PRODUCTIZATION AND COMMERCIALIZATION OF IT-ENABLED HIGHER EDUCATION IN COMPUTER SCIENCE: A SYSTEMATIC LITERATURE REVIEW

Irja Kankaanpää[1] and Hannakaisa Isomäki[2]
[1]Postdoctoral researcher, Department of Computer Science and Information Systems
[2]Research Director, Adjunct Professor, Department of Mathematical Information Technology
P.O. Box 35, FI-40014 University of Jyväskylä, Finland

ABSTRACT

This paper reviews research literature on the production and commercialization of IT-enabled higher education in computer science. Systematic literature review (SLR) was carried out in order to find out to what extent this area has been studied, more specifically how much it has been studied and to what detail. The results of this paper make a contribution to research by indicating a gap in the recent literature concerning the production and commercialization of higher education on practical level.

KEYWORDS

Commercialization, higher education, productization, systematic literature review, IT-enabled learning

1. INTRODUCTION

The productisation of information technology (IT) enabled higher education is one way to improve the competitiveness of educational organisations, and also the key factor to the global market. Thus, IT-enabled higher education entails many opportunities as it requires careful planning, resources and adoption of the new teaching culture. In order to ensure both the quality and effectiveness of IT-enabled higher education, educational institutions need to consider productization of their higher education.

Productization refers to the modification of a material good or an immaterial service, or their combination, into a commercial product that can be replicated in large quantities using a certain method. In an educational context, the target of productization may be for example course or program, training or consulting service, learning materials and content, learning technologies, or related research results and services. Successful productization necesitates that the company identifies its core competence areas and the possible additional or supporting services (Sipilä 2005.)

A systematic literature review (SLR) was carried out in order to identify current practices for the productization of IT-enabled higher education in computer science. Firstly, we present the SLR method applied, and secondly, the results and, finally, conclude by discussing the resulting nine categories of commericalization and productization of higher education found by the SLR.

2. RESEARCH METHOD

The research process follows Kitchenham et al. (2010) by including the following steps: defining the research questions, describing the search process, describing the how the included papers were selected, quality assessment, and data extraction process. Other guidelines for conducting a SLR (Okoli and Schabram 2010) were used in a complementary manner. The research was carried out by two researchers (later referred to as researcher 1 and researcher 2).

The purpose of our study is to identify studies reporting ways of productizing or commercializing IT-enabled higher education in computer science. Since we were aware of only a few of such studies, the research question was formulated in a broad sense so that it would capture the aspect of how much this area has been studied as well as the aspect of how deeply it has been studied: *"To what extent the commercialization and productization of higher education in computer science and information technology has been studied so far?"*

2.1 The Search Process

The search process started with word search in electronic databases. Researcher 2 searched eight digital libraries (on-line databases) and one automated search engine. The digital libraries included: ACM Digital Library, IEEE Xplore Digital Library, Web of Science, Science Direct, Education Resources Information Center (ERIC), EBSCOhost, InderScience Publishers, and Springer Link. Google scholar search engine was used to complement the above mentioned electronic libraries. The search was carried out between August and October 2011 and it was limited to articles published between 2001 and 2011. The following search words were used: *productization, commercialization, higher education, information technology, computer science, and information systems.* The word search was targeted at title, abstract, review, and keywords. The following combinations of search words were used as a base search for each electronic library:

```
1.  "productization AND higher education AND commercialization"
2.  "commercialization AND higher education AND productization"
3.  "productization OR higher education OR commercialization"
4.  "commercialization OR higher education OR productization"
5.  "productization AND higher education OR commercialization"
6.  "higher education AND productization OR commercialization"
7.  "productization AND commercialization OR higher education"
8.  "commercialization AND productization OR higher education"
9.  "productization OR commercialization AND higher education"
10. "productization OR higher education AND commercialization"
11. "commercialization AND higher education OR productization"
12. "commercialization OR higher education AND productization"
13. "commercialization OR productization AND higher education"
```

These basic combinations were adapted to the particular search possibilities of each database. If the database did not have automatic lemmatization option, then the "z-search" was followed by identical search with "s-search" (e.g. productisation instead of productization). Advanced search was used as default if provided. The details of the literature search were recorded along the whole search process (see Okoli and Schabram 2010) in MS Excel file with appropriate metadata.

2.2 Paper Selection

Paper selection process took place in two phases (see Figure 1). Firstly, researchers 1 and 2 undertook an initial screening (Kitchenham et al. 2010) of the found 1559 papers. Papers were distributed to the researchers by database in a way that one reviewed all papers belonging to the allocated database. The researchers read through all the tittles, abstracts and keywords individually and marked each paper as excluded or included. The researchers then discussed about the selected papers and after reaching a consensus made a decision on which articles to exclude and which to include.

Secondly, quality screening was performed. Quality appraisal during the paper selection process was carried out as multiple coding by two researchers who checked the suitability and relevance of the articles regarding the topic of the study. Multiple coding was carried out as parallel coding of the articles and simultaneous discussion about the quality and content of the articles (Barbour, 2001). This way both the coding and content of the papers as well as inclusion and exclusion criteria were double checked during paper selection. The abstracts were read thoroughly and, if necessary, the whole paper was read in order to assess the compliance with the inclusion criteria. Next, suggestions were made for excluding papers that

appeared suitable at first glance but did eventually not meet with the inclusion criteria. Finally, the final included papers were discussed and consensus was reached.
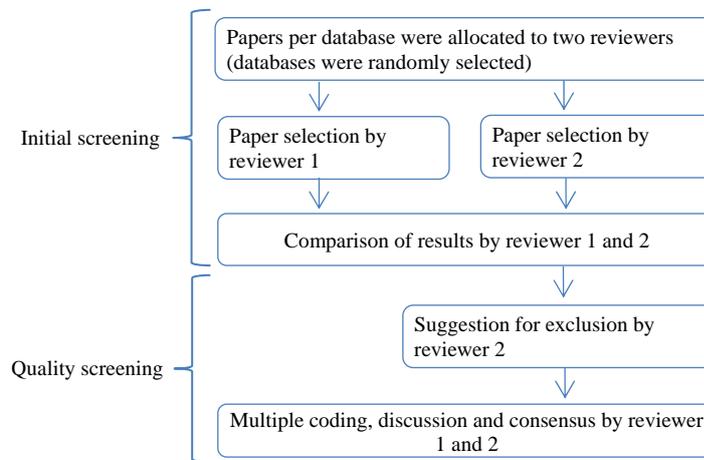

Figure 1. Paper selection process.

The criteria for inclusion were 1) the paper has to deal with higher education or university education, 2) the issue of commercialization or productization had to be present, and 3) the article has to be published in a refereed journal or conference proceedings. Articles concerning the commercialization or patenting of university research were included for additional value. The exclusion criteria included that the article 1) was concerned with lower level education (e.g., high school), or 2) was published on a non-refereed forum.

The initial screening reduced the amount of articles from 1559 to 126. This was followed by a redundancy check after which double articles were removed within the results. This was done in two steps: firstly removing the doubles within each database and then removing doubles across databases. After removing double-articles within each database the amount of articles was 78. After removing all the doubles across the databases and search engines, the amount of articles was 63. As a result of quality screening, 23 articles were removed after which the final amount of included articles was 40.

3. RESULTS

In comparing the content of the included 40 papers to our research question it was obvious that the results did not directly match to the focus of the study. Hence, a classification of the articles was carried out in order to define their subject matter. The articles were classified against the following criteria: distribution of articles by publication forum (journal, conference), and distribution of articles by subject (see Ngai and Gunasekarun 2007).

3.1 Distribution by Publication Forum

The identified papers were mainly published in refereed journals and conferences. The results include a total of 29 journal articles from 21 journals. The highest publishing results were in *Industry and higher education* (4 articles), *Scientometrics* (4 articles), *Globalisation, Societies and Education* (2 articles) and *Assistive Technology Outcomes and Benefits* (2 articles). The rest of the journals had published one article.

The articles were distributed in journals from various disciplines (see Table 1). Majority of the journal articles (24 articles) were published in journals on higher education and related fields. We classified these journals in five categories, namely higher education, teaching and learning, education policy and planning, educational technologies, and international education. The second largest category of journals (7 articles) was based on discipline. It was divided into subcategories of natural sciences, relationship between science and public, library sciences, and information processing and analysis. The third category of journals (1 article) was concerned with European policies.

Table 1. Distribution of papers in journals.

Subject Category	Journal name	Number of articles
1. Education		*(24)*
1.1 Higher Education	Industry and higher education	4
	Research in higher education	1
	Higher Education Quarterly	1
	Thought & Action	1
	Journal of further and higher education	1
	Higher education	1
1.2 Teaching and learning	Journal of University Teaching and Learning Practice	1
	e-Journal of Business Education & Scholarship of Teaching	1
	International Journal of Learning and Change	1
	Learning and Teaching: The International Journal of Higher Education in the Social Sciences	1
1.3 Education policy and planning	Higher Education Policy	1
	Journal for critical education policy studies	1
	The International Journal of Higher Education and Educational Planning	1
	Journal of Higher Education Policy and Management	1
1.4 Educational technologies	Assistive Technology Outcomes and Benefits	2
1.5 International education	Globalization, Societies and Education	2
	Russian education and society	1
	Journal of Studies in International education	1
2. Information sciences		*(5)*
2.1 Library sciences	Scientometrics	4
2.2 Information processing and analysis	Scientific and Technical Information Processing	1
3. European policies		*(1)*
3.1 Planning studies	European planning studies	1
Total		**29**

The results included 11 conference papers (Table 2). There was a great variety in the field and distribution of the conferences, which were categorized according to their subject area in the following categories: computer science, engineering, information technology, technology management, education management, and business management.

Table 2. Distribution of papers in conferences.

Subject category	Conference name	Number of articles
Computer science	IEEE International Conference on Fuzzy Systems	1
Engineering	Canadian Conference on Electrical and Computer Engineering	1
	IEEE International Conference on System Engineering and Technology	1
	IEEE International Conference on Industrial Engineering and Engineering Management	1
Information technology	ICO International Conference on Information Photonics	1
	International Conference on Communication Systems, Networks and Applications	1
	International Convention on Information and Communication Technology, Electronics and Microelectronics	1
Technology management	IEEE International Technology Management Conference	1
	International Conference on Education Technology and Computer	1
Education management	International Conference on Education and Management Technology	1
Business management	International Conference on Business Management and Electronic Information	1
Total		**11**

The distribution of articles by publication forum indicates that our topic was over three times more popular in journals. The high dispersion in both journals and conferences indicates that there is no established journal for the topic.

3.2 Distribution by Subject

The articles were classified according to their subject content. Nine different classes were recognized: *commercialization of research, technology transfer, commercialization of education, educational reform, knowledge transfer, patenting, educational system, academic entrepreneurship, and technology commercialization effects* (Table 4).

Table 4. Classification of papers by subject.

Class #	Class name	Number of papers	References
1	**Commercialization of research**	8	Dube and Lisk (2011), Harman (2010), Hussain et al. (2010), Kerr (2011), Li and Xia (2011), Smith (2010), Suvinen et al. (2010), Yang and Chang (2010)
2	**Technology transfer**	7	Fraser (2010), Gonnova and Kavtaradze (2010), Lane (2010), Leahy and Lane (2010), Prokopiev (2011), Somsuk (2010), Wang and Cao (2010)
3	**Commercialization of education**	6	Arnold (2010), Naidoo (2010), Robertson (2010), Tait (2010), Tsai and Yang (2010), Wong and Westwood (2010)
4	**Educational reform**	5	Aboites (2010), Graeme and Peim (2011), Liu and Crossley (2010), Raciti (2010), Susanti (2011)
5	**Patenting**	4	Benneworth and Jongbloed (2010), Klitkou and Gulbrandsen (2010), Leydesdorf and Meyer 2010), Wong and Singh (2010)
6	**Educational system**	4	Allen (2010), Dubin and Zorkaia (2010), Shore (2010), Yassin et al. (2011)
7	**Knowledge transfer**	2	Bezic et al. (2011), Kuiken and van der Sijde (2011)
8	**Academic entrepreneurship**	2	Arapostathis (2010), Goldstein (2010)
9	**Technology commercialization effects**	2	Powers and Campbell (2010), Wong and Singh (2011)

Commercialization of research class includes nine papers on the enhancement or measurement of commercialization of academic research. It includes, for instance, framework through which the researchers can engage commercialization into the research process as a vital part of it (Smith 2010), perceptions of the success of innovation and research commercialization in Australia (Harman 2010), and the role of intermediary organizations (Suvinen et al. 2010) or university lawyers (Hussain et al. 2010) in the process of commercialization of academic research. Further, it includes studies on the influence of entrepreneurial commitment (Yang and Chang 2010) and federal funding (Kerr 2011) or governmental programs (Dube and Lisk 2011) on research commercialization. Also, the aspects of knowledge commercialization modes and effects in universities (Li and Xia 2011) were included. The papers in this class focus on the means of enhancing or measuring the commercialization of university research in general and do not provide results on the specific area of commercialization of higher education.

Technology transfer class includes seven papers that explain how to enhance, understand and analyse the academic technology transfer. These include factors explain factors influencing improving university technology transfer (Wang and Cao 2010), analysis of university-industry technology transfer programme's success (Somsuk 2010), measurement and enhancement of the impacts of technology transfer (Fraser 2010), enhancement of technology transfer and commercialization by business games (Gonnova and Kavtaradze 2010), description of how Canadian innovation and commercialization program enhances industry-academia technology transfer (Prokopiev 2011), the barriers and carriers of successful technology transfer of assistive technology devices in USA (Leahy and Lane 2010), and the confluence of academic research of technology transfer of assistive technologies for value creation (Lane 2010). These papers focus on technology transfer and not on education.

Commercialization of education class includes six papers on the commercialization of higher education in the changing global business context. Naidoo (2010) examines the export readiness of universities and its implications on export recruitment of students. Robertson (2010) studies the commercialization,

corporatization and competitiveness of U.K. universities emerging from the transformation of higher education toward globally competitive education system. Wong and Westwood (2010) provide empirical findings from the conflicting interests and tension that the commercialization pressure have brought at universities. Arnold (2010) addresses the same issue from university teacher's perspective while Tsai and Yang (2010) discuss about the role and profession of teachers in commercialized education. Tait (2010) studies the commercialization of education from the perspective of Chinese student in Western university format. These papers provide insights on the impact of the global commercialization pressure on university education. They fail to provide, however, views how to productize or commercialize higher education.

Educational reform class includes five papers discussing the strategic and political aspects of educational system reforms and related commercialization of higher education including experiences on marketing the university programmes in China (Liu and Crossley 2010), analysis of the privatization and marketization of higher education in Indonesia (Susanti 2010), the implication of the reform and commercialization of Australian higher education (Raciti 2010), a critical analysis of the negative implications of Bologna Process on Latin American universities (Aboites 2010), and results of the quality of exported higher education (Graeme and Peim 2011). These papers provide knowledge of national university reforms that have shifted higher education from traditional research to commercial business.

Patenting class includes four articles concerning the relationship between academic patenting and scientific publishing (Klitkou and Gulbrandsen 2010, Wong and Singh 2010), the development of university patenting due to external forces such as Bayh-Dole (Leydesdorf and Meyer 2010) and the unequal position of soft sciences in comparison to hard sciences in relation to patenting and commercialization (Benneworth and Jongbloed 2010). In this class, commercialization is related activities leading to patenting while academia is defined as a source for material for patenting.

Educational system class includes four articles reporting the current state of national educational systems. Survey results of Dubin and Zorkaia (2010) show that in Russia the higher education has social value. Yassin et al. (2011) presents an instrument for the evaluation of research performance and results of its use in Malaysian universities. Shore (2010) analyses the challenges of the modern university due to contradictory requirements between the traditional and new, economic and strategic pressures. Allen (2010) analyses the Royal Society's suggestions for enhancing science in UK and contrasts them to United States. The papers in this class address the issues of commercialization and higher education in national context by describing the country's educational systems with its characteristics and recent developments.

Knowledge transfer includes two articles on the transition of scientific knowledge from academia to public sector and commercialization of such knowledge. Kuiken and van der Sijde (2011) study the commercialization and dissemination of academic knowledge by using communication theory in interpreting the results. Their research provides topics for further research in relation to dissemination capacity. Bezic et al. (2011) discuss about the role of Croatian national technology transfer office as a channel for transferring university research results into economy. These studies include some elements of commercialization and higher education without focusing on commercialization process of higher education.

Academic entrepreneurship class consists of two papers studying the role of entrepreneurship within research universities and national politics. They focus on the position of academic entrepreneurship with respect to national politics and innovation policies (Arapostathis 2010), and on national attitudes toward entrepreneurship and commercialization of university (Goldstein 2010). The aspect of commercialization in these articles focuses on university research and innovation in relation to entrepreneurship.

Technology commercialization effects class includes two studies. Powers and Campbell (2010) argue that in U.S. universities the licencing or patenting of technologies do not have an effect on research productivity research. Wong and Singh (2011) examine university-industry collaboration by measuring the amount of university-industry co-publications on technology commercialization. These papers do not take a stand on the ways or extent to which IT-enabled higher education could be commercialized or productized.

4. CONCLUSIONS

The productization of IT-enabled higher education is one solution for improving the competitiveness of educational organisations, and to respond to the increasing demand for globalizing the higher education. We reviewed the current literature in order to identify ways in which the productization of IT-enabled higher

education in computer science has been done. The SLR yielded 40 papers, including 29 journal articles and 11 conference papers. The articles were classified according to their study subject into nine categories: academic entrepreneurship, patenting, educational system, knowledge transfer, educational reform, commercialization of research, commercialization of education, technology transfer, and technology transfer effects. Unfortunately, the results did not provide the answer that we were looking for. The results show that commercialization and productization of higher education has been studied on institutional, national and international level. However, studies concerning productization of courses, learning technologies, contents or learning materials, were not found. Based on this, we claim that there is a gap in research that requires further studying.

REFERENCES

Aboites, H., 2010. Latin American universities and the Bologna Process: From Commercialisation to the "Tuning" Competencies Project. *Globalisation, Societies and Education*, Vol. 8, No. 3, pp. 443-455.

Allen, H.L., 2010. Lessons from the United Kingdom's Royal Society. *Thought & Action*, Fall, 115-120.

Arapostathis, S., 2010. Academic Entrepreneurship, Innovation Policies and Politics in Greece. *Industry and Higher Education*, Vol. 24, No. 3, pp. 165-176.

Arnold, J., 2010. What Do University Teachers Do All Day (and Often into the Night)? *Journal of University Teaching and Learning Practice*, Vol. 7, No. 1. Available at: http://ro.uow.edu.au/jutlp/vol7/iss1/2

Barbour, R.S., 2001. Checklists for improving rigour in qualitative research: a case of the tail wagging the dog? *British Medical Journal* 322, No. 7294, pp. 1115-1117.

Benneworth, P., Jongbloed, B. W., 2010. Who Matters to Universities? A Stakeholder Perspective on Humanities, Arts and Social Sciences Valorisation. *The International Journal of Higher Education and Educational Planning*, Vol. 59, No. 5, pp. 567-588.

Bezic, H., Karanikic, P., Tijan, E., 2011. The Role of University in Efficient Transfer of Scientific Knowledge. *Proceedings of the 34th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, pp. 1434-1437.

Dube, V., Lisk, D., 2011. Commercialization of university research in Canada: An NRC/IRAP perspective. *The 24th Canadian Conference on Electrical and Computer Engineering (CCECE)*, Niagara Falls, Ontario, Canada.

Dubin, B., Zorkaia, N., 2010. The system of Russian education as assessed by the population: The problem of level and quality. *Russian Education and Society*, Vol. 52, No. 12, pp. 15-79.

Fraser, J., 2010. Academic technology transfer: tracking, measuring and enhancing its impacts. *Industry and Higher Education*, Vol. 24, No. 5, pp. 311-317.

Goldstein, H.A., 2010. To What Extent Is Academic Entrepreneurship Taken for Granted within Research Universities? *Higher Education Policy*, Vol. 23, No. 1, pp. 1-15.

Gonnova, S.M., Kavtaradze, D. N., 2010. Modelling the process of the creation of business companies by federally funded scientific and educational institutions. *Scientific and Technical Information Processing*, Vol. 37, No. 2, pp. 132-136.

Graeme, M., Peim, N. (2011) Cross-border higher education: who profits? *Journal for critical education policy studies*, Vol. 9, No. 1.

Harman, G., 2010. Australian university research commercialization: perceptions of technology transfer specialists and science and technology academics. *Journal of Higher Education Policy and Management*, Vol. 32, No. 1, pp. 69-83.

Tsai, H., Yang, C., 2010 A discussion on teacher professionalization in commercialized education with Peter McLaren's position on critical pedagogy. *The 2nd International Conference on Education Technology and Computer (ICETC)*, Shanghai, China.

Hussain, bin Wan, W.M.H., Rahman, M.N.A., Yaakub, N.I., Zainul, Z.A., Mujani, W.K., 2010. Online legal marketing: How lawyers assist in commercialization of university research. *International Conference on Education and Management Technology (ICEMT)*, Cairo, Egypt.

Kerr, F.W., 2011. Commercialization of University Research for Technology-Based Economic Development. *Industry and Higher Education*, Vol. 25, No. 3, pp. 161-172.

Kitchenham, B., Pretorius R., Budgen, D., Brereton, O.P., Turner, M., Niazi, M., Linkman, S., 2010. Systematic literature reviews in software engineering – A tertiary study. *Information and Software Technology*, Vol. 52, pp. 792-805.

Klitkou A., Gulbrandsen, M., 2010. The relationship between academic patenting and scientific publishing in Norway. *Scientometrics*, Vol. 82, No. 1, pp. 93-108.

Kuiken, J., van der Sijde, P., 2011. Knowledge transfer and capacity for dissemination: A review and proposals for further research on academic knowledge transfer. *Industry and higher education*, Vol. 25, No. 3, pp. 173-179.

Lane, J., 2010. State of the science in technology transfer: At the Confluence of Academic Research and Business Development: Merging Technology Transfer with Knowledge Translation to Deliver Value. *Assistive Technology Outcomes and Benefits*, Vol. 6, No. 1, pp. 1-38.

Leahy, J.A., Lane, J.P., 2010. Knowledge from Research and Practice on the Barriers and Carriers to Successful Technology Transfer for Assistive Technology Devices. *Assistive Technology Outcomes and Benefits*, Vol. 6, No. 1, pp. 73-86.

Leydesdorf, L., Meyer, M., 2010. The decline of university patenting and the end of the Bayh-Dole effect. *Scientometrics,* Vol. 83, No. 2, pp. 355-362.

Liu, N.R., Crossley, M., 2010. marketing university programmes in China: Innovative Experience in Executive and Professional Education. *Journal of Further and Higher Education*, Vol. 34, No. 3, pp. 321-334.

Naidoo, V., 2010. From Ivory Towers to International Business Are Universities Export Ready in Their Recruitment of International Students? *Journal of Studies in International Education*, Vol. 14, No. 1, pp. 5-28.

Ngnai, E.W.T., Gunasekaran, A., 2007. A Review for mobile commerce research and applications. *Decision Support Systems*, Vol. 43, pp. 3-15.

Okoli, C., Schabram, K. 2010. Guide to Conducting a Systematic Literature Review of Information Systems Research. *Sprouts: Working Papers on Information Systems*, Vol. 10, No. 26. Available at: http://sprouts.aisnet.org/10-26

Powers and Campbell (2011) Technology commercialization effects on the conduct of research in higher education. Research in Higher Education, Vol. 52, No. 3.

Prokopiev, D. 2011. Ontario innovation and commercialization programs: Industry-academic aspect. ICO International Conference on Information Photonics (IP), pp.1-2, 18-20 May 2011.

Raciti, M. (2010) Marketing Australian higher education at the turn of the 21th century: A précis of reform, commercialization and the new university hierarchy. *e-Journal of Business Education & Scholarship of Teaching*, Vol. 4, No. 1, pp. 32-41.

Shore, C., 2010. The reform of New Zealand's university system: "after neoliberalism". *Learning and Teaching: The International Journal of Higher Education in the Social Sciences*, Vol. 3, No. 1, pp. 1-31.

Smith, S.L., 2010. The Yorkshire Enterprise Fellowship: A framework for successful commercialization of computational intelligence research. *IEEE International Conference on Fuzzy Systems (FUZZ),* Barcelona, Spain.

Somsuk, N., 2010. University-Industry Technology Transfer programme's success analysis: Using the Analytic Hierarchy Process-based model. *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM),* Xiamen, China.

Robertson, S. L., 2010. Corporatisation, competitiveness, commercialisation: new logics in the globalising of UK higher education. *Globalisation, Societies and Education*, Vol. 8, No. 2.

Susanti, D., 2011. Privatization and marketization of higher education in Indonesia: the challenge for equal access and academic values. *Higher education*, Vol. 61, No. 2.

Suvinen, N., Konttinen, J., Nieminen, M., 2010. How Necessary are Intermediary Organizations in the Commercialization of Research? *European Planning Studies*, Vo. 18, No. 9, pp. 1365-1389.

Tait, C., 2010. Chinese Students' Perceptions of the Effects of Western University Examination Formats on Their Learning. *Higher Education Quarterly*, Vol. 64, No. 3, pp. 261-275.

Wang, J., Cao, H., 2010. Improve the university technology transfer: Factors and framework. *Second International Conference on Communication Systems, Networks and Applications (ICCSNA),* Hong Kong, China.

Li, W., Xia, Q., 2011. The modes and effects of knowledge commercialization Based on knowledge spill over theory. *International Conference on Business Management and Electronic Information (BMEI)*, Guangzhou, China.

Wong, R.H.C., Westwood, R., 2010. The public good vs. commercial interest: research scientists in search of an accommodation. *International Journal of Learning and Change*, Vol. 4, No. 1, pp. 77-97.

Wong, P.K., Singh, A., 2010. University patenting activities and their link to the quantity and quality of scientific publications. *Scientometrics*, Vol. 83, No. 1, pp. 271-294.

Wong P.K., Singh, A., 2011 Do co-publications with industry lead to higher levels of university technology commercialization activity? *IEEE International Technology Management Conference (ITMC),* San Jose, CA, USA.

Yang, P.Y., Chang, Y., 2010. Academic research commercialization and knowledge production and diffusion: the moderating effects of entrepreneurial commitment. *Scientometrics*, Vol. 83, No. 2, pp. 403-421.

Yassin, I.M., Zabidi, A., Johari, M.A., Hijaz, F., Yussuf Izzudin, A.H., Tahir, N.M., Hamzah, M.K., Abdul Majeed, A.B., 2011. Entity-Relationship analysis for development of Malaysian University Research Assessment Instrument (MyRA) information system. *IEEE International Conference on System Engineering and Technology (ICSET),* Shah Alam, Malaysia.