Learning with the Semantic Web: The Case of a Research Methodology Semantic Wiki

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Abstract. The Semantic Web extends the read/write Web 2.0, allowing meaning to be assigned to content and the links between content, leading to the machine processability of this content and potential benefit to teaching and learning. Considering the difficulty that research students have with the concepts that make up the structure of a research methodology, this research explored the value of using a semantic wiki to support the learning and teaching of this structure in computing fields of study. This will add to current online approaches to research methodology learning as well as the use of the Semantic Web in and for learning. Following a design science research approach, a conceptual model of the domain led to an ontology, which formed the basis of the content and structure of the semantic wiki. Research methodology concepts and relationships were realised in the wiki and semantic annotations added to allow improved presentation and exploration of domain knowledge. The wiki was evaluated by both supervisors and research students, finding that there was value in the approach, but that it was not a quick-fix solution.

Keywords: Semantic Web · Semantic wiki · Research methodology · Smart learning environment · Online teaching environment · Higher education

1 Introduction

The emergence of Web 2.0, as well as the possibility of users being both consumers and producers of content, has altered the environment in which information is accessed and knowledge created [1]. University online learning management systems often include tools that can be used to support learning and collaborative knowledge generation, such as discussion forums, blogs, wikis, online debates, group meetings, and reflective journals, and which are also commonly used in massive open online courses (MOOCs) [2]. There is also a growing acknowledgement of the role that other, more open and social, online tools, offered by Web 2.0, can play in promoting learning, albeit informally and outside university control: Facebook, Twitter, and YouTube [3].

Extending Web 2.0, the Semantic Web refers to a "new form of Web content that is meaningful to computers" [4, p. 34], where semantic web technologies provide consistent meaning to online content and support linking such data from various sources

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and in different formats. The meaning of data is tied to concepts present in a formal knowledge representation schema, an ontology, that will allow a machine to understand and process the content. Semantic markup is then used to annotate text based on the ontology and to provide meaning and intelligent linking of material.

Recognising that research students often find research methodology complex and confusing, with little consistent use of the constructs employed in the domain [5], the role that the Semantic Web can play in exploiting virtual environments to facilitate learning the structure of a research methodology will be explored in this paper. The research question is, thus, as follows: to what extent can the Semantic Web be used to represent research methodology structure and provide a semantically enriched environment to support learning? This was explored using a semantic wiki to present research methodology structure and was limited to research methodologies common in computing fields of study.

2 Background Literature

2.1 Online Approaches to Research Methodology Learning

There has been considerable growth in alternative approaches to face-to-face modes of delivery at postgraduate level, led by increasing access to web-based technologies [6]. Alternatives to the dyadic supervisor-student relationship include blended learning, where the supervisory relationship is extended to the use online tools to support learning [7]. For example, web pages are used to provide teaching materials and links to further resources (such as language editors and statistics experts) [7]. Furthermore, document submission and supervisors' comments are processed online, thus providing a record of discussions and progress [7]. Asynchronous online discussions have also been used to discuss students' reflective responses to their reading and assignment answers [8].

Research methodology education is not an established field of its own, with knowledge scattered across several disciplinary journals and special interest groups [9, 10]. There is also no formal, proposed pedagogy aimed at teaching research [10], which is acknowledged as a challenging task [5].

2.2 Learning and the Semantic Web

Currently, students searching the Web have to rely largely on keyword searches, often leading to irrelevant material being identified in the large amount of educational material available [11]. The Semantic Web opens up the possibility of more focused searching, leading to better discovery of research material.

Formal semantic annotation has been used in the tagging of learning materials, making them searchable and retrievable (for example, EdNA, Educational Modelling Language (EML), and SCORM) [12, 13]. There are even language-specific resource descriptors, such as the French ScoLOMER, used for learning object metadata [14]. This has led to the move towards collecting existing distributed learning objects, rather than creating them, from multiple sources by intelligent, adaptive e-learning software

agents, using known properties of a student and automated reasoning to assemble learning material into a personalized collection, thus using semantic metadata to construct individualised courses [11, 13, 15].

Making resource discovery more accurate, unambiguous, and structured via semantic annotation requires ontologies, which are formal representations of a domain's conceptualisation, providing a controlled, limited, and common vocabulary that defines the concepts and the relationships between these concepts [11, 15]. Ontologies for use in learning include those about students, curricula, educational metadata, and specific subject domains, allowing for the search, reuse, and personalisation of online learning [14, 16, 17]. Ontology use can also be seen in online education environments such as the EduProgression ontology, the official common base of French educational concepts and skills, which has been extended to include pedagogical resources [14]. A semantic wiki has also been used for the maintenance of a vocational ICT curriculum [18].

2.3 Wikis and Semantic Wikis

A wiki is a collection of web pages used to foster the recording of community knowledge and is a widely used tool for knowledge exchange in shared, virtual, and distributed communities, including in higher education [19]. However, a wiki is just a flat set of pages without a strong structure and with a focus on human readers [19], leading to limited search capabilities.

A semantic wiki is the merging of the benefits of a traditional wiki with the Semantic Web, using an ontology to structure and annotate the information included in the wiki. Users provide both content and semantic annotations, which allow machine processability and querying of the content. Every element in the domain, both domain concepts and the typed relationships that link them, is represented by a page in the semantic wiki [20]. Machine processability also allows knowledge in the wiki to be visualised in graphs, leading to better understanding and navigation of the content [18], as well as overcoming the drawbacks associated with traditional wikis.

Although current students are generally believed to be capable users of Web 2.0 affordances, use of online tools for learning may require new ways of thinking, new literacies, and new ways of locating and evaluating information [1]. Yet even though such tools are freely available, they are often used for social purposes by both staff and students and are largely not accepted for academic purposes, leaving questions about how effectively they can be used to support learning [21].

3 Research Methodology

Pragmatism, with its commitment to improving lived experience and effective action [22], formed the philosophical underpinning of this research, which was guided by design science research (DSR) – a problem-solving research design focused on the utility of a designed artefact [23]. The eventual artefact was a semantic wiki that would be used to present the structure of a research methodology in a semantically enriched learning environment.

Noting the need for an ontology on which to base the semantics of the wiki, DSR was merged with ontology engineering approaches, which led to the following four steps/artefacts.

1. Conceptual modelling: the main concepts and relationships representing a research methodology structure were modelled using Unified Modelling Language (UML). This was evaluated using an expert focus group made up of 10 experienced supervisors and is reported elsewhere [24].
2. Description logics (DL): the conceptual model was expressed formally in a knowledge representation language and evaluated manually, ensuring consistency of conversion from the UML model to DL.
3. Ontology: the DL model was expressed in Web Ontology Language (OWL) using Protégé. This was evaluated by populating the ontology with sample data and running queries to test for expected results; the built-in reasoner ensured ontology consistency.
4. Semantic wiki: the ontology knowledge was presented online using Semantic MediaWiki (SMW). This was evaluated using a focus group made up of 10 supervisors, as well as an online questionnaire sent to graduate students doing a research report course. Only this evaluation will be presented here.

SMW is an open-source extension of MediaWiki, which is the engine used to create Wikipedia, and is considered the most popular semantic wiki engine [25]. A thematic analysis approach was used to explore the main themes that emerged from the focus group and open-ended questions in the questionnaire, and simple descriptive statistics gave an overview of the questionnaire responses. Ethical clearance was obtained from the relevant university committees to undertake the research and to include university staff and students in the evaluation process.

4 SWaRM: Semantic Web and Research Methodology

4.1 Semantic Wiki Overview

Conceptual Model Implementation. The semantic wiki, which can be accessed at http://eagle.unisa.ac.za/mediawiki/index.php/Semantic_Web_and_Research_Methodology, was based on a model (Fig. 1) conceptualising research methodology structure. Broadly, there are four main components: a ResearchScheme, PhilosophicalWorldView, ResearchDesign, and ResearchMethod. While these four components each have specific properties, there are also relationships that link the various components. For example, a ResearchScheme isUnderpinnedBy a PhilosophicalWorld View and hasResearchDesign, which may be one or more ResearchDesigns. Both ResearchDesign and ResearchMethod are subclassed into types of designs/methods. The landing page of the wiki presents an overview of this structure, orientating users to the conceptual model used in the wiki; it also describes how the wiki can be used as a consumer and producer and provides links to the four main concepts. Following these links takes the user to pages that describe the concepts and their associated properties.

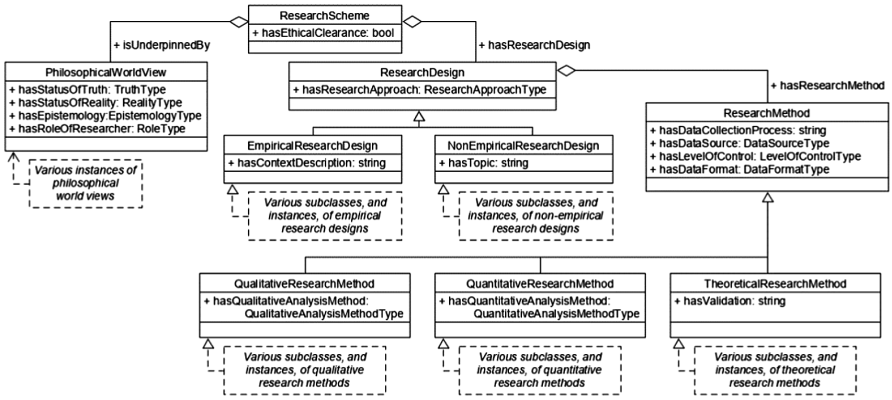
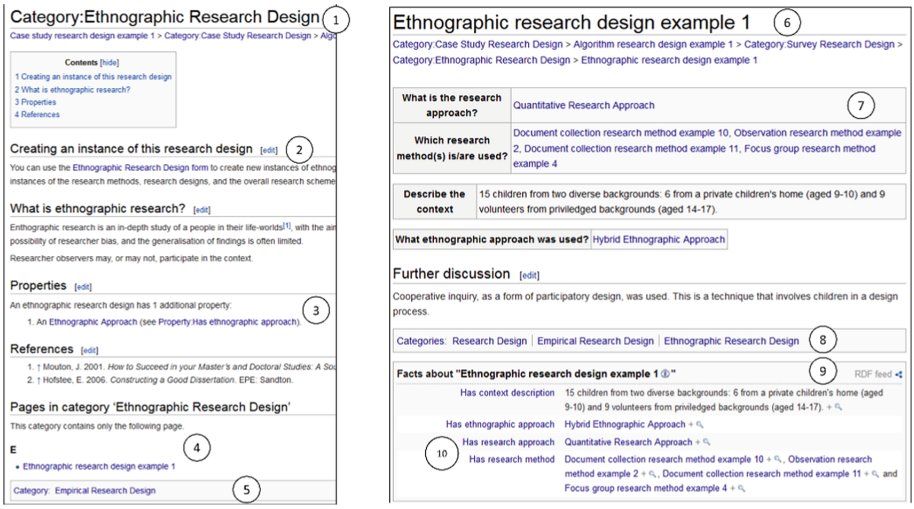


Fig. 1. UML class diagram of the conceptual model.

Semantic Implementation. Each concept in the conceptual model is realized as a Category page (Fig. 2(a) point 1), and both properties associated with concepts (such as Property: Has ethnographic approach, Fig. 2(a) point 3) and the semantic links between concepts (such as hasResearchMethod, Fig. 1) are accomplished using Property pages; these pages provide knowledge about the concept/property, additionally ensuring their consistent use. Semantic annotations are added to concept pages to indicate a parent concept (where there is one in the concept hierarchy, Fig. 2(a) point 5) and the property links, making the concepts and properties machine readable. Forms (Fig. 2(a) point 2) are used to help users create instances of the concepts, so that the semantics are added automatically, and the user does not need to know how to include them. The semantics allow links to pages that fall into the current category to be displayed on the page (Fig. 2(a) point 4); these are generated dynamically as concepts and instances are added to the wiki and so are always up to date. Queries can also be added to pages to present users with dynamic, updated results.

Instances. Normal web pages are used to actualise instances of wiki concepts or categories (Fig. 2(b) point 6). Such pages are created by users for research projects that have been undertaken, showing which components made up the specific research. Once created, these pages display clickable links for the properties of the instance (Fig. 2(b) point 7), which users can follow to find out more about the property. At the bottom of each page are links to the hierarchy of concepts that indicate what sort of page this is (Fig. 2(b) point 8) as well as a fact box (Fig. 2(b) point 9) summarizing all semantics found on the page. Clicking on a property link (Fig. 2(b) point 10) links the user to that Property page, where all other pages where this property has been used can be viewed. The eye symbol in the fact box heading directs users to a page where the incoming links to the instance page can be found, allowing backwards movement through the semantic links. It is, thus, possible to use the semantics present in the wiki to move around the dynamic links that make up the wiki and follow how research methodologies have been structured.



(a) Example Category page (b) Example instance page.

Fig. 2. Example category page and instance page.

4.2 Responses to the Semantic Wiki

While the supervisor focus group and student survey were used as part of the DSR evaluation process, they may also be seen as an implementation of the wiki in a teaching environment to assess its benefit to supervisors and students in a research report course.

Supervisor Focus Group. The focus group was made up supervisors with a range of levels of supervision experience, and four themes emerged. *What is this wiki?* explored themes around whom the wiki was aimed at and its being a starting point for one approach to the problem of methodology structure. It emerged that a more visual, step-by-step approach might be needed. *Where is its utility?* focused on its potential benefits, and the value of the examples was noted. *How can it be used?* concentrated on how contributing to the wiki would be of benefit, providing students with a variety of approaches that could be used in active learning and fun approaches; however, it would take time to master the approach taken. *Why not use it?* highlighted the uncertainty about the utility of the wiki, with concerns raised about it being confusing and students getting lost in the material. The overall narrative that emerged regarding the value of the semantic wiki was that it would take effort to come to grips with and that it was not a quick-fix solution to research methodology structure.

Student Questionnaire. A web-based questionnaire, hosted in Google Forms, was sent to 316 graduate students; 59 responses were received (a 19% response rate). While 86% of the students had used a wiki 10 or more times, 78% had never contributed to one. Students found that the wiki was easy to navigate (90%), provided valuable information (97%), and helped them understand research methodology structure (85%). Only 19% contributed to the wiki, with lack of enough knowledge being the main

concern (38%). Overall, 43% enjoyed using the wiki, 72% found it useful, and 50% indicated that it made them think and that they would use it again. Only 36% would recommend it.

Seven themes were identified in student textual responses. Many found it *useful* and informative, comprehensive, and easy to understand. However, some felt that *more was required* and wanted more of an *overview* and high-level introduction to the content, looking for mind maps, videos, and a step-by-step process to follow. Furthermore, there were requests for *more resources*, such as references to articles and links to relevant software. While the instances in the wiki provided examples, there was a call for *more examples*. There appeared to be a *lack of confidence*, and students were reticent to add content. Finally, students wanted the *content checked*, as they felt that some material was missing or needed editing.

5 Discussion

The aim of this research was to determine the extent to which the Semantic Web, expressed as a semantic wiki, could be used to represent research methodology structure and support its learning. SMW uses semantics to help make browsing and searching more efficient and intelligent through ensuring consistency of structure and content, as well as content reuse [25]. Its dynamic nature means that it will also support the evolution of domain knowledge over time as changes in the domain and the addition of individuals occur. The research methodology semantic wiki demonstrated that it was possible to present domain knowledge in a semantically enabled online environment. Additionally, that pages could be annotated with parent concepts allowed reasoning to be used when dynamically displaying content belonging to a particular concept or property. Likewise, semantic queries on pages enabled related information about the page to be dynamically displayed. These semantic affordances allowed links to be used to navigate the concepts and relationships present in the wiki. Also, the use of semantic forms reduced the complexity of adding semantic annotations to new content.

While there is no single learning theory that can be used to understand online learning [26], any learning environment must be informed by a pedagogy. In this. case, Siemens's connectivist theory of learning [27] may be used to support a semantic wiki approach. Connectivism considers knowledge to have a distributed, networked structure with nodes linked by interactive relationships [28]. Learning is, thus, a process of network formation and navigation. This model of learning is capable of expressing how research students gain knowledge about research methodology structure using semantic links to build interconnections between research methodology constructs. Furthermore, as the semantic wiki networked knowledge is machine processable, dynamic knowledge representations and reasoning over such representations are also possible.

A semantic wiki also supports sociocultural views of learning and their associated communities of practice [29], and such wikis are well suited to the presentation and development of the body of knowledge that such a community maintains. The wiki approach allows research students to be brought into communities of professional research and scholarship practice, where an apprenticeship into the academic discipline may occur [5].

Although many of the responses to the wiki pointed to a preferred approach that provided a recipe-like, step-by-step process, it needs to be understood that the wiki is not a quick point-and-click solution to understanding and building a research methodology. Furthermore, as the basic structure of research schemes had already been set up based on the conceptual model, the participation that followed was expected to be the addition of instances of research schemes, providing examples of how researchers had structured their work. Thus, although the wiki could support learning and teaching in a community of practice, it was not used like this in any substantial way. Its use was largely limited to exploring the structure and examples that were already present, and little new material was added by supervisors or students. This could be because supervisors had their own conceptualisations of the domain, which did not fit with that presented in the wiki; students might not have thought that they had the knowledge to do so.

However, the feedback from students suggested that the approach was comprehensive and valuable and helped in understanding methodology structure. Thus, although the provision of a standard terminology, which helped students navigate the complexities of research methodology structure, might not have been seen by some as that useful yet, it might have helped students negotiate the domain. It is believed that the utility of the wiki lies in its providing a starting point from which a research student can explore research methodology structure and does provide beneficial value in the learning and teaching of such structures, often through the provision of examples. Additionally, it can help prevent novice researchers from using entirely inappropriate philosophical world views, research designs and methods when structuring their own research. There is, thus, a place for such a wiki, even though time and effort will be required to understand how the parts fit together, which may limit its use by those seeking a simpler solution to the problems surrounding the learning and teaching of research methodology.

6 Conclusion

The research methodology semantic wiki considered here sought to provide a platform addressing the "lack of shared language describing important foundational concepts of research methodology" [5, p. 230] using the affordances provided by the Semantic Web. The Semantic Web can be seen as a smart learning environment, and although it is not yet recognised by the NMC Horizon Report [30, p. 36] as one of the enabling technologies that will transform what can be expected of online tools, it has a place in the provision of learning content in online teaching environments. The research contributes to the organising of digital strategies in higher education that "transcend conventional ideas to create something that feels new, meaningful, and 21st-century" [30], which does not, however, mean that success is guaranteed.

The contribution of this work, then, is an implemented and evaluated conceptual model, expressed in a semantic wiki, that can provide a basis for new ideas for online learning of the structure of research methodologies.

There are several ways in which this research can be extended, such as broadening the scope of the initial conceptual model to include a model for research question types,

alternative ways of categorising research designs, and broadening of the scope to disciplines beyond computing.

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