

## *When cloud computing meets with Semantic Web: A new design for e-portfolio systems in the social media era*

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### **Abstract**

The need, use, benefit and potential of e-portfolios have been analysed and discussed by a substantial body of researchers in the education community. However, the development and implementation approaches of e-portfolios to date have faced with various challenges and limitations. This paper presents a new approach of an e-portfolio system design based on Private–Public (PrPI) data index system, which integrates cloud computing applications and storages with Semantic Web architecture, making semantic web-based visualisation and advanced intelligent search possible. It also discusses how the distinctive attributes of the PrPI-based digital asset management system can serve as a large-scale robust e-portfolio system that can address issues with scalability, sustainability, adoptability and interoperability. With such a new distinctive design, a large-scale deployment at a state or national level becomes possible at a very cost-effective manner and also such large-scale deployment with intelligent digital asset management and search features create numerous opportunities in education.

### **Introduction**

A portfolio is a purposeful collection of student work that exhibits the student's efforts and achievements (Paulson, Paulson & Mercer, 1991; Wiedmer, 1998) and progressive improvement over time (Barrett, 1994; Challis, 2005) in a life-long journey with academic and professional endeavours. With the advent of the digital age, the emergence of electronic portfolios (e-portfolios) appeared as a logical next step for portfolios. In fact, over half of US higher education institutions are using some form of e-portfolios (Green, 2008), and the popularity of e-portfolio has grown out from the higher education arena to flood into a broader population: Rhode Island implemented a state-wide e-portfolio system for its high school students (RINET, 2009), and Minnesota provides life-long e-portfolios for all residents (eFolio, 2009). Not only serving as a repository of digital artefacts or evidence of mastery and achievement, an e-portfolio also serves as an assessment tool for users and becomes a learning place where a student matures learning through self-reflection (Bhattacharya & Hartnett, 2007). These recognised benefits convinced many institutions of higher education in the US to college system-wide e-portfolio implementation initiatives such as e-portfolio California project funded by a grant from the California Community Colleges System Office (CVC, 2009).

Furthermore, the ease and diversity of content creation afforded by social web tools, and the ubiquity of technology use amongst learners today, the range of e-portfolio activities and the

kinds of digital artefacts that could possibly be representative of an individual's e-portfolio have increased substantially. For example, educators have reported and discussed the use of e-portfolio systems in creating a collaborative learning space (Greenberg, 2004), fostering peer assessment (Stevenson, 2006), student advisement and career planning (Lorenzo & Ittelson, 2005a), content visualisation with electronic concept maps (Kim, 2006), planning and managing instruction (Sherman, 2006), and improving the effectiveness of faculty (O'Brien, 2006).

Despite the growing interest and use, there is a series of issues and challenges that austerey hinder the implementation and the wide use of e-portfolio systems firmly integrated in academic and professional activities. Therefore, this paper attempts to identify challenges and issues from current cases of implementations and development approaches with e-portfolio systems; introduces a new radical design approach as a viable solution; and shares potential implications of such design.

### **Current efforts to implement e-portfolio systems**

Efforts in implementing e-portfolio systems in education have been pursued and well-documented in various European countries, Australia, as well as in the US. For example, the European Institute of ELearning (EifEL) set up a Europortfolio group with a mission to 'engage upon an orchestrated effort involving both educational and corporate institutions to define, design, and develop digital portfolio systems that meet the needs of all stakeholders' (EifEL, 2007). The Australian e-portfolio Project was awarded to a consortium of four universities—Queensland University of Technology, The University of Melbourne, University of New England and University of Wollongong—to, amongst other goals, 'provide an overview and analysis of the national and international e-portfolio contexts, document the types of e-portfolios used in Australian higher education,' and 'identify any significant issues relating to e-portfolio implementation' (AeP, 2008). In the US, the premier example is eFolio Minnesota, considered the first state-wide e-portfolio system in the US. eFolio provides every resident in the state of Minnesota a free lifetime e-portfolio with limited storage space (<http://www.efoliominnesota.com/>). Since it was launched in October 2002, over 90 000 residents and students in Minnesota have used the e-portfolio system. The number of registered users has grown linearly at a rate of approximately 1 300 new users each month, and over the year ending in 2005, eFolio received an average of over 2 million hits and 67 000 unique visits per month (Cambridge, 2008).

With reference to the functionalities of an e-portfolio system, Greenberg (2004) described the e-portfolio as 'a network application that provides the author with administrative functions for managing and organising work (files) created with different applications and for controlling who can see the work and who can discuss the work (access)'. From a technical perspective, adopting an e-portfolio system typically involves setting up the e-portfolio application on a server, and providing a large data storage facility to house user files. Students then create accounts, add data files into the system and create different assemblages of the data files targeted towards particular audiences.

In terms of the technical implementation of e-portfolios, there is currently great diversity in the technologies being used by various institutions. The Australian ePortfolio Project (2008) reported a range of tools and applications being used by Australian universities. Some universities used extensive applications like full e-portfolio systems, virtual learning environments and adapted learning management systems, whereas others simply employed student web pages and blogs. In the US, Lorenzo and Ittelson (2005b) observed four basic approaches in implementing e-portfolio systems: (1) home-grown, proprietary systems like the DU Portfolio Community system from the University of Denver and the UW Catalyst Portfolio tool from the University of Washington; (2) open source, publicly available systems like the VT Electronic

Portfolios pilot from Virginia Tech; (3) commercial, licensed systems like Avenet eFolio, which provides the e-portfolio platform for the Minnesota project; and (4) common hyper text mark-up language editors like Microsoft Frontpage and Adobe Dreamweaver.

### **Existing implementation issues and challenges**

Despite numerous benefits of e-portfolios recognised throughout the academic community, only a handful number of institutions are reported as having mature campus-wide e-portfolio systems (Paoletti, 2006). In fact, many institution-wide implementation initiatives were stalled or are remaining at pilot stages on many US university campuses (Paoletti, 2006). The impeded acceptance of e-portfolios on many campuses can be explained by a number of barriers observed during e-portfolio implementation sites throughout the US and other parts of the world. Studies observe a range of challenges against a successful e-portfolio implementation at higher education institutions (Canada, 2002; Lorenzo & Ittelson, 2005a, b; Sherry & Bartlett, 2005; Tosh, Light, Fleming & Haywood, 2005; Wetzal & Strudler, 2005). In sum, such challenges include the insufficient technical infrastructure (hardware, software and IT support), lack of skills and knowledge among students and staff, demand on increased time commitment for users (especially on the part of teaching staff), and the problems with security and privacy of data. Especially, the myriad of technologies currently being employed, and the increase in range, file size and diversity of possible digital artefacts have given rise to a number of implementation issues and challenges:

#### *Scalability and sustainability*

Current e-portfolio systems generally provide users storage space in a centralised server for all of their data. This poses immediate problems of scalability and sustainability, especially for institutions with large populations of active users. With the increasing use of multimedia, and the ease of creation of media-rich content, there is a drastic increase in storage load imposed by any user on the e-portfolio system. For example, the 3 Mb storage space provided for each user in the eFolio Minnesota system would hardly be enough for the avid user today. In fact, Cambridge (2008) reported that users in the Minnesota system had given feedback that the 'small amount of storage space allotted to them by the eFolio software impedes their ability to include substantial personalising multimedia content'. In addition to immediate storage requirements, questions such as storage growth rates and the duration of each user's membership in the system after graduation from educational institutions have yet to be addressed.

#### *Data transportability*

As users import all their data into the centralised e-portfolio server of an institution, it is essential for users to be able to transport their information as they move from one educational institution to another. Most of the e-portfolio systems in use today are not interoperable. As Jafari (2004) described, 'we do not yet have all the necessary interoperability requirements defined for various types of e-portfolios, and this is causing ever-increasing challenges for developers of e-portfolio software environments as the projects increase in size and complexity'. This challenge in data transportability has in turn given rise to issues with data ownership. Naturally, any user would like to export the data and to carry it with him when he moves on to other institutions, but who is the real owner of the data in the e-portfolio? Is it the author or the institution?

#### *Barriers to user adoption*

'If we build it, will they come?'—this question is a line adapted from the 1989 film, *Field of Dreams*. Patent (2007) asked this question in the context of an e-portfolio system—highlighting that 'it is not a foregone conclusion that just because we build an e-portfolio into a course, students will want to use it, or find it beneficial in developing their learning in the ways it was designed to do'. The critical question we need to ask ourselves is whether there are barriers to the use of e-portfolios by learners.

An e-portfolio system is to provide a useful personal space where students can collect the digital artefacts that present evidence of their experiences and achievements. On the other hand, the learners of today, who are more accurately referred to as ‘digital natives’ are adept at using Web 2.0 tools. They already ‘rely heavily on communications technologies to access information and to carry out social and professional interactions’ (Kennedy, Judd, Churchward, Gray & Krause, 2008). ‘Web 2.0 tools tend to be relatively unstructured and are characterised by an ease of publishing, a high level of interaction, self-assigned semantics (tagging) and are often media rich’ (Cotterill, White & Currant, 2007). With learners already using (or fluent in) social and Web 2.0 technologies in interacting with each other and in showcasing their media artefacts, current e-portfolio systems require users to go through an additional process of duplicating the media artefacts which may already be residing in these diverse web applications, and uploading them onto the e-portfolio system. This is potentially time-consuming and laborious, and could pose as a barrier to user adoption.

### **Introducing PrPI**

As highlighted earlier, with Web 2.0 technologies and applications, a significant amount of user data, or media artefacts, is stored in online storage services in the Internet cloud. Users today are inundated with a myriad of online services that offer data storage in the cloud for free. Such cloud computing services (eg, Google Docs, Facebook, Flickr, MySpace, Picasa, YouTube) allow users to share their data with anyone, anywhere and at anytime. Online blogging sites also offer free hosting services to users, and social networking sites provide free platforms for user interactions over the web. Furthermore, the technology trend is moving towards offering software as a service on the cloud, rather than as a standalone product. Software applications like Adobe Photoshop and Google Docs already operate on data stored in the cloud. Rather than operating an e-portfolio system apart from these online services, cloud computing offers a potential solution to the challenges to e-portfolio implementation—issues of sustainability, scalability, data portability and user adoption.

Unfortunately, until recently, in spite of its potential, cloud computing has posed more challenges than solutions. Cloud computing services range from the narrow, like uploading pictures onto Flickr, to broad ones like Facebook, where users have the ability to define applications. The bulk of cloud computing services is currently application-centric, and requires the user to explicitly upload data to different websites. This results in data scattered across diverse devices and websites. Any one form of media can be stored across a variety of different services. With the potentially exponential rise in the amount of data stored across various services online, it is becoming increasingly difficult to keep track of one’s own data. Consequently, this poses problems of inconvenience and potential loss of data ownership and privacy due to reduced capacity to monitor and manage the data (Seong *et al*, 2009).

PrPI (which stands for Private–Public) is a personal-cloud computing infrastructure being developed from an on-going NSF-funded project (POMI, 2009) lead by researchers at Stanford University. Tapping on the wide range of free cloud computing services available to the user, PrPI adopts a user-centric design approach to create a federated storage system out of existing web services and applications. It is a collaborative and semantically indexed data management system which functions as a simple index of data that users may already have stored in other services. PrPI therefore allows users to continue to take advantage of the free storage services—the PrPI infrastructure then serves to present ‘a unified, location-agnostic view of the data in a user’s personal cloud’ (Seong *et al*, 2009).

There are two key concepts in the PrPI infrastructure:

### PrPI Semantic Index

The PrPI infrastructure creates a semantic index of all the data available to it, and presents a semantic interface that facilitates retrieval of relevant information. According to Seong *et al* (2009), 'the PrPI Semantic Index is a Semantic Web that keeps track of all the data in a personal cloud. The metadata includes enough information to answer typical queries about the data, and location of the body of the larger data types. In addition, it also keeps track of the access rights granted to our friends at fine granularity. With the help of a uniform resource identifier, the protocol eliminates data copying by allowing the application to retrieve data directly from storage'.

### Personal-Cloud Butler (PCB)

In the PrPI system, each user has a PCB, a program that manages a user's personal cloud of information on his or her behalf (Seong *et al*, 2009). The PCB functions as a single interface that mediates between all the data repositories and cloud computing services of the user, thereby providing the user with one-stop access to all his or her data in the cloud. Although the detailed description of the functional algorithms involved in the security management is beyond the scope of the paper, in short, the user provides access credentials of each cloud computing service in a database for the PCB to reference as needed in managing numerous artifacts in the cloud automatically.

Therefore, the semantic index enables the user to track and organise numerous personal digital artifacts in the cloud without actually storing them (eg, large video files) in a centralised server, eliminating the need of a vast storage space. Also, the semantic attributes of the index make it possible for the user to efficiently organise and visualise personal cloud artifacts while allowing intelligent searches that go much beyond conventional keyword-based searches. In addition, PCB is a personal cloud crawler that tracks, verifies and updates personal cloud artifacts with minimum user involvement. The combination of unique features of PrPI system infrastructure enables educators to design a much more scalable and intelligent e-portfolio system.

### A PrPI-based e-portfolio system

The key features of PrPI, namely the Semantic Index and the PCB, are keenly aligned to the elements of an e-portfolio system—the PrPI platform thus appears to be a natural fit to address the challenges currently faced.

As illustrated in Figure 1, PrPI functions as a simple index of data that users may already have stored in other services. It allows them to access these services in a centralised way, thus

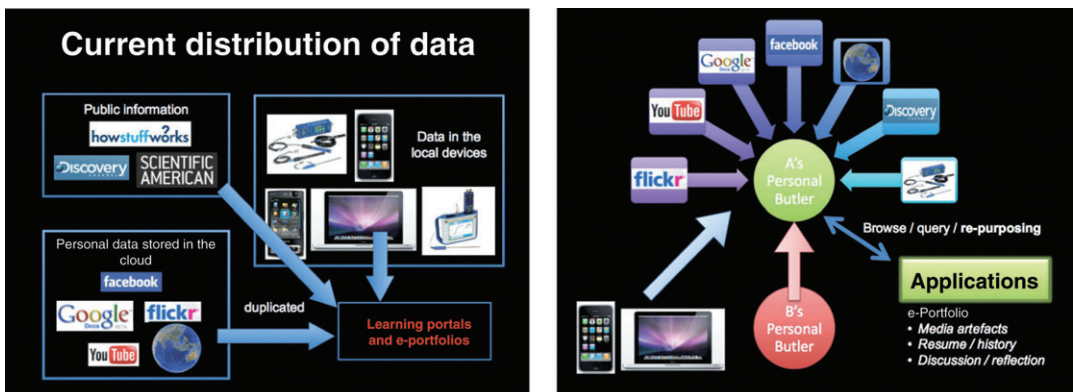


Figure 1: A comparison between how current e-portfolios manage data distributed on the cloud, and how the proposed PrPI-based e-portfolio system facilitates integration



presenting the functional equivalent of a closed e-portfolio platform without the drawbacks. Data in the PrPI system is semantically indexed using a resource description framework (RDF) triple store, allowing it to be retrieved using the SPARQL Protocol and RDF Query Language (SPARQL) queries. Coupled with the emerging technology in translating natural language into the SPARQL query language (See Ran & Lencevicius, 2007), more convenient ways of searching and retrieving data within the e-portfolio system can be expected.

As discussed earlier, researchers highlighted the challenges to implementing an e-portfolio system. Certainly, PrPI is not a panacea and there might be a whole new set of other issues with its full implementation. However, it addresses some of the currently well known challenges. Here, we present the attributes of a successful e-portfolio and present how a PrPI-based e-portfolio system may be aligned with those attributes:

#### *Ease of use*

According to Jafari (2004), a successful e-portfolio must offer an attractive and relatively simple interface, with little or no training required. One of the key design factors of the PrPI architecture is that of integration and simplicity. The PCB presents a single, unified view of one's data and relations in the personal cloud, hiding 'the complexities of authentication and authorisation' (Seong *et al.*, 2009). The users can also continue to use their existing data storage services on the cloud and does not need to go through the laborious process of duplicating the data into the e-portfolio server—thereby concurring with the attribute of 'ease of use'.

#### *Sustainability*

Long-term sustainability is a key issue in any e-portfolio project. The sustainability of providing large storage services for a high quantity of existing users notwithstanding, an e-portfolio project also has to address questions of whether and how long to archive data from users who have left the institution. The PrPI-based e-portfolio system does not need to address issues like these, because the users' data remain with their personal data services in the cloud. Even if the user creates and showcases media-rich, storage-intensive data, this storage load is imposed on their personal cloud computing services, rather than on the PrPI-based e-portfolio system. The system merely stores small scripts which enable the PrPI system to query these other data sources. At the same time, such small database could be easily picked up and operated as a free global directory service. Hence, this system is built for sustainability, and can easily be scaled exponentially.

#### *Advanced features*

Jafari (2004) emphasised that a successful e-portfolio system needs to have sufficiently advanced features to attract users who are concurrently inundated with numerous new web-based services and products each day. Due to the fact that the PrPI architecture is built to leverage on existing, and perhaps even hitherto unreleased software applications, a PrPI-based e-portfolio system does not need to 'compete' with these new services and features. The user is free to capitalise on these services—one just needs to open up access to these services. Furthermore, the proposed e-portfolio is built on an open architecture that is flexible and dynamic, and can integrate new features and applications as they arise from the user community.

#### *Robust integrated technology architecture*

An integrated technology architecture was advocated by Jafari (2004) as he anticipated that users would need to access and make reference to multiple types of data across various platforms and housed in different servers. The PrPI architecture precisely addresses this concern. The PCB functions as an integrated interface—it maintains 'an up-to-date PrPI Semantic Index for all the data in an owner's federated storage system. The Butler keeps track of all the owner's storage

devices' (Seong *et al.*, 2009). Users retrieve data through applications which send queries only through the Butler, hence presenting an integrated system.

#### *Lifelong support*

One great concern regarding e-portfolio systems is what happens to the data when a student graduates, or moves on to another institution, but wishes to continually update the media artefacts showcased in the e-portfolio system. Offering lifelong support would attract a user to commit her time and effort to build up the e-portfolio, as she would be able to continually build and use it even after graduation. The PrPI-based e-portfolio system allows for this, as the user can continue to build on, and load data onto her personal cloud computing storage space which can be also portable. As this does not impose excessive storage load on the PrPI server (beyond additional small scripts), this lifelong support becomes highly sustainable.

#### *Standards and transportability*

Issues of standards and transportability have plagued the e-portfolio space since its inception. The IMS Global Learning Consortium, consisting of several dozen universities and corporate partners, has developed and implemented a set of XML-based standards that allow interchange of data between e-portfolio systems. The efficacy of these standards has yet to be determined, but issues of data ownership, long-term storage, and non-portability of data remain, while the continuous rapid advancement of new technology features at various fronts make the standardisation even harder. To date, the PrPI-based indexing system for content spanning multiple data hosts remains a novel one in the e-portfolio space, and presents a viable solution that circumvents these issues. Data are still owned and controlled by the user, and data portability is a non-issue.

### **Semantic Web attributes of the PrPI system**

#### *'X' attribute*

In his paper, Jafari (2004) refers to an 'X' attribute—'other important unknown attributes that may contribute to the success of an e-portfolio project'. With reference to the PrPI-based e-portfolio system, its ability to support semantic query is a crucial attribute for success. Semantic-aware applications have been highlighted in the 2009 Horizon Report (Johnson, Levine & Smith, 2009) as an upcoming technology piece predicted to feature even more prominently within the next four to five years. The PrPI architecture keeps track of data through the use of a semantic index—this allows for searching of data by using the semantics, or meaning, of information rather than strict key word searches. Hilzensauer, Hornung-prahauser and Schaffert (2006) have highlighted that Semantic Web technologies can be leveraged in e-portfolio systems to: (1) derive formal descriptions of artifacts; (2) overcome interoperability issues; (3) facilitate knowledge management, linking artifacts to personal development plans; and (4) support reasoning, and perform matching of users of appropriate profiles with relevant learning paths, or even job openings or ad hoc professional engagements.

#### *Content organisation and visualisation*

The PrPI-based e-portfolio system is as close as one can get to a semantic-based e-portfolio—this may yet be the crucial 'X' factor for its success, as there is much potential to leverage on both the Semantic Web and e-portfolios in education (Schaffert, 2006). The grand vision is that the PrPI-based e-portfolio system will serve as a place to collect, select, manage and present one's data or achievement for multiple purposes. The Semantic Web infrastructure enables user-defined access for different groups of audience. The system thus allows for multipurpose presentations of the portfolio assets, facilitating the repurposing of assets for user-defined targets.

In terms of content visualisation, which needs much more work in the overall project, various approaches might be taken to maximise the usability and efficiency of the user interface. Among

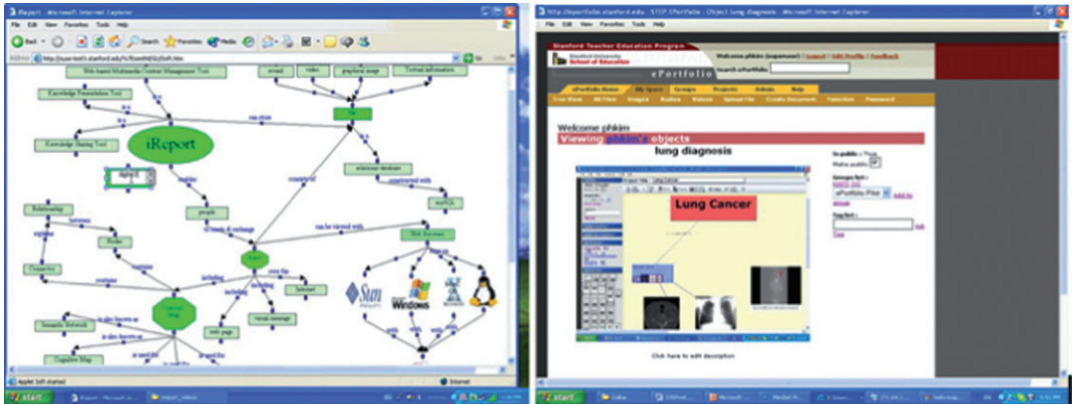


Figure 2: Prototype iterations of visual map-based e-portfolio interface

the substantial amount of relevant studies, there is a growing number of researchers who are supporting the idea of adopting a visual-mapping approach in the design of advanced digital content-management systems (Alpert, 2005; Coffey, 2005; Kim, 2006; Tergan, 2005). The consensus among them is that the integration of a visual-mapping interface in knowledge-management systems such as e-portfolio systems may lead to a better understanding of the aggregated content in comparison to systems incorporating a traditional display method (eg, conventional tree or hierarchical folder structures for organising and presenting digital contents). As an empirical study, Kim and Olaciregui (2008) examined the effects of visualisation variations and found that the visual map-based interface (ie, knowledge and content presentation on a visual map foundation) was superior to a conventional presentation method (eg, tree or hierarchical content organisation) in overall performance test, access time and retention. In other words, the visual map layout might have helped the user understand how multiple digital artefacts were meaningfully connected, organised and presented.

With PrPI-based e-portfolio system, the visuospatial layout (eg, sample shown in Figure 2) can be constructed from parsing and analysing the attributes of the Semantic Web (ie, metadata described in RDF as a series of subject-predicate-object triples) and by doing so it provides a snapshot of overall artefact organisation and may aid the user in navigating and internalising the content more efficiently. Nonetheless, since most conventional layouts of electronic resumes or web presentations are in the form of straight top-down or hierarchical fashion, the visuospatial layout will need to be one of optional interfaces the user can choose until the user finds the novel approach suitable and useful.

#### *Unique identifier*

The PrPI-based e-portfolio system will utilise a user's mobile phone number as a unique identifier. A user's mobile phone number is proposed as a novel strategy for user account identification as it is user-centric, institution-independent and portable. This resolves issues of transportability and lays the ground for future global mobile transactions and interactions (eg, short message service [SMS]-based inquires/requests/approvals/receipts/certificates, m-banking, m-learning, m-ERP (Enterprise Resource Planning), etc.) in the global knowledge economy. A user's mobile phone number, consisting of the country code, followed by area code and number, presents a number string that is unique in the world. Metadata in the PrPI-based e-portfolio system can therefore be tied to the user's mobile phone number. For example, simple metadata of a user's full name, email address and associated information can be represented as shown in Figure 3.



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prpl://identity/# 16502807769 @pcb_provider.com
prpl://identity/# 16502807769 @pcb_provider.com rdf:type foaf:Person
prpl://identity/# 16502807769 @pcb_provider.com foaf:name "Paul"
prpl://identity/# 16502807769 @pcb_provider.com foaf:firstName "Kim"
prpl://identity/# 16502807769 @pcb_provider.com foaf:mbox ``digitalschema@gmail.com``
prpl://identity/# 16502807769 @pcb_provider.com foaf:phone ``16502807769``

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Figure 3: Representing metadata in RDF

Furthermore, a Semantic Web infrastructure facilitates much easier search and retrieval of data and artefacts. It allows users a greater degree of control over the dissemination of the information they contain by defining what is public or private information. For example, users can make certain information, such as a list of degrees earned, classes taken or competencies achieved widely available to colleagues, potential employers and the general public as desired. More personal and specific information, such as GPA (Grade Point Average), faculty remarks, salary requirements or endorsement statements can be restricted only to potential employers who are approved with access privileges. The access privileges can be given through simple SMS approvals and set to expire if needed. Conversely, the PrPI-based e-portfolio will facilitate searching for people matching a particular criterion. For example, potential employers might wish to instantly create (ie, instead of keyword searching) a list of candidates meeting a specific set of requirements; as PrPI uses a semantic index, this type of task can be accomplished using simple queries of the pertinent information that potential candidates make available in their e-portfolios.

## Conclusion

The benefits of a portfolio, and subsequently, with the advent of technology, an e-portfolio system, have been identified and extolled since a long time ago (Greenberg, 2004). Around the world, colleges, universities and governmental agencies have begun using electronic portfolios to facilitate lifelong and life-wide learning (AeP, 2008; EIFEL, 2007; Hartnell-young, Smallwood, Kingston & Hartley, 2006). However, there are yet many challenges to be overcome on the way to implementing a successful e-portfolio system that is stable, scalable and sustainable (Jafari, 2004). In this paper, a collaborative, semantically-indexed data management system, PrPI, was proposed as the platform for a future e-portfolio system. The features of this PrPI-based system which enable it to circumvent a number of issues currently faced by e-portfolio systems have also been discussed. A prototype of this system is currently being built and field tested. The potential of this system for successful implementation and application will be studied more as the project progresses further. As the development of this system parallels the development of the Semantic Web worldwide, it remains to be seen how the merging of cloud computing, the Semantic Web and the e-portfolio system will prove to revolutionise the world of e-portfolio application development, institutional implementation, and user adoption.

Most interestingly, the current strand of Semantic Web research promises a series of new possibilities applicable in education and obviously, PrPI will be harnessing the core features of the Semantic Web architecture. One apparent possibility is to make student learning artefacts more understandable by computers using the semantic web-based PrPI index database. With such e-portfolio system design, evaluating student learning outcomes (ie, products as well as the process) will become more efficient, scalable and objective. Thus, with e-portfolio objects linked to fine grained semantics and metadata, critical analyses on student learning in a longer term, examining the effect of e-portfolios on academic and professional development endeavours, and research on teacher intervention or academic program accountability will become more feasible. Subsequently, such benefits will win over resistance to use e-portfolios and more constructive and productive ways of using e-portfolios will be introduced and examined.

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