A Conceptual Model of the Research Methodology Domain
With a Focus on Computing Fields of Study

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Abstract: Recognising the need for the development of research capacity and changing learning paradigms that include online and collaborative approaches, an ontology of research methodology needs to be developed to allow for the shared creation of knowledge in this domain. An ontology engineering approach is followed in developing a conceptual model of the domain using UML, with a focus on studies in the computing disciplines. A research scheme that is made up of a philosophical world view, a research design, and research methods is proposed. Appropriate relations between these are identified, as well as attributes of the various concepts in the conceptual model. A focus group consisting of senior researchers in the field of computing was utilised to validate the model.

1 INTRODUCTION

Developing research capacity is vital if there is to be the creation of new knowledge and innovation, as well as having economic benefits (Crossouard, 2008; Green Paper, 2012). Postgraduate enrolments have been increasing globally (Engebretson et al., 2008), and the inclusion of online and collaborative learning approaches in educational paradigms (Johnson et al., 2014) should be harnessed to support the increase in postgraduate output, particularly as it relates to the supervision of these postgraduate students. Supervisors are faced with a range of dilemmas in the context of increasing student numbers, with increasing student diversity, and often with additional problems associated with distance education (Wisker et al., 2007). As the Internet has expanded and online technologies have become more popular, the way students access and build knowledge has also become more diverse (Häkkinen and Hämäläinen, 2012). However, use of technology is not just about getting content to students (where intelligent search engines can locate material) – students also need to be brought into learning networks (Chatti et al., 2007).

It has been noted that research methodology is often a problem for masters and doctoral students (Hofstee, 2006). Thus, to support postgraduate students in their collaborative, online learning of research methodologies, an ontology of the domain will provide the necessary communication support through the development of a common vocabulary, as well as allowing for accessing, sharing, integrating, and annotating such semantically driven knowledge (Bera et al., 2010; DiGiuseppe et al., 2014; Motik et al., 2002; Noy and McGuinness, 2001). Central to this task is the creation of a conceptual model of the research methodology domain, and the purpose of this paper is to propose a model of the domain that would be suitable for use by postgraduate students studying in computing disciplines. The research question is thus: What are the main concepts and relations that make up a research methodology that will guide and support students in their understanding of the domain?

Recognising that the provision of software tools in the support of postgraduate supervision may be inadequate (Yew et al., 2011), such a conceptual framework could provide the basis for learning environments that may be of value in both online as well as blended approaches to postgraduate research and supervision. Such support can be offered to supervisors and students separate from a particular model of postgraduate supervision or research education, in both physical and virtual learning environments. However, the model will also be limited to the support of the discovery and learning of research methodologies and will not cover the whole scope of research education such as developing research questions, doing a litera-

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ture review, or writing up the results.

A review of the field of ontologies and ontology engineering (section 2) will provide the basis for the development of a conceptual model. The research methodology domain and its conceptualisation will then be described (section 3). Finally, conclusions will be drawn and pointers to future work outlined (section 4).

2 ONTOLOGIES AND ONTOLOGY ENGINEERING

The concept of the Semantic Web, dating back to 2001, refers to a "new form of Web content that is meaningful to computers" (Berners-Lee et al., 2001), and it aims at allowing for the interconnection of facts or data (Gonzalez, 2013) in diverse locations and formats. This term captures two important concepts (Feigenbaum, 2013a):

1. "Semantic" refers to the meaning of the data that is explicitly represented, and this meaning is transferred along with the data.
2. The individual facts or pieces of data are linked in a network of information.

The two point to the centrality of data in the Semantic Web and that reasoning about it should not become the primary objective (Feigenbaum, 2013b). It is believed that it is in the potential behind the linking of data with consistent interpretations across a variety of sources that the power of the Semantic Web lies (Berners-Lee et al., 2006). Furthermore, an educational Semantic Web that seeks to link educational knowledge will occur in tandem with developments in the wider semantic web technology sphere (Carmichael and Jordan, 2012).

2.1 Ontologies in Education

One approach to the Semantic Web proposes the use of ontology-based formal annotations (Dzbor et al., 2007), which can enhance an educational social networking approach (such as semantic wikis, for example) (Limpens et al., 2008). This formal approach has been used in e-learning, where semantic technologies have been used in the tagging of learning materials (Cuéllar et al., 2011) – efforts that can be seen in EdNA, Educational Modelling Language (EML), SCORM, and IMS Learning Design specifications (Cope and Kalantzis, 2011; Dzbor et al., 2007). This approach has led to a move away from creating content to the collecting of current distributed learning objects from multiple sources into a personalised assemblage of learning material, using semantic metadata to construct individualised courses (Wen et al., 2012). The effect of the Semantic Web on e-learning has, thus, not just been in the semantic tagging of learning material, but also in the non-trivial provision of brokerage tools and services that match students to learning materials (Dzbor et al., 2007; Wen et al., 2012), and these tools and services could be used in research methodology studies for postgraduate students. The purpose of using semantic metadata in these situations is primarily to open up the way to resource discovery – a primary purpose of the Dublin Core standard (Cope and Kalantzis, 2011; Dzbor et al., 2007).

In this work of making resource discovery more accurate and unambiguous via semantic annotation, formal ontologies play an important role (Cope and Kalantzis, 2011; Limpens et al., 2008). An ontology provides structure to data by providing a shared, formal, and explicit conceptual model of a domain (Berners-Lee et al., 2006; Charlton et al., 2012; Naeve, 2005) and allows a common understanding of data by providing a controlled and limited vocabulary that defines the concepts of a particular domain rigorously as well as defining the relationships among them (Berners-Lee et al., 2006; Cope and Kalantzis, 2011). Although such ontologies are often built by an expert, this is not a requirement of an ontology per se, and there are approaches (such as CGMeaning) that allow a community of users to extend such an ontology and establish a dialogue with the community on the particular expression of reality in the ontology (Cope and Kalantzis, 2011). The critical value of such a shared domain model where co-construction of knowledge is contemplated and a common vocabulary is necessary has been noted previously (Charlton et al., 2012), as tools based on an ontology are able to interpret what the user is intending, as the semantics, or meaning, of words is formally represented, and, as such, are an improvement over simple character strings and mark-up languages such as metadata tags and XML (Charlton et al., 2012).

2.2 An Ontology Engineering Approach

It has been argued that there is no single, correct ontology engineering methodology, as well as there not being only one correct way to model a domain (Brusa et al., 2006; Di Maio, 2011; Nagypál, 2007; Noy and McGuinness, 2001). Various approaches have been proposed and used (Corcho et al., 2003; De Leenheer and Christiaens, 2007; Di Maio, 2011; Keet et al., 2013; Nagypál, 2007; Noy and McGuinness, 2001).

Yet such a methodology, or ontological engineering process, is useful, if not crucial, as it facilitates a pragmatic and systematic path through the complex processes and tasks of building an ontology (Devedzic, 2002; Di Maio, 2011; Nagypál, 2007). The ontology engineering process used in this research is based on the work of

- Nagypál – METHONTOLOGY, which has been suggested to be the most mature of the various approaches (Corcho et al., 2003; Nagypál, 2007),
- Noy and McGuinness – Ontology Development 101 (Noy and McGuinness, 2001),
- Di Maio – JEOE (Just Enough Ontology Engineering), although the author proposed this an approach to ontology engineering rather than a methodology (Di Maio, 2011), and
- Brusca, Caliusco, and Chiotti (Brusa et al., 2006),

all of which are largely application independent methodologies.

The strategy that will be applied in the case of the research methodology ontology will be a middle-out approach (Nagypál, 2007). This will allow a form of brain-storming at the start of the process to find the most salient concepts in the research methodology domain. Once this is done, the model can be refined, and the ontology can grow both upwards (to more abstract concepts) and downwards (to more specific concepts).

Ontology development methodologies suggest separating the two main tasks of the process – specification, and implementation (Di Maio, 2011) – and in this paper the focus will be on specification. However, the conceptualisation of the research methodology model is seen as separate from its specification (Brusa et al., 2006; Nagypál, 2007), and this was added as a separate step; specification and conceptualisation can thus be taken as the knowledge acquisition part of the ontology engineering process (Devedzic, 2002). Figure 1 lays this process out in summary form. The approach followed allowed the ontology to be expressed in a conceptual model first before being implemented in an ontology representation language.

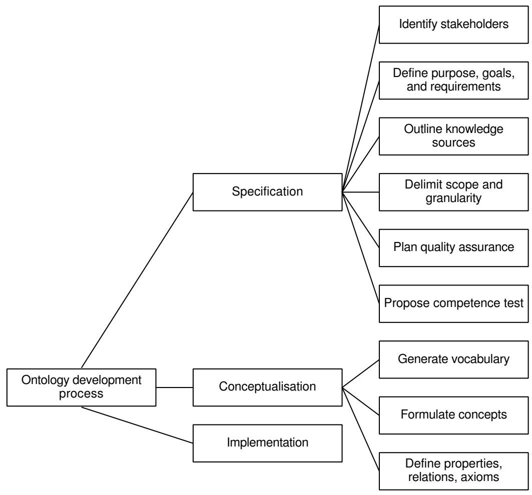

Figure 1: An ontology development process map.

2.2.1 Specification

The point of this step is to gain knowledge about the domain, and what needs to be achieved.

Stakeholders: The stakeholders would include this researcher, postgraduate students (and their supervisors) in the fields of computer science and information systems, as well as researchers more generally.

Purpose, goals, requirements: The purpose of the ontology is to be a content- and communication-oriented ontology that describes the research methodology field/domain and allows for sharing of knowledge, with the goal being to allow the ontology to be used to tag data in research publications, as well as set up and consolidate a knowledge base about research methods that can be used by stakeholders; semantic searching and reasoning over the content of the ontology should also be possible. The ontology should be usable by both masters and doctoral students (novices) and supervisors (experts).

Knowledge sources: These would be current, experienced supervisors/researchers in the domain under consideration, as well as books that have been written to support the postgraduate student in the learning of research methodologies.

Scope: This would be a domain ontology that will cover all major research methodologies used in postgraduate studies in computer science and information systems.

Quality plan: The quality was initially ensured via a focus group discussion based on the conceptual model of the domain being modelled, and will be further tested in the next phase of the research.

Competence/knowledge boundary tests: The research methodology ontology should be able to answer questions similar to the following.

- Which methods are used by a particular design?
- What are a particular design's assumptions/theoretical base?
- With a particular theoretical base, which designs could be used?
- Which designs can specific methods be used with?
- Which is the best design to achieve a certain outcome?

- What are the characteristics of a particular design?

2.2.2 Conceptualisation

This is one of the most complex tasks in ontology development (Nagypál, 2007), and aims to produce a model of the research methodology domain in a form that will allow communication with domain experts who may not be fully conversant with ontology languages (Nagypál, 2007) – UML in this case. This phase has been referred to as "developing the artefacts" (Di Maio, 2011, 7), and here the use of semantic networks, brainstorming, and mind maps are recommended for the early stages of the development process (Nagypál, 2007). The following steps were not attempted linearly, recognising that many of these ideas are closely interlinked (Noy and McGuinness, 2001), and thus they were accomplished as a group of tasks rather than completed individually.

Vocabulary: The important terms in the research methodology domain were listed and organised in an informal way as a start to the process of building the ontology.

Concepts: A concept could be described as "fundamental to our ability to think, express, represent and communicate, ... Concepts can correspond to things, but also to fuzzy clouds of ideas and notions identified by words and related to a certain thing or subject. ... cognitive artifacts that support categorization and communication, and are necessary to support human and artificial thinking and reasoning." (Di Maio, 2011, 7). Concepts in a research methodology that were considered important in this domain related to the types of designs of a research endeavour as well as the methods that would be used. The grounding in some philosophical position was also considered important.

Properties: The properties, or attributes, of the identified concepts were established.

Relations: Relations are the "semantic interdependence" (Di Maio, 2011, 8) between concepts, and these were identified. It is in this task that a concept or taxonomic hierarchy is developed (Noy and McGuinness, 2001).

2.2.3 Implementation

Transferring the conceptual model to a formal notation such as first order logic or description logics is sometimes included as a formal part of the ontology engineering process (Nagypál, 2007), and this approach will also be followed here in work in developing the ontology further into description logics and, finally, OWL. As work has been done on transferring a UML conceptual model directly to OWL (Zedlitz and Luttenberger, 2014), this can be used to check the OWL implementation developed from the description logics phase. The implementation activity thus involves taking the conceptual model and representing it in some ontology language.

3 A CONCEPTUAL MODEL OF THE RESEARCH METHODOLOGY DOMAIN

There are several books that discuss the research methodology domain for postgraduate students that will be referenced in this section, as well as the Sage Research Methods Online (SRMO) website (http://srmo.sagepub.com), and although these cover much the same material, there are differences in the way the research methodologies are structured and discussed, what topics are included, and the terminology used. It is hoped that in the construction of a conceptual model of the domain, a single model can be designed that would bring these various disparate ideas together in a form that will ultimately benefit the postgraduate student. Similar work has been done in the Ontology of Clinical Research (OCRe) where such a model serves as a common semantics for human clinical studies supporting data description, data sharing, and knowledge-based decision support (Sim et al., 2014).

Conceptual modelling can be seen as "identifying, analyzing and describing the essential concepts and constraints of a domain with the help of a (diagrammatic) modeling language" (Guizzardi et al., 2002, 69). There is, furthermore, basic agreement that a conceptualisation is a "formal structure" (Guarino, 2005, 7), or representation, about some aspect of the real world with the aim of allowing that domain to be better understood and communicated – that is, providing clear and unambiguous semantics is an essential objective (Bera et al., 2010; Partridge et al., 2013; Wand et al., 1999; Weber, 2003).

The conceptual model will be built using UML, and so a discussion of this will precede the presentation of the model. The model will then be presented following the main components of the conceptual model. Note that only some representative classes will be included in the diagrams of the model to give an idea of the structure of the model, and that the data types that are given in the class diagrams will be listed in a table along with possible instances. Note that the string data type used in the diagrams allows for the entry of any string that would describe the data variable, and that bool(ean) allows for yes/no or true/false type values. The validation of the model will close the discussion of the model.

3.1 Modelling using UML

Conceptual models are often built using some modelling grammar (Bera et al., 2010; Weber, 2003), and as conceptual models largely subscribe to object-oriented views of the world (Borgida and Brachman, 2003), it was decided to use UML as the modelling grammar for this conceptual model – a choice that has often been been made (Zedlitz and Luttenberger, 2014). Further reasons for using UML include its open standard and that it has a strong history in conceptual modelling (Burek, 2003).

It has been noted that there are problems with using UML as a conceptual modelling grammar as it is not based on sound ontological theory (Burek, 2003; Weber, 2003). Such problems relate to questions about creating one single, all-encompassing conceptual modelling grammar as against several specialised grammars, although no definitive answer is arrived at (Weber, 2003). However, it is conceded that UML is the current standard conceptual modelling grammar, and acknowledged that it does offer powerful conceptual modelling constructs (Weber, 2003). UML also models specialisation/generalisation relations, and uses composition/aggregation to handle part-whole relations(Keet and Artale, 2008). It is on this basis that the choice of UML has been maintained.

3.2 Research Scheme

A conceptual model is easier to understand and manage if it has a root concept or class (Motik et al., 2002), and thus the model presented here is rooted in the concept of a research scheme. It is necessary to make it clear what is meant by the term research methodology as against the term research scheme (as these terms are used in this paper). Research methodology has been used in various ways in the literature, from being a synonym for a research design, to being the research process, to being the specific implementation of the methods (Balian, 2011; Hammond and Wellington, 2013; Mouton, 2001; van Wyk, sa). Here it is taken to mean the overall justification, rationale, or logic for undertaking the research in terms of locating it within the larger body of scientific enquiry, explaining which, how, and why particular research designs should be applied in the research, and deciding and describing which appropriate methods will be employed (Clough and Nutbrown, 2007; Grix, 2010; Hofstee, 2006; Kothari, 1985). A research scheme, on the other hand, is a structure that describes the concepts that are included in a research methodology, and covers the choice of particular approaches and methods (as opposed to methodologies) to meet the needs of the proposed overall methodology.

A research scheme is thus made up of a philosophical world view which underpins the research, a research design which provides the structure of the research, and research methods that are used in a design. A detailed description of all the various options for these three elements will not be provided, and this can found elsewhere (Biggam, 2011; Creswell, 2014; Grix, 2010; Hammond and Wellington, 2013; Hofstee, 2006; Mouton, 2001; Oates, 2006; Olivier, 1999; Wisker, 2001). Figure 2 shows that this root class (the *ResearchScheme*) is

- underpinned by a single *PhilosophicalWorldview*, and
- has one or more *ResearchDesign*s – thus allowing for mixed-method type studies where more than one method is used in the research methodology.

The inverses of these two relationships indicate that a *PhilosophicalWorldview* may underpin, and a *ResearchDesign*s may be used in, none or many *ResearchScheme*s. The *ethicalClearance* attribute ensures that this important part of any research scheme is included in the model.

Note that the relationship of *ResearchScheme* to *PhilosophicalWorldview* and *ResearchDesign* is a part-whole relationship, where the philosophical world view and research design are part of the research scheme. This is a meronymic, component–complex/integral object type relation, where the category of the parts differ from the category of the whole. The two components provide the philosophical basis and guiding design structure employed in a research scheme.

Note also that *PhilosophicalWorldview*s and *ResearchDesign*s need to be consistent with each other, and that a research scheme would not simply be underpinned by any world view, and use any designs.

Further, each *ResearchDesign* may have one or more *ResearchMethod*s, and each *ResearchMethod* may be used in none or many *ResearchDesign*s. Again, the method, or methods, employed may be seen as a part of the research design in a similar part-whole relationship as that that exists between the research scheme and a research design.

Each of these three main components of a research scheme will be presented separately below.

3.3 Philosophical World View

All research is based on some (albeit sometimes

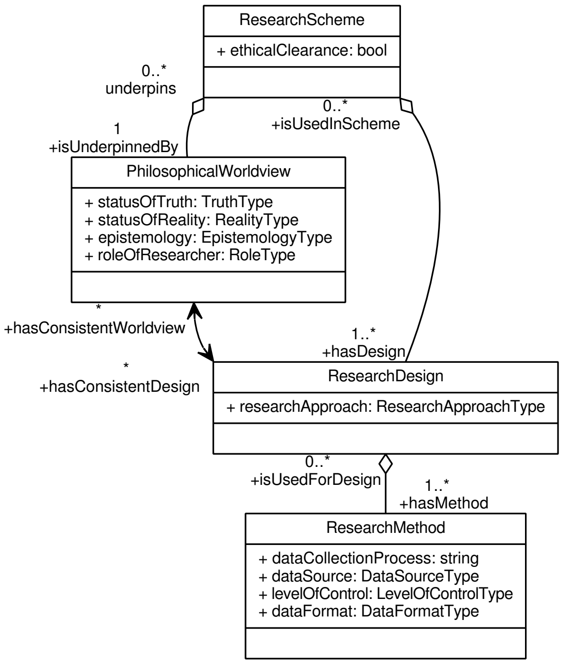

Figure 2: The high level classes that make up a research scheme.

undeclared and implicit) philosophical world view (Wahyuni, 2012). This is also sometimes known as a (meta-theoretical) paradigm, tradition, perspective, or meta-science (Creswell, 2014; Ebersohn, 2011; Grix, 2010; Hammond and Wellington, 2013; Mouton, 2001; Wisker, 2001). Essentially, though, this provides the underlying fundamental beliefs, or basis, for statements about the status of truth and reality in the research endeavour, as well as the grounding for what is to be studied, how it is to be studied, and the nature of the knowledge found or created by the research (Creswell, 2014; Hammond and Wellington, 2013; Wisker, 2001).

Common examples of philosophical world views include post-positivism, constructivism, transformative/critical theory, interpretivism, and pragmatism.

It does need to be noted that there is also reference to qualitative and quantitative paradigms in the literature on research methodologies (Clarke, 2005), although these are also referred to as approaches (Creswell, 2014).

The *PhilosopicalWorldview* class is related to the five classes that represent common philosophical world views in computer science and information systems research via an inheritance relation (see Figure 3). The relationship is one of subsumption where each of the world views is in an is-a relation with the superclass, *PhilosopicalWorldview*, and could be seen as subclasses of this class (Welty, 2002).

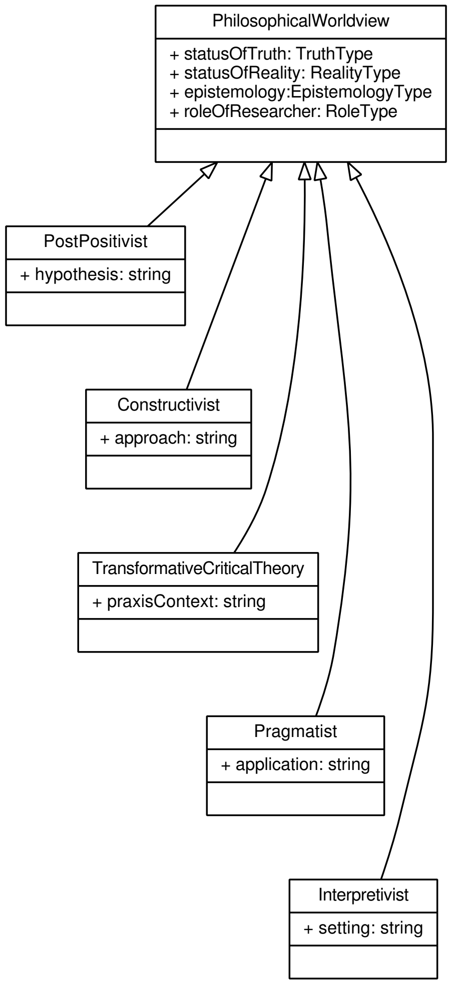

Figure 3: Subclasses of the *PhilosophicalWorldview* class.

See Table 1 for possible values/instances for the *PhilosopicalWorldview* class.

3.4 Research Design

A research design (or strategy, method, or methodology, as it is also sometimes known (Biggam, 2011; Creswell, 2014; Hofstee, 2006)) identifies and describes the overall kind of study that will be done (Mouton, 2001) and provides a structure/framework/blueprint/plan for the whole process (Hammond and Wellington, 2013; van Wyk, sa). Different research designs are best suited to answering certain types of questions (Mouton, 2001), and the decision of which design to use is usually guided by the research questions and the kind of information that the researcher is wanting (Hammond and Wellington, 2013; Wahyuni, 2012; Wisker, 2001). The design should also be consistent with the philosophical world view which underpins the research scheme.

Table 1: *PhilosopicalWorldview* data types.

Data type	Possible values
TruthType	Absolute Relative/CriticalRealism MultipleTruths
RealityType	External/Independent Objective Rational Subjective
EpistemologyType	Empiricism Constructivism LogicalPositivism Realism
RoleType	ObjectiveRole SubjectiveRole ParticipantRole AdvocateRole

Research designs are often divided into two main groups, or types, of designs (Mouton, 2001; Remenyi and Money, 2004): empirical and non-empirical/theoretical designs. However, this is not a universal approach, and some authors prefer to divide designs by the basic approach: qualitative or quantitative (Kothari, 1985). It has been argued that it is a mistake to group research designs in this way as designs are not intrinsically qualitative or quantitative (Biggam, 2011). Furthermore, it has been pointed out that the empirical/non-empirical division neatly follows the types of questions that designs can be used to answer (Mouton, 2001). Also, a particular design could use both qualitative and quantitative research methods with it being rare that only one such approach will be used (Biggam, 2011), and so the empirical/non-empirical approach will be used here. However, the alternative qualitative/quantitative structure, or even a basic/applied structure, can also be accommodated in the ontology. A observational/interventional classification has also been proposed (Sim et al., 2014).

A research scheme may use more than one research design (either concurrently or sequentially) in answering the research questions, and the study becomes what is known as a mixed methods one that often integrates both qualitative and quantitative approaches (Balian, 2011; Creswell, 2014; Hofstee, 2006); this is sometimes used as a deliberate attempt to triangulate, and so reach a deeper understanding of the research topic (Hammond and Wellington, 2013). Also, it is possible that a variation of a standard design can be used (Hofstee, 2006), although such adaptations will not be addressed in the ontology; rather, the basic design will be covered, allowing the individual researcher to adapt as necessary, and after further reading about the chosen design.

Table 2: *ResearchDesign* and sub-class data types.

Data type	Possible values
ResearchApproachType	Qualitative Quantitative Hybrid/MixedMethod
CaseStudyDesignType	SingleCase MultipleCase
CaseStudyFocusType	CriticalCase UniqueCase RevelatoryCase ExploratoryCase DescriptiveCase ExplanatoryCase
SurveyType	Longitudinal CrossSectional Panel Cohort
SampleType-Random	SimpleRandom Stratified Cluster Systematic
SampleType-NonRandom	Convenience Quota Accidental Theoretical Purposive SystematicMatching Snowball
ExperimentalSettingType	Laboratory Field
ExperimentalGoalType	Explore Test Prove
PresentationType	Graphical Mathematical
ModelTheoryType	ReducedScale Abstraction

Common examples of research designs in computer science and information systems include case studies, surveys, algorithm development, model or theory building, and experiments.

Thus, the *ResearchDesign* class has been sub-classed into two basic research design types: *EmpiricalResearchDesign* and *NonEmpiricalResearchDesign* – see Figure 4. These two sub-classes are again sub-classed into common research design types according to the two main categories.

See Table 2 for possible values/instances for the *ResearchDesign* class and its sub-classes.

3.5 Research Methods

Research methods are the tools or instruments that will be used to gather data, and a research design may use several different research methods (Balian, 2011; Hammond and Wellington, 2013; Hofstee, 2006). Commonly, methods may be categorised as either

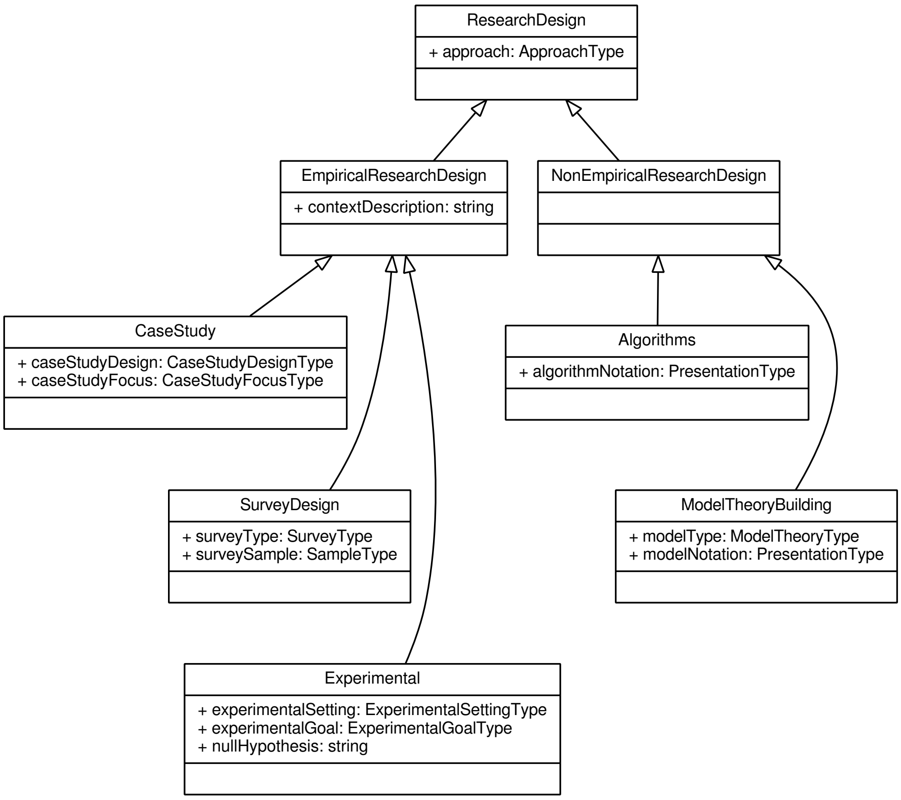

Figure 4: Subclasses of the *ResearchDesign* class.

quantitative or qualitative (Grix, 2010; Hammond and Wellington, 2013). However, it has been argued that researchers need to be aware that the methods themselves are atheoretical and do not have philosophical or methodological assumptions (and can thus be used in various research designs), and that it is why they are chosen, and how they are applied, that is linked to such assumptions (Grix, 2010; Wahyuni, 2012).

The collected data must be analysed so that it can be interpreted and used as evidence in the research argument to generate research findings (Biggam, 2011; Creswell, 2014; Hofstee, 2006), again using specific approaches and tools. Note that the analysis will not be dealt with in detail in this research scheme, and is an avenue for developing the ontology further.

Common examples of research methods in computer science and information systems include interviews, observations, measurements, argumentation, and survey questionnaires.

The *ResearchMethod* class has also been subclassed to provide for qualitative, quantitative and theoretical research methods - see Figure 5. This largely follows the usual categorisation, although a sub-class has been added for the methods that can be used in the more theoretical research designs.

See Table 3 for possible values/instances for the *ResearchMethod* class and its sub-classes.

3.6 Validating the Model

A focus group was organised (with the necessary ethical clearance) to validate the conceptual model of the research methodology domain. This was an exploratory focus group which has been recommended for refining the design of artefacts such as this model (Hennink, 2014; Tremblay et al., 2010). The focus group allowed the participants to spontaneously interact with each other in reviewing the initial conceptual model that was discussed, permitting the moderator to use the group synergy and dynamic to gain an understanding of the perceptions and impressions of the participants about the model (Stewart et al., 2007; Krueger and Casey, 2009).

The focus group was made up of ten senior researchers (six professors, three associate professors, and a senior lecturer who teaches a module on research methodologies; five from computer science and five from information systems backgrounds) who supervise postgraduate students in a distance education environment. These researchers knew each other, which allowed the group to relate to each other eas-

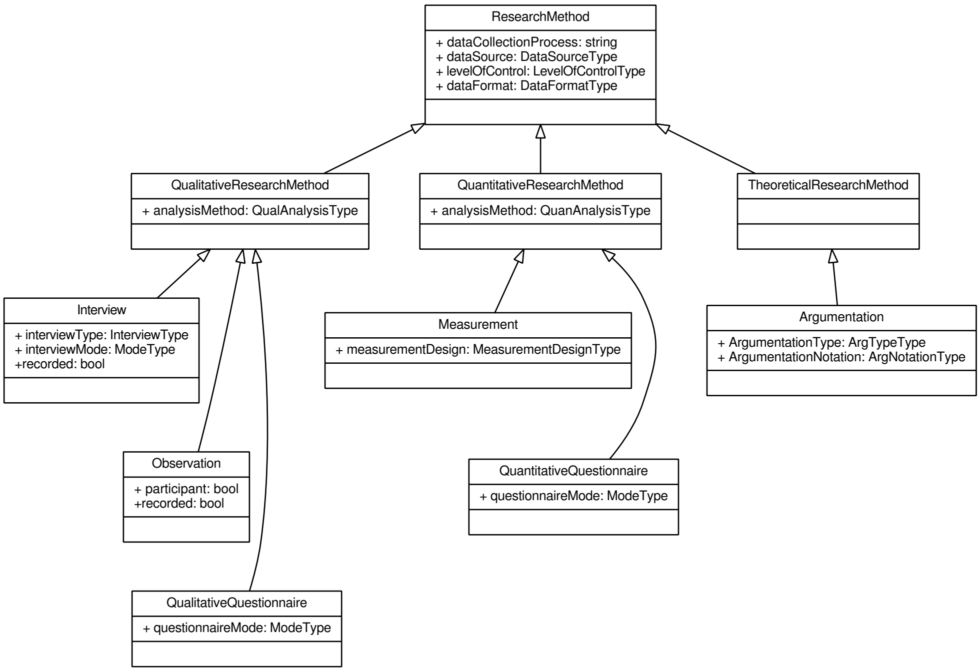

Figure 5: Subclasses of the *ResearchMethod* class.

ily, but were all senior enough to respect the ideas of others in the group and not to be threatened by such views. There was also no dominant member in the group, which could have limited its usefulness (Hennink, 2014). Group participants were provided with a copy of the model, as well as the proposed questions, before the group met.

The focus group was moderated by the developer of the conceptual model, realising that this role needed to balance the aspects of having someone present the model who knew it well but at the same time avoiding introducing any bias into its presentation (Tremblay et al., 2010). However, this approach allowed the model developer to interact directly with the researchers, enhancing opportunities to probe and follow-up on comments made in the interactions.

The one factor that was problematic relates to the expected outcome of the focus group. Generally, the aim of a focus group is not to come to a consensus (Hennink, 2014; Krueger and Casey, 2009; Stewart et al., 2007). However, the point of an ontology is a shared conception of a domain. So the focus group's expected outcome was to understand to what extent the model could be accepted by the group participants, rather than to reach final consensus, so that decisions could be made concerning the model.

The focus group led to refinements to the model in the following ways:

- The use of some terminology had to be modified to reduce misunderstandings. For example, the research method class named *Measurement* was originally named Experimental, and it was felt that *Measurement* better encapsulated the task of the method.

- A relationship indicating a consistency between *PhilosphicalWorldview*s and *ResearchDesign*s was added to improve the structure of the hierarchy of concepts.

- Some specific research designs and research methods were added, although these are not part of the fragment that is presented here.

- Alternative categorisations (or sub-classing) of the research designs were proposed such as the qualitative/quantitative and basic/applied categorisations mentioned before (see 3.4).

- Some additional concept attributes were added to classes. For example, it was felt that introducing the *ethicalClearance* attribute in the *ResearchScheme* class would highlight the importance of this aspect of research.

- The scope of the model was refined in terms of what should be included and what is seen as external to the model. The conceptual model thus focusses only on the philosophical world views, research designs, and research methods that are common in computing fields of research.

Table 3: *ResearchMethod* and sub-class data types.

Data type	Possible values
DataSourceType	Observed Self-reported Archival Physical
LevelOfControlType	Low Medium High
DataFormatType	Video Image Audio Text Numeric Hybrid
QualAnalysisType	Thematic GroundedTheory
QuanAnalysisType	DescriptiveStatistics InferentialStatistics NonParametricStatistics
InterviewType	StructuredInterview UnstructuredInterview SemiStructuredInterview
ModeType	FaceToFace Telephonic Postal Electronic PaperBased
MeasurementDesignType	SingleGroup Blind Experimental/Control
ArgTypeType	Inductive Deductive
ArgNotationType	MathematicalNotation Symbolic Textual

4 CONCLUDING REMARKS

Ontology development, and thus its conceptual modelling, is an iterative process (Noy and McGuinness, 2001), and this paper is just one step in the process of modelling the research methodology domain. Three key concepts were identified (the philosophical world view, the research design, and the research methods), modelled around a central research scheme (which encapsulates the decisions being made about a research methodology). The relationships linking these major components were explained, and depicted in a UML class diagram. Moreover, each key concept, modelled as a UML class, was extensively expanded into its subclasses, as they occur in the research methodology literature. This comprehensive model of these key concepts constitutes a novel contribution to the formalisation of the research methodology for computing domain towards the development of an ontology. The development of such an ontology in OWL forms part of future work.

While there may be little controversy surrounding the three key components of a research scheme, it is at the level of the research designs and methods that finding consensus may be more problematic, even though the proposed model has been largely accepted by a focus group of senior supervisors in computing research. A workable and shared conceptual model has to be agreed upon to allow an OWL ontology of the domain to be developed. It does need to be made clear, however, that this model will not (as with others (Devedzic, 2002)) fully represent the whole research methodology domain, but only that part that will allow computer science and information systems postgraduate students to explore, and contribute to, an understanding of this domain.

The conceptual model could be expanded to include a wider variety of research designs and methods (particularly for study domains that may use other research designs and methods from those commonly used in computing). Further, an ontology (once built) could be integrated into a semantic wiki to allow for the learning of, and collaborative generation of knowledge about, research methodologies. It could also allow research articles to be parsed, drawing data relevant to the ontology into a searchable form to further assist students in learning how such research schemes have been implemented by other researchers.

REFERENCES

Balian, E. S. (2011). *The Graduate Research Guidebook: A Practical Approach to Doctoral/Masters Research*. Silver Sky Publishing, Encinitas, CA, 4th edition.

Bera, P., Krasnoperova, A., and Wand, Y. (2010). Using ontology languages for conceptual modeling. *Journal of Database Management*, 21(1):1–28.

Berners-Lee, T., Hall, W., Hendler, J. A., O'Hara, K., Shadbolt, N., and Weitzner, D. J. (2006). A framework for web science. *Foundations and Trends in Web Science*, 1(1):1–130.

Berners-Lee, T., Hendler, J., and Lassila, O. (2001). The Semantic Web. *Scientific American*, 284(5):34–43.

Biggam, J. (2011). *Succeeding With Your Master's Dissertation: A Step-By-Step Handbook*. Open University Press, Maidenhead, 2nd edition.

Borgida, A. and Brachman, R. J. (2003). Conceptual modeling with description logics. In Baader, F., McGuinness, D. L., Nardi, D., and Patel-Schneider, P. F., editors, *The Description Logic Handbook: Theory, Implementation, and Applications*, chapter 10, pages 359–381. Cambridge University Press, Cambridge.

Brusa, G., Caliusco, M. L., and Chiotti, O. (2006). A process for building a domain ontology: An experience in developing a government budgetary ontology. In

Proceedings of the Australasian Ontology Workshop – Conferences in Research and Practice In Information Technology, Volume 72, pages 7–15. Australian Computer Society, Inc.

Burek, P. (2003). Conceptual modeling based on upper-level ontologies and meta-ontological foundations. *Content-und Wissensmanagement*, pages 117–122.

Carmichael, P. and Jordan, K. (2012). Semantic web technologies for education – time for a turn to practice? *Technology, Pedagogy and Education*, 21(2):153–169.

Charlton, P., Magoulas, G., and Laurillard, D. (2012). Enabling creative learning design through semantic technologies. *Technology, Pedagogy and Education*, 21(2):231–253.

Chatti, M., Jarke, M., and Frosch-Wilke, D. (2007). The future of e-learning: A shift to knowledge networking and social software. *International Journal of Knowledge and Learning*, 3(4/5):404–420.

Clarke, R. J. (2005). Research models and methodologies. HDR Seminar Series, Faculty of Commerce, Spring Session.

Clough, P. and Nutbrown, C. (2007). *A Student's Guide to Methodology*. Sage, London.

Cope, B. and Kalantzis, M. (2011). Creating an interlanguage of the social web. In Cope, B., Kalantzis, M., and Magee, L., editors, *Towards a Semantic Web: Connecting Knowledge in Academic Research*, pages 371–427. Oxford: Chandos.

Corcho, O., Fernández-López, M., and Gómez-Pérez, A. (2003). Methodologies, tools and languages for building ontologies. Where is their meeting point? *Data & Knowledge Engineering*, 46(1):41–64.

Creswell, J. W. (2014). *Reseach Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE, Thousand Oaks, 4th edition.

Crossouard, B. (2008). Developing alternative models of doctoral supervision with online formative assessment. *Studies in Continuing Education*, 30(1):51–67.

Cuéllar, M., Delgado, M., and Pegalajar, M. (2011). Improving learning management through semantic web and social networks in e-learning environments. *Expert Systems with Applications*, 38(4):4181–4189.

De Leenheer, P. and Christiaens, S. (2007). Mind the gap!: Transcending the tunnel view on ontology engineering. In *Proceedings of the 2nd International Conference on the Pragmatic Web*, pages 75–82. ACM.

Devedzic, V. (2002). Understanding ontological engineering. *Communications of the ACM*, 45(4):136–144.

Di Maio, P. (2011). 'Just enough' ontology engineering. In *Proceedings of the International Conference on Web Intelligence, Mining and Semantics*, pages 1–10. ACM.

DiGiuseppe, N., Pouchard, L. C., and Noy, N. F. (2014). Sweet ontology coverage for earth system sciences. *Earth Science Informatics*, 7(4):249–264.

Dzbor, M., Stutt, A., Motta, E., and Collins, T. (2007). Representations for semantic learning webs: Semantic web technology in learning support. *Journal of Computer Assisted Learning*, 23(1):69–82.

Ebersohn, L. (2011). Postgraduate supervision. Workshop presented at the University of South Africa, 9 July 2011.

Engebretson, K., Smith, K., McLaughlin, D., Seibold, C., Terrett, G., and Ryan, E. (2008). The changing reality of research education in Australia and implications for supervision: A review of the literature. *Teaching in Higher Education*, 13(1):1–15.

Feigenbaum, L. (2013a). The many names for the Semantic Web, Semantic University, Cambridge Semantics. http://www.cambridgesemantics.com/semantic-university/many-names-for-the-semantic-web.

Feigenbaum, L. (2013b). Semantic Web misconceptions, Semantic University, Cambridge Semantics. http://www.cambridgesemantics.com/semantic-university/semantic-web-misconceptions.

Gonzalez, R. (2013). Introduction to the Semantic Web, Semantic University, Cambridge Semantics. http://www.cambridgesemantics.com/semantic-university/introduction-to-the-semantic-web

Green Paper (2012). Green paper for post-school education and training. Department of Higher Education and Training, Republic of South Africa.

Grix, J. (2010). *The Foundations of Research*. Palgrave, Houndmills, Basingstoke, 2nd edition.

Guarino, N. (2005). Ontology-driven conceptual modelling. 9th East-European Conference on Advances in Databases and Information Systems (ADBIS'2005).

Guizzardi, G., Herre, H., and Wagner, G. (2002). On the general ontological foundations of conceptual modeling. In *Proceedings of 21st International Conference on Conceptual Modelling, ER 2002, LNCS 2503*, pages 65–78, Tampere, Finland.

Häkkinen, P. and Hämäläinen, R. (2012). Shared and personal learning spaces: Challenges for pedagogical design. *Internet and Higher Education*, 15:231–236.

Hammond, M. and Wellington, J. (2013). *Research Methods: The Key Concepts*. Routledge, Abingdon.

Hennink, M. M. (2014). *Focus Group Discussions*. Series in Understanding Qualitative Research. Oxford.

Hofstee, E. (2006). *Constructing a Good Dissertation*. EPE, Sandton.

Johnson, L., Adams Becker, S., Estrada, V., and Freeman, A. (2014). NMC Horizon Report: 2014 Higher Education Edition. Technical report, The New Media Consortium, Austin, Texas.

Keet, C. M. and Artale, A. (2008). Representing and reasoning over a taxonomy of part–whole relations. *Applied Ontology*, 3(1):91–110.

Keet, C. M., Khan, M. T., and Ghidini, C. (2013). Ontology authoring with FORZA. In *Proceedings of the 22nd ACM International Conference on Information & Knowledge Management*, pages 569–578. ACM.

Kothari, C. R. (1985). *Research Methodology: Methods and Techniques*. Wiley Eastern, New Delhi.

Krueger, R. E. and Casey, M. A. (2009). *Focus Groups. A Practical Guide for Applied Research*. Sage, Thousand Oaks, 4th edition.

Limpens, F., Gandon, F., and Buffa, M. (2008). Bridging ontologies and folksonomies to leverage knowledge sharing on the social web: A brief survey. In *23rd IEEE/ACM International Conference on Automated Software Engineering-Workshops, 2008*, pages 13–18. IEEE.

Motik, B., Maedche, A., and Volz, R. (2002). A conceptual modeling approach for semantics-driven enterprise applications. In *On the Move to Meaningful Internet Systems 2002: CoopIS, DOA, and ODBASE, LNCS 2519*, pages 1082–1099.

Mouton, J. (2001). *How to Succeed in your Master's and Doctoral Studies: A South African Guide and Resource Book*. Van Schaik, Pretoria.

Naeve, A. (2005). The human semantic web shifting from knowledge push to knowledge pull. *International Journal on Semantic Web and Information Systems*, 1(3):1–30.

Nagypál, G. (2007). Ontology development: Methodologies for ontology engineering. In Studer, R., Grimm, S., and Abecker, A., editors, *Semantic Web Services: Concepts, Technologies and Applications*, chapter 4, pages 107–134. Springer, Berlin.

Noy, N. F. and McGuinness, D. L. (2001). Ontology development 101: A guide to creating your first ontology. Technical report, Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880.

Oates, B. J. (2006). *Researching Information Systems and Computing*. Sage, London.

Olivier, M. S. (1999). *Information Systems Research: A Practical Guide*. Published by author.

Partridge, C., Gonzalez-Perez, C., and Henderson-Sellers, B. (2013). Are conceptual models concept models? In *Proceedings of ER 2013, Lecture Notes in Computer Science 8217*, pages 96–105.

Remenyi, D. and Money, A. (2004). *Research Supervision for Suprevisors and their Students*. Academic Publishing International, Reading.

Sim, I., Tu, S. W., Carini, S., Lehmann, H. P., Pollock, B. H., Peleg, M., and Wittkowski, K. M. (2014). The ontology of clinical research (OCRe): An informatics foundation for the science of clinical research. *Journal of Biomedical Informatics*, 52:78–91.

Stewart, D. W., Shamdasani, P. N., and Rook, D. W. (2007). *Focus Groups*. Sage, Thousand Oaks.

Tremblay, M. C., Hevner, A. R., and Berndt, D. J. (2010). Focus groups for artifact refinement and evaluation in design research. *Communications of the Association for Information Systems*, 26(Article 27):599–618.

van Wyk, B. (s.a.). Research design and methods, Part I. http://www.uwc.ac.za/Students/Postgraduate/Documents/Research_and_Design_I.pdf.

Wahyuni, D. (2012). The research design maze: Understanding paradigms, cases, methods and methodologies. *Journal of Applied Management Accounting Research*, 10(1):69–80.

Wand, Y., Storey, V. C., and Weber, R. (1999). An ontological analysis of the relationship construct in conceptual modeling. *ACM Transactions on Database Systems*, 24(4):494–528.

Weber, R. (2003). Conceptual modelling and ontology: Possibilities and pitfalls. *Journal of Database Management*, 14(3):1–20.

Welty, C. (2002). Ontology-driven conceptual modeling. Slide presentation at CAISE-02.

Wen, L., Brayshaw, M., and Gordon, N. (2012). Personalized content provision for virtual learning environments via the semantic web. *ITALICS Innovations in Teaching and Learning in Information and Computer Sciences*, 11(1):14–26.

Wisker, G. (2001). *The Postgraduate Research Handbook. Succeed with your MA, MPhil, EdD and PhD*, volume Palgrave Study Guides. Palgrave, Houndmills, Basingstoke.

Wisker, G., Robinson, G., and Shacham, M. (2007). Postgraduate research success: Communities of practice involving cohorts, guardian supervisors and online communities. *Innovations in Education and Teaching International*, 44(3):301–320.

Yew, K.-T., Ahmad, W., and Jaafar, J. (2011). A framework for designing postgraduate research supervision knowledge management systems. In *National Postgraduate Conference (NPC)*, pages 1–6.

Zedlitz, J. and Luttenberger, N. (2014). Conceptual modelling in UML and OWL-2. *International Journal on Advances in Software*, 7(1 and 2):182–196.