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Exploring the Potential of Dooyeweerd's Aspects and Critical Realism for Evaluating Robustness of Ontology in Information Systems

Fuad Khan Baloch
AUT University, khanbaloch@gmail.com

Brian Cusack
AUT University, New Zealand, brian.cusack@aut.ac.nz

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Fuad Khan Baloch
School of Mathematics and Computer Science
AUT University
Auckland, New Zealand
Email: khanbaloch@gmail.com

Brian Cusack
School of Mathematics and Computer Science
AUT University
Auckland, New Zealand
Email: brian.cusack@aut.ac.nz

Abstract

Complex IS artifacts, such as the Internet and surrounding ontology, remain little understood within Information Systems. The usage of varying systems of thought, derived from competing understandings of reality, when applied on an artifact such as the Internet, leads to incommensurable perspective positions that cannot be easily reconciled. Consequently, attempts at constructing normative ontologies through reductionist epistemology or naïve realism often produce contradictory results. As the a priori theoretical constructs of an evaluator distort the ontology's lifeworld, an IS ontology is subjected to a narrow understanding of reality that does not lead towards a holistic understanding of it. Furthermore, the incommensurability of such developed ontologies makes it difficult to establish their robustness. Secondly, ontology development efforts in IS have traditionally led towards iterative and experiential methods for establishing the robustness of the ontology, as against utilizing a framework for investigating its coherence on a holistic scale. This research paper explores the potential of using Dooyeweerd's philosophy in conjunction with Critical Realism to construct a model that can be used for evaluating ontology within its old lifeworld and establish its robustness and coherence.

Keywords

Dooyeweerd, Philosophy in IS, Critical Realism, Ontology

INTRODUCTION

Ontology, defined for this paper as agreed "*set of concepts e.g. entities, attributes, processes, their definitions and their inter-relationships"* in a complex reality (Uschold and Gruninger 1996), has historically been a philosophical pursuit. Citing the 2,000 year old Western philosophical tradition (Lyytinen 2003) suggests that a search for 'ultimate foundations', or ontological certainty, is hopeless. However, he argues that it is still possible to construct a philosophical stance that may enable development of frameworks for understanding. The issues raised by the philosophical quest for coherent ontology manifest in IS ontologies as well, for instance, whether ontology rises from epistemology, or whether it exists in an abstract or real form (Basden, 2009a).

The IS field of research interacts in a sphere where social issues such as freedom, power, social control, and values are intricately involved with issues of technology. Ambitious research programmes within IS such as construction of the complex artifact Internet, have resulted in mixed success with competing ontological models and epistemological findings (Baloch and Cusack 2011). Slippages in semantics for constructs such as Internet and Cyberspace have led to a drainage of meaning hindering meaningful discourse (Strate 1999). Furthermore, while the utilization of positivistic sciences' core theories such as verificationism, falsifiability have led some IS researchers (Bukatman 1993; Delaney 1988; Koepsell 2003; Lee et al. 2002; Mueller 2004) to the conclusion that the Internet is primarily its physical implementation without a contextual real Cyberspace, competing core theories from other academics have led to the recognition of Cyberspace as a construct necessary to fashion meaningful discourse on the Internet. The debates continue to proliferate without recourse to an accepted ontology providing shared horizons (Baloch and Cusack 2009).

The first section of this paper briefly outlines attempts at constructing ontology within IS and discusses issues that have risen out of them. The following sections introduce the philosophy of Dooyeweerd and his fifteen aspects of reality, along with an introduction to Critical Realism. The last section introduces a proposed model for evaluating robustness of ontology utilizing Dooyeweerd's Aspects and Critical Realism.

ONTOLOGY IN IS

Ontologies in the IS literature are widespread (Bunker et al. 2005; Guarino 1998; Smith 2003). The sub-research fields of Database Modelling, Artificial Intelligence, Computational Linguistics, and others, have made extensive use of ontologies. However, while traditional philosophy has defined ontology as an account of Being in the abstract, Guarino (1998) shares his insight that often within IS, *"the term ontology is just a fancy name denoting the result of familiar activities like conceptual analysis and domain modelling" (Guarino 1998)*.

Husserl proposes a 'principle of principles' to guide ontological research:
> *"… that every originary presentive intuition is a legitimizing source of cognition, that everything originarily (so to speak, in its "personal" actuality) offered to us in 'intuition' is to be accepted simply as what it is presented as being, but also only within the limits in which it is presented there." (Spader 1994)*

Divorcing a priori constructs while constructing an ontology is difficult (Husserl 1954), due to the subject being deeply immersed in the world having been *thrown* into it (Heidegger 1962). To this end, (Honneth et al. 1981) suggest that the act of examining the world utilizing reductionism results in losing its lifeworld-ness. (Dooyeweerd 1955) suggests that a suitable theory of the world may have explanatory powers if it does not narrow the world by ignoring aspects or creating divisions. The proposal is similar to Quine's insistence on holism for examining scientific statements as a while instead of utilizing reductionism (Quine 1969). By way of illustration, Basden (2009) suggests that even a division between facts and values imposes an artificial divide within a lifeworld by creating constructs that do not exist in reality and risks becoming reified.

While some ontologies are limited by their given task of depicting extensions, relations, and hierarchies between objects within a constrained world, akin to describing a particular state of affairs, sophisticated attempts at ontology creation within IS have been involved with meaning of the relations to better understand and depict the world (Smith 2003). These sophisticated ontologies hint at the acceptance of the Habermasian lifeworld, or everyday life within the ontology, as having transformative and explanatory potential within IS (Basden 2009a).

Attempts at ontology construction in IS are often initiated with a pre-conceived philosophical worldview and the chosen methodology reflects it. Furthermore, whereas a traditional philosopher might intend to *seek* when constructing an ontology, the usage of ontology within IS has largely been an effort at gaining *predicative* knowledge (Smith 2003).

Limitations of IS Ontologies
Lakatos (1970) defines a research programme as the sum of scientific achievement, instead of isolated hypotheses and the result of many sub processes of inquiry, testing and dis-proofs (Lakatos 1970). A research programme may span multiple fields of research, and an individual field of research may have interactions with other fields of research. A field of research may utilize one or more core theories to guide research. As the Information Systems research discipline spans multiple disciplines due to its involvement in both social and technological spheres of human experience (Mingers 2001), it follows that the nature of IS research discipline leads to research programmes that deal with multiple fields of discipline. Moreover, the core theories of the various research fields can also manifest themselves in a single IS research programme. As core theories derive from differing philosophical foundations that may not be commensurable, the juxtapositioning of various core theories within a single research programme or ontology can yield contradictory results due to the lack of a shared *horizon* (Basden, 2009a).

The integration of social and technical within IS poses ontological issue of incommensurability. For instance, reductionist ontological examinations proposing a 'mathematization of nature' (Harvey 1989; Husserl 1970; Smith 2003) share little with ontologies created using interpretive methods dealing with the human social aspects. (Myers and Klein 2011) suggest that the discord is due to the absence of fundamental unifying principles for research in IS and contend that while it may not be possible to create a comprehensive set of methods that could be used to guide research, it is still possible to suggest a set of common principles that can be utilized. Other academics acknowledge the incommensurability but suggest that the point is moot (Falconer and Mackay 1999). (Basden 2002) suggests the continued insistence for incommensurability between research paradigms is supported by Immanence Thinking, which allows for duality in nature, and leads towards reductionism. For (Basden 2004), the discord rises due to incompatible initial philosophical stances.

Guarino (1998) proposes that ontology is language-dependent instead of being independent. By extension, ontology cannot retain a singular understanding when different schools of thought interact with it, without the risk of reification. The language and context dependence of ontology poses the problem of integration, where two ontologies may not share the same horizons, due to having been shaped by competing core theories of divergent worldviews of reality. Often, the terms associated and ascribed with meaning by one ontology carry contrary meanings in the other

Chua (1986) suggests that *"the issue of ontology lies prior to and governs subsequent epistemological and methodological assumptions" (Chua 1986).* Within IS, the proliferation of proposed models and frameworks for bounding and categorizing reality presume a coherent ontology, however, while a lot of academic effort has historically gone in the construction of the models, the same is untrue for the latter (O'Raghallaigh et al. 2011). An accompanying issue for IS ontologies is the lack of models to ascertain their robustness and sustain a critique. While traditional philosophy has multiple examples of critique of ontology, such as Kant's scholarship on metaphysics, the same is largely untrue for IS. For instance, while (Seedorf and Schader 2011) introduce their ontology by providing the contextual problem area and articulate avenues where their proposed ontology may be utilized, they do not provide a criterion or evaluation of the ontology's suitability and comprehensiveness vis-à-vis its lifeworld. By way of further illustration, while causality plays a vital role within a traditional ontology due to possessing predictive and explanatory powers for a particular state of affairs (Schopenhauer 1974), it has received little attention in the IS academic literature (Gregor and Hovorka 2011).

DOOYEWEERD'S ASPECTS
Herman Dooyeweerd, a Dutch philosopher, in 1955 proposed a framework for theoretical thinking by introducing fifteen modal Aspects of reality. He suggests that these fifteen Aspects are transcendental in nature, and allow for a holistic examination of a phenomenon by providing extra spheres of meaning (Dooyeweerd 1955). The aspects are Quantitative (dealing with amount), Spatial (projection and extension), Kinematic (movement, flow), Physical (energy), Biotic (life functions), Sensory (dealing with the senses and emotions), Analytical (logic), Formative (history, contextual), Lingual (syntactic, discourse), Social (institutions), Economic (resources), Aesthetic (harmony), Juridical (balance of rights and responsibilities), Ethical (moral), and Pistic (vision, goal).

By arguing that the Aspects are ontologically irreducible and modes of being, Dooyeweerd contends that no study of a single Aspect of a being can be held as Absolute understanding of the subject, and by extension objects to positivism and strict rationalism. Instead Dooyeweerd suggests that any phenomenon, entity, theory, idea can be better examined by subjecting it to a holistic examination of all applicable Aspects (Basden 2009). By way of illustration, cause and effect of a classical Newtonian physics law can be examined by carrying an investigation on the Analytical aspect of the phenomenon dealing with the logic and laws governing the phenomenon, and on the Physical aspect dealing with the effect. Dooyeweerd allows for scenarios where not all fifteen aspects will be applicable, for instance while this research paper can be investigated against its Analytical, Formative, Lingual aspects, its Physical and Biotic aspects are absent as modes of being.

Dooyeweerd (1955, p14) suggests that the core value of a *being* is its *meaning* as against existence. He attempts to construct a coherent philosophy wherein neither ontology, epistemology, nor normativity may be reduced to each other. Dooyeweerd attempts this through the usage of his aspects which he contends can be understood in union with the other aspects.

CRITICAL REALISM
Critical Realism proposes the division of reality into three spheres being real, actual, and empirical (Collier 2004). By proposing a division of reality, Critical Realism aims to allow for co-existence of competing paradigms and methodologies within the strata. As a research philosophy, Critical Realism has gained considerable currency within the field of Information Systems (Carlsson 2005; Morton 2006; Raduescu and Vessey 2009). However, (Carlsson 2006) suggests that while Critical Realism is well suited as an overarching philosophy of science that can be used within IS, it is not as developed on the methodological level.

Bhaskar (1978) explains the three divisions of reality:

> *"Real structures exist independently of and are often out of phase with the actual patterns of events. Indeed it is only because of the latter that we need to perform experiments and only because of the former that we can make sense of our performances of them. Similarly, it can be shown to be a*

> *condition of the intelligibility of perception that events occur independently of experiences. In addition, experiences are often (epistemically speaking) 'out of phase' with events—e.g., when they are misidentified. It is partly because of this possibility that the scientist needs a scientific education or training. Thus I will argue that what I will call the domains of the real, the actual and the empirical are distinct.*" (Bhaskar 1978)
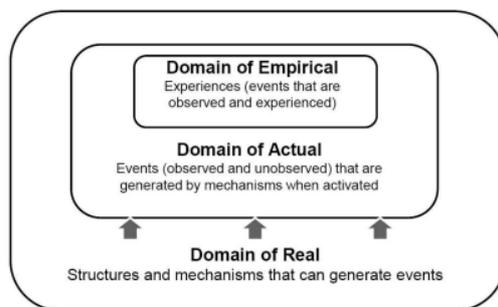

Figure 1: Three domains in Critical Realism (Mingers, 2004)

Bhaskar (1978) suggests that a phenomenon may have one or more manifestations in the strata of reality. For instance, as per table 1 below, the cause of event A may result in experience E that can be investigated within the Real, Actual and Empirical strata. The cause C of A however may only be investigated within the Real strata.

Table 1: Three domains in Critical Realism by Bhaskar (1978)

	Real	Actual	Empirical
Mechanisms	X		
Events	X	X	
Experiences	X	X	X

(Bhaskar 1991) argues that it is a mistake to analyze statements about ontology (being) in light of statements about what is known about them through epistemology (Dobson, 2001). A core idea of Critical Realism is the contention that causality may lie in the unobservable world (domain of Real) and may not be subjectable to empirical methods. However, it may be possible to investigate the causal agent by initiating an empirical investigation in the domains of Empirical and Actual leading towards the cause (Bhaskar, 1978).

(Miles and Huberman 1994) propose that Critical Realism can allow for the co-existence of core theories of both positivistic and realist philosophical traditions by accepting that facts can be laden with value, yet may be used to depict stable relationships.

TOWARDS A MODEL FOR EVALUATING ONTOLOGY

We propose that an ontology may be evaluated by examining the explanatory power it yields over its own lifeworld, and by examining the comprehensiveness of its categorizations and constructs. By way of illustration, let's assume an ontology *O* has been proposed for the Internet lifeworld *LifeI* as a pre-requisite to a Theory of Governance of the Internet *ToGoI*, which contains constructs such as the Internet *cI*. For the ToGoI to be considered robust and able to sustain a discourse, the ontology O of the LifeI should be as reflective as possible without narrowing and bounding the lifeworld, and the proposed constructs within LifeI should not be limited by narrow examination from one or few aspects.

For evaluating ontology, we propose an 'Ontology Evaluation Grid' (abbreviated as OEG hence forth) in Table 2, which has been developed utilizing the fifteen modal aspects proposed by Dooyeweerd and three aspects of reality supported by Critical Realism.

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In order to evaluate the robustness of the ontology, O can be examined by utilizing the OEG. If the proposed O provides insight, critique, or offers transformative potential for the Quantitative aspects of the LifeI within the Empirical strata of reality, the relevant grid cells can mark the first reference for evaluation. Similarly, O may also be referenced against the Social aspect in both Actual and Empirical strata of reality. Once an examination against all applicable fifteen aspects and three strata of reality within the OEG has been performed, the reference lattice can be examined for the aspect-reality that O described, or omitted.

Following individual aspect examination, a meta-view of the LifeI as per O can be constructed by mapping Aspect relationships and dependencies as per Figure 2. The meta-view mapping allows a holistic examination of the relationships that O describes with LifeI.

Once O has been evaluated in this manner, its constructs such as cI may also be subjected to the same examination by placement in OEG to achieve further granularity. For instance, cI may manifest itself in Physical and Spatial aspects with one or more strata of reality and a similar meta-mapping between constructs may be drawn.

Table 2: Ontology Evaluation Grid

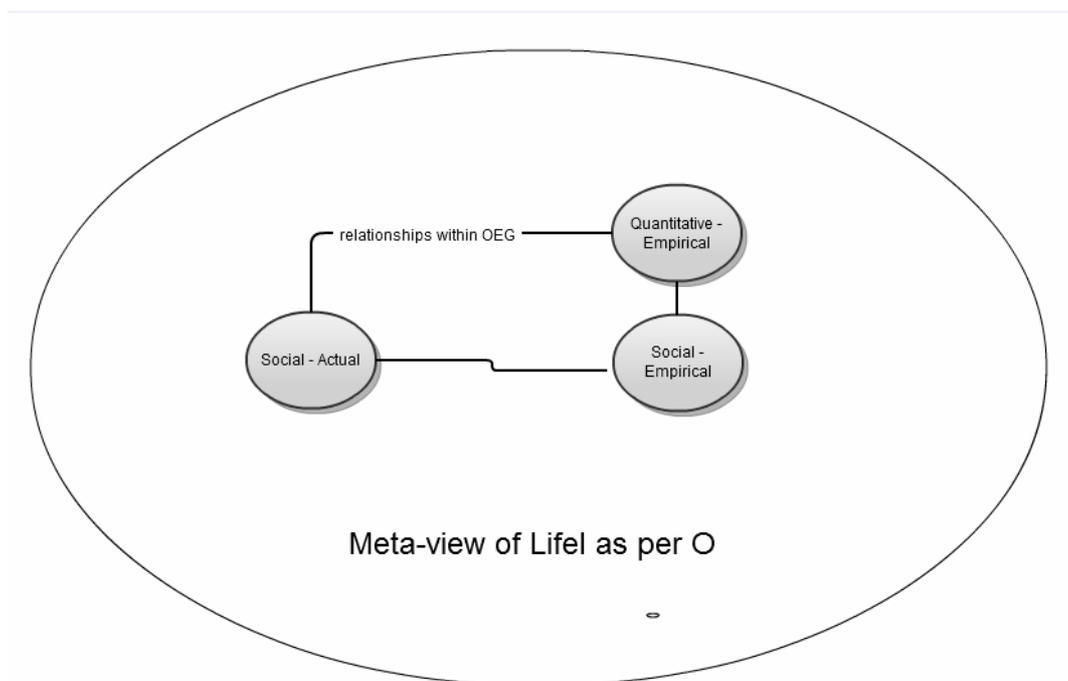|	Real	Actual	Empirical
Quantitative			
Spatial			
Kinematic			
Physical			
Biotic			
Sensory			
Analytical			
Formative			
Lingual			
Social			
Economic			
Aesthetic			
Juridical			
Ethical			
Pistic			

Figure 2: Meta-view of LifeI as per O

DISCUSSION

The OEG provides a model that can be used for evaluating the coherence and comprehensiveness of an ontology by enabling an examination of the Being, Occurring, and Knowing of the whole of temporal reality, enabling meaningful human functioning of diverse kinds. A suitable analogy can be that of a lamp that illuminates the many facets of an ontology as against a bright ray of light illuminating merely the focus at the expense of the whole. The examination of an ontology across fifteen different aspects, which according to Dooyeweerd function as all possible spheres of meaning, and across three strata of reality as supported by Critical Realism, allows for a meta-evaluation of the lifeworld the ontology attempts to describe.

The depiction of aspect relationships through a meta-view allows the OEG to situate causality within an ontology's lifeworld. By way of illustration, actors and actants within the lifeworld can be mapped against the aspect relationships to build a complex ontological framework to trace flows of activity, investigate causative origins, and determine any co-relations through the workflow.

The advocated diversity of normative aspects within an ontology, such as analytic, lingual, social, ethical, economic, allows for freedom within it while allowing for any repercussions or issues across aspects to be mapped and enable later epistemological scholarship. Furthermore, such an examination through the OEG allows the examination of an ontology's impact from both aspectual and holistic perspectives.

The OEG provides the potential to overcome incommensurability to a degree between different ontologies shaped by contrary core theories of competing schools of thought. This is achieved by allowing the OEG model to examine the ontologies through the aspects and strata of reality they engage. While completely shared horizons are not enabled by the OEG, it does allow for the commensurable elements of the ontologies to be directly compared where the same aspects are utilized. This commensurability to a degree can enable a scaffolding of shared meaning (Hirschhein et al. 1996) to sustain later research and discourse.

Furthermore, the OEG provides the means to overcome incommensurability between the researcher's (the observer) outlook and the researched lifeworld (the observed). While neutrality and objectivity are not enforced, the achieved commensurability provides a shared horizon where the aspect relationships of the research programme may be mapped, allowing for an investigation of the research programme itself.

The OEG does not enable decision making to establish an ontology's supremacy over another by means of comprehensiveness and robustness. Instead, it allows for both a comparison between commensurable elements, and help the researcher carry out an analysis on the ontology's completeness. While it is assumed that a more comprehensive and robust ontology of a lifeworld will engage more aspects of the OEG Model as against a few, there is a lack of supporting evidence at this stage.

CONCLUSION

Epistemological attempts at understanding phenomenon may not always require an ontological framework. However, a research programme dealing with a complex IS artifact, such as the Internet that lacks an ontology describing and defining the contextual lifeworld, can digress due to the lack of a common woldview that comes with an accepted ontology. While it is the ultimate goal of a philosopher to construct a single consistent ontological theory that comprehends the whole of reality, at least up to a high level of abstractness, both ontology construction and evaluation attempts within the IS field remain at a nascent stage. The proliferation of ontologies in IS that are incommensurable or mere conceptualizations instead of comprehensive descriptors of a lifeworld, have led to academic research concentrating on micro debates, instead of arriving at a macro discourse that bounds and situates these micro debates.

The paper introduced the Ontology Evaluation Grid as a model that can furnish normativity while allowing for diversity based on the thinking of Dooyeweerd and tenets of Critical Realism. A critical insight provided by the model is that while normativity in an ontology might escape human interpretation, and reside in domains of reality not open to empirical methods, IS researchers can still acknowledge the limitation and produce ontologies that are comprehensive, allow commensurability to a degree, and function as holistic representations of lifeworlds.

It is anticipated that future research will be carried out utilizing the OEG to evaluate the representation of reality proposed by an IS ontology as against reality itself, enabled by the fifteen modal Dooyeweerd aspects across the three strata of reality.

REFERENCES

Baloch, F., and Cusack, B. 2009. "Re-Visualizing Cyberspace: Using Quasi Objects for Spatial Definitions," *ACIS 2009*, Melbourne, Australia.

Baloch, F., and Cusack, B. 2011. "Utilizing Philosophical Critical Realism and Actor Network Theory to Develop the Construct Internet," in: *UKAIS*. Oxford, UK.

Basden, A. 2002. "A Philosophical Underpinning for Isd," *ECIS*, Poland.

Basden, A. 2004. "On Appealing to Philosophy in Information Systems," *AMCIS*, NY, USA.

Basden, A. 2009. "On Using Philosophy to Define and Dignify the Is Discipline," *UK Academy for Information Systems Conference*, UK.

Bhaskar, R. 1978. *A Realist Theory of Science*. Sussex: Harvester Press.

Bhaskar, R. 1991. *Philosophy and the Idea of Freedom*. Oxford: Blackwell.

Bukatman, S. 1993. *Terminal Identity: The Virtual Subject in Postmodern Science Fiction*. Durham, NC: Duke University Press.

Bunker, D., Cole, M., Courtney, J., Haynes, J., and Richardson, S. 2005. "Philosophical Foundations of Information Systems: A Review of the First 10 Years," *AMCIS*, NE, US.

Carlsson, S. 2005. "A Critical Relaist Perspective on Is Evaluation Research," in: *ECIS 2005*. Regensburg, Germany.

Carlsson, S. 2006. "Design Science Research in Information Systems: A Critical Realist Perspective," in: *ACIS 2006*. Adelaide, Australia.

Chua, W.F. 1986. "Radical Developments in Accounting Thought," *The Accounting Review* (61), pp. 601-632.

Collier, A. 2004. *Critical Realism: An Introduction to the Philosophy of Roy Bhaskar*. London: Verso.

Delaney, S. 1988. "Is Cyberpunk a Good Thing or a Bad Thing?," *Mississippi Review* (47:48), pp. 28-35.

Dooyeweerd, H. 1955. *A New Critique of Theoretical Thought*. Ontario: Paideia Press.

Falconer, D., and Mackay, D. 1999. "Ontological Problems of Pluralist Research Methodologies," in: *AMCIS 1999*. Milwaukee, USA.

Gregor, S., and Hovorka, D. 2011. "Causality: The Elephant in the Room in Information Systems Epistemology," in: *ECIS 2011*. Helsinki, FInland.

Guarino, N. 1998. "Formal Ontology and Information Systems," *FIOS 98*, Trento, Italy: IO Press, pp. 3-15.

Harvey, C.W. 1989. *Husserl's Phenomenology and the Foundations of Natural Science*. Athens: Ohio University Press.

Heidegger, M. 1962. "Dasein, Worldhood, and Reality," in *Being and Time*. New York: Harper & Row, p. 205.

Hirschhein, R., Klein, H., and Lyytinen, K. 1996. *Information Systems Development and Data Modelling: Conceptual and Philosophical Foundations*. Cambridge University Press.

Honneth, A., Knodler-Bunte, E., and Windmann, A. 1981. "The Dialectics of Rationalization: An Interview with Jurgen Habermas," *Telos* (49), pp. 3-31.

Husserl, E. 1954. *The Crisis of European Sciences and Transcendental Phenomenonology*. Evanston, Illinois: Northwestern University Press.

Husserl, E. 1970. *The Crisis of the European Sciences and Transcendental Phenomenology*. Evanston: Northwestern UP.

Koepsell, D. 2003. *The Ontology of Cyberspace: Philosophy, Law, and the Future of Intellectual Property*. Chicago: Open Court.

Lakatos, I. 1970. "Falsification and the Methodology of Scientific Research Programmes," in *Criticism and the Growth of Knowledge,* I. Lakatos and A. Musgrave (eds.). London: Cambridge University Press.

Lee, H., Liu, Y., Chen, S., Tang, S., Huang, C., Huang, P., Chang, Y., Chang, K., and Chen, K. 2002. "A Comparative Study of Protocol Analysis for Spatiality of a Text-Based Cyberspace," *Connecting the Real and the Virtual - design e-ducation [20th eCAADe Conference]*, Warsaw, Poland, pp. 262-266.

Lyytinen, L. 2003. "Information Systems and Philosophy: The Hopless Search for Ultimate Foundations," *AMCIS 2003,* J.I. DeGross (ed.), Atlanta, USA: Association for Information Systems.

Miles, M., and Huberman, M. 1994. *Qualitative Data Analysis.* Thousand Oaks, CA: Sage.

Mingers, J. 2001. "Combining Is Research Methods: Towards a Pluralist Methodology," *Information Systems Research* (12:3), pp. 240-259.

Morton, P. 2006. "Using Critical Realism to Explain Strategic Information Systems Planning," *Journal of Information Technology Theory and Applications* (8:1).

Mueller, M. 2004. *Ruling the Root.* Cambridge, MA: MIT.

Myers, M., and Klein, H. 2011. "A Set of Principles for Conducting Critical Research in Information Systems," *MISQ* (35:1), pp. 17-39.

O'Raghallaigh, P., Sammon, D., and Murphy, C. 2011. "Towards an Ontology of Innovation Models - a Conceptual Framework," in: *ECIS 2011*. Helsinki, FInland.

Quine, W. 1969. "Ontological Relativity," in *Ontological Relativity and Other Essays*. New York: Columbia University Press.

Raduescu, C., and Vessey, I. 2009. "Methodology in Critical Realist Research: The Mediating Role of Domain Specific Theory," in: *AMCIS*. San Francisco, USA.

Schopenhauer, A. 1974. *On the Fourfold Root of the Principle of Sufficient Reason.* Chicago: Open Court Publishing Co.

Seedorf, S., and Schader, M. 2011. "Towards an Enterprise Software Component Ontology," in: *AMCIS 2011*. Detroit, USA.

Smith, B. 2003. "Ontology," in *Blackwell Guide to the Philosophy of Computing and Information,* L. Floridi (ed.). Oxford: Blackwell, pp. 155-166.

Spader, P.H. 1994. "Phenomenology and the Claiming of Essential Knowledge," *Husserl Studies* (11:3), pp. 169-199.

Strate, L. 1999. "The Varieties of Cyberspace: Problems in Definiton and Delimitation," *Western Journal of Communication* (63:3), pp. 382-413.

Uschold, M., and Gruninger, M. 1996. "Ontologies: Principles, Methods and Applications," *The Knowledge Engineering Review* (11), pp. 93-136.

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