

Integration analysis of solutions based on software as a service to implement Educational Technological Ecosystems

PhD Thesis

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Abstract

One of the main characteristics of the current Knowledge Society lies in the value of knowledge as an active resource in any kind of entity, from educational institutions to large corporate companies. Knowledge management emerges as a competitive advantage in such a way that entities allocate part of their resources to develop their capacity to share, create and apply new knowledges continuously over time.

Technology, considered the engine, the core element, in the Information Society, becomes a support for learning, for the transformation of tacit knowledge into explicit, and also individual knowledge into group one. Internet, information and communication technologies and in particular the information systems go from being elements that guide the development of society to being tools whose development is guided by the needs of knowledge management and learning processes.

The technological ecosystems, considered the evolution of the traditional information systems, are positioned as knowledge management systems that encompass both the technological component and the human factor. In the case that knowledge management is aimed at fundamentally supporting learning processes, the technological ecosystem might be called learning ecosystem.

The metaphor of ecosystems, which comes from the biology area, is used in different contexts to convey the evolutionary nature of processes, activities and relationships. The use of the natural ecosystem concept is applied to the technological field to reflect a set of characteristics or properties of natural ecosystems that can be transferred to technological ecosystems or software ecosystems in order to provide solutions that allow solving knowledge management problems, and which adapt to the constant changes suffered by any kind of entity or context in which some type of technological solution is deployed.

Despite the advantages offered by technological ecosystems, the development of this type of solutions has greater complexity than traditional information systems. The problems inherent to software engineering, such as the interoperability between components or the evolution of the ecosystem, are combined with the difficulty of managing complex knowledge and the diversity of people involved.

The different challenges and problems of technological ecosystems, primarily those focused on managing knowledge and learning, require improving the definition and development processes of this type of technological solutions.

The present PhD thesis focuses on providing an architectural framework that allows improving the definition, development and sustainability of technological ecosystems for learning. This framework will be composed, mainly, of two results associated with this research; an architectural pattern that allows to solve the problems detected in real learning ecosystems and a learning ecosystem metamodel, based on the pattern, that allows to apply Model Driven Engineering to sustain the definition and development of learning ecosystems.

To carry out the research, three cycles have been defined following the Action-Research methodological framework. The first cycle was focused on the analysis of several real case studies in order to obtain a domain model of the problem. Technological ecosystems for knowledge and learning management deployed in heterogeneous contexts have been analyzed, in particular, the University of Salamanca, the GRIAL research group and the European project TRAILER (focused on managing informal learning at institutions and companies). As a result of this cycle, a set of characteristics that a technological ecosystem must consider was detected and an architectural pattern was defined. The pattern allows laying the foundations of the ecosystem, giving solution to some of the detected problems and ensuring the flexibility and adaptability of the components of the ecosystem in order to allow its evolution.

The second cycle was focused on the improvement and validation of the architectural pattern. The problems detected in the previous cycle was modeled using Business Process Model and Notation. To do this, the problems related to similar knowledge management processes was clustered and a diagram with a high abstraction level was made for each cluster of problems. Then, for each diagram, once again the problems to be solved was identified and a new diagram was defined applying the pattern. This allowed to validate the architectural pattern and lay the foundations for its formalization.

Finally, the third cycle raised the Model Driven Development of technological ecosystems for the knowledge and learning management. In particular, a learning ecosystem metamodel, based on the architectural pattern specified in the previous cycle, was defined. The metamodel was validated through a set of model-to-model

transformations automated through transformation rules. In order to carry out this process, a platform specific metamodel was defined. This metamodel provides a set of recommendations, both technological and human, to implement learning ecosystems based on open source software.

The learning ecosystem metamodel and the platform specific metamodel to define ecosystems based on open source software provide the necessary guides to model learning ecosystems that solve the main problems detected in this type of software solutions.

The three real case studies that were developed to validate the results obtained during the Action-Research cycles, especially the architectural pattern to define learning ecosystems, the learning ecosystem metamodel and the platform specific metamodel to model ecosystems based on open source software, allow us to conclude that it is possible to improve the definition and development of technological ecosystems focused on knowledge and learning processes management. More specifically, the use of model-driven engineering, based on a solid architectural proposal, allows defining learning ecosystems that evolve and adapt to the changing needs of the environment and users, as well as solving a set of common problems identified in this type of technological solutions.

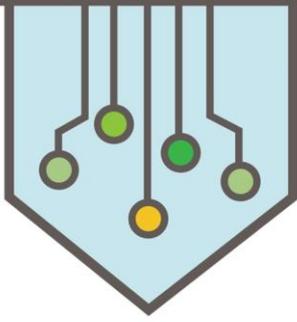
Keywords: Technological Ecosystem, Software Ecosystem, Learning Ecosystem, Information Systems, Knowledge Management, Model Driven Development, Architectural Pattern, Human Factor.

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Chapter 6

Conclusions

The objective of this chapter is to present the conclusions of this doctoral thesis. To do this, we start with the initial problem and describe the main contributions of the work developed to accept the hypothesis formulated at the beginning of the investigation. Namely, the possibility of improving the processes of definition and development of technological ecosystems for learning, with the aim of allowing them to evolve and adapt to the needs of the environment and users.

Moreover, a set lines for future work are proposed, since the present proposal lays the foundations to continue research in the field of technological ecosystems focused on knowledge management.

This chapter is organized into four sections. First, a summary of the research work developed is presented. Second, the main contributions made are described. Third, the research lines that can be developed from this work are presented. Finally, the results associated with the doctoral thesis are listed, among which are a series of impact publications, a doctoral stay and a set of research projects.

6.1 Summary of work done

Technological ecosystems are a general framework that allows defining and developing any type of technological solution in which data and information are the center of the

problem [1]. The metaphor of technological ecosystem comes from the world of biology and in recent years has been transferred to other areas to better represent the evolutionary component of the relationships that take place in social, economic, etc. [2]. In particular, in the technological field, the concept of business ecosystem proposed by Moore [3] and Lansiti [4] has been adapted in order to define the software ecosystems or technological ecosystems.

There are many definitions of natural ecosystems, but all refer to three main elements: organisms or biotic factors; the relationships between organisms; and the physical environment or abiotic factors. The definition of technological ecosystem proposed in this doctoral thesis extrapolates these elements to the field of technology in such a way that the software components and the people that form the technological ecosystem correspond to the biotic factors; the information flows represent or establish the relationships between the organisms; and abiotic factors are the elements that allow the functioning of the ecosystem (hardware, network connection, etc.). In this way, a technological ecosystem is a set of users and software components that are related to each other through information flows in a physical medium that provides support for said flows.

Technological ecosystems are positioned as the evolution of traditional information systems with two key elements to be highlighted. First, technological ecosystems have a strong evolutionary component based on the integration of different software tools capable of evolving separately and together in order to adapt to the changing needs of the context. Second, people are a fundamental component of the ecosystem, not just simple users who interact with the system, but elements that direct the evolution and functioning of the system.

Technological ecosystems can be oriented to different domains, depending on the problems they solve. In the field of education, technological ecosystems for learning pose a true network of learning services beyond providing a collection of fashion technologies [5-8]. These technological ecosystems make it possible to establish learning ecologies, learning environments with a strong interactive component that allow the exchange of knowledge in an informal and unstructured way.

Despite the advantages offered by technological ecosystems, the development of this type of solutions has a greater complexity than traditional information systems. Learning ecosystems must be able to incorporate the emerging tools for knowledge

management, as well as withdraw those that are obsolete or that users do not use. Ecosystems must be able to withstand the increase in internal complexity to offer more functionality and simplicity to users in a transparent manner. That is, the interoperability between the different components must ensure a high degree of integration and cohesion, while allowing the ecosystem to evolve and adapt to the changing needs of the environment and users.

In this context, the present doctoral thesis hypothesizes that it is possible to improve the processes of definition and development of technological ecosystems for learning, with the aim of allowing the ecosystem to evolve and adapt to the changing needs of the environment and of the users. These improvements should allow solving the main problems associated with technological ecosystems. This hypothesis allows to state the main objective and a set of sub-objectives that must be reached to affirm it. In particular, the main objective is to propose a solution based on software and engineering architectures guided by models or Model Driven Development (MDE) that allows improving the processes of definition, development and evolution of technological ecosystems based on open source software for the management of knowledge and processes of learning in heterogeneous contexts.

The research carried out is part of the Action-Research methodology and through several cycles responds to each of the objectives set, all based on a study of the state of the art carried out through a systematic review. This has allowed us to determine a set of shortcomings in the architectural and engineering proposals directed by models in the learning and knowledge management ecosystems.

In response to these lacks and to validate the initial hypothesis, two learning ecosystem metamodels with a solid architectural base have been developed; one focused on modeling the conceptual part of the ecosystem, namely, an independent platform metamodel, and another focused on providing the necessary guidelines to transform concepts into real solutions, or in other words a specific platform metamodel. The definition of both metamodels is based on a reference architecture defined by an architectural pattern to define learning ecosystems. This pattern allows defining the architecture of learning ecosystems capable of evolving over time and adapting to internal and external factors to the organization, as well as incorporating the human factor inherent in knowledge management processes as part of the ecosystem itself. Likewise, the metamodel that emerges from this pattern allows to define all the

elements of real learning ecosystems capable of adapting to heterogeneous contexts. Finally, the platform-specific metamodel allows transforming concepts into open source software components, so the combination of these three results allows us to affirm that the main objective and the sub-objectives of the doctoral thesis have been reached and, therefore, the initial hypothesis is valid.

6.2 Conclusions

The main objective of the present investigation is to propose a solution based on software and engineering architectures directed by models or MDE, that allows to improve the processes of definition, development and evolution of technological ecosystems based on open source software for the management of knowledge and learning processes in heterogeneous contexts.

Throughout the investigation, different results have been obtained that have allowed to reach the secondary objectives defined from the main objective mentioned, as well as to confirm the formulated hypothesis.

In this sense, there are three main contributions of the present doctoral thesis:

- The architectural pattern to define learning ecosystems [2, 9-18].
- The learning ecosystem metamodel [19-23].
- The platform-specific metamodel to define ecosystems based on open source software [23, 24].

First, the architectural pattern provides a reference architecture to define technological ecosystems focused on knowledge management and learning processes in heterogeneous contexts. The pattern allows to define real ecosystems that support evolution over time and that incorporate the human factor as part of the ecosystem itself, not only as actors that interact with the ecosystem, but through the methodology as a fundamental part for success of the ecosystem.

The definition of the pattern covers two of the three Action-Research cycles that have been carried out. This is because the pattern supports the definition of the two metamodels that are part of the main contributions of the doctoral thesis. For this reason, the process of defining the pattern includes six case studies of real ecosystems in heterogeneous contexts.

On the one hand, three case studies have been used to identify the main problems of the learning ecosystems and serve as a basis to determine the main characteristics that a solution of this type should have, that is, the characteristics on which the pattern definition is based. The other three case studies have been used to carry out the validation of the pattern, all of them are defined from the architectural pattern and framed in projects or contracts in which the doctoral candidate has been involved as part of the research process of the doctoral thesis. Highlight the last case study, the WYRED ecosystem [18, 25], although it is part of the second Action-Research cycle, it has been carried out after completing the validation stage of the pattern, so its objective has been to ratify the validity of the pattern and apply all the acquired knowledge throughout the development of the present doctoral thesis.

Moreover, the validation process of the pattern has included the validation of the human factor itself and the need for the methodology as a key element of the pattern. For this, the second case study developed in the context of the PhD Program Education in the Knowledge Society [26-28] has been transferred to two Mexican universities, one private and one public, to manage two doctoral programs. In both implementations the base of the ecosystem is the same, but they have evolved in a totally different way. The analysis of each of the ecosystems after several years in operation has made it possible to determine that the lack of methodology in the two ecosystems implemented in Mexican universities has been the trigger for the lack of activity in these ecosystems.

The second relevant contribution of the present doctoral thesis is the learning ecosystem metamodel. It is a metamodel initially defined from the MOF (Meta-Object Facility) standard [29] and subsequently transformed into an Ecore instance in order to use automated processes for the validation of the metamodel. The aim of the metamodel is to allow the definition of models of real learning ecosystems based on the architectural pattern previously described, in such a way that the models instantiated from the metamodel serve as a guide to later develop the corresponding technological ecosystem.

The learning ecosystem metamodel represents the different elements that make up a technological ecosystem: the technological components, the human factor and the information flows. Moreover, it incorporates a set of restrictions defined in Object Constraint Language (OCL) [30] that allow to ensure the correct use of the different concepts defined in the metamodel. The restriction to ensure minimum elements in any

ecosystem should be highlighted, following the guidelines provided by the architectural pattern.

The metamodel has been validated in order to provide a solid and reliable solution. The validation process consisting of eight phases has also ensured the quality of the metamodel. On the one hand, a quality framework has been applied to the three metamodels involved in the process. On the other hand, some phases have been used to review and improve the Ecore learning ecosystem metamodel.

The third contribution is the platform-specific metamodel to define learning ecosystems based on open source software. This metamodel is part of the validation process of the learning ecosystem metamodel, but it has great relevance to achieve the objective of this doctoral thesis, since from the beginning there has been special emphasis on the use of open source software to define the learning ecosystems. The present platform-specific metamodel, combined with a set of transformation rules defined in ATL (ATLAS Transformation Language) [31-33], allows the translation of learning ecosystem models into platform specific models, where the software components of the ecosystem are defined from open source software.

Although there is no explicit validation of the platform-specific metamodel for learning ecosystems, the validation process in which it is involved ensures its validity and quality. In this sense, the case study carried out to conclude the validation allows to affirm that the models instantiated from the learning ecosystem metamodel and, subsequently, translated into instances of the platform-specific metamodel, correspond to real ecosystems defined initially from the architectural pattern.

None of the two metamodels defined and validated in this doctoral thesis aims to allow the automatic generation of code. Its objective is to serve as a map upon implementing learning ecosystems based on open source software, so the metamodel provides a set of recommendations about the components that must be present in the ecosystem and the necessary information flows to satisfy the methodology.

Finally, although it is not a contribution directly related to the objective of this research, it is worth highlighting the systematic literature review (SLR) carried out to determine the systematic reviews and mappings on software ecosystems or technological ecosystems carried out over the years. This review, in addition to identifying the need to carry out the SLR described in Chapter 3, provides a state of the art at a global level

that covers different aspects of technological ecosystems, taking as reference points the systematic mapping carried out by Barbosa and Alves [34] in 2011 and the systematic review conducted by Manikas and Hansen [35] in 2013 and updated in 2016 [36].

The results of this doctoral thesis do not replace other existing solutions in the field of technological ecosystems or software ecosystems. They are postulated as a solution that covers a gap identified through the systematic literature review described in Chapter 3. In particular, the studies analyzed to determine the need for a systematic review [34-46] have made it possible to identify the lack of studies in the field of Model-Driven Engineering applied to technological ecosystems and more specifically to learning ecosystems.

Moreover, the different solutions and studies analyzed make it possible to complement the present proposal, in such a way that the use of Key Performance Indicators (KPI) [44], the improvement of the governance mechanisms [46], the requirements engineering [37] or the solutions or proposals to improve the state of the ecosystem [41], can be applied to the learning ecosystems defined from the architectural pattern and the learning ecosystem metamodels.

The present doctoral thesis provides a solid base to implement technological ecosystems that cover the needs of knowledge management and learning processes in any type of context, from small and medium enterprises to public institutions or large corporations. These are solutions that incorporate the human factor as an inherent part of the ecosystem and that are capable of evolving to adapt to both internal and external changes, which allows the ecosystem life cycle to be greater than traditional information systems life cycle.

6.3 Future research lines

The work developed in this doctoral thesis provides the basis to continue research related to learning ecosystems, in particular, and to technological ecosystems in general, since this type of software solutions can be applied in heterogeneous contexts to manage different knowledge management processes.

First, the possibility of applying the methodology defined in this research to adapt the architectural pattern and the learning ecosystem metamodel to other contexts, such as the health and mental wellbeing of people. In this line, several studies have been analyzed as part of the systematic review but the application of the pattern and the

metamodel to this context focuses on knowledge management in these areas, not so much in providing a telemedicine or AAL ecosystem [47-51].

Second, the learning ecosystem metamodel provides a conceptual basis that can be translated into different metamodels. The platform-specific metamodel to define learning ecosystems based on open source software is not the only way to develop learning ecosystems. You can work on the definition and validation of other platform-specific metamodels that allow extending the solution proposed in this doctoral thesis.

Finally, although the need for the human factor as an inherent part of the ecosystem, and particularly through methodology and management, has been evident through several case studies, as future work can be explored the human factor in ecosystems since a point of view closer to the social sciences, namely, through the definition of instruments that allow evaluating the impact of methodology and management on learning ecosystems. Likewise, these studies can serve as a basis to provide the necessary guidelines to define methodologies as base to build ecosystem for learning or knowledge management.

6.4 Associated results

Throughout the development of the present doctoral thesis, a set of scientific publications have been carried out to validate the proposal. The process of publication in different media has allowed to obtain feedback from experts in the area. Specifically, 9 articles have been published in indexed journals, 22 papers in international conference proceedings, 1 book chapter, 1 edited book and 1 technical report. Figure 1 shows a summary of the publications organized by year and by type.

In relation to journal publications, all are indexed in JCR or in SJR. Figure 2 shows the classification in quartiles of the publications indexed in both indices.

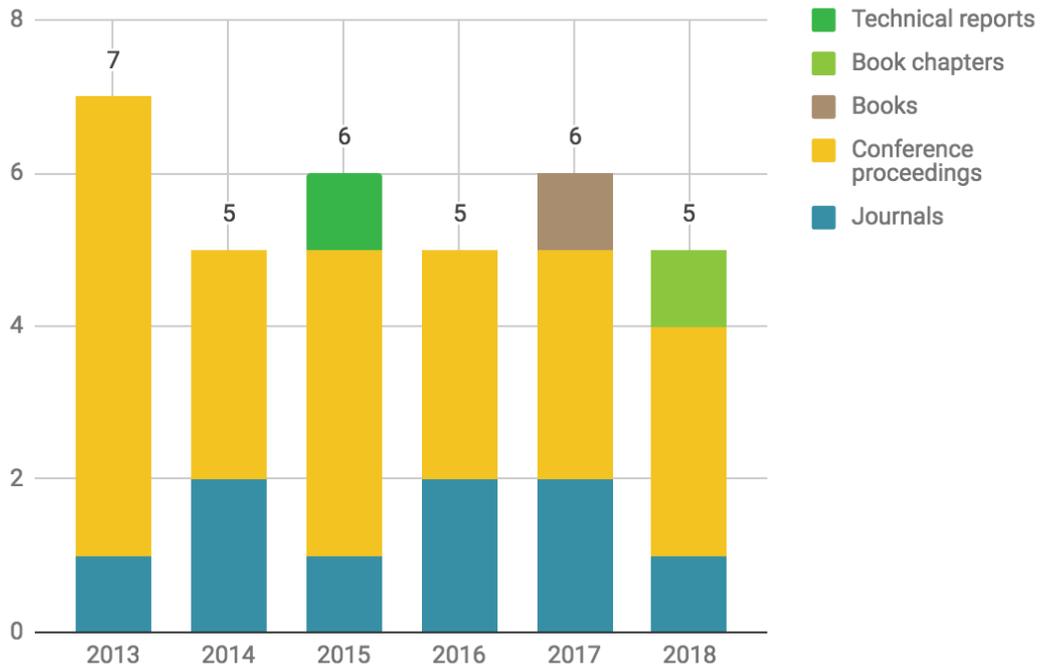


Figure 1. Scientific production associated with the doctoral thesis organized by year and type of publications. Source: own elaboration

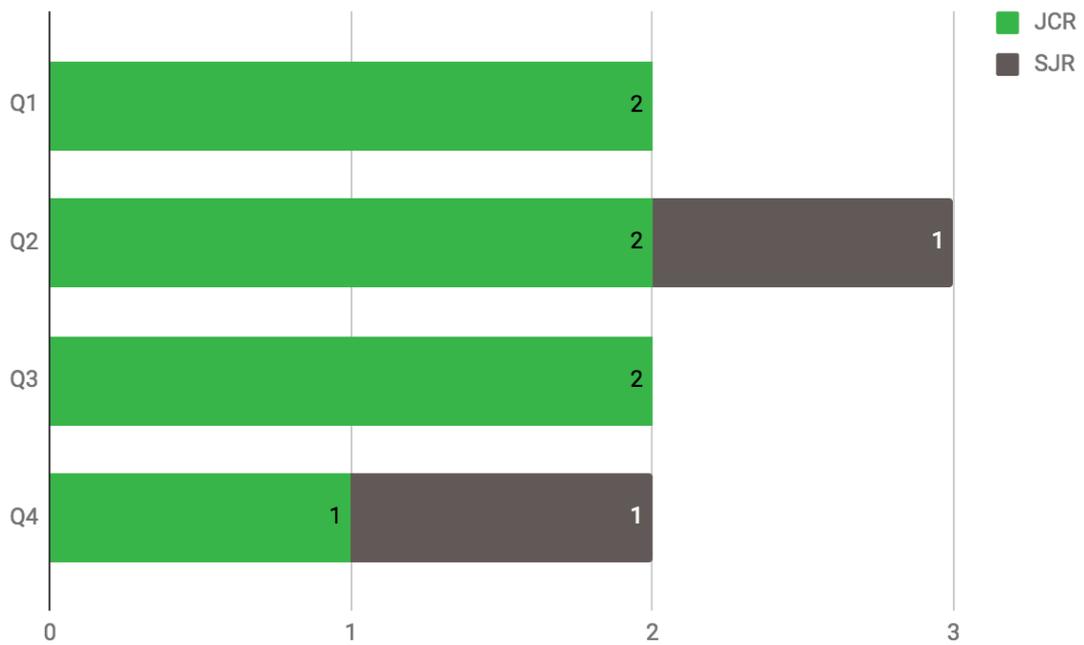


Figure 2. Scientific production associated with the doctoral thesis organized by type of publication. Source: own elaboration

Then, the national and international publications related to this doctoral thesis are detailed:

- Journals indexed in JCR
 1. García-Peñalvo, F. J., Conde-González, M. Á., Zangrando, V., García-Holgado, A., Seoane-Pardo, A. M., Alier, M., Galanis, N., Brouns, F., Vogten, H., Griffiths, D., Mykowska, A., Alves, G. R., & Minović, M. (2013). TRAILER project (Tagging, recognition, acknowledgment of informal learning experiences). A Methodology to make visible learners' informal learning activities to the institutions. *Journal of Universal Computer Science*, 19(11), 1661-1683. doi:10.3217/jucs-019-11-1661. ISSN: 0948-695X (JCR SCI – COMPUTER SCIENCE, SOFTWARE ENGINEERING – Q4 (99 de 105); COMPUTER SCIENCE, THEORY & METHODS – Q4 (89 de 102) – JIF 0.401).
 2. Conde-González, M. Á., García-Peñalvo, F. J., Rodríguez-Conde, M. J., Alier, M., & García-Holgado, A. (2014). Perceived openness of Learning Management Systems by students and teachers in education and technology courses. *Computers in Human Behavior*, 31, 517-526. doi:10.1016/j.chb.2013.05.023. ISSN: 0747-5632 (JCR SSCI – PSYCHOLOGY, MULTIDISCIPLINARY – Q1 (20 de 129); PSYCHOLOGY, EXPERIMENTAL – Q2 (24 de 85) – JIF 2.694).
 3. Conde-González, M. Á., García-Peñalvo, F. J., Fernández-Llamas, C., & García-Holgado, A. (2015). The Application of Business Process Model Notation to describe a Methodology for the Recognition, Tagging and Acknowledge of Informal Learning Activities. *International Journal of Engineering Education (IJEE)*, 31(3), 884-892. ISSN:0949-149X (JCR SCI – ENGINEERING, MULTIDISCIPLINARY – Q3 (61 de 85); EDUCATION, SCIENTIFIC DISCIPLINES – Q4 (31 de 40) – JIF 0.559).
 4. García-Holgado, A., & García-Peñalvo, F. J. (2016). Architectural pattern to improve the definition and implementation of eLearning ecosystems. *Science of Computer Programming*, 129, 20-34. doi:10.1016/j.scico.2016.03.010. ISSN: 0167-6423 (JCR SCI – COMPUTER SCIENCE, SOFTWARE ENGINEERING – Q3 (71 de 106) – JIF 1.064).
 5. García-Peñalvo, F. J., Franco Martín, M., García-Holgado, A., Toribio Guzmán, J. M., Largo Antón, J., & Sánchez-Gómez, M. C. (2016).

- Psychiatric patients tracking through a private social network for relatives: development and pilot study. *Journal of Medical Systems*, 40(7), Paper 172. doi:10.1007/s10916-016-0530-5. ISSN: 1573-689X (JCR SCI – HEALTH CARE SCIENCES & SERVICES – Q2 (28 de 90); MEDICAL INFORMATICS – Q2 (9 de 23) – JIF 2.456).
6. Toribio-Guzmán, J. M., García-Holgado, A., Soto Pérez, F., García-Peñalvo, F. J., & Franco Martín, M. (2017). Usability Evaluation of a Private Social Network on Mental Health for Relatives. *Journal of Medical Systems*, 41(9), 137. doi:10.1007/s10916-017-0780-x. ISSN: 1573-689X (JCR SCI – HEALTH CARE SCIENCES & SERVICES – Q2 (46 de 94); MEDICAL INFORMATICS – Q3 13 de 25) – JIF 2.098).
 7. García-Holgado, A., & García-Peñalvo, F. J. (2018). Validation of the learning ecosystem metamodel using transformation rules. *Future Generation Computer Systems*, *In press*. (JCR SCI - COMPUTER SCIENCE, THEORY & METHODS – Q1 (7 de 103) – JIF 4.639).
- Journals indexed in Scopus
 1. Viegas, C., Marques, M., Alves, G., Mykowska, A., Galanis, N., Alier, M., Brouns, F., Janssen, J., García-Peñalvo, F. J., García-Holgado, A., Zangrando, V., & Conde-González, M. Á. (2014). TRAILER: A Tool for Managing Informal Learning. *International Journal of Human Capital and Information Technology Professionals (IJHCITP)*, 5(3), 1-17. doi:10.4018/ijhcitp.2014070101. ISSN: 1947-3478 (SJR 0.265 – COMPUTERS SCIENCE (MISCELLANEOUS) – Q2; MANAGEMENT OF TECHNOLOGY AND INNOVATION – Q3).
 2. Tena-Espinoza-de-los-Monteros, M. A., García-Holgado, A., Merlo-Vega, J. A., & García-Peñalvo, F. J. (2017). Diseño de un plan de visibilidad científica e identidad digital para los investigadores de la Universidad de Guadalajara (México). *Ibersid: Revista de sistemas de información y documentación*, 11(1), 83-92. ISSN 1888-0967. (SJR 0.116 – COMMUNICATION – Q4; COMPUTER NETWORKS AND COMMUNICATIONS – Q4; INFORMATION SYSTEMS – Q4; LIBRARY AND INFORMATION SCIENCES – Q4).

- International conference proceedings
 1. García-Holgado, A., & García-Peñalvo, F. J. (2013). Análisis de integración de soluciones basadas en software como servicio para la implantación de ecosistemas tecnológicos corporativos. In J. Cruz-Benito, A. García-Holgado, S. García-Sánchez, D. Hernández-Alfageme, M. Navarro-Cáceres, & R. Vega-Ruiz (Eds.), *Avances en Informática y Automática. Séptimo Workshop* (pp. 55-72). Salamanca: Departamento de Informática y Automática de la Universidad de Salamanca. ISBN: 846958670X.
 2. García-Peñalvo, F. J., Zangrando, V., García-Holgado, A., Conde-González, M. Á., Seoane-Pardo, A. M., Alier, M., Galanis, N., López, J., Janssen, J., Brouns, F., Finders, A., Berlanga, A., Sloep, P., Griffiths, D., Johnson, M., Waszkiewicz, E., Mykowska, A., Minovic, M., Milovanovic, M., Marques, M. A., Viegas, M. C., & Alves, G. R. (2013). A Tool to Aid Institutions Recognize Their Employees Competences Acquired by Informal Learning. In D. Hernández-Leo, T. Ley, R. Klamma, & A. Harrer (Eds.), *Scaling up Learning for Sustained Impact* (Vol. LNCS 8095, pp. 552-555). Berlin, Heidelberg: Springer. doi:10.1007/978-3-642-40814-4_56. ISBN: 978-3-642-40813-7. (SJR 0.36 – COMPUTER SCIENCES (MISCELLANEOUS) – Q2; THEORETICAL COMPUTER SCIENCES – Q3).
 3. Conde-González, M. Á., García-Peñalvo, F. J., Zangrando, V., García-Holgado, A., Seoane-Pardo, A. M., Alier, M., Galanis, N., Griffiths, D., Johnson, M., Janssen, J., Brouns, F., Vogten, H., Finders, A., Sloep, P., Marques, M. A., Viegas, M. C., Alves, G. R., Waszkiewicz, E., Mykowska, A., Minovic, M., & Milovanovic, M. (2013). Enhancing informal learning recognition through TRAILER project. In F. J. García-Peñalvo, M. Á. Conde-González, & D. Griffiths (Eds.), *Proceedings of the Workshop on Solutions that Enhance Informal Learning Recognition (WEILER 2013). Co-located with 8th European Conference on Technology Enhanced Learning (EC-TEL 2013) (Paphos, Cyprus, September 18, 2013)*: CEUR Workshop Proceedings. ISSN: 1613-0073.
 4. Viegas, C., Marques, M., Alves, G. R., Galanis, N., Brouns, F., Janssen, J., Waszkiewicz, E., Mykowska, A., Zangrando, A., García-Holgado, A., Conde-González, M. Á., & García-Peñalvo, F. J. (2013). Using the

- TRAILER tool for managing informal learning in academic and professional contexts: the learner perspective. In F. J. García-Peñalvo (Ed.), *Proceedings of the First International Conference on Technological Ecosystem for Enhancing Multiculturality (TEEM'13) (Salamanca, Spain, November 14-15, 2013)* (pp. 529-534). New York, NY, USA: ACM. doi: 10.1145/2536536.2536617. ISBN: 978-1-4503-2345-1.
5. García-Holgado, A., & García-Peñalvo, F. J. (2013). The evolution of the technological ecosystems: an architectural proposal to enhancing learning processes *Proceedings of the First International Conference on Technological Ecosystem for Enhancing Multiculturality (TEEM'13) (Salamanca, Spain, November 14-15, 2013)* (pp. 565-571). New York: ACM. doi: 10.1145/2536536.2536623. ISBN: 978-1-4503-2345-1.
 6. García-Peñalvo, F. J., García-Holgado, A., & Cruz-Benito, J. (2013). Formal and informal learning experiences in multicultural scopes *Proceedings of the First International Conference on Technological Ecosystem for Enhancing Multiculturality (TEEM'13) (Salamanca, Spain, November 14-15, 2013)* (pp. 523-527). New York, NY, USA: ACM. doi: 10.1145/2536536.2536616. ISBN: 978-1-4503-2345-1.
 7. García-Holgado, A., & García-Peñalvo, F. J. (2014). Patrón arquitectónico para la definición de ecosistemas de eLearning basados en desarrollos open source. In J. L. S. Rodríguez, J. M. D. Beardo, & D. Burgos (Eds.), *Proceedings of 2014 International Symposium on Computers in Education (SIIE) (Logroño, La Rioja, Spain, November 12-14, 2014)* (pp. 137-142). Logroño, La Rioja, España: Universidad Internacional de la Rioja (UNIR). ISBN: 978-84-16125-41-8.
 8. García-Holgado, A., & García-Peñalvo, F. J. (2014). Knowledge management ecosystem based on Drupal platform for promoting the collaboration between public administrations. In F. J. García-Peñalvo (Ed.), *Proceedings of the Second International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'14) (Salamanca, Spain, October 1-3, 2014)* (pp. 619-624). New York, NY, USA: ACM. doi: 10.1145/2669711.2669964. ISBN: 978-1-4503-2896-8.
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It is worth highlighting the completion of a three-month doctoral stay, from January 9, 2016 to April 9, 2016, at the School of Education, Humanities and Social Sciences (EEHCS), current School of Humanities and Education, of the Tecnológico de Monterrey (Mexico). During the stay, the technological ecosystem for knowledge management in the PhD programs of the EEHCS was defined and implemented. This has allowed studying the transfer of technological ecosystems between different contexts, specifically between two universities, the University of Salamanca, where the ecosystem was originally implemented, and the Tecnológico de Monterrey, where the ecosystem has been transferred successfully.

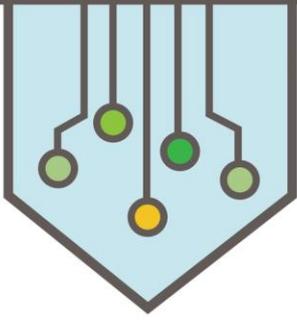
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- *Tagging, Recognition and Acknowledgment of Informal Learning Experiences* (TRAILER) (ref. 519141-LLP-1-2011-1-ES-KA3-KA3MP). Funding by European

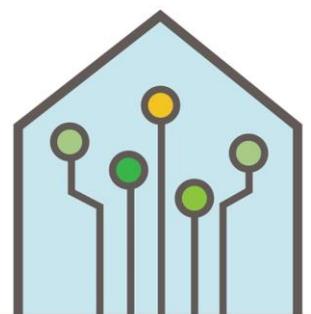
Union through the sub-programme ICT KA 3 Multilateral projects in the Lifelong Learning Programme. Coordinator: GRIAL – University of Salamanca. From 1-1-2012 to 31-12-2013. Budget: 544.349€

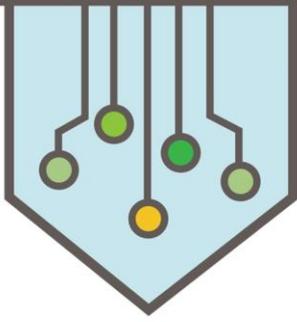
- *Virtual Alliances for Learning Society (VALS)* (ref. 540054-LLP-1-2013-1-ES-ERASMUS-EKA). Funding by European Union through Lifelong Learning Programme and the sub-programme Erasmus Knowledge Alliances. Coordinator: GRIAL – University of Salamanca. From 1-10-2013 to 9-02-2016. Budget: 533.337€
- *Ecosistema tecnológico para el Observatorio de Empleabilidad y Empleo Universitarios (OEEU) de la Cátedra UNESCO de Gestión y Política Universitaria de la Universidad Politécnica de Madrid*. Collaboration with the UNESCO Chair in Higher Education Management and Policy at the Polytechnic University of Madrid (Spain). From 2014 until nowadays.
- *WYRED: netWorked Youth Research for Empowerment in the Digital society* (ref. 727066). Funding by European Union through the Horizon 2020 programme, Europe in a changing world – inclusive, innovative and reflective Societies. Coordinator: GRIAL – University of Salamanca. From 1-11-2016 to 31-10-2019. Budget: 993.662,50€
- *TE-CUIDA, propuesta de un Ecosistema TEcnológico para apoyo a CUIDAdores asistenciales* (ref. SA061P17). Funding by Castilla y León Education Department (Spain) in the support programme for research projects co-financed by the European Regional Development Fund. Principal investigator: Francisco J. García-Peñalvo. From 26-7-2017 to 31-12-2019. Budget: 117.000€
- *A Digital Ecosystem Framework for an Interoperable NEtwork-based Society (DEFINES)* (ref. TIN2016-80172-R) Funding by *Ministerio de Economía y Competitividad* in the 2016 call of R+D+i projects of the Spanish State Research, Development and Innovation Program Oriented to the Challenges of Society. Principal investigator: Francisco J. García-Peñalvo. From 1-1-2017 to 31-12-2020. Budget: 82.900€

Finally, part of the results of the present research have been published in GitHub under GPLv3 license <https://github.com/aliciagh/ecometamodel>, and the results of the systematic review and mapping of the literature <https://github.com/aliciagh/slr-architecturesMDE-SECO>.



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