Case-Based Learning, Pedagogical Innovation, and Semantic Web Technologies

Agustina Martínez-García, Simon Morris, Michael Tscholl, Frances Tracy, and Patrick Carmichael

Abstract—This paper explores the potential of Semantic Web technologies to support teaching and learning in a variety of higher education settings in which some form of case-based learning is the pedagogy of choice. It draws on the empirical work of a major three year research and development project in the United Kingdom: "Ensemble: Semantic Technologies for the Enhancement of Case-Based Learning" which has been oriented toward developing a better understanding of the nature of case-based learning in different settings, but also exploring the potential for Semantic Web technologies to support, enhance, and transform existing practice. The experience of working in diverse educational settings has highlighted Semantic Web technologies that may be particularly valuable, as well as some of the enablers and barriers to wider adoption, and areas for further research and development.

Index Terms—Education, knowledge modeling, knowledge sharing, collaborative learning, web technologies.

1 Introduction

The Semantic Web is conceptualized as "an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation... data on the web [is] defined and linked in a way that it can be used for more effective discovery, automation, integration, and reuse across various applications" [1]. The flexibility of key Semantic Web technologies such as semantic triplestores and data standards in combination with conversion utilities and visualization tools, allows the integration of user-generated content with that from digital repositories, web services and nonsemantic data such as "legacy" databases. They offer users advanced search tools and a range of representations and visualizations of data. They also support "social software" functions such as reviewing, rating, and collaborative annotation. This means that these technologies can provide a framework capable of supporting individual and collective engagement in a variety of teaching and learning environments.

While the transformative potential of the Semantic Web in educational settings has been recognized from the outset [2], [3], [4], the majority of applications in educational settings have been concerned with enhancement of search and resource discovery, and with the development of systems to match individual learner profiles with appropriate online learning materials [5]. Since its inception, two particularly significant developments have impacted both on the way in which the Semantic Web has been understood and developed and on its potential for implementation in educational settings.

The first of these is the rapid rise of "Web 2.0" or "Social Web" applications and their widespread adoption both by the wider public and, to some extent, in higher education institutions [6]. This is reflected both in the expectations of teachers and students of what the affordances of new web technologies might be, and in the direction of some recent work on the Semantic Web for Education into areas described as the "social semantic" web [7], [8]. The complexities of the emerging relationship between the "Social" and "Semantic" web projects are exemplified by work on the relationship between the informal "folksonomies" of Social Web applications and the formalized, expert ontologies that have been central to Semantic Web developments [9], [10], [11].

The other significant development is the reframing of some Semantic Web activity as contributing to a "Linked Web of Data" [12]. For example, moves to offer "open data" from government sources online in order to extend and enhance a linked data cloud [13], [14] have encouraged discussion of opportunities for public engagement and new educational possibilities, despite the limitations that current information practices place on this development [15]. While less ambitious than the broader vision of the Semantic Web, the idea of the linked web of data has lowered the bar to participation and to the realization of the benefits of a wide range of Semantic Web technologies. In higher education settings this has enabled a more pragmatic adoption of technologies with the potential to enhance existing systems and applications, but without the demands of full engagement with the broader Semantic Web vision [16].

- *A. Martínez-García, S. Morris, and F. Tracy are with the Liverpool John Moores University, I.M. Marsh Campus, Barkhill Road, Aigburth, Liverpool L17 6BD, United Kingdom. E-mail: {a.martinez-garcia, S.E.Morris1, F.E.Tracy}@ljmu.ac.uk.*
- *P. Carmichael is with the University of Stirling, Stirling, FK9 4LA, United Kingdom. E-mail: patrick.carmichael@stir.ac.uk.*
- *M. Tscholl is with the Centre for Applied Research in Educational Technologies, University of Cambridge, Cambridge CB2 1SB, United Kingdom. E-mail: m.tscholl@cs.ucl.ac.uk.*

Manuscript received 1 Apr. 2011; revised 1 July 2011; accepted 3 Nov. 2011; published 5 Dec. 2011.
For information on obtaining reprints of this article, please send e-mail to: lt@computer.org, and reference IEEECS Log Number TLTSI-2011-04-0042. Digital Object Identifier no. 10.1109/TLT.2011.34.

2 The Ensemble Project

The work reported here has taken place as part of a three year research and development project, "Ensemble: Semantic

Technologies for the Enhancement of Case-Based Learning,"[1] itself part of the "Technology Enhanced Learning" programme[2] funded by the United Kingdom Economic and Social Research Council and Engineering and Physical Sciences Research Council.

The original proposal identified the particular pedagogical challenge of learning with cases in these terms.

> "Case-based learning is the pedagogy of choice when knowledge domains are complex, unpredictable, politically or ethically contentious, or so rapidly changing and fluid that a curriculum defined in terms of knowledge or competencies alone is inadequate as the basis of developing expertise. Engagement in case-based learning and the reflective processes that accompany it allows learners to achieve the higher levels of understanding and capability that characterize the "expert" or "virtuoso," especially in domains where dealing with complexity is seen as indicative of this expert performance."

The project proposal also recognized the potential of semantic technologies to contribute to teaching and learning with cases because of

- the opportunities they offered for teachers and students to bring current, authentic data into learning environments (online, blended, and face-to-face),
- the potential for aggregation of heterogeneous online content in different formats,
- the support they offered for reasoning across data and cases from diverse sources,
- the basis they provided for simulations, role-plays, and scenario-building, where learning outcomes were contingent and unpredictable, and
- the support they offered for open-ended tasks in which initial problems, cases or scenarios could be developed in different directions with sometimes unpredictable learning outcomes.

In development terms, one of the most significant aims of the project was to provide:

> "environments providing teachers and learners with the combined affordances for long-term preservation of digital repositories; the collaborative and annotation tools characteristic of social and community software platforms; and the expressive and flexible search and visualization potential of the [rich web applications] of the SIMILE project's semantic tools."

This aim clearly reflected the pragmatic response to the blurring of the distinction between "Social Web" and "Semantic Web" described above. It also reflected the desire to engage learners not only with existing cases written by teachers or other domain experts, but also in the construction and reconstruction of the cases themselves. The SIMILE toolkit mentioned in the project aims, [17], and in particular the Exhibit Web Application Framework [18], offered an accessible, open source, rapid prototyping environment. The Ensemble project team was interested to see how this could be applied and extended to support teaching and learning with cases in different educational settings.

The empirical work of the project has been oriented, then, toward developing a better understanding of the nature of case-based learning in different settings, but also exploring the potential for Semantic Web technologies to support, enhance, and transform existing practice. The range of these technologies offered both a challenge and an important opportunity. On the one hand, it has meant that the project has not introduced any single technology or application into what Lankshear et al. [19] and Edwards and Usher [20] call "spaces of enclosure," to see how it "lands." Instead, following studies such as those by Ciborra [21] and Suchman [22], it has undertaken the more challenging task of exploring how technologies are integrated (or not); made sense of (or not) and selectively appropriated by individuals and groups in pursuit of pedagogical aims that themselves may be changing.

3 Exploring Learning with Cases

Rather than seeking to develop generic design specifications based on a single model of case-based learning, the project recognized both in the existing literature on cases and in its pilot work a range of understandings of the nature, role, and scope of cases in learning. While there is a core set of commitments: to developing learner autonomy; to engagement with authentic data and situations; and to the representation of "the real world" through this engagement; we have had to engage with highly differentiated enactments and realizations of these. We also found that within several of our settings there was a concern to use cases to equip students for changing disciplinary practice: for example, using Geographical Information Systems in fieldwork; engaging in cross-disciplinary projects or working with industrial partners in sciences; and incorporating new technologies into performing arts.

Cases and the pedagogical practices and discourses that accompany them take place in a wide range of settings that demanded approaches to design and development that involved teachers and students in collaborative design activities and rapid prototyping and evaluation on a setting-by-setting basis. It also led to the incorporation of different aspects and combinations of Semantic Web technologies into the applications developed for each setting. In settings, where courses were being redesigned or revalidated, the project worked initially with groups of teachers to map out opportunities to introduce technologies and relate these to course objectives. In other settings, existing technological platforms (such as virtual learning environments or collaborative tools) already existed, so the project team worked with teachers and support staff responsible for content development. In some settings, advanced technologies were already being used to enhance teaching and learning: the most obvious example was Contemporary Dance, where teachers and students were using combinations of video-conferencing and social software in "telematic" performances. In this case, the priority was to establish which combinations of semantic technologies could be integrated into existing pedagogical and technological practices through participatory design activities (see [23] for a more detailed account of these variations).

Across all of these settings, as well as structured requirements-gathering exercises (which included conceptual modeling, prioritization exercises, and paper prototyping), project researchers and developers worked for extended

1. http://www.ensemble.ac.uk.
2. http://www.tlrp.org/tel.

TABLE 1
Ensemble Project Settings

Inst.	Description	Subject Area	Curriculum Setting	Project Participants
A	An urban 'post-92' former polytechnic university, specializing in technical, vocational and professional courses and with close community ties. The settings in which the project worked are all within a single faculty with its own campus, a former teacher education college	**Education Studies**, with specialist routes in Early Years, Inclusion and Physical Education	Year 1 UG compulsory course.	6 staff, 60 students (3 x 20 specialist routes) in single year of project activity
		Contemporary Dance, with options in performance, choreography, education and management	Year 2/3 UG optional course in Telematic Dance Practice	2 staff, 6-14 students in each of two years of project activity
		Fluvial Geomorphology, courses and projects taken by students of Geography, Outdoor Education and Environmental Education	Year 2/3 UG optional courses and PG research projects	1 staff, 2 groups of 15-20 students in a single year of project activity
B	An 'old', research-intensive university with a wide range of specialist areas, high entrance requirements and intensive teaching support for students with expectation of further academic study	**Plant Sciences**, a multi-disciplinary course ranging from molecular biology to ecology	Year 3 UG optional module.	3 staff, 12-15 students in each of three years of project activity
		Archaeology, both a full Undergraduate course and as a minor course within other undergraduate routes	Year 2 and 3 UG optional modules and dissertations	5 staff, 20 students across courses in single year of project activity
C	An urban 'new' university specializing in professional and business oriented courses and with close links to professional bodies	**Maritime Operations and Management**, a course catering for students with experience in, or preparing for management roles in maritime industries	Core PG module focused on cases, with close links to other modules in course	1 staff, 6-12 students in each of three years of project activity

periods with teacher and student participants, and, at the same time, students from some settings were placed within the project to assist with and guide content development, design and evaluation. We found instances of intersetting influences and sharing of practice as participants saw, in prototypes and applications ostensibly from disciplines with very different "signature pedagogies," technological affordances with the potential to enhance or transform their own practice.

We found examples in which, following the established "case method," the dominant form was the *narrative*, presented or controlled to some extent by the teacher, or in some settings, developed by the student in the form of a personal narrative. In other cases, teachers who wanted to expose students to the diversity and complexity of "real world" situations wanted to present them with *collections* of: documents, data sets, images, video, and other resources from which they had to construct an argument or develop a persuasive "case." In practice, however, the distinctions between these were blurred: having developed collections of resources, teacher discourse often focused on guiding students in constructing a particular narrative. While these initially looked like straightforward narratives, they were discursively reworked, embellished and associated with broader themes, ideas, and resources. Rather than asserting a binary opposition between "narratives" and "collections," this meant that it was necessary to explore the discursive practices through which the cases were introduced, related to prior learning and goals, how different elements within it were mobilized and how different representations were then developed.

This recognition had significant implications for the technological development work of the Ensemble project. Had we focused solely on the development of a framework for implementing semantically rich documents (to support narrative cases) or putting all of our efforts into digital curation of complex collections (to support engagement with diverse content) would have limited our potential engagement with participants and the subsequent uptake of educational software applications. Thinking about cases as heterogeneous *assemblages* (an idea articulated by De Landa [24] and explored in relation to computing sciences specifically by Selber and Johnson-Eilola [25]) meant that our technological development activities were framed by a need to support componentization and flexibility, transclusion and ease of reconfiguration, and a wide variety of representations of case data: data browsers, texts, concept maps, maps, and timelines as well as combinations of all of these. This realization also highlighted the need to provide means by which teachers and students themselves could construct and reconstruct cases in different ways, both as individual authors and collaboratively, as part of discursive case construction activities in classrooms and other learning environments. We will return to the technological implications of these requirements and the extent to which current Semantic Web technologies were able to support these in the latter part of this paper, but first we will review the settings in which the project was active.

4 Settings, Cases, and Technologies

The research settings in which the project has worked over a three year period are distributed across three United Kingdom higher education institutions, and include both undergraduate and postgraduate courses as shown in Table 1. These settings were selected in order to provide a range of conceptualizations of cases as well as a spread across undergraduate and postgraduate courses and disciplines. Settings ranged from those in which the introduction of semantic technologies was explicitly linked with leveraging changes in pedagogical practice, to those in which technological and pedagogical innovation were already established and the role of the project was to explore how they could extend this further. In some cases, technological development took place in relation to well-defined teaching and learning activities, in others, against a background of pedagogical inquiry and innovation. The four settings we describe in detail here are those in which development, deployment, and evaluation has proceeded furthest, but, as we shall demonstrate at the end of this section, they provide between them exemplification and framing of the main technological challenges which the project has faced and which represent areas for development of Semantic Web technologies in education in general.

4.1 Plant Sciences

In final year undergraduate studies in Plant Sciences at University B, a lecture course on algal biofuels had been identified as offering an opportunity to engage students in group projects on an important and emerging field of research and development. After an initial presentation, students were organized into groups of three or four and worked together for about a week to develop empirically based and persuasive cases in support of a programme of research into one of a number of areas where algae might have the potential to contribute significantly to biofuel production.

The subject matter was current as this field is rapidly developing, so a primary concern was that students develop experience in critically evaluating recent research papers and drew on these in the reports and presentations which they made at the end of the project. At the same time, teaching staff were concerned that students maintained a focus on the "science" behind their proposals rather than being drawn into the economic, political, and environmental aspects of biofuel production. So while groups of students were encouraged to research using online sources of information and draw on the expertise of "consultants" (teaching staff and research supervisors) they were, at the same time, carefully guided through the provision of indicative reading lists and "consultant" directions.

The course was supported online through the institutional Virtual Learning Environment which provided file storage, communication, and collaboration tools including a wiki. Observations of the students at work and in their presentations, interviews with teachers and a final student focus group identified two areas of potential project engagement: one being bibliography management and the other being the support of collaborative writing. The contribution of semantic technologies was focused on the provision of a means by which teachers could provide initial sets of readings (primarily journal articles, literature reviews, and patents) to students who could then add further resources, describe and annotate these and then share them prior to their incorporation into written reports and presentations.

Metadata records collated by teachers from online sources such as PubMed[3] and Scopus[4] were stored in a digital repository and then presented using the SIMILE

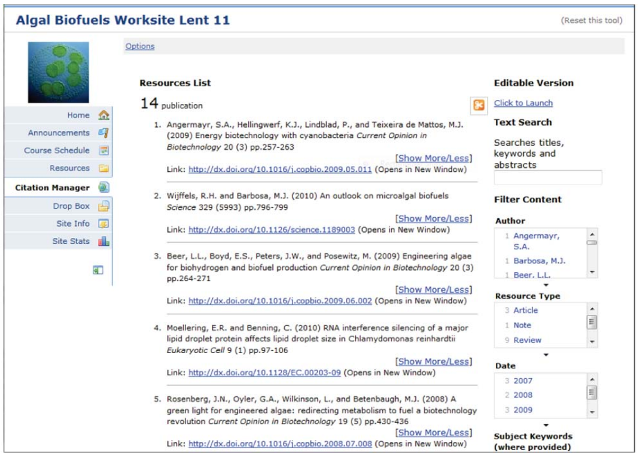

Fig. 1. Faceted browser in a VLE "workspace," together with other tools to support student projects.

Exhibit framework within an institutional Virtual Learning Environment. This allowed "faceted browsing" so that students could filter, visualize, and organize records (see Fig. 1). Even early evaluations indicated that combinations of: readily available publishers' metadata; a means of storing the results of teacher selections; and a web application framework which allowed these to be presented easily and in different ways within an existing online environment, was highly valued and had wider applications. This was particularly the case in fields that were developing rapidly (where teachers wanted to offer students latest readings) or where students were required to produce the literature reviews charting the development of a field or area of research.

The requirement that students be able to add additional resources and to annotate those were already provided while also collaborating in groups presented more of a challenge, and several approaches (a wiki with limited semantic features; SIMILE Exhibit combined with Google Applications; standalone versions of SIMILE Exhibit with editing facilities) were trialled with groups of students who kept records of their experiences and subsequently participated in focus groups in which they reported on their practice and suggested further design features. What emerged from these was that for students (used to the features of "Web 2.0" applications such as "social bookmarking") what was required was a solution which, while it might be underpinned by authoritative collections and teacher recommendations, was oriented toward easy editing, sharing of metadata and resources, and the rapid incorporation of these into their own writing.

Unlike networks of academic staff involved in building authoritative collections of resources, described in consistent terms in order to support continuing research activity, what students were more concerned with the availability of tools that would allow them to "extract" relevant information in order to address their more immediate concern to rapidly produce reports, essays, and presentations.

4.2 Archaeology

Also at University B, final-year students in undergraduate Archaeology courses were involved in final year projects in which they produced case studies of a specific locality, collection, or artifact. These projects were explicitly related

3. http://www.ncbi.nlm.nih.gov/pubmed.
4. http://www.scopus.com/home.url.

to established disciplinary practices and the report that the students produced was close in format and content to the short papers or briefings that might be written by professional or academic archaeologist, curator, or conservator. Examples included a study of a hoard of coins, analyzed so as to show patterns of trade across early medieval Europe and a historical account of the development of a manor house from the medieval period until the present day, drawing on images, maps, historical accounts, and census records.

Though similar in some respects to the situation in Plant Sciences described above, in that students were required to integrate external resources into a complex document of their own, what additionally emerged from discussions and design activities with teachers and archivists in Archaeology was the value of incorporating "live" data into interactive segments of the student reports. This parallels recent work on models of "semantic publishing" in which online academic publications contain data islands, interactive visualizations such as maps and charts, or simulations and "microworlds" [26].

In one particularly rich example, a student report on the excavation of a small collection of Anglo-Saxon brooches was reconstructed as a "data aggregating document," itself drawing on digital repository content and external data sources. This allowed the main narrative account to be enhanced by

- a photo gallery of historical and contemporary images from the excavation site,
- a timeline of excavations at the site with links to associated publications,
- an interactive map of similar finds across the region, drawing on metadata from museum databases and linking in turn to images of artifacts,
- a table of types of brooches with illustrations populated from the same databases, and
- a searchable and sortable bibliography with links to online sources of further information.

This was realized in practice by converting and storing museum database content in a Fedora digital repository and then building web documents using SIMILE "Exhibit" visualizations (thumbnail gallery, map, timeline, tabular data, lists) along with faceted browsing where user interaction was seen to be beneficial. In initial evaluations of this application, the main pedagogical affordance that was recognized was the ability to link students' own observations to those from broader databases, and further opportunities for linking data were identified: for example from the user-generated data offered through the "Portable Antiquities Scheme"[5] and photo-sharing and geotagging initiatives such as GeoGraph,[6] which offer metadata in "Semantic Web ready" formats such a RDF/XML and RSS/XML.

Rather than this simply "supporting" student writing, these combinations were seen as offering new pedagogical opportunities and challenges for students who would be required to develop a narrative that explored the relationships between their own work, authoritative sources such as museum databases, and user-generated content of

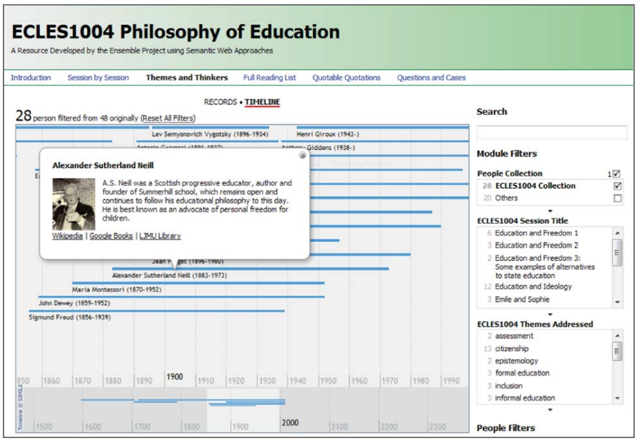

Fig. 2. Interactive "timeline" as an organizing device for diverse content related to education themes and cases.

varying quality. It also raised interesting questions about the challenge to authors of writing "semantic texts" designed to invite reader interaction and of writing a narrative in the knowledge that the data presented might change with subsequent archaeological finds, new publications and reinterpretations. Evaluations of these applications from teachers were encouraging, but also significant was the positive feedback from representative of data providers such as museums and archives who were keen to see their own collections accessed and reused in support of student learning.

4.3 Educational Studies

Encouraging students to engage with multiple sources of information and to relate these to their own experience was also the rationale for the project's engagement with teachers of Education Studies at University A. Education Studies undergraduate students were required not only to link current policy and educational practice (in both formal and informal settings) but also to locate these against enduring historical themes and philosophical ideas about the nature and purpose of education. Students found this very challenging and while it was recognized that teaching with cases (both those introduced by the teachers, and those generated by students) represented part of the solution to their difficulties, the role of learning technologies in order to do this had not been explored to any significant extent.

Participatory design activities and prototyping led to the identification of an interactive timeline (see Fig. 2) as the most appropriate "organizing device" as this would allow collections of resources to be located not only in relation to course aims and learning activities, but also in a broad historical framework. Once again, the combination of a Fedora digital repository and elements of the SIMILE Exhibit framework allowed the development of interactive, data-driven web applications, but in this setting, it was teachers, supported by project staff and a student researcher (a recent Education Studies graduate) who were involved in their production.

This was the setting in which there was the most interest in drawing upon recent initiatives to provide "open government data" [14] as they related to educational studies, but also where teaching staff, based on their particular interests and experience, were also able to offer suggestions as to

5. http://www.finds.org.uk.
6. http://www.geograph.org.uk.

sources of information which might usefully be aggregated for use in teaching. As well as existing course content, examples included data sets of

- governments, political personalities, and associated social developments,
- key educational legislation and other reports, and
- key demographic measures such as school populations and socio-economic indicators.

Other sources which teachers had already begun to incorporate into their teaching included selected data from the United Kingdom census, videos from the Pathe's Cinema News Archive, the British Film Institute's "Mitchell and Kenyon" archive of films from the early part of the 20th century and various public and commercial photo archives.

What was perhaps more significant still was the enthusiasm of teachers to use this as a framework within which they themselves could become providers of data and other resources, particularly of "case collections" that they used (or wished to use) in their own teaching within Education Studies modules. As a result, further themed collections began to emerge and with support from the project team, these were incorporated into a growing collection of data sets for use across the course. Examples, all of which could then be incorporated into the "organizing" timeline included

- representations of school in the children's literature,
- school architecture,
- development of educational media,
- radical schooling initiatives, and
- international education charities and nongovernmental organizations.

In this research setting, the introduction of Semantic Web technologies and the discourses that accompanied them did not simply replicate existing classroom practice. As well as encouraging teachers to locate and assess the value of available online resources for their work, the aggregation of data from different sources promoted discussion of how course elements could be better integrated. The timeline was not only a tool by which resources could be presented to students. It allowed the identification of previously unrecognized or unrealized associations, new foci for cases emerged as the potential to explore, for example, the relationships between educational legislation, the school building programmes that followed and changes in school architecture and pedagogical practices could be explored. Resources such as images, texts, or videos, which had been seen in isolation, are now potentially the starting points for inquiry and case building and could form parts of multiple, intersecting and overlapping assemblages. The overview the timeline provided also made this a useful resource for student revision and patterns of access logging to the web application showed both initial use related to lectures and seminars, but also subsequent use during periods prior to assessment.

4.4 Contemporary Dance

Support for the use scenarios that were envisaged in Education Studies had made it necessary to extend the Fedora and Exhibit frameworks: specifically to allow teachers to develop timelines and other representations in which they could select which of the many data sets they wanted to display. But in a fourth setting, Contemporary Dance at University A, emerging requirements for repository functions, visualization tools, and "Web 2.0" type annotation tools made more extensive development work necessary. In this setting, the project engaged with teachers and students who were already involved not just in pedagogical development but technological innovation as part of a "telematic dance" performance project [27].

This involved students at University A and another university collaborating via a video link and other network technologies to produce a joint performance "on screen," with audiences in the two locations viewing both part of the "live" performance and the joint "virtual" one. Every performance, therefore, generated several streams of video data, together with still images and audio, and these were then complemented and extended by reflective diaries and the outcomes of joint "debriefing" sessions. In this setting, the introduction of Semantic Web technologies represented the latest stage in a complex process that had involved choreographic, pedagogical, and technological innovation.

The immediate concern of the teachers and students involved in the project was how they could use Semantic Web technologies to manage the large and complex collections of diverse data that every rehearsal, performance, and debriefing session generated. Participatory design activities and paper prototyping helped to define a series of web applications which allowed teachers and students to

- upload, convert, and provide descriptive metadata for video excerpts, images, and other resources,
- use faceted browsing features to manage and select sets of images from across performances, and
- play back and review video during reflective debriefing sessions.

Two more specific (and more challenging) requirements also emerged, both of which demanded development of existing repository and web application frameworks. The first of these was to provide support for the description of resources using both formal vocabularies that provide a means of communication across settings and contexts (in this case, the vocabulary associated with the Laban notation system) and at the same time, the emergent vocabulary that developed during the choreography of performances. The second was the need not simply to describe videos of whole performances, but to be able to add semantic markup *within* these, allowing formal and informal terminology to be associated with specific segments or landmarks within the video content. This involved writing extensions to the Exhibit web application framework: a "video facet" which linked with other elements, and annotation tools to allow teachers and students to "mark up" video extracts through a browser interface and construct narrative accounts supported by annotated video segments.

What this meant in practice was that individual dance students were then able to browse video extracts and other resources, identify those that were relevant to their current thinking about their practice, annotate these and incorporate these into reflective narratives. These might be about the development of a particular part of the performance ("this is how this section developed over a series of rehearsals"); about an theme or pattern ("this is how

TABLE 2
Summary of Nature of Cases, Requirements and Semantic Technologies

Inst.	Setting	Nature and role of cases	Significant Requirements
A	Education Studies	Historical collections to support critical inquiry related to key themes in social inquiry and to personal practice	Improved access to linked data, and improved metadata. *Many sources already available, but not in linked data formats, or lacking metadata*
			Ability to rapidly develop and display collections of resources for classroom use
			Visualisation of complex data and trends at different levels of granularity
	Contemporary Dance Education	Illustrated reflective narratives of how performances, techniques and personal abilities developed	Improved ingest, description and sharing of user-generated multimedia content
			Ability to rapidly develop and display collections of resources for classroom use
			Ability to annotate and edit multimedia content non-destructively
	Fluvial Geomorphology	Collections of field data including historical multimedia content used to solve 'life-like' problems	Improved access to linked data. Some excellent resources and data providers already available
			More accessible ontologies and improved descriptive and geo-spatial metadata
			Visualisation of complex data using a range of representations (timelines, maps, images)
B	Plant Sciences	Using published resources to support a persuasive narrative in support of a research proposal in a complex field	Access to publications , ontologies and some data well developed in this field already
			Ability to annotate and collate source, bibliography management, contents alerting
			'Social semantic' visualisation tools linking research activities to published outcomes
	Archaeology	Narratives of discovery, analysis and curation, linking examples to broader historical or geographical context	Improved access to linked data, especially museum and archive databases
			Visualisation of complex data using a range of representations (timelines, maps, images)
			Easy production of rich multimedia publications including linked data
C	Maritime Operations and Management	Narratives of complex problems or events designed to prepare students to deal with analogous situations	Improved access to linked data though some well developed provision e.g. weather data, spot prices
			Visualisation of complex processes to guide students through decision making processes with multiple possible solutions

different dancers interact with the camera in segments of the same performance"); or about some aspect of their own technical abilities. The "cases" being assembled here were, in some respects, similar to those we have seen in Plant Science or Archaeology—students were developing case narratives, drawing on collections of diverse content—but in this case the content was largely something they had generated themselves—reflecting the specificities of their own learning being as important as its relationships to broader disciplinary practices and discourses.

5 Semantic Web Technologies: Challenges and Opportunities

As these examples make clear, the way in which the "Ensemble" project engaged in different settings was highly contingent on the potential for different combinations of Semantic Web technologies. These combinations varied according to established and emergent pedagogical practices. Table 2 shows that despite the differences in the settings, many of the same issues arose: some of settings highlight the need for better linked data access, others share the need for better and new metadata vocabularies or subject-specific ontologies.

Project experiences and requirements across the settings, then, allowed the identification of elements of a development agenda to which the project would need to respond and which represent at least some of the prerequisites for the wider adoption of Semantic Web technologies in education more generally. While these are technical issues, they reflect the real challenges that emerged in settings where teachers were involved in trying to balance authenticity and access to "real world" data with the need to frame and support student learning. These framed an implementation strategy for the project, but one that has broader relevance for the development of semantic technologies and their take-up more widely.

As the semantic technologies and the practices to which they contribute continue to develop, emphasis was placed not on conducting a conventional evaluation of a system presented as "stable" or "finished," but on informing what Boedker and Peterson [28, pp. 61-80] describe as "learning-in-use...understanding and developing use...once a computer-based artifact has been taken over by users...[yielding] insight about the developmental aspects of use". As these are emergent technologies, the evaluation carried out has been largely qualitative, has depended upon the different patterns of engagement of teachers and students, and has fed back into subsequent design and development activities. Evaluative data has been gathered through combinations of

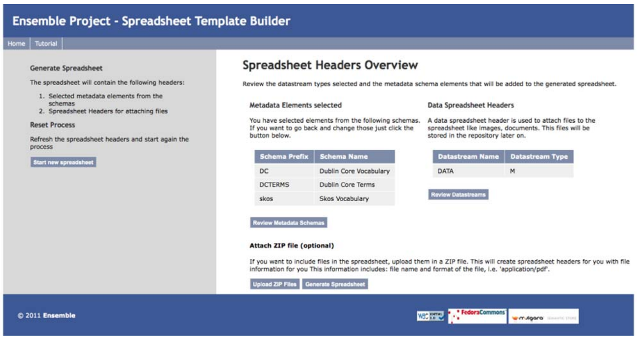

Fig. 3. Metadata elements selection among multiple schemas and Fedora relationships Ontology.

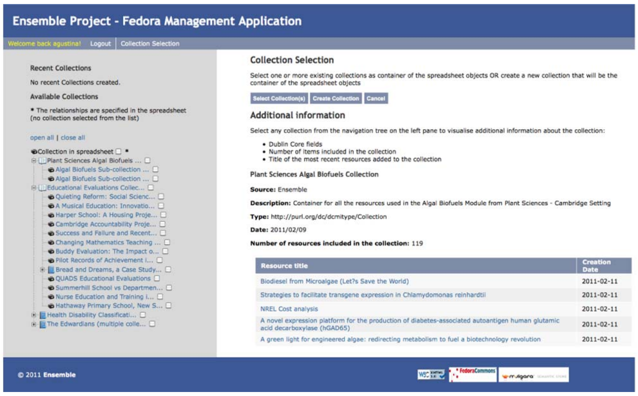

Fig. 4. Fedora collections can be explored and selected to include new resources from spreadsheets. New collections can be created as well.

- web traffic analysis, user logs, and data from online feedback forms,
- structured individual and group interviews,
- student focus groups and prioritization ("where next?") activities,
- think-aloud protocols with prototypes as the focal artifact, and
- reflective diaries.

The emerging development agenda, we present here, was, therefore, not only derived from evaluation data, but was also validated by our increasingly expert user groups.

5.1 Data Conversion, Ingest, and Sharing

The first of these areas relates to the availability and reusability of data for incorporation into learning environments. While in some of the settings we studied a culture of data and metadata sharing was established, in others, the "authentic practice" of the associated disciplines did not extend to data sharing, although efforts were being made to address this, for example, in education and the social sciences where this has been driven by interest in secondary analysis and qualitative data reuse [29].

Looking across the four examples in the previous section, it was in Plant Sciences where the project had the least "work to do" in this respect as it was able to make use of established and Semantic Web ready data sources such as the PubMed and Scopus databases. In other settings data were structured and available online (as in the case of the databases used in Archaeology) so data conversion was comparatively straightforward. In other settings, the data upon which teachers and students wanted to draw was more diverse and disaggregation and conversion of course materials, reading lists, and existing digital resources such as websites demanded the use of custom conversion tools, web "scrapers" and in some cases manual editing. This experience highlighted both the need for easy-to-use data conversion utilities and repository ingest tools that assist data providers with ways of contributing data and metadata in ways that are "future proof" and avoid the need for further phases of conversion and editing.

With drives toward a "linked web of data" and initiatives such as "open government data" [30], such tools have applications beyond the educational world, particularly when potential data providers have limited technical skills and/or limited resources to devote to data sharing. While there has been considerable effort in the area of developing user-friendly front-ends to digital repositories, these still tend to focus on the archiving needs of well-defined user communities. In this project, we needed a different approach as we had to support a wide range of users—both teachers and students—by providing tools that were easy to use and were based on technologies with which they were already familiar, but which still allowed them to benefit from the data sharing and semantic capabilities offered by digital repositories. While the vast majority of our educational users did not require complete repository management tools they still needed access to simple web front-ends that would allow them to progress from, for example, sharing a spreadsheet, reading list or case collection through a virtual learning environment to using a digital repository that allowed them to explore existing collections and construct their own, and to upload resources and access resources.

To address these needs the project has developed two web applications that allow users to prepare spreadsheets representing resources annotated consistently and to allow them to create "collection structures" along with their associated data resources and store them in the repository. While these applications are not complete repository management tools, they are easy to use and work with familiar data sources such as spreadsheets. The first of these applications ("Spreadsheet Builder") is a web interface underpinned by a Java library that presents users with a stage-by-stage spreadsheet creation process, beginning with their selection of the metadata standards and namespaces that are necessary to describe their data. This generates spreadsheets that can then be completed to express both data and collection structures while avoiding the tendency for individuals to improvize metadata fields or to use established standards like Dublin Core in inconsistent ways. The latter could ultimately prevent their discovery or effective reuse (see Fig. 3). Another web application ("Collection Manager") allows users to browse and manage collections stored in the repository as well as creating and uploading new collections and their associated digital resources (see Fig. 4).

In some settings, the primary reason for using digital repositories has been to store, share, and provide web access to learning resources. Fedora's flexibility allows it to be used in the first instance as a "nonsemantic" repository, with the potential of Semantic Web services and technologies then being explored on the basis of an established collection of resources and associated metadata. In other cases, it functions as a "virtual repository" containing only metadata and pointing to resources elsewhere: video servers, publishers' websites or web services which in turn provide the actual data which is then exposed to users.

Together, these two applications provide a basis for prospective data providers to describe and share resources and metadata, with the spreadsheets providing a familiar starting point. In addition, those users who have already used tools such as SIMILE Exhibit (which can be populated from MS Excel or Google spreadsheets) can easily "scale up" to digital repository use, increasing the size and complexity of the data with which they work, as well as the reach and reuse of the data they upload. These will be released as open source so they could be extended and used in combination with Fedora Repository[7] and Mulgara triplestore.[8]

In our evaluations of these applications, many participants have found it less easy to appreciate their benefits—compared to linking to external sources, data visualization, or annotation tools, for example. Their value has tended to be realized after an initial period working with smaller data sets, at the point when the pedagogical demand for larger data sets, or for cross-case analysis emerges. Most significant, though, is the recognition of the potential of digital repositories, with suitable ingest and management tools, to support learning over time. For example: fieldwork data being collected by successive cohorts of students; dance students being able to review previous performances and plant scientist teachers and students highlighting the value of seeing how an emerging field of research develops from year to year.

5.2 Extending the Reach of Linked Data

A second important set of requirements that emerged were informed by the desire to bring "authentic" or even real-time data into teaching and learning environments, both to inform case building and to give students experience of the kinds of real world data management, interpretation, and analysis activities that characterize professional or workplace activities. In the Education Studies setting described in Section 4.3, teachers were keen to use web applications and data visualizations not just to present students with lists of available data sets, but for them to be able to search across or "step into" these data sets and view these without needing to download files and use client side applications. This kind of case pedagogy demands of Semantic Web applications not just the curation and retrieval of resources, but the ability to incorporate aspects of the data themselves into web applications and the pedagogical discourses that take place around them.

This required further extension of the Fedora digital repository implemented by the project. Fedora's object model facilitates working with multiple metadata schemas or vocabularies and provides semantic capabilities [31] since it embeds a semantic triplestore instance (Mulgara Semantic Store). This has proved useful in some of the settings because it allows the association of digital assets with descriptive metadata in different formats (using different vocabularies) along with user-generated annotations and commentaries (for example, in the Plant Sciences setting described in Section 4.1, students contributed bibliographical citations and added comments and recommendations as to their relevance). It also permits the use of Fedora not only as a provider of resources (images, texts, complete data sets) and rich metadata but also as the data source for "non-Semantic Web" formats (Excel, CSV, Plain Text) as well as for converted RDF-XML or N3 data for inclusion into semantic triplestores or other applications.

Storing data sets (rather than just metadata) in such formats is significant since they can be brought into a triplestore, aggregated with other data, reasoned across and can be exposed to other applications by using programmatic APIs, queried using SPARQL query language from a dedicated endpoint and presented using browser-based visualization tools (such as the SIMILE Exhibit Framework) which act as front-ends to the repository. Currently, this function is not supported by Fedora as standard, so it proved necessary to implement customizations: a set of Java libraries implement mechanisms for aggregating any RDF data available in the repository into the triplestore instance. This was initially tested with structured data in the Plant Sciences setting, based on plant distribution data from the Global Biodiversity Information Facility (GBIF) but with the release of increasing amounts of "open government data" the opportunities to support other kinds of inquiry—such as those envisaged by the teachers of Education Studies—look more achievable.

Our evaluation of these features has uncovered some ambivalence, on the part of teachers in particular. This centered around the continuing need to direct and guide students, and to develop and maintain their understandings of "quality" in the data and sources on which they drew. While the value of linked data in offering students access to more "authentic" learning was recognized, there was also concern to establish boundaries to their enquiries, outside which lay untrusted sources and "gray literature" that might be retrieved by what one teacher of plant sciences described as "a magical web-based electronic slurping system." The need for expert mediation of access to linked data remained of high importance for both teachers and students [32].

5.3 Rapid Development Environments

Engagement with participants in the settings described in Section 4 has involved processes so as to make clear in terms that are easily comprehensible to educational users the advantages and possibilities offered by the different technologies and how their use can enhance teaching and learning. For example, in Education Studies, the possibilities that were ultimately realized through digital repositories, triplestores and working with linked data were approached from pedagogical starting points, and requirements and possibilities were explored using a series of rapidly developed demonstrators and prototypes based on test data sets. Critical to this prototyping process has been the availability of a set of software applications and services provided by the SIMILE project at MIT, including the Babel

7. Fedora Commons Digital Repository, http://www.fedora-commons.org.

8. Mulgara Semantic Triplestore, http://mulgara.org.

data conversion utility[9] and the Exhibit web application framework. These allow browser-based application based on small, exemplary data sets to be produced and then used as a focus for further discussions and user testing.

Exhibit is a framework for creating Semantic Web applications that operate entirely within a standard web browser. It uses HTML, CSS, JavaScript, and other client side web technologies to create dynamic pages supporting faceted browsing and a rich set of data visualizations including lists, galleries, charts, timelines, and Google Maps. The toolkit is entirely client side-based and can be included on a web page like any other regular component; it does not require special server software or web server configuration. Once the toolkit's script file(s) have been included in a web page's header, they scan the page code looking for mark-up elements with special Exhibit attributes, translating them into dynamic facets and view components. Facets (selection boxes, numerical range sliders, hierarchical lists) allow selection of those data to be displayed and also interact, providing feedback on how current choices affect potential subsequent lines of enquiry.

Exhibit continues to be developed as a community project to which the Ensemble project is contributing; new facets and view are being developed; and ways are being devised to link Exhibit to Wikis, blogs, and other popular technologies. What is significant here is that it has provided a vital means of engaging teachers and students with the work of the project and with ideas about semantic technologies, "linked data" and information visualization. The comparative speed and ease with which prototypes can be built (a matter of days or hours) has contributed significantly to the dynamism of discourses of technological and pedagogical innovation which the project has sought to promote. This represents an important enabler of semantic technology use in education, and has been highlighted by teachers and students across project research settings.

More than just speeding up development and maintaining momentum, however, is the change that this brought about in the expectations and engagement of participants. In an evaluation session in Contemporary Dance, the students, who had been involved in these processes, produced a "mindmap" of potential directions in which the applications described in Section 4.4 might now develop. These included richer representations of performances; new approaches to choreography; opportunities to review performances from different sources; and the production of electronic portfolios by individual students.

5.4 Annotation and Editing

Another area of research within the project is the integration of semantic technologies with the concepts, practices and technologies of "Web 2.0" or the "Social Web": including blogs, wikis, recommender systems, and person-to-person social networks [33], [34]. This is an emerging area of research and development across all aspects of semantic technology development, but in the context of higher education in particular, where "Web 2.0" technologies and metaphors have transformed not only teaching and learning practices, but also student expectations, the potential overlap between emerging semantic technologies and "social" software is particularly apparent.

Furthermore, some features of the "Social Semantic Web" have relevance in those teaching and learning settings in which students work together in extended knowledge-building activities. Students in our Plant Sciences settings, for example, worked collaboratively to build up information sources on which they subsequently draw when taking part in group or individual assignments. At the same time, the processes of narrative development and case building that have been highlighted across settings seem to point to the value of reflective diaries and "blog-like" environments with which semantic technologies are closely coupled. A common requirement was for content originally provided by teachers to be offered to students as starting a point for their inquiries: this might be a series of readings, or a more varied collection of primary and secondary literature, data sets, images, video, and web links.

Students then needed ways to draw on these authoritative collections along with resources and data that they identified (as in Plant Sciences or Archaeology) or generated themselves (as in Contemporary Dance). This involved adding new resources, combining metadata from different sources and deleting those which were not relevant to their particular project or study. They also wanted to be able to add additional information to resources—personal metadata, in effect—and to have a way of drawing on these in the narratives they then constructed. Dance students, for example, wanted to be able to write personal, reflective accounts, in which they identified salient features of performances and link resources (such as video, audio, images) into these.

Visualization tools, especially timelines and maps, are very useful to support the processes of case display and sense making out of the multiple data sources on which the cases draw on, but supporting the reconstruction processes and students' discussions requires on one hand, allowing to modify the data once it is displayed and on the other, having mechanisms to store in the digital repository these modifications in nondestructive ways, i.e., original data sets are preserved at the same time that coexist with the new created collections. To support adding editing capabilities to the visualization tools, the project has been working with a framework developed by the SIMILE project at MIT called DIDO[10] ("Data Interactive DOcument"), which adds editing functionality to Exhibit [35].

Students in plant sciences trialled the tool when they were working collaboratively to generate and annotate bibliographies, which were then used when writing their final reports. The researchers organized a focus group with the students once they finalized their projects and some feedback revealed that they found the tool complex to use, especially when editing, although they liked the functionalities of saving and sharing their edited documents. In response to the need not to provide a full set of design and editing tools, but to support these requirements for easy metadata editing and annotation, the Ensemble project produced FELIX: the "Form Editor Lightweight Interface for eXhibit." FELIX, like Exhibit, is a Javascript library and

9. http://simile.mit.edu/babel.

10. MIT Simile Project: DIDO, http://projects.csail.mit.edu/exhibit/Dido.

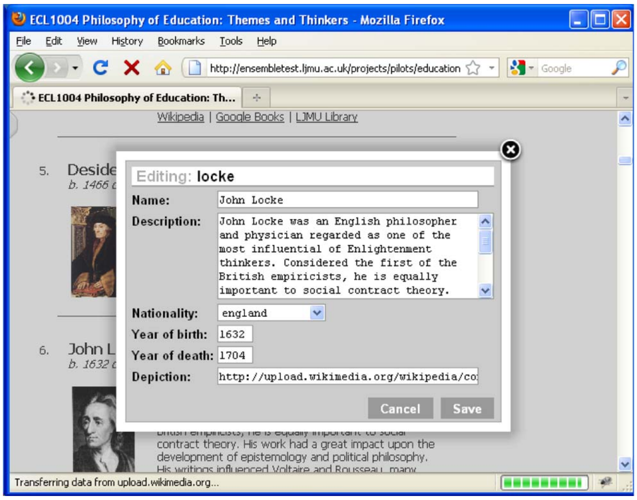

Fig. 5. The FELIX lightweight editor tool.

so can be included on a page by simply adding its a reference into the page header, alongside the references that call the main Exhibit libraries.

It uses a record-based editing scheme, where page authors can define editing lenses (using special mark-up attributes applied to standard HTML elements) to control what details of a given record type can be edited by the page visitor, and how (see Fig. 5).

A standard text field editor is provided for editing single lines of text, a text area editor is provided for editing long-form text, a numeric editor is present to edit integer numbers, and a different "enum" types are provided to select one or many options from a prescribed list. Each of these field editors (plus others) are fully configurable, and permit validators to be added so the data can be checked before it is saved into Exhibit's internal (client side) data store. Several standard validators are available ("is the field empty?", "is it a valid URL?", and so on), but a page author with JavaScript skills can easily write their own validator functions.

The FELIX editor differs from other efforts to include editing facilities into Exhibit (including DIDO) in that it permits editing of data attributes even if they do not actually appear on screen. This ability to edit "all" the data, even those records providing semantic links behind the scenes, and the ability to control how the data is edited and vetted, set FELIX apart from other Exhibit editors, and allows editors to "step behind" the page to edit at least some of the semantic associations that generate the views of the data that are presented through the web browser.

Once FELIX has been used to edit, add or annotate records, the edited collection can be saved to a local file, written to a server or shared-document store such as a Google spreadsheet or fed through the ingest processes outline in Section 5.1 into a digital repository. This might be the same repository from which the "teacher-authored" collection might have originated: but as the student collection is kept separate from the original, this remains intact.

Teachers and students alike have been quick to see the potential for these tools: a common requirement across settings was for teachers to initiate a learning activity by presenting a data set or collection to which students were then invited to contribute and then to review how different students (individuals or groups) have made additions, edits, annotations, and reflective comments. This ability to combine authoritative teacher-mediated information and student-generated content is another significant driver of engagement and adoption of Semantic Web technologies in ways that address teacher concerns about "quality," while allowing students to engage with and contribute semantically rich content within case-based and collaborative learning activities. This kind of "transfer" of capability from teachers to students has been identified as an important enabler of desirable changes in pedagogical practice, and this represents an important future area of the project team's work.

5.5 Support for Multiple Ontologies and "Folksonomies"

Related to these requirements for easy editing while at the same time recognizing the importance of established disciplinary practice was a need, identified across research settings, to support formal ontologies, local "soft" ontologies and emergent "folksonomonies." What research in settings revealed is that even in those areas where formal ontologies existed (examples included botanical terms in Plant Sciences; periodization systems in Archaeology; the Laban notation in Contemporary Dance) these were often adapted, selectively used and mediated by teachers into more "soft" and situated ontologies and taxonomies. In addition, in some settings, local, emergent "folksonomonies" existed and were encouraged as an important aspect of student learning and meaning-making: of Ensemble project settings, this was most obvious example of this was Contemporary Dance.

This relationship between formal ontologies and "folksonomies" has been widely discussed [37], [10], [7], with the consensus view being that while they represent different poles of a continuum, there is potential for "crowd sourced" vocabularies or "soft ontologies" associated with "Web 2.0" to support the development of formal ontologies where these are poorly articulated [9], [11], [16]. Our work suggests, rather, that maintaining a separation between formal ontologies and local, situated practices and discourses, and encouraging learners to explore the relationships between these, offers pedagogical opportunities leading to important learning outcomes and understandings.

In one application developed for use by Contemporary Dance students, SIMILE Exhibit was used to present collections of images and other resources from performances, which could be searched and filtered using a "faceted browsing" interface. Each was described in terms of

- its place in the performance sequence, which was divided into sections and segments (although the duration and order of these might change),
- formal description of the formation and movement portrayed, which drew on the vocabulary associated with the Laban notation for contemporary dance [38], [39], and
- local and situated vocabularies developed by the performers themselves in the course of the choreography of their performances and reflexive discourses.

This allowed students to explore the relationships between the three dimensions of metadata listed above.

For example, a particular sequence of movements, for which the name "skitters" had been adopted across the two dance sites, could be also described in terms of the Laban vocabulary. In this instance, there was a broad consensus as to the nature of "skitters" as being (in Laban terms) a fast, sustained, group movement. The location of episodes of "skittering" in the sequence of the performance could also be determined, and images and videos retrieved from across the collection in order to explore how the movement had evolved and whether there was variation in "skittering" in practice. In other examples, there was less consensus about the use of terms, leading to discussions as to whether different performers interpreted local or Laban terms differently, or whether performers in the different sites were in fact using different local terms for the same activity.

There was no evidence of the abandonment of local terms: rather the opposite, in fact, with the establishment of relationships with the formal Laban vocabulary lending weight to locally derived and often evocative terminology. The value of the semantic technologies implemented lay in their capacity to support the exploration of these relationships, patterns and disjunction. The opportunities to relate their own practice to formal language understood across disciplinary and professional community was identified by both students as pedagogically valuable: a learning outcome that was recognized as a competency reflected in assessment criteria.

With the development of editing tools such as FELIX (as described in Section 5.4), the potential for editable Semantic Web applications to support both the application of formal ontologies with constrained vocabularies alongside unconstrained, personal annotations and "tagging" can be realized. More broadly, this experience led to a broader vision on the part of teachers and students: semantic technologies were seen as a means of supporting students in providing structured, codified evidence of learning outcomes (for example, in e-Portfolios and Personal Development Plans), while also leaving room for improvisation and innovation.

Our experience of working with the teachers and students of contemporary dance in particular challenges the view that formal ontologies and user generated and descriptive "folksonomies" are incommensurable, or that latter represent some kind of "proto-ontologies." Rather, it has highlighted the pedagogical value of technologies in which learners are supported in reflective discourses in which formal ontologies and vocabularies coexist with local knowledge and practice. Following Allert et al. [36], this suggests that a fruitful area for future research would be to explore the role of ontologies in the practices and discourses of teachers and students: not just in the "sharing" of expert knowledge but in the development of new "shared knowledge." This clearly has implications beyond contemporary dance and performing arts and extends to other domains and settings in which knowledge is materialized and represented not only in formal language but embodied in practice.

6 Conclusions

What we have described here is the way in which the particular commitments and requirements of teachers and students involved in different kinds of case-based learning have engaged through dialogues with researchers and developers with ideas and applications associated with the Semantic Web. As such these are emergent understandings of how the overall vision of the "grand structures" of the Semantic Web vision might be understood and enacted in particular pedagogical settings.

Our emphasis on engagement and research in these settings has led us not to develop any single technology, but rather to explore the combinations and convergences of technologies (semantic and others); pedagogical practices and discourses; and existing patterns of innovation and from this has emerged a practical and pragmatic agenda of technological development which has the potential to encourage and support these innovations.

The project and its participants has begun to see the impact of these developments, even though in some settings, there remain significant challenges. Not least among these is the need to understand better the processes by which disciplinary and professional practice is mediated by teachers as they represent it in classroom settings: how "real world" cases are transformed into pedagogical ones; and the technologies that are needed to support and enable this kind of transformation. The view of cases, then, as mediating processes of assemblage, rather than as a containers or narratives, has informed an exciting programme of Semantic Web technology development and has encouraged a wide range of teachers and students to engage with our work and to play active roles in determining what some of the "Semantic Web for education" might be.

Acknowledgments

This work was supported by a grant under the United Kingdom ESRC/EPSRC Teaching Enhanced Learning Programme under research award RES-139-25-0403(A).

References

[1] T. Berners-Lee, J. Hendler, and O. Lassila, "The Semantic Web," *Scientific Am.*, vol. 284, no. 5, pp. 34-43, 2001.

[2] H. Allert, "Coherent Social Systems for Learning: An Approach for Contextualised and Community-Centred Metadata," *J. Interactive Media in Education*, vol. 2, 2004.

[3] M. Lytras and A. Naeve, "Semantic E-Learning: Synthesising Fantasies," *British J. Educational Technology*, vol. 37, no. 3, pp. 479-491, 2006.

[4] R. Koper, "Use of the Semantic Web to Solve Some Basic Problems in Education: Increase Flexible, Distributed Lifelong Learning, Decrease Teacher's Workload," *J. Interactive Media in Education*, vol. 2004, pp. 1-23, http://jime.open.ac.uk/2004/6/koper, May 2004.

[5] V. Devedzic, *Semantic Web and Education.* Springer, 2006.

[6] T. O'Reilly, "What Is Web 2.0? Design Patterns and Business Models for the Next Generation of Software," http://oreilly.com/web2/archive/what-is-web-20.html, Sept. 2005.

[7] P. Mika, *Social Networks and the Semantic Web.* Springer, 2007.

[8] J. Breslin, *The Social Semantic Web.* Springer, 2009.

[9] P. Spyns, A. Moor, J. Vandenbussche, and R. Meersman, "From Folksologies to Ontologies: How the Twain Meet," *Proc. On the Move to Meaningful Internet Systems (OTM)*, pp. 738-755, 2006.

[10] L. Specia and E. Motta, "Integrating Folksonomies with the Semantic Web," *Proc. Fourth European Conf. Semantic Web (ESWC '07)*, pp. 624-639, 2007.

[11] C. van Damme, M. Hepp, and K. Siorpaes, "Folksontology: An Integrated Approach for Turning Folksonomies into Ontologies," *Proc. Bridging the Gap between Semantic Web and Web 2.0 Workshop (ESWC '07)*, pp. 71-84, 2007.

[12] C. Bizer, T. Heath, and T. Berners-Lee, "Linked Data—The Story So Far," *Int'l J. Semantic Web and Information Systems,* vol. 5, no. 3, pp. 1-22, 2009.

[13] H. Alani, D. Dupplaw, J. Sheridan, K. O'Hara, J. Darlington, N. Shadbolt, and C. Tullo, "Unlocking the Potential of Public Sector Information with Semantic Web Technology," *Proc. Sixth Int'l Semantic Web Conf. (ISWC),* http://eprints.ecs.soton.ac.uk/14429, 2007.

[14] L. Ding, D. Difranzo, A. Graves, J. Michaelis, X. Li, D. McGuinness, and J. Hendler, "Data-Gov Wiki: Towards Linking Government Data," *Proc. AAAI Spring Symp. Series,* http://www.aaai.org/ocs/index.php/SSS/SSS10/paper/view/1154, 2010.

[15] D. Robinson, H. Yu, W. Zeller, and E. Felten, "Government Data and the Invisible Hand," *Yale J. Law and Technology,* vol. 11, p. 160, 2009.

[16] T. Tiropanis, H. Davis, D. Millard, M. Weal, S. White, and G. Wills, *SemTech Project Report,* Univ. of Southampton/JISC, 2009.

[17] S. Mazzochi, S. Garland, and R. Lee, "Simile: Practical Metadata for the Semantic Web," http://www.xml.com/lpt/a/2005/01/26/simile.html, 2005.

[18] D. Huynh, D. Karger, and R. Miller, "Exhibit: Lightweight Structured Data Publishing," *Proc. 16th Int'l Conf. World Wide Web,* 2007.

[19] C. Lankshear, M. Peters, and M. Knobel, "Critical Pedagogy and Cyberspace," *Counternarratives,* H. Giroux, C. Lankshear, P. McLaren, and M. Peters, eds., Routledge, 1996.

[20] R. Edwards and R. Usher, *Globalisation and Pedagogy: Space, Place and Identity.* Routledge, 2007.

[21] C. Ciborra, *The Labyrinths of Information: Challenging the Wisdom of Systems.* Oxford Univ., 2002.

[22] L. Suchman, *Human-Machine Reconfigurations: Plans and Situated Action.* Cambridge Univ., 2007.

[23] M. Tscholl, F. Tracy, and P. Carmichael, "Case Methods, Pedagogical Innovation and Semantic Technologies," *Proc. First Int'l Workshop Semantic Web Applications for Learning and Teaching Support in Higher Education (SemHE '09),* http://eprints.ecs.soton.ac.uk/18050, Sept. 2009.

[24] M. De Landa, *A New Philosophy of Society: Assemblage Theory and Social Complexity.* Continuum, 2006.

[25] S. Selber and J. Johnson-Eilola, "Plagiarism, Originality, Assemblage," *Computers and Composition,* vol. 24, no. 4, pp. 375-403, 2007.

[26] D. Shotton, K. Portwin, G. Klyne, and A. Miles, "Adventures in Semantic Publishing: Exemplar Semantic Enhancements of a Research Article," *PLoS Computational Biology,* vol. 5, no. 4, pp. 1-17, 2009.

[27] P. Brooks and L. Kahlich, "Reflections on a Two-Year Joint International Project Using Web-Cam Technology to Create New Opportunities for Student Choreographic Collaborations," *Innovations in Practice,* vol. 2, no. 1, pp. 41-48, 2009.

[28] S. Boedker and M. Peterson, "Design for Learning in Use," *Scandinavian J. Information Systems,* vol. 12, pp. 61-80, 2000.

[29] L. Corti and L. Bishop, "Strategies in Teaching Secondary Analysis of Qualitative Data," *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research,* vol. 6, no. 1, http://www.qualitative-research.net/index.php/fqs/article/view/509/1099, 2005.

[30] HM Government, "Opening Up Government," http://data.gov.uk, Mar. 2010.

[31] C. Lagoze, S. Payette, E. Shin, and C. Wilper, "Fedora: An Architecture for Complex Objects and Their Relationships," *Learning in Health and Social Care,* vol. 6, no. 2, pp. 124-138, 2006.

[32] R. Edwards, F. Tracy, and K. Jordan, "Mobilities, Moorings and Boundary Making in Developing Semantic Technologies in Educational Practices," *Research in Learning Technology.*

[33] P. Mika, "Flink: Semantic Web Technology for the Extraction and Analysis of Social Networks," *J. Web Semantics,* vol. 3, no. 2, pp. 211-223, 2005.

[34] T. Gruber, "Collective Knowledge Systems: Where the Social Web Meets the Semantic Web," *Web Semantics: Science, Services and Agents on the World Wide Web,* vol. 6, no. 1, pp. 4-13, http://dx.doi.org/10.1016/j.websem.2007.11.011, Dec. 2007.

[35] D. Karger, S. Ostler, and R. Lee, "The Web Page as a WYSIWYG End-User Customizable Database-Backed Information Management Application" *Proc. 22nd Ann. ACM Symp. User Interface Software and Technology (UIST),* pp. 257-260, http://projects.csail.mit.edu/exhibit/Dido/dido-uist.pdf, 2009.

[36] H. Allert, H. Markkanen, and C. Richter, "Rethinking the Use of Ontologies in Learning," *Proc. Rethinking the Use of Ontologies in Learning,* pp. 115-126, 2006.

[37] K. Weller, "Folksonomies and Ontologies: Two New Players in Indexing and Knowledge Representation," *Proc. Applying Web 2.0 Innovation, Impact and Implementation,* pp. 108-115, 2007.

[38] J. Adshead-Lansdale, *Dance Analysis: Theory and Practice.* Dance Books, 1988.

[39] J. Newlove, *Laban for Actors and Dancers: Putting Laban's Movement Theory into Practice.* Nick Hern Books, 1993.

Agustina Martínez-García is currently working toward the PhD degree at Liverpool John Moores University, in which she is exploring the potential of semantic technologies to enhance qualitative research and digital archiving. She is also a research associate in the ENSEMBLE Project.

Simon Morris works for the ENSEMBLE Project at Liverpool John Moores University, where he is responsible for programming Semantic Web applications and APIs. His chief areas of interest include user interface programming and computer graphics.

Michael Tscholl is a research associate on the ENSEMBLE Project. His research includes learning, education, and cognition, specializing on group learning and case-based learning in a variety of disciplines.

Frances Tracy is a senior lecturer in education studies at Liverpool John Moores University. She is also a research associate in the ENSEMBLE Project.

Patrick Carmichael is Professor of Education at the University of Stirling and, since 2008, has been the director of the ENSEMBLE Project.