Towards greater Flexibility in the Learning Ecosystem – Promises and Obstacles of Service Composition for Learning Environments

Gerhard Wurzinger[1,2], Vanessa Chang[2] and Christian Guetl[1,2]

[1] Institute for Information Systems and Computer Media, Graz University of Technology, Graz, Austria
e-mail: {gwurz|cguetl}@iicm.edu
[2] School of Information Systems, Curtin University of Technology, Perth, Australia,
e-mail: {gerhard.wurzinger|vanessa.chang|christian.guetl}@cbs.curtin.edu.au

Abstract — **Today's knowledge society of the 21st century requires a flexible learning environment which is capable to adapt according to teaching and learning objectives, students' profiles and preferences for information and communication technologies and services. To combine tasks and context dependent services to a tailored ad-hoc learning environment, service orchestration and choreography are promising and interesting concepts. In this paper, backed by an ecosystem-based conceptual architecture, SOAP-based and lightweight Web service technologies for service composition, will be reviewed, and the promises and challenges for both approaches will be discussed. Based on these findings our motivation for a light-weight web services composition is given and a first approach is outlined which builds on the combination of machine-readable service description, mechanism of tool-assisted mashup creation and standardizes languages for service composition.**

Index Terms — **e-learning, service composition, service orchestration and choreography, Web services, Web 2.0**

I. Introduction

At the beginning of the 21st century our society was influenced more than ever by rapid development and ever-changing political, social, economical, technological and environmental situations. Society expects citizens to adapt their knowledge and skills to this fast changing environment. Consequently, today's educational approaches have changed towards today's modern learning with an understanding to be more independent in the learning process, strengthening of meta-cognitive and teamwork skills as well as linking knowledge in a cultural context in order to prepare for lifelong learning. Based on the above, instructional designs have adopted modern educational strategies which include aspects of self-directed learning, collaborative learning, participative learning, interactivity, and content creation [3, 27, 28].

For centuries, the application of *learning media* in learning settings have been influenced by technology such as the invention of printed material in the 15th century or television in the 1950s. Each of the new technologies have impacted learning, however expectations of practical experiences have not been met. Since the mid-1990s the penetration of computers in virtually every part of our life has caused a significant increase in the use of *computers for learning purposes* in a variety of learning settings in school, university, industry and military [26]. Interestingly, although numerous research and development projects have been administered over the years, not many success stories have been reported. The Institute for Higher Education Policy (2000), cited by Reiser in [27], clearly points out one important aspect: "*As the demand for distance learning programs has grown, so has the recognition that in order to be effective, such programs cannot simply be on-line replicas of the instruction delivered in classrooms; instead, such programs must be carefully designed in light of the instructional features that can, and cannot, be incorporated into Internet-based courses*."

It is our belief that in order for an enhanced learning-teaching process to be successful, learners and teachers must take into account the individual's way of receiving and processing the information described by learning characteristics, the learners' objectives, the didactic objectives, strategies and approaches as well as success criteria and assessment methods [12]. Furthermore, different usage pattern and preferences of user groups of modern information and communication technologies (ICT) and services influence the demand and expectation of learning environments. *Digital natives*, a generation who grow up with modern ICT uses this technology everywhere, and at anytime for any purpose; they are experienced multi-taskers using several media simultaneously for communication, learning and entertainment. But also the *digital immigrants*, who have learned to adopt modern ICT, and to some extent have routinely set preferences and services in their daily life [28, 31]. In order to prevent uninteresting and boring learning activities in an artificial or traditional learning environment, we strongly advocate the integration of state-of-the-art technologies to support a variety of modern learning activities. This should give students and teachers freedom to choose the tools and services they are familiar with which are not necessarily restricted to the learning process [14]. Moreover, learning must be contextualised and linked to other processes of our daily life [11]. Unlike most pre-existing computer-based learning environments which are mostly predictable with well-defined organizational and system borders, we propose the integration of diverse technologies and distributed services which increase the complexity considerably.

Following our overall goal towards a flexible learning environment enabling a variety of learning activities and using various end devices and services according to users' preferences and needs, the aim of this paper is to assess approaches and technologies of how services can be composed to fulfil specific learning goals; with the focus mainly on technological aspects. To this end, the remainder of this paper is organised as follows: Section II illustrates the high complexity of modern learning settings and infer high-level requirement for a modern learning environment. Based on these findings, a conceptual approach for a flexible learning environment is outlined in Section III and Section IV discusses Service Orchestration and Choreography as concepts to support such flexible environment. Section V covers in particular our lightweight approach for Service Composition, and Section VI summarizes our findings.

II. The Learning Ecosystem and its High-Level Requirements for Flexible Learning

The aim of this section is to outline the complex situation for learning in environments of the 21st century by applying the ecosystem notion and identify high level requirements for our proposed flexible learning environment. The section is based on Chang & Gütl [5] work on learning ecosystem.

Given the need to consider a range of factors to facilitate learning in complex and intricate situations, an ecological and holistic approach is considered to be appropriate. The term 'ecosystem' conceived in 1935 by A.G. Tansley, an ecologist, defined it as "*a biotic community or assemblage and its associated physical environment in a specific place*" [30]. The definition implicitly highlights the interactions wit h the living (biotic) and non-living (abiotic) components, and intrinsically within highly complex elements. A broader definition of ecosystem in [8] as well as Pickett and Cadenasso insights on the applicability of ecosystem to "*any system of biotic and abiotic components interacting in a particular spatial area*" [24] led Chang and Gütl in [5] to apply the idea of the ecosystem to the learning domain. The framework developed by Chang and Gütl was termed a Learning Ecosystem (LES).

The LES (see Fig. 1) highlighted the separation of living or biotic (learners, teachers) from non-living or abiotic (utilities, systems) components. This separation is to accentuate that learning is a simple process between the living and non-living components but complexity arose due to individual learning styles, preferences, and strategies and the existence of modern utilities, technologies, and systems compounded by internal and external environmental factors. Due to this, there is a greater need to offer flexibility to survive in a complex learning environment.

The LES framework emphasizes *"a holistic approach whereby the notion of thinking highlights the significance of each component, their behaviour, relationship and interactions, as well as the environmental borders in order to examine an existing system or form an effective and successful system"* [5].

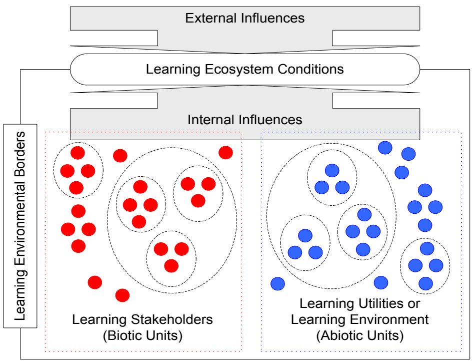

Fig.1 ***Learning Ecosystem Model taken from (Chang & Gütl, 2007)***

LES highlights three main components of the ecosystem that "*consists of the stakeholders incorporating the whole chain of the collaborative learning processes, the learning utilities and the learning environment, within specific boundaries, called environmental borders*". The authors emphasize that LES can be applied to any learning situation, such as in classroom teaching or e-learning. This is to state that in any learning situation, the biotic and abiotic components, their relationships and interactions together with the ecosystem's conditions have to be considered. These components of learning stakeholders (biotic units), learning utilities (abiotic units), learning environment and the other conditions are also dynamic. This view gives a better picture about a learning situation, and allows educators and practitioners to have a holistic approach for the development of more flexible and effective learning.

The learning communities constitute individuals who can *"interact and collaborate synchronously and asynchronously with one another"* [7]. Individuals and communities have learning attributes that can have a crucial impact on their learning experiences. The learner's learning styles, strategies, preferences, demographics, experience, skills, IT competence, objectives, motivations and needs are elements demanding consideration. Other stakeholders are those who provide the learning pedagogy, learning content, or learning support through the provision of expertise and services. Content providers, knowledge experts and IT support groups who facilitate collaborative learning activities are important non-learning stakeholders whose input to the ecosystem is considered vital. In the learning context, it is expected that staff members will assume either the role of 'learner' or 'teacher' at different points depending on the particular activity being. Hence, they engage in collaborative learning, where 'learners' and 'teachers' exchange ideas and messages in an iterative fashion to increase the overall knowledge.

Providing greater flexibility in and around the learning context is increasing in significance; hence it is necessary to consider the need for and suitability of learning utilities or *'technology networks'* which Por in [5] defines as *"all the technological means that support communication and collaboration for knowledge creation, sharing and utilization"*.

The relationships and interactions between the living and non-living components can be significantly affected by the ecosystem conditions, hence external and internal factor must be well understood and managed so they do not hinder learning processes. External factors include economic or industry dynamics, domain knowledge, competition, government policies and technology advancements. Cultural and sociological influences are examples of internal factors. The ways the stakeholders behave or collaborate could also affect the nature of the internal ecosystem environment. To create a successful system, each individual and group must adapt to the environmental conditions to find their niches [5].

The term 'learning' referred to in the three main components is indicative that knowledge is created through acquiring and integrating of different types of data and information. This evolution of learning which generate new knowledge will be stored and transmitted via learning utilities to other participants in the learning process. An understanding of all the components will reveal insights on the interactions that occur within the environmental borders. This concept supports the view of capturing and providing greater flexibility in the learning ecosystem [13].

Findings from the above outlined learning ecosystem can be summarized as follows: demands for learning in the 21st century are diverse and a sound learning environment is complex in terms of pedagogical, cognitive, social, organizational and technological aspects as well as influenced by ever-changing environmental situations. Thus, a learning environment must be flexible to support a variety of teaching strategies; it must cope with the individual learning goals, and take into account teachers' and learners' preferences and competencies. It must also provide an appropriate selection procedure of learning content and background material but also services to support various devices. Consequently, the setup must be adaptable for different learning activities, learning settings and learning groups. Most importantly, this learning environment must be sustainable to capture all facets of modern learning strategies, new learning technologies, and learners' characteristics.

III. A Conceptual Approach for a Flexible Learning Environment

In order to transform the visionary ideas and high-level requirements from the previous section into a concrete ICT-based solution, a conceptual architecture (see also Fig. 2) of the proposed flexible learning environment is introduced and discussed in this section.

Unlike today's common e-learning system, an approach that gives the highest flexibility in an ICT-based learning environment must be considered. We propose an ad-hoc learning environment which is influenced by numerous learning characteristics such as the pedagogic approach, the learning goal, the context, preferences, knowledge state in the subject domain, meta-cognitive skills and tool experiences. In order to be successful for learning and training purposes in the 21st century, the flexible learning environment must consider learning task dependent on a variety of knowledge sources, tools and application available on the Web with public and private accessibility. We want to define such accessible resources as *services*. According to the variety of characteristics of such services we further classify them as basic or auxiliary services. *Basic services* provide specific learner background knowledge and other activities supporting different learning settings such as authoring, communication and collaboration. *Auxiliary services* are defined as services which support basic services useful for a business process or learning activity. This includes support for retrieval and access, data processing, information extraction and fusion but also information presentation. Services are based on but also strongly influenced by environmental issues as well as trust and security. In order to provide a support and a tailored learning environment for a specific learning task, appropriate services must be carefully selected and composed in an intelligent way. This is discussed in the following section.

Combining services in a flexible way has become increasingly popular in recent years as the concept of the *Service-Oriented Architecture* (SOA). In short, in the SOA paradigm, a distributed system can be built by a composition of interacting services. The approach found in the beginning with its main application on business intelligence is also applicable for building a flexible learning environment. In order to be useful in a SOA, each of the services must provide a certain basic functionality which is accessible through a well defined interface. From a technical viewpoint the connections between services is seen as message exchange between services. [9, 10, 22, 33]

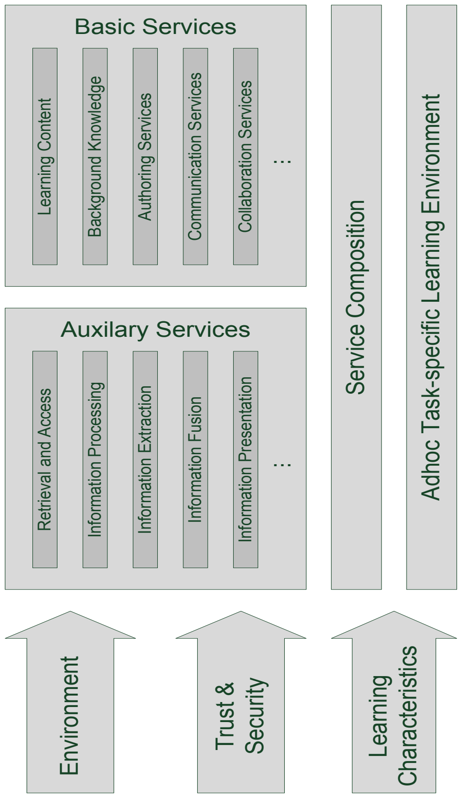

Fig.2 *Conceptual Architecture of a Flexible Learning Environment*

IV. Service Orchestration and Choreography - A Technological Viewpoint

There is obviously a need to coordinate the exchange of messages between the participating services to reach an overall goal and this can also be defined as a business process. Service orchestration and choreography deal with this issue. In general both concepts describe the exchange of messages between composed web services to fulfil a business process or in our context a learning process activity. *Service orchestration,* akin to a conductor's viewpoint, describes the message flow between all participating web services as well as the execution order. *Service choreography* is linked to a collaborative view where each involved party describes its own part in the interaction of services [18, 23]. Consequently, service composition enables flexible business services to be built. The challenge is to decompose and break down the parts comprised of the overall goal in order to find services and interfaces required for the composition to meet each of the sub goals.

A system or framework claiming to be able to dynamically orchestrate web services has to take into account aspects like the *specification and annotation* of the participating services, the *dynamic configuration* of the service orchestration, and the dynamic *process adaptation* [29].

According to Verma and Sheth in [32] the *specification and annotation* of service interfaces has to be done in accordance with four categories of semantics: a) functional semantics: formal description of the functionality which is crucial for reuse and discovery of services; b) data semantics: the exchanged data in a formal description enabling the interoperability of services; c) non-functional semantics: defining service level agreement and quality of service attributes to differentiate between services; d) execution semantics: describing the runtime and exceptional behavior.

The aspect of *dynamic configuration* describes the process of organizing the procedure of orchestration into three chronological steps: a) publication and discovery of services meeting the functional requirements; b) configuration and constraint analysis to deal with the fulfilment of non-functional requirements; c) data mediation to ensure data schema interoperability.

Process adaptation handles the fact of how a system adopts to runtime events and exceptions. The system has to take into account all possible events which could cause the need for a process adaptation. Adaptation strategies consider facts such as event probabilities, the cost impacts and penalties, constraints between services to ensure that the overall process optimality requirements are met.

One concrete concept which supports the idea of composing units of functionality to form business services encompassing the organizational borders is the *Web Service technology*. The starting point of distributed programming was the usage of shared libraries followed by the object-oriented programming paradigm where the CORBA approach emerged. The gap to the web as principle communication carrier was closed by the concept of web services which are understood as "*[…] well defined, reusable, software components that perform specific, encapsulated tasks via standardized Web-oriented mechanisms. They can be discovered, invoked, and the composition of several services can be choreographed, using well defined workflow modeling frameworks*" [4].

The use of XML standards as common data syntax for the definition of web service standards led to a wide adoption of business intelligence. As the main communication protocol the *Simple Object Access Protocol (SOAP)* and XML format are used to exchange structured and typed information between two parties. Several standards are used to orchestrate SOAP style web services to business processes. The foundation of a protocol stack is the transport layer – HTTP, SMTP or others can also be used. The description of web services is mostly realised with the *Web Service Description Language* (WSDL). In addition several different standards are addressing further aspects of the protocol stack such as Service Repositories, Coordination, Semantics and Composition [7].

For web services orchestration, Daniel and Pernici in [7] classified the existing approaches in two categories: model-based composition and ontology-driven composition. *Model-based service composition* approaches define the overall process flow. The process definition and all participating services are input for an execution engine which actively manages the orchestration of the services. The methods used for the orchestration are: a) State Charts and Petri Nets, b) Pi-Calculus and c) rule-based orchestration [1]. Representatives include the Business Process Execution Language (BPEL, BPEL4WS or WS-BPEL) and the Business Process Management Language (BPML). The *Ontology-driven composition approaches* includes the Ontology Web Language for Web Services (OWL-S) and the Web Service Modeling Ontology (WSMO). Semantic web technologies are the foundation for these approaches. They try to facilitate frameworks and service ontologies to automatically orchestrate services according to defined goals and pre- and post-conditions over service inputs and outputs [7].

Unlike the traditional web service technology, a light weight approach is available by *Web2.0 services*. In general, Web2.0 is a collection of web applications that reuse user-generated content, initiate social interaction, enable collaborative functionalities and provide user interactions based on AJAX. Wikipedia, Flickr, Facebook or Google Maps are representatives of Web2.0 applications [16]. An important characteristic of these applications is that they provide a range of their functionality and data via web interfaces for third parties. This leads to the idea of combining Web2.0 services by so called mashups. "*Mashup is a website or Web application that seamlessly combines content from more than one source into an integrated experience.*" [17] The matter of mashups is on information sharing and the aggregation of existing information realized through the implementation of Web APIs and RESTful service interfaces. This supports content publishing for a new generation of web applications. Benslimane, Dustdar and Sheth in [2] outlined key issues of mashups: a) *sharing* by means of registration and publication refers to the same issues noted under specification and annotation of web services; the aspect of b) *finding* deals with search and discovery of services; c) *reusing* as invocation of services and finally d) *integrating* by the means of mediation between services and their composition.

Orchestration and choreography with the "old" web services is in contrast to the "light-weight" web services, where the 'light-weight' is much more matured. At the time of writing this paper, no agreed standard for "light-weight" services exist. However the approach to use HTML mircoformats for describing RESTful services and APIs (hRESTs in [19]) is one of the interesting developments. Most of the web API's are described in plain text within a HTML document. The use of the *hRESTs mircoformats* adds machine-readable descriptions for services, covering operations, inputs and outputs. The concept of SA-REST [29] expands the aforementioned concept with two aspects. Firstly a description of the data format to enable data mediation between services and secondly, a declaration in which the programming language a client library for the service is available. Client libraries simplify the process of consuming services.

In order to realize Semantic Web Services (SWS) with RESTful services the use of a light-weight version of the Web Service Modeling Ontology, namely *MicroWSMO,* is proposed as working draft [20]. MicroWSMO together with the concepts before – hRESTs and SA-REST – enable a semantic model of the combination of 'light-weight' web services. This should increase the automation of service discovery, composition and use. Another approach for describing light weight web services is the *Web Application Description Language (WADL)* which is designed to provide a machine process-able description of HTTP-based Web applications. The description includes (a) the available resources (analogous a site map), (b) relationships between resources (referential and causal links), (c) apply-able methods to each resource (HTTP method), and (d) the used data schemas as the expected inputs and outputs [15]. WADL is therefore a method to describe services which is only the basis for an automated orchestration. On-going higher level concepts like the aforementioned MicroWSMO are not proposed in relation to WADL.

Summing up our review on approaches of composing Web services (SOAP style and light weight style) some issues has been identified. A fundamental common need is to specify the public interfaces. The technical standards in describing a web service vary from pure syntactical up to a complete semantically enriched definition of service interfaces. Another problem lies in the process of data exchange where data schemas of individual Web services have to be compatible or data mediation must be considered. Once the services interfaces and data schemas are specified they are prepared to be combined. Issues like the registration and the locating of suitable services but also security and trust must be taken into account. Higher level facts include (a) the degree of automation in the orchestration process also play a role, (b) considerations of non-functional parameters such as service level agreements and quality of service attributes, and (c) the adaptation process to runtime events and exceptions is an interdependent issue found while orchestrating web service regardless of the type of service.

SOAP style web services have the advantage of matured standards, frameworks and tools. They are integral part of modern business intelligence systems. Problems occur through the quantity of different standards (missing common understanding, critics on standardisation process) and their complexity (tools of different vendors are incompatible). Much research covers aspects of automated service orchestration; and the generated outcomes proved to be promising.

Light-weight web services benefit from their simplicity by means of the uniform interface based on HTTP operations. The use of well known and widely used standards with low complexity is also promising. This is proven by the enormous growth of mashups on the Internet. But orchestrating RESTful services is still a manual task. Active research has started to deliver results. The lack of implementation and the use of these results so far is one of the obstacles.

V. Towards a Lightweight Approach for Service Composition

Referring to the review outlined in the previous section it is a challenge to decide on which technology to follow. Due to the facts that the Web 2.0 concepts has become increasingly popular and also results in a great availability of existing services, we have concentrated our research on light-weight web services composition for learning purposes. Since this process is currently a manual task [34], we want to outline our path towards automated orchestration in the remainder of this section.

The starting point is the creation of manual mashup. RESTful web services do not have a registry of services and an entity who acts as broker for services. Therefore, the first step is to find appropriate services. Creators of mashups use web search engines and listings like ProgrammableWeb (http://www.programmableweb.com/) to get to adequate services. Once these suitable services are found the need of knowledge about schemas and semantics of data arises. Such information is found in textual descriptions for the services. However, to support automatic processes machine-readable descriptions of services are required. The aforementioned approaches like WADL and hRESTs are promising. The problem is that these standards are not used in practice by publisher of services. Another approach was introduced by Gomadam et al. [10]. They search and rank web APIs according their description in HTML. The method adopts current approaches in the field of document classification and faceted search resulting in a ranking of services according to their utilisation and popularity.

To bring mashup creation to the next level several tools for this purpose were build. Industry giants like Google (Google Mashup Editor: http://editor.googlemashups.com), Yahoo! (Pipes: http://pipes.yahoo.com), IBM (QEDWiki: http://services.alphaworks.ibm.com/qedwiki), Microsoft (Popfly: www.popfly.com) and Intel (Mash Maker: http://mashmaker.intel.com) introduced tool-assisted mashup creation. The popularity of these tools is not consistent with their degree of simplicity to create mashups. End-users without programming skills still have problems to create non-trivial mashups. An overview and discussion of the used concepts can be found in [34].

Current research also addresses the use of domain specific languages to orchestrate web services. This approach facilitates a language to describe web services and APIs as well as their interconnections in order to create a mashup. The approach introduced from Maximilan et al. in [21] also includes a web application enabling users to entirely code and test the mashups in one application. Another interesting approach was published by Curbera et al. in [6] which build as main the component on a "Web-Centric Flow language", a XML-based workflow language following the principles of BPEL utilising a light-weight process model based on a simple graph model.

VI. Conclusions and Further Work

In this paper we have argued that a modern learning environment at the beginning of the 21st century must take into account the individual's way to receive and process information, the learners' objectives, the didactic objectives but also the user's preferences of specific information and communication technologies and services. In order to combine task and context dependent services to a tailored learning environment, service orchestration and choreography are interesting and promising concepts but there remain obstacles at organizational and technological levels. The facts that Web 2.0 concepts has become increasingly popular and keeps the level for active contribution low which also results in a great availability of existing services, we have concentrated our research on light-weight web services composition for learning purposes. Our proposed approach builds on the combination of machine-readable service description, mechanism of tool-assisted mashup creation and standardizes languages for service composition.

Currently, we work on proof of concepts to evaluate different approaches from organizational and technological viewpoints. The findings will be used to build a prototype capable to support a subset of learning activities in academic learning settings.

VII. Acknowledgement

This paper is part of research resulting of visiting academic activities of Gerhard Wurzinger and Christian Gütl in the School of Information Systems. The visits were supported and sponsored by School of Information Systems and Curtin Business School, Curtin University of Technology, and Institute for Information Systems and Computer Media (IICM) at Graz University of Technology.

VIII. References

[1] Alonso, G., Casati, F., Kuno, H., & Machiraju, V.(2004). Web services - Concepts, architectures and applications. Berlin Heidelberg. Springer-Verlag.

[2] Benslimane, D., Dustdar, S., & Sheth, A. (2008). Services Mashups: The New Generation of Web Applications. Internet Computing, IEEE, 12(5), 13-15. doi: 10.1109/MIC.2008.110.

[3] Bransford, J.D., Brown, A.L., & Cocking; R.R. (Eds.) (2000). How People Learn: Brain, Mind, Experience, and School. Expanded Edition. Washington DC: National Academies Press.

[4] Cabral, L., Domingue, J., Motta, E., Payne, T. R. and Hakimpour, F. (2004) Approaches to Semantic Web Services: An Overview and Comparison. In: European Semantic Web Conference.

[5] Chang, V., & Gütl, C. (2007). E-Learning Ecosystem (ELES) – A Holistic Approach for the Development of more Effective Learning Environment for Small-to-Medium Sized Enterprises (SMEs). In Proc. Inaugural IEEE International Digital EcoSystems Technologies Conference (IEEE-DEST 2007), Cairns, Australia, 420-425.

[6] Curbera, F., Duftler, M., Khalaf, R., & Lovell, D. (2008). Bite: Workflow Composition for the Web. In Service-Oriented Computing – ICSOC 2007 (pp. 94-106).

[7] Daniel, F., & Pernici, B. (2006). Insights into Web Service Orchestration and Choreography. International Journal of E-Business Research, 2(1), 58-77.

[8] Encyclopaedia Britannica (2008). Ecosystem. Britannica Online Encyclopedia, last retrieved Jan 26th, 2009 from http://www.britannica.com/EBchecked/topic/178597/ecosystem

[9] Fielding, R. T. (2000). Architectural Styles and the Design of Network-based Software Architectures. Doctoral dissertation, University of California, Irvine.

[10] Gomadam, K., Ranabahu, A., Nagarajan, M., Sheth, A. P. & Verma, K. (2008). A Faceted Classification Based Approach to Search and Rank Web APIs.

[11] Gütl, C. (2007). Moving Towards a Generic, Service-based Architecture for Flexible Teaching and Learning Activities. In C. Pahl (Ed.) Architecture Solutions for E-Learning Systems (peer-reviewed), Idea Group Inc., Hershey, USA.

[12] Gütl, C. (2008). Enhanced Computer-based Support for Personalized Learning Activities. Postdoctoral Lecture Thesis, Graz University of Technology, Austria, 2008.

[13] Gütl, C., & Chang, V. (2008). Ecosystem-based Theoretical Models for Learning in Environments of the 21st Century. iJET, Vol 3, 50-60.

[14] Gütl, C., & Chang, V. (2008b). The use of Web 2.0 Technologies and Services to support E-Learning Ecosystem to develop more effective Learning Environments. In proceedings of ICDEM 2008, Tiruchirappalli, India, pp. 145-148.

[15] Hadley, M. J. (2006). Web Application Description Language (WADL), Retrieved January 25, 2009, from http://wadl.dev.java.net/.

[16] Heath, T., & Motta, E. (2008). Ease of interaction plus ease of integration: Combining Web2.0 and the Semantic Web in a reviewing site. Web Semantics: Science, Services and Agents on the World Wide Web, 6(1), 76-83. doi: 10.1016/j.websem.2007.11.009.

[17] Jackson, C., & Wang, H. J. (2007). Subspace: secure cross-domain communication for web mashups. In Proceedings of the 16th international conference on World Wide Web (pp. 611-620). Banff, Alberta, Canada: ACM. doi: 10.1145/1242572.1242655.

[18] Kavantzas, N., Burdett, D., & Ritzinger G. (2004). Web Services Choreography Description Language Version 1.0. W3C. Retrieved January 25, 2009, from http://www.w3.org/TR/2004/WD-ws-cdl-10-20040427/.

[19] Kopecký, J., Gomadam, K., & Vitvar, T. (2008). kno.e.sis - hRESTS: an HTML Microformat for Describing RESTful Web Services. Retrieved August 25, 2008, from http://knoesis.wright.edu/research/srl/projects/hRESTs/.

[20] Kopecký, J., Vitvar, T. & Fensel, D. (2008). D38v0.1 MicroWSMO. Retrieved January 25, 2009, from http://wsmo.org/TR/d38/v0.1/20080219/.

[21] Maximilien, E., Wilkinson, H., Desai, N., & Tai, S. (2007). A Domain-Specific Language for Web APIs and Services Mashups. In Service-Oriented Computing – ICSOC 2007 (pp. 13-26).

[22] Nickull, D. (2005). Service Oriented Architecture. Whitepaper. Adobe Systems, Inc. 2005, Retrieved February 9, 2007, from http://www.adobe.com/enterprise/pdfs/Services_Oriented_Architecture_from_Adobe.pdf

[23] Peltz, C. (2003). Web Services Orchestration and Choreography. Computer, 36(10), 46-52.

[24] Pickett, STA & Cadenasso, ML (2002) 'The Ecosystem as a Multidimensional Concept: Meaning, Model, and Metaphor', *Institute of Ecosystem Studies*, vol. 5, pp. 1-10.

[25] Por, G (2000). The Ecology of Knowledge: A Field of Theory and Practice, Key to Research & Technology Development. *Consultation Meeting on the Future of Organisations and Knowledge Management of The European Commission's Directorate*, Brussels, May 23-24. Retrieved Jun 7, 2008, from http://www.co-i-l.com/coil/knowledge-garden/kd/eoknowledge.shtml

[26] Reiser, R. A. (2001a). A History of Instructional Design and Technology: Part I: A History of Instructional Media. ETR&D, Vol. 49, No. 1, 2001, pp. 53–64

[27] Reiser, R. A. (2001b). A History of Instructional Design and Technology: Part II: A History of Instructional Design. ETR&D, Vol. 49, No. 2, 2001, pp. 57–67

[28] Rogers, P.C., Liddle, S.W., Chan, P., Doxey, A., and Isom, A. (2007) A Web 2.0 Learning Platform: Harnessing Collective Intelligence, Turkish Online Journal of Distance Education (TOJDE), July 2007, Vol. 8, No. 3.

[29] Sheth, A. P., Gomadam, K., & Ranabahu, A. (2008). Semantics enhanced Services: METEOR-S, SAWSDL and SA-REST. IEEE Data Eng. Bull., 31(3), 8-12.

[30] Tansley, A. G. (1935). The use and abuse of vegetational concepts and terms. Ecology, 16, 284-307.

[31] Thompson, J. (2007). Is Education 1.0 Ready for Web 2.0 Students? Innovate Journal of Online Education, 2007, Vol. 3, No. 4

[32] Verma, K., & Sheth, A. (2007). Semantically Annotating a Web Service. Internet Computing, IEEE, 11(2), 83-85. doi: 10.1109/MIC.2007.48.

[33] Wang, G., & Fung, C.K. (2004). Architecture paradigms and their influences and impacts on component-based software systems. *Proceedings of the 37th Annual Hawaii International Conference on System Sciences.* Retrieved Feb. 9, 2007, from http://csdl.computer.org/comp/proceedings/hicss/2004/2056/09/205690272a.pdf

[34] Yu, J., Benatallah, B., Casati, F., & Daniel, F. (2008). Understanding Mashup Development. Internet Computing, IEEE, 12(5), 44-52. doi: 10.1109/MIC.2008.114.