New LIS Technologies and Services in Biosciences Education

Artemis Chaleplioglou[1,2], Ioannis A. Papadakis[2,†] and Sozon Papavlasopoulos[2]

[1]Library Department, Biomedical Research Foundation of the Academy of Athens, Athens, Greece
[2]Department of Archives, Library Science and Museology, Faculty of Information Science & Informatics, Ionian University, Corfu, Greece

[†]This author passed away on August 30, 2017.

Abstract: The advances in data management technologies lead to the transformation of biosciences into Big Data disciplines. Traditional and digital biomedical libraries utilize modern tools to support both teaching and learning of biosciences in all levels of education, from primary school to doctoral educational environment. Herein, we will describe the Semantic web technologies and services in the setting of biological and educational linked data. In particular, we will discuss the different types of open access web data and the challenges of volume, variability and complexity in their analyses. Currently, the use of distinct ontologies for biosciences and education represents a major problem in biomedical teaching. Their compilation and assembly is a priority for integrated functionality. The accessibility needs and preferences of biomedical students differ between traditional and e-learning contexts, while different existing and experimental virtual learning solutions have been proposed. From the Semantic web point of view the information should be organized and structured to produce curated metadata, linking different data sets into aggregated semantic LIS services. Such systems will facilitate the rapid retrieval and validation of biological data for educational purposes, building e-textbooks from open resources and shortening the information from multiple resources towards knowledge discovery, available for all teachers, students, doctoral fellows and residents. However, the developing Semantic web services need continuously evaluation and monitoring, since drawbacks arise in data retrieval and result errors because of information import from external datasets. To overcome the limitations of intelligent processing, we should focus in the accuracy and expressiveness of an integrated biomedical education ontology.

Received: 2.5.2018 / Accepted: 28.5.2018 ISSN 2241-1925
© ISAST

Keywords: Semantic web, ontologies, linked data, e-learning

1. Introduction

In the last five decades scientific research output is almost duplicated every nine years, with an annual pace of 10% (Bornmann, and Mutz, 2015). If we compare the annual pace of the scientific research output with previous ages in human history, it becomes evident that it has been triplicated since the interwar period, five-fold increased since the 19th century, and ten-fold increased since the 17th century. In biosciences more than a million new scientific articles are added each year in the growing registry of 28,000,000 publication records listed to PubMed database (http://www.nlm.nih.gov). However, there is a paradox since scientific communication and scientific publishing has not change significantly over the past 400 years up to the last three decades when the World Wide Web became publically available. The development of the web change fundamentally the scientific information search and retrieval, while it transforms the traditional librarian profession into the librarian information scientist.

A variety of human health threats are emerging worldwide including old and new, communicable, such as HIV, the world's leading infectious killer, accompanied by malaria and foodborne germs, poor sanitary conditions in developing countries and antibiotic resistance infections, and non-communicable diseases like cardiovascular diseases, cancer, diabetes and chronic respiratory disease, as well as environmental problems, such as global warming, environmental pollution, ozone layer depletion and the reduction of biodiversity (http://www.who.int). In their fight against these problems scientists from different disciplines, medical physicians, epidemiologists, biologists, pharmacologists, environmentalists, chemists, physicists, statisticians, computer and information scientists, have to be properly informed, educated and interconnected into an individualized manner in order to achieve maximal parallel implementation and their data assimilation. Despite the efforts of computer and information scientists towards the quality assurance of biomedical scientific information, the majority of the open accessible scientific data are lacking integration and interoperability, which remain major obstacles for the solution of complex biological questions. Albeit the existence of a strong subject headings tool in biosciences, the Medical Subject Headings (MeSH), that allows the information retrieval from different datasets, this system by itself cannot integrate data of a high degree of specialization originated from different scientific fields (Theodosiou, Vizirianakis, Angelis, Tsaftaris, and Darzentas, 2011). Bridging of all these sources of information, bench to bed side, is a demanding challenge that can only been resolved through the utilization of the most recent library and information science (LIS) technologies and services, the Semantic web tools.

In parallel, learning and teaching changed since the 1970s with the introduction of personalized learning and the application of fundamental psychology principles in teaching (Knowles, 1975). The idea is not a complete departure from traditional education practice, however for decades it remains mostly in theory and only recently the means for its application became available through the rapid evolution of computer science (Christensen, Horn, and Johnson, 2011). As initially proposed by Victor Garcia Hoz (García Hoz, 1975), personalized education has two objectives. Firstly, learning goals should be created with input from the learner, taking into account its own preferences, creativity, freedom, originality, autonomy, socialization, and communication. Secondly, the learning environment and activities should be organized around the learner, and the learner should create and discover knowledge by using a variety of learning resources. These two objectives can resolve the modern challenges of education, in specific, the pressure to expand the curriculum scope and depth (Kaplan, and Chan, 2011), the limited time for training and planning due to new data accumulation (Hassel, Hassel, and Impact, 2012), the need to increase the learner motivation (Christensen et al., 2011), and the adoption of new technologies (Judd, and Kennedy, 2010). The technological enriched education scheme is focused in interoperability and the reuse of resources and data (Dietze, Yu, Giordano, Kaldoudi, Dovrolis, and Taibi, 2012). However in practice there is not a single solution available but rather an ecosystem of different and competitive metadata protocols that occasionally target in information archiving, as in the case of Dublin Core (Boulos, Roudsari, and Carson, 2002), or target towards more specialized educational purposes as in the cases of IEEE Learning Object Metadata (Barker, 2005; Holzinger, Kleinberger, and Muller, 2001), and Advanced Distributed Learning (www.adlnet.org) (Ismail, 2001). In addition, social network metadata are monitoring the ability of learners to absorb information and the degree of success of the different educational approaches (de Santiago, and Raabe, 2010). Computer and information scientific community is actively developing new methods and protocols to retrieve metadata from different research environments and repositories in order to achieve the optimum management, computing and distribution of biomedical information.

2. Education stages and practices in biosciences

The biosciences enter in the curriculum as early as the primary education level either as an independent or as part of a broader science study subject, together with physics and chemistry, in the vast majority of OECD (Organisation for Economic Co-operation and Development) countries. From this point forward, biosciences remain at the heart of the national education programs at the secondary education, middle and high schools, worldwide, with a mean coverage of 11% of all compulsory subjects, compare to the 14% mean coverage of reading, writing and literature, among OECD members (OECD, 2017). The dissemination of standard and up-to-date biological knowledge to all civilians to establish a minimal scientific background for the public, is a strategic choice for most countries in order to support the public healthcare systems, establish healthy lifestyles, fight against pandemics, protect the natural environment, support viable agriculture, attain social equity in health, stand against racism, emerge bioethics and inform against biotechnology abuse. Last but not least, the majority of states recognize biosciences as one of the pillars of future economic growth through research and biomedical development. In the tertiary education the study programs are highly specialized to cover the specific needs for the academic credentials of medical doctors, dentists, nurses, biologists, pharmacologists, veterinarians and bioinformaticians, while other scientific domains such as mathematics, physics, chemistry, teaching, engineering and information sciences also include bioscience lectures in their curricula. Graduate schools provide the advanced academic degrees in biosciences of the highest level of specialization and depth (Zhaozhao, 2007). In addition, lifelong learning in biosciences is an important concept (Jarvis, 2004), not only for the experts (Miflin, Campbell, and Price, 2000), not only to develop the public understanding, critical thinking and responsibility of biomedical issues (Ranson, 1995; Simonds, 1974), but also to understand the pathology and treatment of human diseases for patients, families and patients' friends (Martin, Hunt, Conrad, and Hughes-Stone, 1990; Moos, and Schaefer, 1984). All these different audiences, the young pupils, the school students, their teachers, the undergraduates, the postgraduates, the residents, the nurses, the dentists, the biologists, the pharmacists, the scientists from different scientific backgrounds, the PhD students, the post-docs, the researchers, the professors, the general public, the patients and their families are in need of immediate, accurate and properly curated biomedical information from the library information scientist employed in the school, public, academic, hospital or research institute library.

3. Semantic web in biosciences education

Over the past twenty years, through the introduction of web technologies for data and knowledge sharing, e-learning has become an equal member of the mainstream in medical education. Many web applications represented as Electronic-Learning Management Systems (EMLS), such as Moodle, are used to remote the educational courses. The educational resources are available for instructors and learners users which can be accessed through the web anytime and anywhere (Peart, Johnstone, Brown, and Bangani, 2014). In addition, the development of web 2.0, the World Wide Web version of internet experience that encourages individual users to upload their own contributions in blogs, wikis, and web applications, facilitated publication, exponentially enriched the content of the web with scientific data, including biosciences, in different digital formats, provided access to valuable education material and improved collaboration, interaction and exchange of knowledge and ideas between professionals, instructors and learners, but in turn raised the questions of information creditability and authenticity (Crook, 2008; Hew, and Cheung, 2013; Ishtaiwa, 2012; Sfetcu, 2017). Thus, in web 2.0, the learners approach learning as active players rather than passive receivers of information from their instructors, but the lack of professional feedback expose the education process to misinformation, because the learners may not be experience enough to critical perceive the available information. On top the information overload could be destructive rather than constructive in knowledge building (Baroncelli, Farneti, Horga, and Vanhoonacker, 2014). The semantic web and linked data technologies represent the permanent solution to transform all, the web of data, the educational systems, the curricula, the digital textbooks and pedagogical practices in all education levels (Carmichael, and Jordan, 2012).

The general scope of biosciences teaching is the basic or advance understanding, depending on the education level, of biological and/or clinical, entities and phenomena, methods and disorders, in order to interpret research data and efficiently communicate with bioscience experts (Simonds, 1974). The standard players to this end involve: the open data resources online, available in different formats, most commonly unstructured and rarely semi-structured; the national or local administrative policies, procedures and institutions, which provide the general material and spaces, setting the general rules and instructional technologies; the instructors, which design the courses and teaching through lectures, demonstrations and experiments, introduce the scientific method and communication, provide course documents and student assignments whilst may involve students in team tasks; the learners, which are implicating in study and practice, in heuristic research, project writing, and critical discussion, while outside of their typical study or working environment, they may participate into scientific events such as seminars, symposia and workshops; and last but not least, the LIS technology managers that actively support the teaching and learning process through facilitating knowledge research and retrieval and assisting the scientific communication (Kaldoudi, Papaioakeim, Bamidis, and Vargemezis, 2008; Kolb, and Kolb, 2005; Spelt, Biemans, Tobi, Luning, and Mulder, 2009; Ten Cate, and Durning, 2007).

The application of the semantic LIS technologies in bioscience education shares the same principles with the Semantic web, interoperability, extensibility, data reuse and automatic reasoning. These principles facilitate the automatic data processing, the auto-organization of metadata and the discovery of new, currently cryptic, knowledge through data mining from existing resources by applied Description Logics (DLs) in structured metadata (Alesso, and Smith, 2009).

The Semantic web is not an independent entity from the web but rather an additional level of information of the existing data that transforms them from human to machine readable forms through intelligent information services, personalized web sites and semantically empowered search engines (Poulos, Bokos, and Vaioulis, 2008). The transformation of the data is based on the use of ontologies, structured controlled vocabularies that describe the concepts and relationships to describe and represent specific areas of knowledge (McGuinness, 2002). The excellent and in depth knowledge of a given scientific knowledge field is a prerequisite for its accurate representation, modeling, systemic organization of information and data processing. In biosciences in particular, the high degree of specialization, the fast pace of novel findings generation, interdisciplinary evidence, and the complicated intrinsic nature of interaction networks of entities and disorders, together with the continuously introduction of new terms, add dramatically in difficulty of ontology building even for the experts professionals of the field (Chaleplioglou, 2016). Technically speaking, ontologies and linked data for a particular scientific domain can be built from scratch or upon the basis of existing ontologies through their merging and alignment (de Coronado, Tuttle, and Solbrig, 2007; Fernandez, Marsa-Maestre, Velasco, and Alarcos, 2013; Vizenor, Bodenreider, Peters, and McCray, 2006).

In the Semantic web the data and metadata are expressed through a set of statements. The ultimate goal is the conversion of the current web, which is full of unstructured or semi-structures documents into a web of data. The Unicode standard serves to represent and manipulate text in many languages. The authority of data is certified with the use Uniform Resource Identifiers (URIs), the unequivocal recognition of these URIs that express all entities and relationships possible and its generalization in resources the Internationalized Resource Identifier (IRI) (Papadakis, Kyprianos, and Stefanidakis, 2015). The XML markup language enables the creation of documents composed of structured data (Bray, Paoli, Sperberg-McQueen, Maler, and Yergeau, 1997), while XML Namespaces provides a way to use markups from more sources (Bray, Hollander, and Layman, 1999). Semantic Web is about connecting data together, and so it is needed to refer more sources in one document. The organization of the Semantic web is based upon Sir Tim Berners-Lee, the web inventor, proposal as a stack, a layer cake of technologies that transform the raw data into gradually computer readable and interoperable metadata (Berners-Lee, 2010). Each Semantic web technology layer exploits the capabilities of the layer below.

The unstructured or semi-structured web data are stored into multiple different formats in data warehouses (Martinez, Berlanga, Aramburu, and Pedersen, 2008). The first step to unlock and organize them is through the use of spreadsheets in the standard Microsoft XLS format or as comma-separated values files (CSV) that save table data as a text. The second step and the major transformation of these metadata occurs with the utilization of the Resource Description Framework (RDF), the W3C standard, and the formation of simple statements in the form of Subject-Predicate-Object, the RDF triples, an ontology that enables the representation of information about resources in the form of graph where each item is recognized by a unique URI (Katz, and Chamberlin, 2004). Subsequently the use of RDF Schema (RDFS), the basic vocabulary for RDF, allow the creation of hierarchies of classes and properties. Through this transformation the upgrade of data quality is achieved, since the metadata are now equally readable and processable by the human user and the machine (Consortium, 2014). The family of Web Ontology Language (OWL) extends RDF and involves formal semantics by allowing classes, class axioms, relationships between classes, relationships between individuals and different types of properties (Ramzan, Wang, and Buckingham, 2014). However, the parallel existence of many rules languages suggest the development of a norm to exchange rules between them, the Rule Interchange Format (RIF) (Kifer, 2008). In this setting of gradually added information about what the data stands for, the RDF query language, the Simple Protocol and RDF Query Language (SPARQL) provides the mean to search, retrieve and manage the RDF triplestores, databases for the storage and retrieval of triples (McCarthy, Vandervalk, and Wilkinson, 2012). The purpose-built datasets for a particular scientific or knowledge domain become gradually interconnected through the triples and form the linked data, a web environment that allows interoperability, data reuse and data mining in a non-predesigned manner (Bizer, Heath, and Berners-Lee, 2009).

The linked data semantic technologies are applicable to libraries through the utilization of their standard cataloging systems. Libraries provide access to collections via the employment of Online Public Access Catalogs (OPACs). The OPAC is a fundamental component of an Integrated Library System (ILS) since it facilitates access for the average user to information (both bibliographic and authority data) stored in MAchine-Readable Cataloging (MARC) format. The main purpose of an OPAC is the locating of books on the shelves and the classification of books by subject. Thus, over decades LIS professionals have collected curated authoritative data that could be transformed into linked data through the Semantic web technologies by interpreting MARC fields into URIs (Papadakis et al., 2015).

On the other hand, the Semantic web technologies are yet lacking applicability, since it suffers in two critical components, the establishment of the web of trust (Halpin, 2017; Iancu, and Sandu, 2016) and the development of a standard and friendly user interface (Hachey, and Gasevic, 2011).

4. Conclusions

The Semantic Web technologies provide an education environment whereas teachers, learners and LIS professionals could engage with a wide range of digital resources and data, explore patterns and formulate scientific questions and hypotheses, and address pedagogical imperatives. In biosciences education in particular, the curriculum, resources, data overload, and intrinsic complexity will be significantly improved through the utilization of Semantic web approaches that make share of information and reuse easily, flexibly, and personalized, whilst facilitating scientific communications. Currently, the Semantic web is still developing and evolving with the building of new and update of existing ontologies, thus its application remaining mostly at the hands of researchers and expert information scientists.

References

Alesso, H. P., and Smith, C. F. (2009). *Thinking on the Web : Berners-Lee, Gödel, and Turing*. John Wiley, Hoboken, N.J.

Barker, P. (2005). What is ieee learning object metadata/ims learning resource metadata. *CETIS Standards Briefing Series, JISC (Joint Information Systems Committee of the Universities' Funding Councils)*

Baroncelli, S., Farneti, R., Horga, I., and Vanhoonacker, S. (2014). Teaching and Learning the European Union. *Innovation and change in professional education* 9,

Berners-Lee, T. (2010). Live the Web. *Sci Am* 303, 80-5.

Bizer, C., Heath, T., and Berners-Lee, T. (2009). Linked data-the story so far. *Semantic services, interoperability and web applications: emerging concepts* 205-227.

Bornmann, L., and Mutz, R. (2015). Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. *Journal of the Association for Information Science and Technology* 66, 2215-2222.

Boulos, M. N., Roudsari, A. V., and Carson, E. R. (2002). Towards a semantic medical Web: HealthCyberMap's tool for building an RDF metadata base of health information resources based on the Qualified Dublin Core Metadata Set. *Med Sci Monit* 8, MT124-36.

Bray, T., Paoli, J., Sperberg-McQueen, C. M., Maler, E., and Yergeau, F. (1997). Extensible markup language (XML). *World Wide Web Journal* 2, 27-66.

Bray, T., Hollander, D., and Layman, A. (1999). Namespaces in XML. *World Wide Web Consortium Recommendation REC-xml-names-19990114. http://www. w3. org/TR/1999/REC-xml-names-19990114*

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

Chaleplioglou, A. (2016). Accelerating Biomedical Research through Semantic Web Services. In *Mobile Computing and Wireless Networks: Concepts, Methodologies, Tools, and Applications*, pp. 2199-2214. IGI Global.

Christensen, C. M., Horn, M. B., and Johnson, C. W. (2011). *Disrupting class : how disruptive innovation will change the way the world learns* (Updated and expanded new ed.). McGraw-Hill, New York.

Consortium, W. W. W. (2014). RDF 1.1 concepts and abstract syntax.

Crook, C. (2008). Web 2.0 technologies for learning: The current landscape–opportunities, challenges and tensions.

de Coronado, S., Tuttle, M. S., and Solbrig, H. R. (2007). Using the UMLS Semantic Network to validate NCI Thesaurus structure and analyze its alignment with the OBO relations ontology. *AMIA Annu Symp Proc* 165-70.

de Santiago, R., and Raabe, A. L. A. (2010). Architecture for Learning Objects Sharing among Learning Institutions-LOP2P. *IEEE Transactions on Learning Technologies* April-June, 91-95.

Dietze, S., Yu, H. Q., Giordano, D., Kaldoudi, E., Dovrolis, N., and Taibi, D. (Year). "Linked Education: interlinking educational Resources and the Web of Data." Paper presented at the Proceedings of the 27th annual ACM symposium on applied computing, 2012.

Fernandez, S., Marsa-Maestre, I., Velasco, J. R., and Alarcos, B. (2013). Ontology alignment architecture for semantic sensor Web integration. *Sensors (Basel)* 13, 12581-604.

García Hoz, V. c. (1975). *Educación personalizada* (3. ed.). Miñón, Valladolid.

Hachey, G., and Gasevic, D. (2011). Semantic web user interfaces: A systematic mapping study. *Athabasca University*

Halpin, H. (Year). "Semantic Insecurity: Security and the Semantic Web." Paper presented at the Society, Privacy and the Semantic Web-Policy and Technology (PrivOn 2017), 2017.

Hassel, B. B. C., Hassel, E. A., and Impact, P. (2012). Teachers in the age of digital instruction. *Education reform for the digital era* 11-33.

Hew, K. F., and Cheung, W. S. (2013). Use of Web 2.0 technologies in K-12 and higher education: The search for evidence-based practice. *Educational Research Review* 9, 47-64.

Holzinger, A., Kleinberger, T., and Muller, P. (2001). Multimedia Learning Systems Based on IEEE Learning Object Metadata (LOM).

Iancu, B., and Sandu, C. (Year). "A Cryptographic Approach for Implementing Semantic Web's Trust Layer." Paper presented at the International Conference for Information Technology and Communications, 2016.

Ishtaiwa, F. (Year). "The use of web 2.0 applications in teacher education: Blogs and wikis as learning tools." Paper presented at the Society for Information Technology & Teacher Education International Conference, 2012.

Ismail, J. (2001). The design of an e-learning system: Beyond the hype. *The internet and higher education* 4, 329-336.

Jarvis, P. (2004). *Adult education and lifelong learning: Theory and practice*. Routledge.

Judd, T., and Kennedy, G. (2010). A five-year study of on-campus Internet use by undergraduate biomedical students. *Computers & Education* 55, 1564-1571.

Kaldoudi, E., Papaioakeim, M., Bamidis, P. M., and Vargemezis, V. (Year). "Towards expert content sharing in medical education." Paper presented at the Proceedings of INTED2008: International Technology, Education and Development Conference, 2008.

Kaplan, C., and Chan, R. (2011). *Time well spent: Eight powerful practices of successful, time-expanded schools*. Boston, MA: National Center on Time and Learning.

Katz, H., and Chamberlin, D. D. (2004). *XQuery from the experts : a guide to the W3C XML query language*. Addison-Wesley, Boston.

Kifer, M. (Year). "Rule Interchange Format: The Framework." Berlin, Heidelberg, 2008.

Knowles, M. S. (1975). *Self-directed learning : a guide for learners and teachers*. Association Press, New York.

Kolb, A. Y., and Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of management learning & education* 4, 193-212.

Martin, D. P., Hunt, J. R., Conrad, D. A., and Hughes-Stone, M. (1990). The Planetree model hospital project: An example of the patient as partner. *Hospital & health services administration* 35, 591-602.

Martinez, J. M. P., Berlanga, R., Aramburu, M. J., and Pedersen, T. B. (2008). Integrating data warehouses with web data: A survey. *IEEE Transactions on Knowledge and Data Engineering* 20, 940-955.

McCarthy, L., Vandervalk, B., and Wilkinson, M. (2012). SPARQL assist language-neutral query composer. *BMC Bioinformatics* 13 Suppl 1, S2.

McGuinness, D. L. (2002). Ontologies come of age. *Spinning the semantic web: bringing the World Wide Web to its full potential* 171-194.

Miflin, B. M., Campbell, C., and Price, D. (2000). A conceptual framework to guide the development of self-directed, lifelong learning in problem-based medical curricula. *MEDICAL EDUCATION-OXFORD-* 34, 299-306.

Moos, R. H., and Schaefer, J. A. (1984). The crisis of physical illness. In *Coping with physical illness*, pp. 3-25. Springer.

OECD. (2017). *Education at a Glance 2017*.

Papadakis, I., Kyprianos, K., and Stefanidakis, M. (2015). Linked data URIs and libraries: the story so far. *D-Lib Magazine* 21,

Peart, D., Johnstone, S., Brown, J., and Bangani, P. (2014). Supporting teaching and learning in biosciences with mobile technology. *The Journal of Research in Higher and Further Education 2014* 5.

Poulos, M., Bokos, G., and Vaioulis, F. (2008). Towards the semantic extraction of digital signatures for librarian image-identification purposes. *Journal of the Association for Information Science and Technology* 59, 708-718.

Ramzan, A., Wang, H., and Buckingham, C. (2014). Representing Human Expertise by the OWL Web Ontology Language to Support Knowledge Engineering in Decision Support Systems. *Stud Health Technol Inform* 207, 290-9.

Ranson, S. (1995). Towards the learning society.

Sfetcu, N. (2017). *Web 2.0 / Social Media / Social Networks: Black & White Edition*. CreateSpace Independent Publishing Platform.

Simonds, S. K. (1974). Health education as social policy. *Health Education Monographs* 2, 1-10.

Spelt, E. J., Biemans, H. J., Tobi, H., Luning, P. A., and Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review* 21, 365.

Ten Cate, O., and Durning, S. (2007). Dimensions and psychology of peer teaching in medical education. *Medical teacher* 29, 546-552.

Theodosiou, T., Vizirianakis, I. S., Angelis, L., Tsaftaris, A., and Darzentas, N. (2011). MeSHy: Mining unanticipated PubMed information using frequencies of occurrences and concurrences of MeSH terms. *J Biomed Inform* 44, 919-26.

Vizenor, L., Bodenreider, O., Peters, L., and McCray, A. T. (2006). Enhancing biomedical ontologies through alignment of semantic relationships: exploratory approaches. *AMIA Annu Symp Proc* 804-8.

Zhaozhao, G. J. Z. (2007). A Summary of the Research of Improving the EducationalQuality of Postgraduates [J]. *Science Mosaic* 4, 073.