Analysis of University Management of Emerging Technologies and Recommendations for Developing Countries

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ABSTRACT
University management seeks to achieve the objectives established by higher educations institutions, including their third mission, which corresponds to the transfer of research results into the industry; in this regard, emerging technologies play an important role to solve problems identified in the industry. Emerging technologies are those found in the embryonic stage of its life cycle. Although they have features that make them difficult to manage, they can quickly change the dynamics of the market. That is why it is necessary to analyze the management process of these technologies at the university level, due to, in many cases, it is in high education institutions where these technologies arise. This paper presents results of a study aiming at analyzing the process of university management of emerging technologies in a developing country, identifying gaps in such process in relation to referent countries, and proposing recommendations to reduce those gaps. The research methodology included benchmarking to identify best practices concerning referent universities and a case study in which a university research group in a developing country was analyzed. Results indicate that universities of developing countries acknowledge the importance of managing emerging technologies, which should lead to structural changes in the Systems of Science and Technology as well as in the higher educations institutions and in the management of the research groups that generate and use these technologies. However, the analysis identified some key success factors of referent universities to be either absent or acting defitienly in the focal case studied. Finally, some recommendations are proposed to reduce the identified gaps.

Keywords: university management, emerging technologies, benchmarking, case study, analysis, recommendations, developing countries.

INTRODUCTION
Higher Education Institutions (HEI) currently face the challenge of directly impact society with the knowledge they generate. In this sense, their third mission consits on a meaningful transfer of the results of the processes of Research and Development (R & D) to the industry, so that they become innovation to be accepted and implemented becoming real solutions to the problems that society presents (Gür, Oylumlu, & Kunday, 2016) . In order for this to happen, it is necessary for HEIs to generate suitable university management processes from within, that enable them to achieve the objectives of technology transfer that support innovation processes (Aceves, Siller, Torres, & Martinez, 2013; Bernardt, Meijaard, & Kerste, 2002; Borges & Jacques Filion, 2013; Cabrera & Soto, n.d.; Rip, 2011). Therefore, it is essential that appropriate management processes are developed regarding technologies that might emerge within research projects, as part of university management (Díez, Valencia & Villa, 2015) .

Given the above, high education institutions have the duty to support and monitor the generation, appropriation and/or adoption of technologies to solve the problems identified in the industry.These processes can give rise to emerging technologies, which are technologies in their initial phase with specific characteristics that differentiate its management (Day & Schoemaker, 2000). Some of those characteristics include lack of historical data that would allow to generate risk projections and analysis, uncertainty about whether the market would accept the technology, the ethical challenges that this new technology might bring, and lack of awareness both about the

existence of such market and the eventual use of these technologies; the foregoing features of emerging technologies imply for their management a high component of risk and uncertainty (Gavankar, Anderson, & Keller, 2014). However, emerging technologies are the ones that move the markets, making a challenge for high education institutions not only to identify them but also to develop and promote their use; ie, their proper management. Studies in the field (Bhattacherjee, 1998; Tegarden, Lamb, Hatfield, & Ji, 2012) have identified that high education institutions that manage emerging technologies in developed countries count on particular characteristics that permit them to be successful (Villa, 2015).

Unfortunately, the study of the management of these technologies in high education institutions of developing countries is just beginning (González Arango, Schmal Simon, Gonzalez Arango, & Schmal Simon, 2005; Llanos, 2004; Ortiz-Riaga & Morales-Rubiano, 2011); despite this fact, its importance to their technological development is recognized. Therefore, the objective of this research study was to analyze the university management of emerging technologies both at the international and local contexts in order to understand the state of the art in this field, and propose recommendations for improvement regarding this matter, to HEIs in developing countries. In order to meet this goal, this paper presents the study and its results in four sections as follows: Section two presents the conceptual background, which elaborates on the concepts involved in the study; section three explains the methodology used to conduct the research, which integrated a benchmarking to establish what universities are doing regarding emerging technology management in the international arena and a case study of a university that manages emerging technologies in a developing country; section four, findings and discussion, presents the analysis carried out in order to (1) identify the salient characteristics of emerging technology management in high education institutions in which these processes are successful and (2) establish the gaps regarding management of emerging technology at the university focus of the case study with respect to universities in countries with greater recognition and legacy; finally, section five presents recommendations for improvement aimed at closing the gaps in developing countries as well as suggestions for further research.

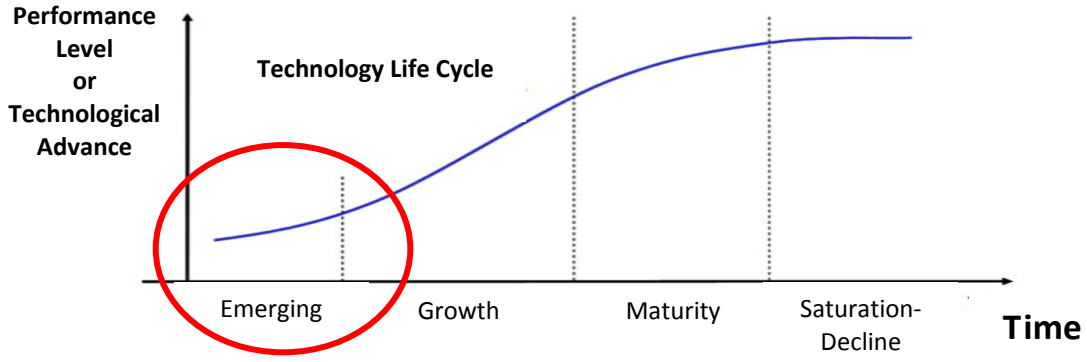
2. CONCEPTUAL BACKGROUND

This section presents the theoretical framework that supports the study. Consequently, it (1) introduces the conceptualization of emerging technologies and its relevance, and (2) describes the processes of university technology management highlighting the importance of identifying gaps in these processes in local contexts with respect to international examples.

2.1 Emerging Technologies

According to the state in which a technology is found in its life cycle, it has a number of special characteristics: the literature reports four basic states of technology (see Figure 1).

Figure 1: Identification of emerging technologies in the technology life cycle, S curve.



Emerging technologies are those found in the nascent stage of its life cycle. One of the important features to highlight about these technologies is that they represent an important opportunity for technological development despite they lack constituted markets and historical data; that is to say, they could become very important technologies within a short term (Atanu, Love, & Schwart, 1994; Day & Schoemaker, 2000; Halaweh, 2013; Khanagha, Volberda, Sidhu, & Oshri, 2013; E. Villa, 2015). However, standards and specifications of use for these technologies are either not developed or immature, they do not count on a pre-established or known business model to use them, and neither the rate of their adoption nor its price or cost can be determined. Additionally, these technologies have network effects; i.e. their value increases according to the increment in the number of users; the cost of an emerging technology is thus high and so is the cost of replacing a traditional technology for an emerging one. On the other hand, these technologies involve a number of both ethical and legal considerations, as well as environmental factors, which are unknown and unpredictable, and therefore

difficult to manage (Atanu et al., 1994; Day & Schoemaker, 2004; Frewer, 1999; Navas, Londoño, Ruiz, & Ruiz, 2012) However, they should not be ignored because they can create disruptive changes in society (Adner & Levinthal, 2002; Fleischer, Decker, & Fiedeler, 2005; Godwin-Jones, 2003; Hung & Chu, 2006; Newman et al., 2012).

Some emerging technologies for 2016 are Internet of Nano things, large-scale energy storage, block chains, 2D materials, autonomous vehicles, Organs-on-Chips, perovskite solar cells, open AI ecosystems, optogenetics, metabolic and immune system engineering, genome editing of plants, human machine interfaces, reusable rockets, robots with the ability to teach each other, Apps for DNA, SolarCity's gigafactory to end the use of fossil fuels, among others (Forum, 2016; Review, 2016). These emerging technologies will be part of the future of citizen science in terms of its research processes, program and participant cultures, and scientific communities.

2.2 University Technology Management (UTM)

University technology management (UTM) consists specifically on inventorying, monitoring, evaluating, enhancing, optimizing and securing technology in organizations (Gaynor, 1999; Jiménez, Castellanos, & Morales, 2007; Tapias G., 2000). In this sense, (Castrejón, Hernández, & Ruiz, 2014), argue that technological management developed in university research groups (UTM) is a triggering element for competitiveness, for which the various aspects within the UTM should be taken into account in innovation systems and should be supported holistically (time, resources, processes and proper management from all areas of the university) to strengthen and enhance their results (E. Villa, 2015).

University technology management is strengthened through the creation of the tie university-industry-society and, in addition, when higher education institutions (HEI) are focused on meeting their so-called "third mission", related to their direct role in economic development and their real impact on society (Arvanitis & Villavicencio, 1994; Friedman & Silberman, 2003; Howland, Good, & Robertson, 2007; E. Villa, Echeverry, & Jiménez, 2015). To achieve such a goal, a new model of entrepreneurial and research driven university emerges in the society of knowledge, bringing challenges as new as: a) impelling the development of society as a product of social and economic progress, which is achieved through the effective application of knowledge; and b) proving that higher education is essential to support the processes of creation, dissemination and appropriation of knowledge: the countries that disregard these challenges are at risk of being left behind in this new world order (Díez et al., 2015; Pineda, 2013). To attain this objective, universities rely on *technology management processes*, specifically from university research groups (Geisler, 1995; Mowery & Shane, 2002; Siegel, Waldman, & Link, 2003; Silva & Nuño, 2014).

As for the mechanisms used in UTM, the protection of intellectual property is emphasized given that it is the tool, at universities, to ensure that scientific and technological production can be exploited by their authors (Audretsch, Lehmann, & Wright, 2014). Another important mechanism of university management of emerging technologies is transfer from university to industry, which specifically consists of the links that each university generates with industry and the support that they give to the adoption of the technology, making it innovation that generates benefits within the economic and social domains (Geisler, 1995; Harmon et al., 1997; Miller, McAdam, & McAdam, 2016)

The aforementioned is achieved with mechanisms such as patent licensing, creation of technology-based companies, technical assistance, and training and professional development among others (Jiménez, Maculan, Otálora, & Cunha, 2013; Valencia, Morales, Vanegas, & Benjumea, 2017). In this regard, there are various models that have been adopted by universities to successfully achieve the objective of technology transfer, including creating Technology Transfer Offices (TTO's), which are responsible for giving the impetus needed to the new technologies and leading them to industry, often in the form of spin-offs or start-ups (Algieri, Aquino, & Succurro, 2013; Ramírez & García, 2010). However, in developing countries the processes of Research, Development and Innovation (R + D + i) do not receive adequate attention that is why it is useful to identify gaps in these processes with regard to international benchmarks and propose recommendations to overcome them (Bermúdez Hernández, Castañeda Riascos, & Valencia Arias, 2014; Valencia-Rodríguez, 2013; Villa, 2015).

3. METHODOLOGY

The methodology of this study involves the application of two techniques of qualitative research: a) benchmarking as a tool to analyze and compare processes of university management of emerging technologies in various fields and b) a case study for the diagnosis of university management of emerging technologies in a

research group of a developing country. These sources would allow us to identify the best practices of international benchmarks and gaps with respect to the case study.

3.1 Benchmarking as a Methodology to Identify Best Practices.

Benchmarking is a "systematic and continuous process to evaluate products, services and work processes of organizations that are recognized as representing best practices for the purpose of making organizational improvements" (Spendolini, 1992, p. 15). To carryout benchmarking, it is key to know what factors are to be measured and compared. Boxwell, Rubiera, McShane, and Zaratiegui (2008) point out the desirability of focusing on a small number of indicators to achieve the necessary improvements, for which it would be indispensable to know what the "key success factors (KSF)" that affect the performance of the organization or business are. Likewise, it is important to identify referents in the local context and also in the international context, in order to achieve a global comparison. Figure 2 shows the methodology of benchmarking conducted for this research, based on the authors mentioned above:

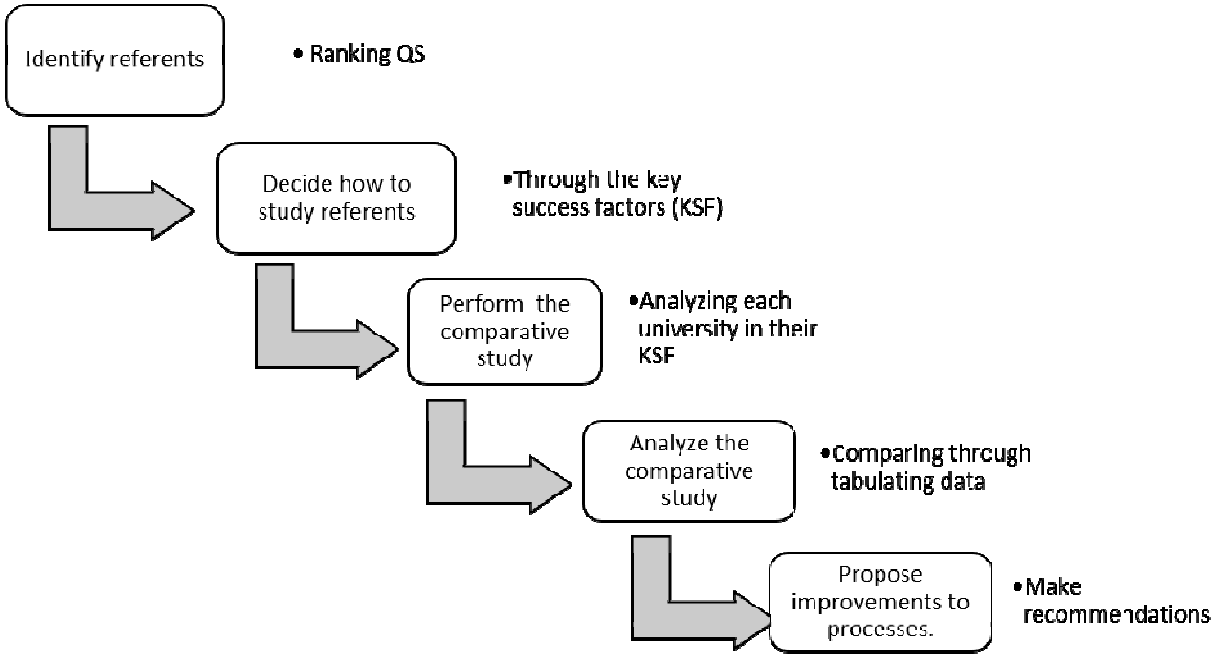


Figure Error! No text of specified style in document.**:** Process for the comparative analysis of university management of emerging technologies.
Source: (E. Villa, 2015)

To perform the benchmarking or comparative analysis as a methodological tool for this study, ten universities of excellence were selected at the global level through the classification made by the British firm Quacquarelli Symonds (QS World University Rankings, 2015). This classification comes from a study that is conducted and published annually ranking the top 600 universities in the world through four key pillars: research, teaching, employability and internationalization. Selected universities are shown in Table 1:

Table 1: Universities selected for benchmarking

Name of the University	Initials	Country	Classification according to the QS Ranking (World)
Massachusetts Institute of Technology	MIT	USA	1
University of Cambridge	UCAM	UK	2
University of Pennsylvania	UPENN	USA	13
University of British Columbia	UBC	Canadá	43
Pontifica Católica Universidad de Chile	UC	Chile	167
Universidad Nacional Autónoma de México	UNAM	México	175
Universidade Estadual de Campinas	UNICAMP	Brasil	206

Universidad de los Andes	UNIANDES	Colombia	262
Universitat Politecnica de Valencia	UPV	Spain	421
Universidad de Antioquia	UdeA	Colombia	501

Source: (Villa, 2015)

According to Arrubla, Oquendo, Preciado, and Londoño (2012), some key success factors identified in well ranked university research groups are coordinator leadership, commitment of members, research training, lines of research, organization, communication, and motivation; all of this framed within a proper university-business-state relationship and supported by a solid National Science, Technology, and Innovation System (NSTIS). In the same vein, Suárez and Díaz (2013) assert that, since they are vital elements in achieving organizational success, KSFs are key factors to be studied in organizations of interest such as the ones analyzed in this study (universities). Based on the authors consulted, the following key success factors for the implementation of benchmarking were selected:

Tabla 2: Key success factors (KSF) identified for benchmarking

Key Success Factors (KSF)	Description
a. Institution Factors at the Central Level	▪ Research Institution's Mission ▪ Strategic Educational and Research Alliances ▪ Technological and Communication Platform ▪ Libraries and library Resources ▪ Industrial Platform ▪ Interinstitutional Colaboration
b. Factors of the Institution's Research Group	▪ Existence of Research Groups Working with Emerging Technologies ▪ Research Group's Function ▪ Innovative Research Lines ▪ Industry-Academia Cooperation ▪ Custom Programs Originated in Research Groups ▪ Strategic Partnerships
c. Factors of the Technology Transfer Process	▪ Existence of an Agency or Office Leading the Process ▪ Research Mission of the Technology Transfer Agency ▪ Existence of an Office Responsible at the Central Level of the Process of Technology Transfer ▪ Support Programs for the Technology Transfer Process ▪ Additional Aspects on the Support of Emerging Technology Management

Source: prepared based on (QS World University Rankings, 2015; Villa, 2015)

3.2 Case study: Management of Emerging Technologies in a Research Group of a Developing Country.
The case study is a research methodology based on the importance of having direct contact with the object of study to generate knowledge. A contemporary case study is a research strategy aimed at understanding the dynamics present in unique contexts. In this regard, the combination of techniques is recommended by some authors to gather data in a mixed manner (qualitative and quantitative) in order to better "describe, verify or generate theory" (Eisenhardt, 1989, p. 8). Case studies are often used to study social phenomena, which are new and unexplored.

For the case study carried out in this research experience, the methodological design included a review of documentation, semistructured interviews and direct observations as suggested by (Yin, 2003). The case study was applied to the research group "Biotechnology" from University of Antioquia, Colombia. The selection of that focal case was made on the basis that this group manages an emerging technology, it is ranked as an A1 research group by Colciencias—the governmental institutional system that leads research technology and innovation in Colombia- and it had geographical accessibility (Villa & Jiménez, 2016).

4. FINDINGS AND DISCUSSION

Countries with developing economies are generating, adopting, and/or adapting emerging technologies; yet there are still many gaps to be closed for those countries to reach the level of developed countries in that field of interest. In the following paragraphs, findings of this study are presented followed by a discussion intended to

interpret them.

4.1 Findings

In order to illlustrate the analysis carried out in this study, Table 3 presents a contrast between the benchmarking and the case study results, using the key success factors analyzed for both the referent universities identified in the benchmarking and the university research group selected as the focus of the case study.

Table 3: Comparative analysis of key success factors: benchmarking-case study

Key Factors Analyzed	Referent Universities Concerning Benchmarking	Case Study
Institution Factors at the central level		
Research Institution's Mission	Yes	Yes
Strategic Educational and Research Alliances	Yes	Yes
Technological and Communication Platform	Yes	Yes
Libraries and Library Resources	Yes	Yes
Industrial Platform	Yes	Yes
Interinstitutional Colaboration	Yes	Yes
Factors of the Institution's research group		
Existence of Research Groups Working with Emerging Technologies	Yes	Yes
Research Group's Function	Yes	Yes
Innovative Research Lines	Yes	Yes
Research Resources at the University	Yes	No
Industry-Academia Cooperation	Yes	Deficient
Custom programs originated in Research Groups	Yes	No
Strategic Partnerships	Yes	Deficient
Factors of the Technology Transfer Process		
Existence of an Agency or Office Leading the Process	Yes	Deficient
Research Mission of the Technology Transfer Agency	Yes	Yes
Existence of an Office Responsible at the Central Level of the Process of Technology Transfer	Yes	Yes
Support Programs for the Technology Transfer Process	Yes	Deficient
Additional Aspects on the Support of Emerging Technology Management	Yes	Yes

Source: calculations based on results benchmarking- case study (Villa, 2015)

The case study revealed some key success factors in the focal case studied that were also found with benchmarking in world-renowned universities. However, the key success factors "Research Resources at the University", "Industry-Academia Cooperation", "Agency or Office that Leads the Technology Transfer Process", and "Support Program for Technology Transfer Process" were either not found in the case study or found to act deficiently. That finding raises evidence that the gaps that must be closed in the case of university management of emerging technologies could be related to those missing aspects. Nonetheless, an important key success factor found regarding the management of emerging technologies carried out in the case study was the existing leadership within the research group. That factor could not be evidenced in benchmarking due to the impossibility of real contact with the research groups at the benchmark universities.

4.2 Discussion

The analysis of the benchmarking evidenced that in the international context the success factors and best practices that lead referent universities to adequately generate and transfer emerging technologies are carried out in three realms of the organization: the contextual, the institutional, and the particular.

a. Regarding the contextual realm, these universities have a strong industrial, economic, financial and commercial environment, at the local, national, and international levels; moreover, technology monitoring processes are carried out from within the universities. Such context fosters the use and development of emerging technologies, which contribute to reduce the problems of the regions in which they are located; all the above mentioned framed by appropriate public policies aimed at promoting

science, technology and innovation (ST & I).

b. Regarding the institutional realm, it was evident that the universities studied have characteristics such as development of partnerships, agreements, participation, and interagency training to reduce the risk and uncertainty that comes with the management of emerging technologies. Similarly, they count on the support of technology platforms, systems of information and knowledge, as well as an institutional mission aimed at strengthening R & D + i. Such conditions stimulate the development, ownership and transfer of emerging technologies (ET), since they represent an adequate institutional support that allows and encourages these processes.
c. Regarding the particular realm, research groups as the basic units of research have support for their creation, maintainment and consolidation, both through institutional policies as well as with adequate and sufficient financial assistance. Likewise, they enjoy the existence of a technology management office supporting processes such as monitoring, evaluation, enrichment, optimization, protection and transfer of technology products.

In addition to the aforementioned and regarding the case study, we conclude that as a fundamental part of research group development, it is paramount to have an adequate leadership able to generate confidence, transmit passion for research, and stand out in the humanistic realm. Besides that, the analysis suggests the need of creating spaces adequate to overcome the sociocultural barriers that the introduction of emerging technologies in society generate as well as demonstrating how they would solve future problems and positively impact society.

Respecting emerging technology management, it was possible to make clear its particular characteristics and the challenges that its management imply.

a. Since these technologies do not count on historical data or real market figures that could help to predict their behaviour, it is necessary to provide them with suitable risk management. In this regard, the case study pointed out this as one of the aspects to improve in order to generate confidence on the entrepreneur to gain access to resources that would permit the generation of innovative projects.
b. It is important to acknowledge the role of emerging technologies to guarantee the future of humanity. It was evident that those areas of research (in this case biotechnology) are of paramount importance to tackle the effects of climate change; thus, it is impossible to disregard the significance of the technology under management despite the high risk and uncertainty that it generates in the market.
c. The impact of technology is unknown. In spite of studies being conducted around it, it is impossible to predict the uses that these technologies could attain, starting with its merging with other technologies—in the case study, for example, the already mentioned bionanotechnolgy.

Based on the comparative analysis between the case study and the benchmarking, it was evident that these characteristics of emerging technologies are managed from within the university, with appropriation of technology by the industry and supported by the research groups, and with dissemination of knowledge around it and strategic alliances with the enterprise, the state, and other research groups that also work on innovative lines. In addition, the university management of emerging technologies is supported by cross-sectional processes of technology management such as technology monitoring, competitive intelligence, and proper management of intellectual property.

5. CONCLUSIONS AND RECOMMENDATIONS

As a result of the study conducted, a series of conclussions and recommendations that would allow to narrow the gaps between benchmark countries and developing countries (as is the case of Colombia), with respect to the university management of emerging technologies, arose:

a. Universities should strive for appropriate management of these technologies as they will be the basis of future changes in market dynamics. However, it is important to consider that emerging technologies represent risks and uncertainties in the market; reason for which creating a risk fund is highly recommended. This will allow leveraging these investigations. In this regard, it would also be advisable to create tax incentives to enable universities to access resources, encouraging research specifically on emerging technologies.
b. Universities should be provided real and effective support by the units of technology management and entrepreneurship to create spin-offs. In this sense, there is a need towards fostering entrepreneurial universities and managing knowledge to carry out this process efficiently, conducting studies on success stories, and adapting the factors that are suited to the characteristics of the particular context of each developing country.
c. Finally, it is advisable to reflect on the importance of support for research, development and innovation

for developing countries (such as Colombia), since without these processes the country will lag behind. For this, it is not only convenient to make a substantial investment year after year in Science, Technology and Innovation, but also to consider that project management and management of research groups and technologies, are different from management of teaching and even of extension. Research has been, and will continue to be, a completely different process due to the time, resources and activities that it requires.

REFERENCES

Aceves, N., Siller, A., Torres, A., & Martinez, O. (2013). TECHNOLOGY BASED ENTREPRENEURSHIP: CHALLENGES AND OPPORTUNITIES TO ENHANCE A UNIVERSITY SPINOFF. *ICERI2013 Proceedings*, 370–378.

Adner, R., & Levinthal, D. A. (2002). The emergence of emerging technologies. *California Management Review*, *45*(1), 50–66.

Algieri, B., Aquino, A., & Succurro, M. (2013). Technology transfer offices and academic spin-off creation: The case of Italy. *Journal of Technology Transfer*, *38*(4), 382–400. https://doi.org/10.1007/s10961-011-9241-8

Arrubla, J. P., Oquendo, S., Preciado, J. M., & Londoño, J. O. (2012). Factores clave de éxito de los grupos y centros de Investigación de excelencia y consolidados de la Universidad de Antioquia. *Unipluriversidad*, *1*(1), 17–23.

Arvanitis, R., & Villavicencio, D. (1994). Transferencia de tecnología y aprendizaje tecnológico. *Reflexiones Basadas En Trabajos*. Retrieved from https://www.researchgate.net/profile/Rigas_Arvanitis/publication/46548039_Transferencia_de_tecnologia_y_aprendizaje_tecnologico_Reflexiones_basadas_en_trabajos_empiricos/links/0912f5119012ddfffa000000.pdf

Atanu, S., Love, H. A., & Schwart, R. (1994). Adoption of emerging technologies under output uncertainty. *American Journal of Agricultural Economics*, *76*(4), 836–846.

Audretsch, D. B., Lehmann, E. E., & Wright, M. (2014). Technology transfer in a global economy. *Journal of Technology Transfer*, *39*(3), 301–312. https://doi.org/10.1007/s10961-012-9283-6

Bermúdez Hernández, J. B., Castañeda Riascos, M. C., & Valencia Arias, J. A. (2014). El papel de la integración universidad-empresa-estado como estrategia en el fortalecimiento de los Sistemas Regionales de Innovación. *Espacios*, *35*(13).

Bernardt, Y., Meijaard, J., & Kerste, R. (2002). *Spin-off start-ups in the Netherlands*. EIM Business and Policy Research.

Bhattacherjee, A. (1998). Managerial Influences on Intraorganizational Information Technology Use: A Principal-Agent Model. *Decision Sciences*, *29*(1), 139–162. https://doi.org/10.1111/j.1540-5915.1998.tb01347.x

Borges, C., & Jacques Filion, L. (2013). Spin-off process and the development of academic entrepreneur's social capital. *Journal of Technology Management & Innovation*, *8*(1), 21–34.

Boxwell, Rubiera, McShane, & Zaratiegui. (2008). Benchmarking para Competir con Ventaja, 203.

Cabrera, A. M. G., & Soto, M. G. G. (n.d.). EMPRENDEDURÍA DE BASE TECNOLÓGICA: HACIA UN MODELO DINÁMICO.

Castrejón Mata, C., Hernández Sampieri, R., & Ruiz Rueda, H. (2014). Análisis de modelos de gestion tecnológica en centros de investigación. *RAITES Antes PANORAMA ADMINISTRATIVO*, *6*(10), 5–20. Retrieved from http://admon.itc.mx/ojs/index.php/panorama/article/viewArticle/210

Day, G. S., & Schoemaker, P. J. H. (2000). Avoiding the pitfalls of emerging technologies. *California Management Review*, *42*(2), 8–33. https://doi.org/10.2307/41166030

Day, G. S., & Schoemaker, P. J. H. (2004). Driving through the Fog: Managing at the Edge. *Long Range Planning*, *37*(2), 127–142. https://doi.org/10.1016/j.lrp.2004.01.004

Díez Echavarría, L. F., Valencia Arias, J. A., & Villa Enciso, E. M. (2015). Promoción de la cultura investigativa como motor de desarrollo económico y social: Una visión sistémica. *Espacios*, *36*(1).

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *The Academy of Management Review*, *14*(4), 532–550. https://doi.org/10.2307/258557

Fleischer, T., Decker, M., & Fiedeler, U. (2005). Assessing emerging technologies—Methodological challenges and the case of nanotechnologies. *Technological Forecasting and Social Change*, *72*(9), 1112–1121.

Forum, W. E. (2016, August 11). Las 10 tecnologías Emergentes de 2016. *Foro Económico Mundial*. Retrieved from https://www.weforum.org/es/agenda/2016/06/las-10-tecnologias-emergentes-de-2016/

Frewer, L. (1999). Risk perception, social trust, and public participation in strategicdecision making: implications for emerging technologies. *AMBIO - A Journal of the Human Environment*, *28*(6), 569. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=8gh&AN=8375444&site=ehost-live

Friedman, J., & Silberman, J. (2003). University technology transfer: do incentives, management, and location matter? *The Journal of Technology Transfer*, *28*(1), 17–30.
Gavankar, S., Anderson, S., & Keller, A. a. (2014). Critical Components of Uncertainty Communication in Life Cycle Assessments of Emerging Technologies. *Journal of Industrial Ecology*, *19*(3), 468–479. https://doi.org/10.1111/jiec.12183
Gaynor, G. (1999). *MANUAL DE GESTION EN TECNOLOGIA. TOMO 1*. Retrieved from http://dspace.ucbscz.edu.bo/dspace/handle/123456789/3173
Geisler, E. (1995). Industry–university technology cooperation: a theory of inter-organizational relationships. *Technology Analysis & Strategic Management*, *7*(2), 217–229.
Gil, A., & Zubillaga, F. (2006). Los ciclos de vida de las tecnologías y la evolución de sistemas. La existencia de factores limitantes en la innovación.
Godwin-Jones, R. (2003). Emerging technologies. *Language Learning & Technology*, *7*(2), 12–16.
González Arango, Ó., Schmal Simon, R., Gonzalez Arango, O., & Schmal Simon, R. (2005). Descripción del sistema universitario de Colombia y de Chile: una relación comparativa. *Cuadernos de Administración*, *18*(30), 221–240. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=35043724&lang=es&site=ehost-live
Gür, U., Oylumlu, İ. S., & Kunday, Ö. (2016). Critical assessment of entrepreneurial and innovative universities index of Turkey: Future directions. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2016.09.008
Halaweh, M. (2013). Emerging Technology: What is it? *Journal of Technology Management & Innovation*, *8*(3), 19–20. https://doi.org/10.4067/S0718-27242013000400010
Harmon, B., Ardishvili, A., Cardozo, R., Elder, T., Leuthold, J., Parshall, J., … Smith, D. (1997). Mapping the university technology transfer process. *Journal of Business Venturing*, *12*(6), 423–434.
Howland, K., Good, J., & Robertson, J. (2007). A learner-centred design approach to developing a visual language for interactive storytelling (pp. 45–52). ACM. Retrieved from http://dl.acm.org/citation.cfm?id=1297286
Hung, S.-C., & Chu, Y.-Y. (2006). Stimulating new industries from emerging technologies: challenges for the public sector. *Technovation*, *26*(1), 104–110.
Jiménez, C. N., Castellanos, O. F., & Morales, M. E. (2007). Tendencias y retos de la gestión tecnológica en economías emergentes. *Revista Universidad EAFIT*, *43*(148), 42–61. Retrieved from http://publicaciones.eafit.edu.co/index.php/revista-universidad-eafit/article/view/701
Jiménez, C. N., Maculan, A. M., Otálora, I., & Cunha, R. M. (2013). Reflexiones sobre los mecanismos de transferencia de conocimiento desde la universidad: el caso de las Spin-offs. *ALTEC 2013. XV Congreso Latino-Iberoamericano de Gestión Tecnológica*, 1–16. https://doi.org/10.13140/2.1.2656.0963
Khanagha, S., Volberda, H., Sidhu, J., & Oshri, I. (2013). Management innovation and adoption of emerging technologies: The case of cloud computing. *European Management Review*, *10*(1), 51–67. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/emre.12004/full
Llanos, R. A. (2004). La universidad: un factor clave para la innovación tecnológica empresarial. *Pensamiento Y Gestión: Revista de La División de Ciencias Administrativas de La Universidad Del Norte*, (16), 28–42. Retrieved from http://dialnet.unirioja.es/servlet/articulo?codigo=2497598
Miller, K., McAdam, R., & McAdam, M. (2016). A systematic literature review of university technology transfer from a quadruple helix perspective: toward a research agenda. *R&D Management*.
Mowery, D. C., & Shane, S. (2002). Introduction to the special issue on university entrepreneurship and technology transfer. *Management Science*, *48*(1), v–ix.
Navas, M. E., Londoño, E., Ruiz, S., & Ruiz, D. (2012). State of the Art of Emerging Technologies in Colombia. In *2012 Proceedings of PICMET '12: Technology Management for Emerging Technologies* (pp. 358–367).
Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., & Crowston, K. (2012). The future of citizen science: emerging technologies and shifting paradigms. *Frontiers in Ecology and the Environment*, *10*(6), 298–304.
Ortiz-Riaga, M. C., & Morales-Rubiano, M. E. (2011). La extensión universitaria en América Latina: concepciones y tendencias. *Educación Y Educadores*, *14*(2), 349–366.
Pineda, L. (2013). PROSPECTIVA ESTRATÉGICA EN LA GESTIÓN DEL CONOCIMIENTO: UNA PROPUESTA PARA LOS GRUPOS DE INVESTIGACIÓN COLOMBIANOS. (Spanish). *Strategic Prospective in Knowledge Management: A Proposal for Research Groups in Colombia. (English)*, *21*(1), 237–259.
QS World University Rankings. (2015). QS World University Rankings® 2014/15.
Ramírez Salazar, M. del P., & García Valderrama, M. (2010). La Alianza Universidad-Empresa-Estado: una estrategia para promover innovación. *Revista EAN*, *68*, 112–133.
Review, M. I. T. T. (2016, August 11). "MIT Technology Review":10 Tecnologías Emergentes de 2016.

Retrieved from http://www.technologyreview.es/negocios/49368/mit-technology-review-presenta-las-10-tecnologias/

Rip, A. (2011). The future of research universities. *Prometheus*, *29*(4), 443–453. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/08109028.2011.639566

Siegel, D. S., Waldman, D., & Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. *Research Policy*, *32*(1), 27–48.

Silva, A., & Nuño, J. P. (2014). Design of an Expert System Model for the Analysis of the Innovation Technology Management Process: A Case Study at the University of Coahuila, México. *IIE Annual Conferance*.

Spendolini, M. J. (1992). *The Benchmarking Book*. *Compensation & Benefits Review* (Vol. 24). https://doi.org/10.1177/088636879202400505

Suárez, & Díaz. (2013). La investigación científica latinoamericana en el contexto mundial. In *GT N°1 Ciencia, Tecnología e Innovación*.

Tapias G., H. (2000). GESTIÓN TECNOLÓGICA Y DESARROLLO TECNOLÓGICO. Universidad de Antioquia. Retrieved from http://datateca.unad.edu.co/contenidos/203029/contenidos gestion tecnologica/GESTION_TECNOLOGICA_Y_DESARROLLO_TECNOLOGICO.pdf

Tegarden, L. F., Lamb, W. B., Hatfield, D. E., & Ji, F. X. (2012). Bringing emerging technologies to market: Does academic research promote commercial exploration and exploitation. *IEEE Transactions on Engineering Management*, *59*(4), 598–608. https://doi.org/10.1109/TEM.2011.2170690

Valencia-Rodríguez, M. (2013). Generación Y Transferencia De Conocimiento / Generation and Transfer of Knowledge. *Ingeniería Industrial*, *34*(2), 178–187.

Valencia, Morales, Vanegas, & Benjumea. (2017). Percepción y conocimiento de los docentes universitarios sobre los procesos investigativos universitarios : estudio de caso, 1–20.

Villa, E. (2015). *Análisis de la Gestión de Tecnologías Emergentes (GTE) en grupo de investigación colombiano e identificación de brechas respecto a referentes internacionales*. Universidad Nacional de Colombia, Medellín. Retrieved from http://www.bdigital.unal.edu.co/50824/

Villa, E., Echeverry, J., & Jiménez, C. (2015). Perspectives of university magement from a comparative analysis of the management of traditional and emerging technologies. (pp. 775–792). Retrieved from https://www.iet-c.net/publication_folder/ietc/ietc2015.pdf

Villa, E. & Jiménez, C. N. (2016). Gestión de Tecnologías Emergentes : Estudio de Caso en un grupo de investigación universitario colombiano, (c), 1–16. Retrieved from http://www.revistaespacios.com/a16v37n31/16373114.html

Yin, R. (2003). Case Study Research: Design and Methods. Sage Publications Inc.