Lightweight Ontologies in Context
Relationship between Ontology Characteristics and Context Parameters

Ilya M. Waldstein[1], Rosina O. Weber[1] and Neal Handly[2]
[1]*School of Information Science and Technology, Drexel University, 3141 Chestnut St., Philadelphia, PA, 19104, U.S.A.*
[2]*Drexel University College of Medicine, 245 North 15th St., Philadelphia, PA, 19102, U.S.A.*

Keywords: Ontology Engineering, Sharing, Reuse, Ontology Characteristics, Context, Context Parameters.

Abstract: Ontologies, mainly lightweight ontologies, are ubiquitous throughout the Internet and are succeeding in replacing human expertise. We conducted a study with physicians and nurses performing a search task in the medical domain that demonstrates that lightweight ontologies perform well as a substitute for expertise. The extent of success of the substitution depends upon context of use. Our study investigates lightweight ontologies with respect to the context of use in which they are applied. The better we understand the context of use, the better we can inform ontology design and evaluation. We describe ontologies through characteristics and context through parameters. By varying ontology characteristics and testing the effect on the performance of an ontology-supported task for a context parameter, such as the level of user expertise, we increase our understanding of ontology design and evaluation. Our study shows that changing ontologies by varying some of its characteristics has a direct and significant impact on the performance of the ontology-supported task for different levels of user expertise.

1 INTRODUCTION

Ontologies are formalisms for knowledge representation commonly used in support of application tasks such as natural language processing and search. Lightweight ontologies are simpler forms that trade expressiveness for usability and ease of implementation in real-world applications (Brewster and O'Hara, 2007). The extensive use of hierarchical information on the Internet brought lightweight ontologies into use.

The context of use for ontologies is expressed by context parameters such as the user, the application task the ontology supports, and the domain. Context plays a crucial role in designing and evaluating ontologies. Most current ontology engineering and evaluation approaches are focused on constructing an ontology that correctly represents only the domain. However, when the ontology is used to support a user performing a task within that domain, the combination of the ontology and context may fail to produce acceptable performance results. The poor result by itself cannot be used to indicate the specific changes to be made in the ontology to improve the combined performance. The reason for this disconnect is that, with respect to context, most ontology evaluation methods are akin to black-box software testing that examine the functionality of an ontology without peering into its internal structure. Moreover, the surrounding context is not described and linked to the characteristics of the ontology.

Ontology research literature describes context as being important and suggests its consideration when designing ontologies (Noy and McGuinness, 2001; Tatir et al., 2010). However there is no current scientific guidance to determine what kind of characteristics an ontology should have for a specific type of user and domain to be adequate to support a specific application task.

Our study investigates the connection between lightweight ontologies, their use within a context, and the effect of expertise within that context to increase understanding of ontology design. For this purpose, we describe our methodology to investigate the performance of ontology-supported application tasks for different contexts of use. By varying characteristics and testing the effect on the performance of an ontology-supported task for a context parameter, we increase our understanding of ontology design and evaluation.

In the next section we provide the background to our research. We then introduce our methodology.

M. Waldstein I., O. Weber R. and Handly N..
Lightweight Ontologies in Context - Relationship between Ontology Characteristics and Context Parameters.
DOI: 10.5220/0004550303080315
In *Proceedings of the International Conference on Knowledge Engineering and Ontology Development* (KEOD-2013), pages 308-315
ISBN: 978-989-8565-81-5

Next, we describe our experimental study that utilizes our methodology using a lightweight ontology in a healthcare context. Finally, we present and discuss the results and conclude.

2 BACKGROUND AND RELATED WORK

Ontologies represent knowledge through explicit conceptualizations, which are consensual views of a domain represented for some purpose (Gruber 1995). In this sense, what is included in the ontology and how it is represented indicate commitments in that the concepts selected and their inter-relationships provide a particular perspective about the world (Brewster and O'Hara 2007). This may take the form of expert knowledge representing a particular view of objects and interrelationships in a domain. Ontologies are eminently suitable for representing taxonomic information (Brewster and O'Hara 2007), and there are numerous applications utilizing this strength to support diverse tasks.

Ontologies range in their specification from lightweight to heavyweight. Lightweight ontologies consist of terms that have only minimal specification of the term meaning whereas heavyweight ontologies consist of rigorously formalized logical theories (Uschold and Grunninger, 2004). Typically, lightweight ontologies consist of a simple taxonomy (Uschold and Grunninger, 2004) where less expressivity is traded for usability (Brewster and O'Hara 2007).

An important aspect to our research is the idea of context. Context can be defined by location, identities of people and objects, changes to those objects (Schilit and Theimer, 1994); environment, (Ryan et al., 1997); orientation, and date (Dey 1998). These list who, where, what, and when – specifically the identity, location, activity, and time (Dey and Abowd, 1999). User (identity), application task (activity), and domain (location) are context parameters that represent the context. They are used in our methodology descriptively because they can link context to ontology characteristics. Context variables vary the context parameters and are used in our methodology to distinguish different configurations of context. For example, Expertise can be used as a variable to vary the User context parameter with the values of "novice" and "expert".

The way to describe, manipulate and evaluate ontology is through its characteristics. Ontology characteristics can be structural, conceptual, or user defined (Yu et al., 2009). Structural characteristics are physical dimensions of the ontology schema. Examples of structural characteristics used in design and evaluation approaches include depth, breadth, tangleness, fanoutness (Gangemi et al., 2006), circularity, and partition (Gomez-Perez, 2001).

Past research has tried to utilize context in design and evaluation approaches. A democratic ranking Web system was proposed that separates the reviewers into groups of domain experts, ontology researchers, and common users that subjectively evaluate ontologies uploaded by other users for some context (Xu and Ma, 2008). A recent task-based research direction for evaluation has looked at equating characteristics to measures based on user requirements that can predict performance in a task (Yu et al., 2009). A three-level evaluation framework looking at concept tagging was used to evaluate how well an ontology performs (Porzel and Malaka, 2005). Precision and recall were used in an evaluation framework to evaluate an ontology in the Web search task (Strasunskas and Tomassen, 2008). Nevertheless, none of the evaluation approaches above test or incorporate the connection between ontology characteristics and context parameters that can provide an actionable guideline for ontology engineers. They do not provide a methodology to do so, nor test the performance of an ontology at that level of specificity.

3 METHODOLOGY TO INVESTIGATE ONTOLOGIES IN CONTEXT OF USE

The methodology we propose associates ontologies with context parameters to assess how changes in ontologies influence overall performance. It is implemented using the performance of an application task that uses an ontology in a context. An objective quality metric measures the performance of the application task; indirectly we are measuring the overall performance. The methodology contains two phases; before changes and after changes. In Phase 1 the context, characteristics, and metrics are defined and performance measured with the unchanged ontology. In Phase 2 the ontology characteristics are changed and performance is measured. Based on the variation of performance, we analyze the impact of the changes on overall performance.

3.1 Elements of the Methodology

The elements of the methodology, shown in Figure 1, are a context *c* in a set of contexts C, multiple selected characteristics *Ch* in a set of characteristics CH, and an application task with performance *p*. The methodology asks:

For a context *c*, does a variation in the value of one or more characteristics *Ch* lead to a variation in performance from p_{BC} to p_{AC}?

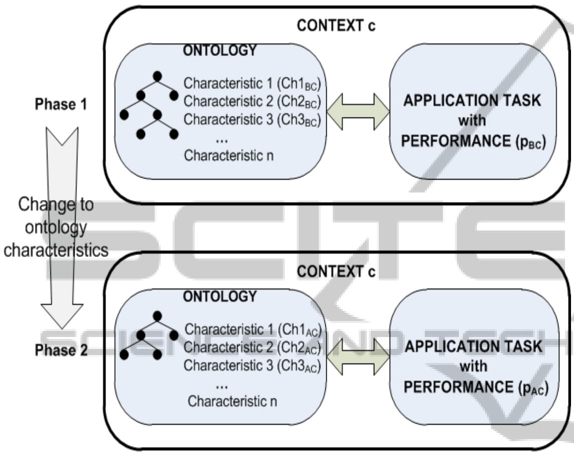

Figure 1: Change in ontology reflecting a change in characteristics and performance for a given context of use.

The context remains the same for both Phase 1 and Phase 2. Only ontology characteristics are changed.

3.2 Methodology Steps

Phase 1

Select (populates and documents the elements)

- First, define the selected context parameter to the variable level and document the remaining parameters that define context.
- Second, select the ontology characteristic(s) for performance measurement.
- Third, select a change to the characteristic(s).
- Forth, select quality metric(s) to use for performance validation.

Measure Initial Performance

- The initial performance (p_{BC}) of the application task supported by the ontology before the change is measured.

Phase 2

Change Values

- The ontology characteristic(s) values are changed.

Measure Resulting Performance

- The resulting performance (p_{AC}) of the application task supported by the ontology after the change is measured.

Analyze

- The difference in results for performance *p* between Phase 1 and 2 is analyzed. Test the difference for statistical significance. A difference in performance indicates that the change to the ontology characteristics impacted perfromance.

Save

- If the results are statistically significant, the specific combination of context *c* and selected characteristics *Ch*, and change is documented for future reference and used as a guideline for ontology engineering and evaluation.

4 EXPERIMENTAL STUDY

In this section, we describe a study where we implement the methodology we introduced in Section 3.

4.1 Study Design

Figure 1 illustrates our two-phase methodology employed in the study. In this study, the ontology design is changed (as further detailed in section 4.5) using the selected structural characteristics of breadth, depth, and fanoutness as shown in Table 1. These structural characteristics were selected for four reasons. First, breadth, depth, and fanoutness are well defined. Second, the characteristics can be easily calculated using their defined formulae. Third, the characteristics are straightforward to understand and thus likely to be applied and documented in an ontology engineering approach. Finally, results from this research can be immediately applied because all ontologies – lightweight and heavyweight – have these structural characteristics.

Table 1: Calculation of characteristics used in the study.

Characteristic	Calculated as
Depth	The average of the sum of all is-a paths starting at the top node and terminating in a leaf node.
Breadth	The sum of all is-a edges per level divided by the number of levels.
Fanoutness	The total sum of the average of is-a edges per node divided by the number of levels. Nodes with zero child nodes are not counted in the calculation.

The parameters that describe and operationalize the context of use are the participating expert and novice healthcare professionals (users), the search task (application task), and the medical guidelines (domain). The lightweight ontology is a pruned MeSH ontology focusing on Internal Medicine. Two metrics are used to determine performance: the selection of query terms and the final selection of relevant documents. The hypotheses we test are:

- **H1:** *A change in the depth, breadth, and fanoutness significantly impacts the performance of the search for medical guidelines for novices in the medical domain.*
- **H2:** *A change in the depth, breadth, and fanoutness does not significantly impact the performance of the search for medical guidelines for experts in the medical domain.*

As hypothesized in **H1**, novices, who are not as intimately familiar with the domain and have less procedural knowledge, will not be able to overcome the effect of the detrimental change. For the novice user the ontology replaces human expertise thereby helping the novice to complete tasks. As hypothesized in **H2**, experts should be able to use their knowledge to overcome the effect of a detrimental change to ontology from a change in its characteristics.

4.2 User Parameter: Participating Healthcare Professionals

We conducted the study with participants in the healthcare field at a local university and university affiliated hospital. We selected novice and expert resident physicians and nurses as participants. Table 2 contains the number of participants for each group. For the resident physician participant group, a novice is a resident physician within the first or second year of residency; an expert is a resident in their last year of residency. For the nursing participant group, a novice is a nursing student in the last year of the B.S.N. program, and an expert is a nurse who is also a student in the M.S.N. program and has work experience.

Table 2: Study participants.

Participant Group	Number of Participants
Resident Physicians	
Expert resident physicians	16
Novice resident physicians	12
Nursing School Students	
Expert nursing school students	17
Novice nursing school students	10

4.2.1 Expertise Variable

The user context parameter is defined by the expertise variable. Experts have knowledge of the domain, and have the experience to apply that knowledge to the application task. It is exactly this expertise that is lacking in novices, which we expect good quality ontologies to enhance and poor quality ontologies to diminish.

We reviewed literature to determine the definition for experts and novices in the healthcare context. Research looking at physician understanding of updated guidelines for the diagnosis and management of asthma found that resident physician test scores improved with duration of training (Doerschug et al., 1999). As residents move through the program, their domain expertise, and especially their diagnostic and procedural knowledge increases. Research looking at the assessment of nursing competence and expertise in nursing utilizing the expert-performance approach described that diagnostic expertise improved with deliberate practice, i.e. extended supervised training with feedback; and that graduate training and specialized training successfully differentiated expertise (Ericsson et al., 2007). Literature confirmed that duration of on the job experience and training can distinguish expertise.

4.3 Application Task Parameter: Search

Each phase, described in Section 4.1, consists of users reading a medical scenario that presents a medical disease or condition, which in turn creates a need for medical guidelines to be searched. Medical scenarios are randomly chosen and assigned for each user out of three scenarios we prepared for the study. Figure 2 is a sample medical scenario.

Participants are given a domain ontology that helps them find and select keywords to be utilized to search for guidelines based on a question in the

A type of hospital-acquired pneumonia (HAP) can occur in people who are on a breathing machine through an endotracheal or tracheostomy tube for at least 48 hours. The pneumonia primarily occurs because the tube allows free passage of bacteria into the lower segments of the lung in a person who often has underlying lung or immune problems. Your patient shows the following signs: alternating fever and low body temperature, purulent sputum, and hypoxia.

What intervention is most likely to decrease the incidence of this type of pneumonia in the intensive care unit?

Figure 2: Sample medical scenario.

medical scenario. Both novice and expert participants in the study completed Phase 1 and Phase 2.

4.4 Domain Parameter: Medical Guidelines

The medical domain consists of guidelines from the National Guideline Clearinghouse (NGC). The NGC is a public resource for evidence-based clinical practice guidelines. The NGC is maintained by the Agency for Healthcare Research and Quality, an operating division of the Department of Health and Human Services.

The domain is specified by a lightweight ontology based on the Medical Subject Headings (MeSH) hierarchy in the NGC. Due to the size of the medical guideline text a sample cannot be provided, but can be viewed at http://www.guideline.gov/. A sample of the MeSH ontology is shown in the next section (Figures 3 and 4) to demonstrate the changes applied to the selected structural characteristics.

4.5 Ontology Design Changes

4.5.1 Phase 1 – Before Changes

Ontology categories are organized in such a way as to have the *basic level* in the middle of the hierarchy with generalization moving upward and specialization moving downward (Uschold and King, 1995). The basic level contains the basic categories. Basic categories are easy to perceive and quick to identify, have the most attributes, have high within-category similarity, and have high between-category dissimilarity (Markman and Wisniewski 1997). Basic categories can be used with the hierarchy to draw inferences based on their location (Markman and Wisniewski 1997) – in our case about the correct intervention for a disease or condition by the novice and expert healthcare professionals for the presented medical scenario.

- L1. Bacterial Infections and Mycoses
  - L2. Bacterial Infections
    - L3. Gram-Negative Bacterial Infections
      - L4. Bordetella Infections
        - L5. Whooping Cough
      - L4. Enterobacteriaceae Infections
        - L5. Escherichia coli Infections
        - L5. Granuloma Inguinale
        - L5. Salmonella Infections
          - L6. Salmonella Food Poisoning
      - L4. Tick-Borne Diseases
        - L5. Tularemia

Figure 3: Excerpt of unchanged MeSH ontology.

Figure 3 displays an excerpt section of the unchanged MeSH ontology used in the study with the hierarchy levels (L*) shown. The starting ontology contained 10 hierarchical levels with level 5 being the basic level.

4.5.2 Phase 2 – After Changes

The modification in the ontology design that changed characteristics values for breadth, depth, and fanoutness was performed at the basic level to impact the selected context user parameter through the expertise variable. The adjustment to the ontology was made by eliminating level 4 entirely (see Figures 3 and 4, L* codes were left to show the change and were not visible in actual study). Level 4 contained superordinate concepts. Figure 4 shows the result where all subordinate categories were moved one level up in the hierarchy. By removing the concepts at Level 4 we eliminated the link between the superordinate and subordinate concepts. This made it necessary for the participants in the study to know specific diseases with a disease etiology that was made less clear by the ontology change. The change was made because it directly impacts the expertise variable that we selected to define the user context parameter.

- L1. Bacterial Infections and Mycoses
  - L2. Bacterial Infections
    - L3. Gram-Negative Bacterial Infections
      - L 5. Whooping Cough
      - L 5. Escherichia coli Infections
      - L 5. Granuloma Inguinale
      - L 5. Salmonella Infections
        - L 6. Salmonella Food Poisoning
      - L 5. Tularemia

Figure 4: Excerpt of changed MeSH ontology with Level 4 removed and Level 5 promoted.

4.6 Measuring Overall Performance

Before performing the application task, study participants were asked to read a medical scenario. It is only after understanding the medical scenario that motivates the need for searching for guidelines, that they traversed the ontology to select keywords to create a query. The path selected through the hierarchy leading to query terms is the first result of using the ontology to perform the application task. We adopted this as the first metric and called it the *Path Selected* quality metric.

When the query is submitted, a set of guidelines is retrieved for a participant to select. The specific guidelines selected by participants to answer the question in the medical scenario are the second metric we adopted and called it the *Guidelines Selected* quality metric. The metrics relate to the Fourth step under **Select** in Phase 1 of the methodology.

5 RESULTS AND DISCUSSION

5.1 Results for Hypothesis 1

Table 3 shows the results for hypothesis H1 for the *Path Selected* and *Guidelines Selected* metrics for novices.

Table 3: Results for Hypothesis 1 (* = significant).

Participants	Phase 1 correct %	Phase 2 correct %	% Decrease in Correctness
Path Selected Quality Metric			
Novice Residents	46	27	41*
Novice Nurses	70	30	60*
Guidelines Selected Quality Metric			
Novice Residents	45	18	60*
Novice Nurses	70	30	60*

The results in Table 3 show that for the *Path Selected* quality metric novice residents selected the correct path to the keywords for 46% of their attempts in Phase 1 (using the initial, i.e. unchanged, ontology) and for 27% of their attempts in Phase 2 (using the changed ontology). Novice nurses selected the correct path to the keywords for 70% of their attempts in Phase 1 and for 30% of their attempts in Phase 2.

A binomial test ($p < 0.05$) revealed that, for the *Path Selected* quality metric, there is a significant decrease between Phase 1 and Phase 2 for both novice participant groups.

This demonstrates that the removal of an essential part from the ontology decreased the performance for novices. This confirms H1 for the metric, showing that novices needed the complete ontology due to their limited expertise.

For the *Guidelines Selected* quality metric, novice residents were able to select a correct guideline for 45% of their selection attempts in Phase 1. They selected a correct guideline for 18% of their selection attempts in Phase 2. Novice nurses were able to select a correct guideline for 70% of their selection attempts in Phase 1. They selected a correct guideline for 30% of their selection attempts in Phase 2.

This result confirms that an ontology changed at the basic level is detrimental to novices that rely on the expertise from the ontology to perform the search application task.

A binomial test ($p < 0.05$) revealed that, for the *Guidelines Selected* quality metric, there is a significant decrease between Phase 1 and Phase 2 for novice participants. The change in the ontology significantly decreased the guideline selection performance for novices confirming H1.

5.2 Results for Hypothesis 2

Table 4 shows the results for hypothesis H2 for the *Path Selected* and *Guidelines Selected* metrics for experts.

Table 4: Results for Hypothesis 2 (* = significant).

Participants	Phase 1 correct %	Phase 2 correct %	% Decrease in Correctness
Path Selected Quality Metric			
Expert Residents	57	69	-
Expert Nurses	53	47	11
Guidelines Selected Quality Metric			
Expert Residents	57	50	12
Expert Nurses	36	24	33

The results in Table 4 show that for the *Path Selected* quality metric, expert residents selected the correct path to the keywords for 57% of their attempts in Phase 1 and for 69% of their attempts in Phase 2.

The change to the ontology eliminated the link between the superordinate and subordinate disease concepts thereby decreasing the specific disease etiology. Nevertheless, expert residents were able to select a path throught the ontology to the correct keywords. Inspection of the post-participation survey revealed that expert residents were knowledgeable about the scenario topic based on their “Very Familiar” and “Familiar” responses to this question and the correct restatement of the scenario topic in their own words.

For the *Path Selected* qualit metric, expert nurses selected the correct path to the keywords for 53% of their attempts in Phase 1 and for 47% of their attempts in Phase 2.

This suggests that expert nurses obtained slightly better support from the unchanged ontology.

A binomial test revealed that there was no significant decrease in the correct *Path Selected* quality metric for expert residents and expert nurses.

The change in the ontology decreased the performance for only one group of experts. The impact of the change was not significant for both groups, confirming our hypotheses H2 for the metric.

For the *Guidelines Selected* quality metric, expert residents were able to select a correct guideline for 57% of their selection attempts in Phase 1, and selected the correct guideline for 50% of their selection attempts in Phase 2. Expert nurses were able to select a correct guideline for 36% of their selection attempts with the initial ontology and for 24% of their attempts using the changed ontology. This suggests that experts obtained moderately better support from the unchanged ontology.

A binomial test revealed that there is no significant decrease in the *Guidelines Selected* quality metric for expert participants. The change in the ontology did not significantly impact expert performance confirming our hypothesis H2 for experts.

5.3 Ontology as a Substitute for Human Expertise

Participants in our study were either experts or novices in order to account for our examination of the impact of lightweight ontologies in human expertise. The results from the study show that there is a significant impact on the performance of an ontology-supported task by novices when that ontology is changed to the detriment of its ability to support that task with respect to expertise. Removing the ontology layer containing the superordinate concepts to the basic level breaks the link to the disease etiology. This causes a significant impact on the search task for the novice groups, and with greater effect on the nursing group.

The type of training conducted within the two groups may play a role. Physician training has a greater focus on diagnostic skills for the identification of disease and its appropriate treatment as compared to training in nursing. The MeSH ontology is based on a taxonomy of disease. A change in the ontology that made it more difficult to link the symptoms to the disease presented in the scenario impacted nurses to a greater extent than physicians. Expert physicians were able to compensate for the lack of knowledge during the navigation through the ontology, and had the smallest decrease in the final task of identifying the appropriate guidelines.

The change to the ontology had the greatest impact on novice nurses, who were the least knowledgeable group about the specific medical conditions in the scenarios presented, followed by novice residents, expert nurses, and then expert physicians.

6 CONCLUSIONS AND FUTURE WORK

From the results presented in this paper, we demonstrate that lightweight ontologies do serve as a replacement for human expertise in a context of use. This is important because many of the current taxonomy and is-a hierarchies on the Web, which are examples of lightweight ontologies, are supporting novices in performing tasks that might require expertise. The study shows that a change in characteristics of the ontology impacts the support of an application task for a context for which the ontology was designed. Specifically, we demonstrated that less complete knowledge structures will interfere with the ability of novice users who lack expertise about the domain.

We also show that there is a relationship between ontology characteristics and context parameters as the change in the characteristics caused a significant impact to performance for the novice value of the expertise variable defining the user context parameter.

Finally, we show that our proposed methodology to investigate the relationship between ontology characteristics and context parameters works as intended. The methodology does associate an ontology with a given context of use and can evaluate ontology supported performance of a task.

Future work will include a closer examination of the post-study survey to determine the details of the performance differences in the results. Additionally, we plan to conduct similar studies outside of the healthcare field to vary the context. Finally, we will implement our methodology with non-structural ontology characteristics.

ACKNOWLEDGEMENTS

This study has been approved by the Institutional Review Board of the Drexel University College of Medicine as of Nov 2011. Protocol # 1111000470 (19799) - "Impact of Ontology Characteristics on Search in the Medical Domain".

REFERENCES

Brewster, C & O'Hara, K. 2007, 'Knowledge representation with ontologies: Present challenges - Future possibilities', *International Journal of Human-Computer Studies*, vol. 65, no. 7, pp. 563-568.

Dey, A. K. 1998, 'Context-Aware Computing: The CyberDesk Project', *AAAI 1998 Spring Symposium on Intelligent Environments*, Tech. Rpt. SS-98-02:51-54.

Dey, A. K. & Abowd, G. D. 1999, 'Towards a Better Understanding of Context and Context-Awareness', GVU Technical Report; GIT-GVU-99-22.

Doerschug, K. C., Peterson, M. W., Dayton, C. S., & Kline, J. N. 1999, 'Asthma Guidelines: An Assessment of Physician Understanding and Practice', *American Journal of Respiratory and Critical Care Medicine,* vol. 159, no. 6, pp. 1735-1741.

Ericsson, K. A., Whyte I. V., J., & Ward, P. 2007, 'Expert Performance in Nursing Reviewing Research on Expertise in Nursing within the Framework of the Expert-Performance Approach', *Advances in Nursing Science*, vol. 30, no. 1, pp. E58-E71.

Gangemi, A., Catenacci, C., Ciaramita, M., & Lehmann, J. 2006, 'Modeling Ontology Evaluation and Validation', In Y. Sure and J. Domingue (Eds.), *Proceedings of the ESWC 2006*, LNCS 4011, pp. 140-154.

Gómez-Pérez, A. 2001, 'Evaluation of ontologies', *International Journal of Intelligent Systems*, vol. 16, no. 3, pp. 391-409.

Gruber, T. R. 1995, 'Toward principles for the design of ontologies used for knowledge sharing', *International journal of human computer studies*, vol. 43, no. 5, pp. 907-928.

Markman, A. B. & Wisniewski, E. J. 1997, 'Similar and Different: The Differentiation of Basic-Level Categories', *Journal of Experimental Psychology: Learning, Memory and Cognition*, vol. 23, no. 1, pp. 54-70.

Noy, N. F. & McGuinness, D. L. 2001, 'Ontology development 101: A guide to creating your first ontology', Technical Report KSL-01-05, Stanford Medical Informatics.

Porzel, R. & Malaka, R. 2005, 'A Task-Based Framework for Ontology Learning, Population and Evaluation', In P Buitelaar et al. (Eds.), *Ontology learning from text: methods, evaluation and applications*. pg. 107.

Ryan, N., Pascoe, J., & Morse, D. 1997, 'Enhanced Reality Fieldwork: the Context-Aware Archaeological Assistant', In V. Gaffney, M. van Leusen, & S. Exxon (Eds.), *Computer Applications in Archaeology*.

Schilit, B. & Theimer, M. 1994, 'Disseminating Active Map Information to Mobile Hosts', *IEEE Network*, vol. 8, no. 5, pp. 22-32.

Strasunskas, D. & Tomassen, S. L. 2008, 'Empirical Insights on a Value of Ontology Quality in Ontology-Driven Web Search', In R. Meersman & Z. Tari (Eds.), *Proceedings of the OTM 08*, *Part II*, LNCS 5332, pp. 1319-1337.

Tatir, S., Arpinar, I. B., & Sheth, A. P. 2010, 'Ontological evaluation and validation', *Theory and Applications of Ontology: Computer Applications*, pp. 115-130.

Uschold, M. & Gruninger, M. 2004, 'Ontologies and semantics for seamless connectivity', *ACM SIGMod Record*, vol. 33, no. 4, pp. 58-64.

Uschold, M. & King, M. 1995, 'Towards a methodology for building ontologies', In *Workshop on basic ontological issues in knowledge sharing*, vol. 74, Montreal, Canada.

Xu, J. & Ma, X. 2008, 'A Web-Based Ontology Evaluation System', Workshop on Advanced Language Processing and Web Information Technology, In *Proeedings of the ALPIT 2008 International Conference*, pp. 104-107.

Yu, J., Thom, J. A., & Tam, A. 2009, 'Requirements-oriented methodology for evaluating ontologies', *Information Systems*, vol. 34, no. 8, pp. 766-791.