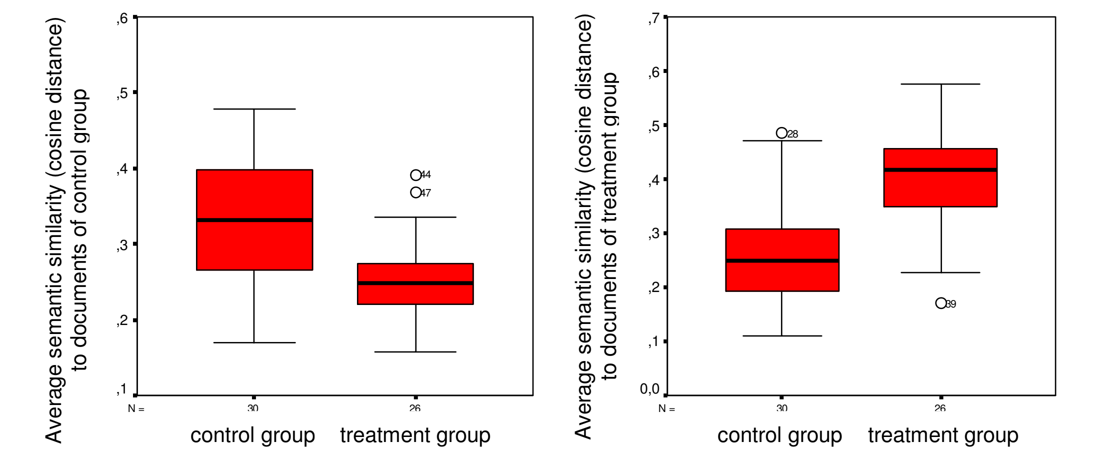

Figure 4. Boxplot for Semantic Similarity within & between Groups

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Ø semantic similarity to documents of control group (0-…)	Equal variances assumed	9,234	,004	3,720	54	,000476	,0747	,02009	,03445	,11499
	Equal variances not assumed			3,853	48,041	,000346	,0747	,01939	,03573	,11371
Ø semantic similarity to documents of treatment group (1-…)	Equal variances assumed	,544	,464	-5,626	54	,000001	-,1491	,02650	-,20220	-,09595
	Equal variances not assumed			-5,563	49,583	,000001	-,1491	,02680	-,20291	-,09524

Figure 5. T-Test Results for Semantic Similarity

To further verify this, we also clustered the data (the cosine distance between documents) using the k-means algorithm (k = 2). Visual inspection confirms that most chat protocols of the control group (prefix of these documents is “0-”) are portioned into the cluster “1” (right ellipse in Figure 6) whereas most chat protocols of the treatment group (prefix of these documents is “1-”) can be found in cluster “2” (left ellipsis in Figure 6).

We interpret our results in the following ways:

- Empractical learning (here: taking courses in an application domain) leads to a group of people (experts) that can be identified by analyzing their linguistic communication with regard to semantic similarity.
- Semantic similarity is on average higher for experts compared to novices (0.4 for treatment group versus 0.32 for control group).
- Hence, both groups (treatment and control group) are identifiable based on the linguistic communication of their members. Empractical learning leads to different linguistic communication; moreover, this is observable without knowing anything about the specific application domain, its terminology or a reference corpus of the domain.

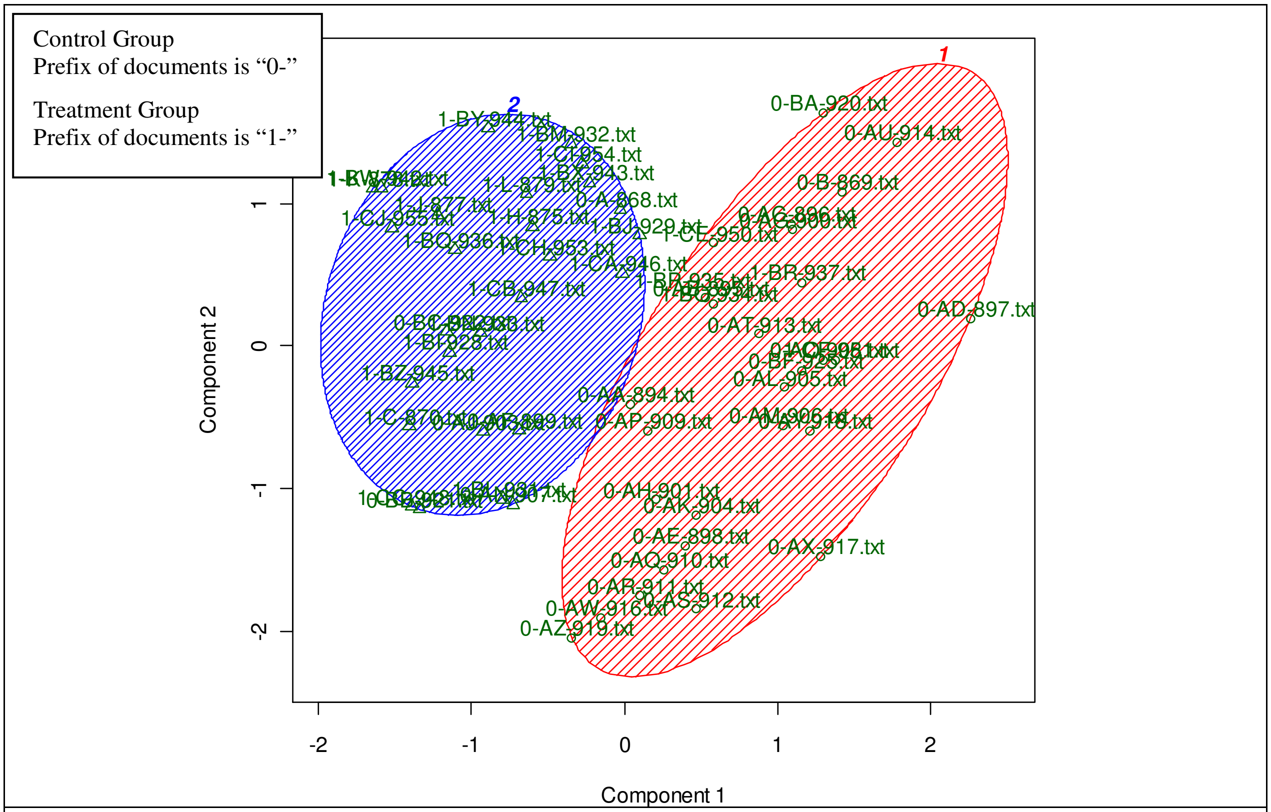

Figure 6. Cluster Plot using K-Means Algorithm (k=2)

Second Test: Semantic Coherence of Groups using Corpus Congruence (with Stop Word List)

In our second test, we used the reference corpus that we developed based on the course materials and lecture notes. The developed corpus comprises 221,288 tokens (number of words) overall, with 13,847 types (different words).

Then we applied LSA to calculate corpus congruence, that is, the semantic similarity between the chat protocols and the reference corpus per two-party team. In the next step, we used LSA to determine the semantic similarity between each chat protocol and the logistics and operations management corpus. As documents, we again used the 56 chat protocols of the two-party teams and the logistics and operations management corpus.[5] Table 3 shows the mean values for corpus congruence for both groups (see also left boxplot in Figure 8). Overall, the mean values for corpus congruence are low: .0583 for the control group and .1023 respectively (of 1.00 for full congruence) for the treatment group. This is acceptable; corpus congruence cannot be near to 1.00 because the corpus has over 15,000 word types compared to roughly 180 words on average in the chat protocols.

Table 3. Descriptive Statistics (Corpus Congruence with Stop Words)

Group	N	Mean value	Standard deviation
Control group (first-year students)	30	.0583	.0413
Treatment group (advanced students)	26	.1023	.04529

We tested whether the difference between the corpus congruences between the teams of the control group and the treatment group is statistically significant. We expected advanced students to have higher corpus congruence than first-year students. Since the corpus congruences for the first-year students are not normally distributed (see histograms in Figure 7) we used a Mann-Whitney-test (U-test).

[5] As stated before (cf. Section "Procedure"), we only used the protocols for part 1 to part 4 of the experimental task.

Median ranks for corpus congruences in control group and treatment group were 21,17 and 36,96; the distributions in the two groups differed significantly (Mann–Whitney U = 170.00, Wilcoxon-W = 635.00, Z = -3.614, P = 0.0003 < 0.05 two-tailed).

To summarize:

- The control group (first-year students) shows on average lower corpus congruence than the treatment group (advanced students). So if a corpus of the domain-specific language or terminology is known or available it can be used to verify membership to this language community. Our results show that this can be empirically observed by using LSA and corpus congruence.
- Advanced students on average use observably more technical terms from the logistics and operations management corpus than first-year students. In terms of LSA, on average, the cosine of the angles between the document vectors (chat protocol and logistics corpus) is higher for the advanced students than for the first-year students. In contrast to the first-year students the advanced students use the terminology that they acquired during their courses and, statistically, "speak a different language".

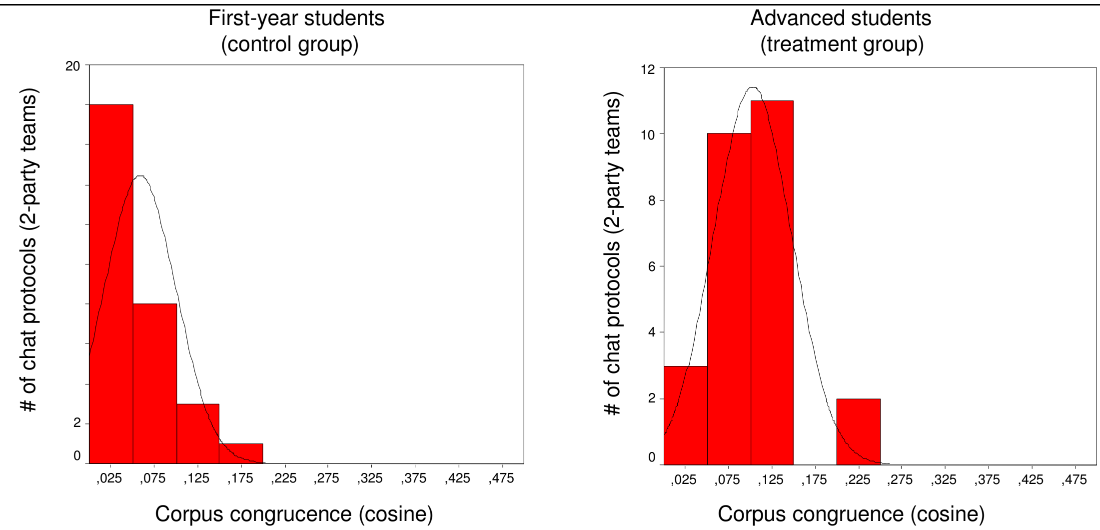

Figure 7. Frequency Distribution of Corpus Congruences for both Groups

Third Test: Semantic Coherence of Groups using Corpus Congruence (without Stop Word List)

According to Landauer and Dumais (2008; Wild 2009), stop-listing and stemming are very rarely used in LSA because neither stemming nor stop-listing is appropriate or usually effective with the underlying theory and model of LSA. However, Landauer and Dumais (2008) claim that when LSA is used to compare word strings shorter than normal text paragraphs (e. g. short sentences), zero weighting of function words is often pragmatically useful. Due to the shortness of our chat protocols, we initially used a stop-list. However, as a double check for our results, we also conducted a second run of our corpus congruence analysis using no stop words or stemming (see Table 4 and right boxplot in Figure 8).

Table 4. Descriptive Statistics (Corpus Congruence w/o Stop Words)

Group	N	Mean value	Standard deviation
Control group (first-year students)	30	0.3095	0.06319
Treatment group (advanced students)	26	0.3498	0.06772

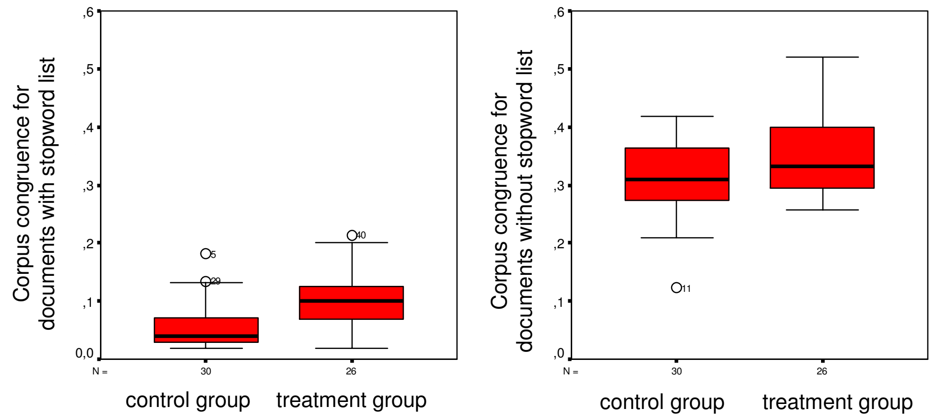

Figure 8. Boxplots of Corpus Congruences for both Groups (with/without Stop Word List)

Median ranks for corpus congruences in control group and treatment group were 24,63 and 32,96; the distributions in the two groups differed significantly (Mann–Whitney U = 274.00, Wilcoxon-W = 739.00, Z = -1.906, P = 0.057 < 0.1 two-tailed); however, probability of error is higher.

Overall, the mean values are higher and the probability of error is also higher (5.2 %) but still within acceptable limits because we can explain this with the shortness of the chat protocols as compared to the logistics and operations management corpus. This also becomes apparent if we compare the mean values for corpus congruence of both groups for both cases (with/without stop word list); with stop word list the mean value for corpus congruence of the treatment group is nearly twice as high as for the control group, whereas without stop word list the mean values of both groups are much closer to each other. Again, we cannot reject the null hypothesis.

Discussion

So far existing research on the role of conceptual modeling in ISD processes mostly has not addressed concerns of pragmatics, and at present, little is known about modeling practice and modeling technique usage overall (see Recker et al. 2009). The role of expertise as regards the modeled domain has been rarely investigated yet. No study that we know of has tried to (a posteriori) measure application domain knowledge, independent of the researcher's (a priori) knowledge of the subjects. This may be because, in general, the possibilities to properly measure and compare constructs such as "understanding", "knowledge" or "meaning" are very limited (Mingers 2004, p. 387). However, previous research has already tried to reduce complex constructs to observable, communication-based measures. For example, Weber and Camerer (2003) use specialized, task-specific languages in order to represent "culture" in a series of experiments.

Using linguistic theory as a foundation, especially Language Critique (Kamlah and Lorenzen 1984), we suggested that domain-specific languages, or terminologies, are an observable expression of the world-view and application domain knowledge of experts. "Knowledge", "understanding" and "meaning" are not just in the mind, in the way people think, they are rather manifested in the way people act. The basis of thinking is terms and concepts, which are expressed in words, which in turn derive their meaning from the way they are used in daily life; rather than looking for abstract representations of meaning in the mind, from a discursive point of view one looks for patterns in the use of terms and words (see Tsoukas 2005, p. 98 for a similar argument). We therefore concluded that laypersons (or novices) and experts should significantly differ in linguistically communicating about tasks in a given application domain.

In our study we showed that domain-specific languages are an indicator for separating novices from experts in a given application domain (here: logistics and operations management). Novices and experts can be distinguished based on the domain-specific language they use in discourse. Linguistic communication within each group is characteristic for that group and differs significantly from the other group. We showed that these different language communities can be observed empirically by employing LSA as an instrument and by measuring semantic similarity. This seems to be advantageous because it requires less effort than other approaches for analyzing discourse-based settings and situations (e. g., Kjaergaard and Jensen 2008; Ravasi and Schultz 2006; Stamper et al. 2000; Weick

1995, p. 172). LSA allows quicker and less time-consuming analyses because it is quantitative and automatable to a degree.

The separation of groups using LSA is also possible if the terminology, the application domain or the expert-layperson-status of the examined group are unknown a posteriori. Therefore the separation based on domain-specific languages is independent of the domain under consideration or the prior knowledge of the researcher. This provides a useful a posteriori measurement instrument for studying the role of application domain knowledge in future research.

Our experiment also shows the importance of empractical learning: a higher degree of application domain knowledge, as illustrated by usage and understanding of domain-specific language, mirrors a higher degree of expertise and requires longer periods of empractical learning. Our results can be interpreted as a first evidence for time-depending development of language communities since the treatment group (advanced students) invested much more time to establish the observed language community compared to the control group (first-year students). The implications of our work are that the semantic and pragmatic dimensions of syntactic signs (see Figure 1) need to be introduced *together*, they have to be learned empractically – people have to *experience* (pragmatics) what the *meaning* (semantics) of a *sign* (syntax) in *specific situations* (semantics and pragmatics) really is (Bühler 1990, pp. 176-179). Therefore empractical learning – acting and living together (Kamlah and Lorenzen 1984, p. 36) – has to take place between members of a language community. This is, of course, a variant of an iterated learning model (Brighton and Kirby 2001; Smith 2004), where individuals acquire their linguistic competence based on observations of the linguistic behavior of other individuals (see also Clark 1996; Deacon 2005; Pask 1975). Recent results from linguistic research mirror these findings. For example, in a series of studies Bromme and collaborators (Bromme 2000; Bromme and Jucks 2001; Bromme et al. 2005a; Bromme et al. 2005b; Bromme et al. 1999; Jucks et al. 2008) examined communication in case of high differences in knowledge between sender and receiver (expert-layperson communication, as can be observed in many IS development projects and contexts of conceptual modeling). They found that expert-layperson communication is characterized by a systematic difference between the perspectives of both actors. In this context the term "systematic" means that not only knowledge elements in the layperson's perspective are missing but they are also embedded in a cognitive reference framework that is mainly determined by the participant's discipline and their specific education (Bromme and Jucks 2001, p. 93) – this is what would name specific application domain knowledge.

Our results suggest that accomplishing shared understanding within groups is critical for all kinds of cooperative activities in organizations that rely on extensive communication. Consequences of our research for IS in general concern the (theoretical) questions why and how IT and communication technology add value to an organization. Concerning conceptual modeling and ISD, a fundamental question is to what degree systems development methods and conceptual modeling languages and grammars do serve as catalysts that accelerate the creation of shared understanding in groups of stakeholders with different application domain knowledge. Following our results, a focus of conceptual modeling then should be on creating shared domain-specific languages when developing and implementing IS in organizations.

A wealth of possible further research settings and applications spawns from our findings. For example, we are interested in understanding whether and how agreement in the ISD team emerges or instead fragmentation occurs, starting from each ISD project member with having a different understanding of concepts. Moreover, which characteristics of individuals favor or hinder the emergence of agreement? The impact of social and cognitive capacities on communication and construction of a shared language has also been observed by linguistic research. For example, a recent experiment on emergent communication relied on an ingenious videogame in which players can only succeed when they communicate with each other (Galantucci 2005). Players in this game are forced to invent a new communication system from the scratch, without natural language or any other established set of signs to start from. The experiment shows that both success in the game and the emergent communication system are tightly embedded in the coordination of the behavioral processes between the game players. Interestingly, the ability to build a communication system seems to require a cooperative attitude: some players fail to realize that their communication is ambiguous, and a task that some teams manage in some minutes takes others hours before they finally give up (Galantucci 2005). Consequently, if a person lacks the basic skills to agree on a terminology, this must give all sorts of problems in real life as well. A variation of this game could be used by ISD project managers to detect such problems in ISD projects beforehand. It has been even suggested that the game could take on a therapeutic value, helping those who lack the social intelligence for communication to develop it (Steels 2006). Our approach could help in building such instruments for ISD project management.

Further research is also required for clarifying to what degree expertise and usage of domain-specific languages influence success of conceptual modeling or success of ISD projects respectively. Domain-specific languages belong to the "pragmatics corner" of the semiotic tetrahedron presented in Figure 1. An open question is, for example, if pragmatic application domain knowledge or expertise of a modeler is more important for ISD success than more syntactic or semantic knowledge of modeling techniques and notations. In this regard two aspects are of special interest:

(1) Joint conceptual modeling of stakeholders (experts and laypersons alike) may help to develop a shared understanding of a situation. Conceptual modeling could speed up the process of creating a shared understanding. This is in line with studies on team cognition by He et al. (2007) who show that communication frequency has an impact on task cognition, and that both communication frequency and task cognition are related to quality of team results and team performance. The findings of He et al. (2007) suggest that ISD teams with a higher degree of domain-specific-language usage are more efficient than teams with lower degrees of domain-specific languages usage.

(2) Conceptual models can be used to specify knowledge of a given situation. Understanding these models then requires expertise concerning domain-specific language on the one hand and expertise concerning modeling technique-in-use on the other hand. In this case conceptual models are designed through linguistic actions of a language community, and therefore are a written expression of shared understanding and knowledge. This is conceptualized as so-called *marks* (Kamlah and Lorenzen 1984, p. 46). Marks are actualized as activities by the one who produces the marks in *writing* them, and again actualized by the one who *reads* them (Gemino and Wand 2004; Kamlah and Lorenzen 1984, p. 46). Conceptual models as marks create persistent things: solidified activities which stay put, are produced and can be read. Accordingly, conceptual models as marks have persistence just as words do.

Finally, it is especially of interest what kind of conditions influence the creation of a language community, and what degree of language community existence is efficient in relation to team performance. For example, LSA has been previously used to characterize team performance by diagnosing the rate of semantic similarity between actors' documents (Dong et al. 2004), for comparing output documents as representations of team discourse, and for evaluating variation in semantic choice and semantic coherence between team members as measures for knowledge convergence (Dong 2005). For example, a positive correlation between semantic similarity and team performance has been shown in studies of simulated military missions and studies of design teams (Martin and Foltz 2004). In a similar setup, the relationship between team performance and semantic similarity could also be tested in ISD settings. Using our approach allows distinguishing different groups with different application domain knowledge, which in turn is observable in their linguistic communication using LSA and measures such as semantic similarity.

Conclusions and Outlook

In this paper we addressed problems in ISD and conceptual modelling of application domain knowledge. Regarding RQ1 ("Is there a difference in groups' linguistic communication?") we measured a significant difference in linguistic communication if a group has created a shared understanding of an application domain in contrast to another group (experts versus novices). Regarding RQ 2 ("Is a group's linguistic communication characterized by a group's domain-specific language (terminology)?") we showed that membership to the group can be determined even if the domain-specific language or level of expertise are *not* known or given a priori.

Our approach allows distinguishing different groups with different degrees of application domain knowledge based on their observable linguistic communication behaviour. This enables us to measure and verify if a shared understanding of an application domain exists within a group of people, using their linguistic communication patterns as a proxy measure. In this paper we described and discussed an approach using text-based documentation and LSA as a method. Our approach has been derived by integrating components of theories from linguistic research and concepts of conceptual modeling from IS research. We conducted an experiment to demonstrate the feasibility and usefulness of our suggestion. From a theoretical perspective this is also an attempt to transfer recent insights from linguistic theory and learning to IS research and conceptual modeling. Social systems are inherently interactive and open and it is difficult to artificially close or control them in a laboratory, which makes it difficult to test theories, since predicted effects may or may not occur depending on a multitude of factors (Mingers 2004, p. 387). As another obvious limitation we only used student participants in our experiment.

We contributed to research by explaining and demonstrating that empirically observable patterns of people's linguistic communication can act as an empirically measurable proxy for more abstract concepts such as application domain knowledge. Researchers and practitioners may benefit from our insights on how to empirically measure the relationship between linguistic communication and application domain knowledge of individual modelers or groups. This is important if "sound" understanding of concepts that are related to pragmatic aspects of conceptual modeling and ISD, such as application domain knowledge or knowledge of a modeling technique, is among the desired goals. Our approach helps to measure and compare those aspects.

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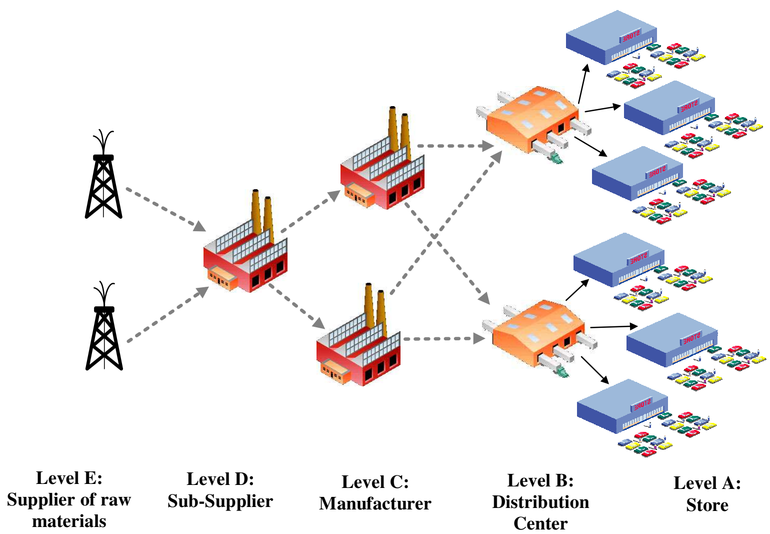
Appendix A – Tasks Description

In a work-sharing economy, businesses concentrate on and specialize in their core competencies. Dependencies between the companies arise because of the division of labour, for example, the specialized companies interchange goods and services with each other. The following figure sketches a work-sharing economic system from the consumer goods industry.



Part (1) Work-sharing Collaboration

Please look at the provided figure above. Which term does best describe this work-sharing collaboration of the depicted companies (supplier of raw materials, sub-supplier, manufacturer, distribution center, store)?

Part (2) Prevention of Out-of-Stock Situations

Which actions/concepts must be implemented by the store manager if s/he wants to prevent out-of-stock situations (i. e., missing products in the shelves)?

Please give at least <u>two</u> actions/concepts!

Part (3) Goals of the Carrier

Which goals does a carrier usually track who delivers products form the distribution center (level B) to stores (level A)?

Please give <u>three</u> goals!

Part (4) Distribution

The products of a variety of manufacturers arrive at the distribution centers. In turn, the distribution centers supply the single stores with those products. Which cost-reducing effects can be realized by interposing the distribution centers between manufacturers and stores?

Please discuss two effects!

Part (5) Fluctuating Demand

The manufacturers of products (level C) face the problem of fluctuating demand for their products, that is, they receive weekly orders of trading companies (Level A + B), which vary quantitatively to a high degree. Accordingly, the producers try to built up a degree of flexibility, that is, they try to design their operations in such a way that they can flexibly react to fluctuations in demand.

(i) What does „flexibility“ in this context mean, and who or what determines the flexibility of a manufacturing company?
(ii) What actions can manufacturers (level C) take in order to obtain more precise statements from the trading companies concerning the needed quantities?
(iii) What action can manufacturers (level C) take in order to match the produced quantities cost-efficiently to the quantities needed by the trading companies?

Part (6) Coordination between Suppliers and Manufacturers

Sub-suppliers (level D) produce preliminary products which are transformed into finished products by the manufacturers (level C). Are there any planning activities that can be jointly solved by both sub-supplier and manufacturer? Which things do they need to coordinate?

Please give and describe two coordination tasks!

Part (7) Logistics

What does “logistics” mean? How can the term “logistics” be described?

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