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The effective integration of ICTs in universities: the role of knowledge and academic experience of professors

Albert Cubeles & David Riu

Management and Technology Department, La Salle – Universitat Ramon Llull, Barcelona, Spain

ABSTRACT

Despite the fact that investment in information and communication technologies (ICTs) in universities has increased dramatically, there is no clear evidence that ICTs have been incorporated effectively in the process of teaching and learning. This article investigates the knowledge that university professors need in order to integrate ICTs into their teaching practices. The Technological Pedagogical Content Knowledge (TPACK) model has been frequently used for this purpose, but its application in higher education has been limited. The objectives of the study are both the confirmation of the applicability of the model in universities, and the study of the key variables of professors for effective technology integration. A self-assessment questionnaire was administered to 113 professors of three different university schools. The results of this study confirm the usefulness of the model and revealed significant differences regarding the previous academic experience of the teacher. The investigation thus contributes to studies that aim to foster the effective integration of technology in teaching and learning.

KEYWORDS: Technology; higher education; knowledge;TPACK

Introduction and current state

Spanish universities have been making conscientious efforts to incorporate information and commu-nication technologies (ICTs) into their teaching methodology for the last 20 years (Baelo & Cantón, 2010). According to the latest report published by the Conference of Spanish Rectors (CRUE, 2015), the implementation of new technologies as a learning support has consolidated and currently accounts for 3.5% of the global annual budget of universities. Commitment to ICTs can be seen in different aspects, with the three most notable being updated classroom equipment, improvements in the infrastructures of connections, and the development of virtual platforms to promote both classroom and distance teaching. Despite these efforts, there is no clear evidence to show that these technologies have been effectively incorporated into the teaching-learning process (Cuban, Kirkpatrick, & Peck, 2001; Hue & Jalil, 2013; Price & Kirkwood, 2011; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). According to Marcelo, Yot, and Mayor (2015), successful integration of technologies occurs when the teaching staff focus their attention not on the technological resources themselves, but on the actual learning experiences they design and on the proper use of the technologies. Furthermore, Roig, Mengual, and Quinto (2015) discussed the need for a 'suitable teaching design' (p. 152) to ensure the correct integration of ICTs. Two fundamental problems have been identified in a bid to meet this challenge. Firstly, the essential need to train and bring teaching staff up to date in the use of technologies, and secondly, the lack of conceptual models available to enable teachers to acquire the knowledge, competence, resources and skills required to effectively integrate technologies into the teaching profession (Cabero, Marín, & Castaño, 2015). The Technological Pedagogical Content Knowledge (TPACK) model, created mainly by Koehler and Mishra (2005), describes the different types of knowledge a teacher should have in order to properly integrate technology into the classroom, and proposes a combination and interdependence of technological knowledge together with teaching methodology and content knowledge. In the space of just a few years, this model has become a tool to diagnose and reflect upon the role of the professor in the proper incorporation of technology in the educational process.

Furthermore, given its widespread application in a great number of countries and environments, it is currently driving a prospering line of research. It is estimated that over 300 articles and conferences have been written and held on the topic and more than 100 instruments and measures have been developed to assess this knowledge (Abbitt, 2011; Chai, Koh, & Tsai, 2013; Voogt, Fisser, Pareja, Tondeur, & van Braak, 2013).

However, the TPACK model has been applied principally in primary and secondary education and its use in the university sector is still in its initial phases and the role of the university professor has yet to be fully defined. This article uses the TPACK model in the Spanish higher education sector to analyse the technological, teaching and content knowledge required to integrate technologies into university teaching. The aim of this work is to explore the applicability of the model in the world of higher education, working from the translation and application of a specific self-diagnosis tool for university teaching staff, and later contributing to the description of the variables of the teacher in order to ensure the proper integration of technology in the educational process.

The TPACK model and its application in higher education

Apart from studying the pedagogical opportunities which the technology presents, the most common approach followed in the proper integration of ICTs in teaching is to focus on the professors as individuals and their corresponding knowledge (Hew & Brush, 2007). Shulman (1987) proposed a model to show how effective teaching needs specific areas of knowledge and he went on to explain the interdependence between them. The PCK model, Pedagogical Content Knowledge, suggests that professors need not only the pedagogical knowledge and a solid grasp of the syllabus contents, but also strategies and skills which can be applied to both the student and the subject itself, which basically means an intersection in the pedagogical knowledge curriculum. Years later and based on that framework, Mishra and Koehler (2005) formulated the TPACK model to explain the knowledge that professors need, to integrate technology into the teaching of a subject. The essence of the model is basically the interdependence between Curricular Knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK). Therefore, in order to create a teacher training approach and the creation of an educational unit, professors need more than the three types of knowledge. They need to know how the three of them interact to give rise to four further knowledge areas which make up the seven domains of the model (Koehler, Mishra, Kereluik, Shin, & Graham, 2014), which are the following:

(1) CK – Content Knowledge. The subject content that a professor teaches.

(2) PK – Pedagogical Knowledge. The knowledge of teaching methodologies, strategies and ways of promoting students' learning.

(3) TK – Technology Knowledge. Knowledge of technologies, both old and new, which can be integrated into content.

(4) TCK – Technological Content Knowledge. Knowledge relating to the reciprocal relationship between technology and content.

(5) PCK – Pedagogical Content Knowledge. Knowledge which facilitates student learning through the interpretation and transformation of content within a learning environment, making it suitable for the student.

(6) TPK – Technological Pedagogical Knowledge. Knowledge of the improvements that Technology can make to practical work and pedagogical components, which enable the professor to enrich or back up her/his teaching methods with specific technologies.

(7) TPCK – Technological Pedagogical Content Knowledge. Knowledge of the complex relationships between technology, pedagogy and course content which enable the professor to develop teaching methodologies which are suitable and specific to the content.

Despite the rapid dissemination and the benefits gained through the introduction of TPACK, the construct has already been refined and conceptualised in multiple ways (Voogt et al., 2013), leading some researchers to suggest the existence of a 'construct boundary issue' (Archambault & Barnett, 2010; Graham, 2011). It has even been suggested that the construct, as it currently exists, is both too vague and too intricate (Brantley-Dias & Ertmer, 2013). Nevertheless, multiple instruments and methods support the TPACK framework as a valid representation of the knowledge base that enables meaningful uses of technology in teaching (Abbitt, 2011).

There is a wide range of tools to measure these types of knowledge of the professor. The very creators of the model elaborated a review before 2014 (Koehler et al., 2014), classifying the 141 different types into five categories. This was done through self-assessment, open-ended questionnaires, performance testing, interviews and observations. The most commonly used were the self-assessment measures, given that they provide the professors' own perceptions of their effectiveness and they are usually good indicators of their actual behaviour (Christensen & Knezek, 2001). In this category, three tools stand out for their reliability and validity: the first which was developed to assess the knowledge of primary and secondary school teachers (Schmidt et al., 2009), a second for K–12 (kindergarten to Grade 12) online professors (Archambault & Crippen, 2009) and a third for professors who specialise in language training (Sahin, 2011).

The findings on TPACK at a university level are limited. The model has been used and adapted, but the research work is just beginning. Until now, the most important findings on TPACK in the higher education sector point to an independence of all the TK and TPCK areas (Benson & Ward, 2013; Blackburn, 2014) and a strong link between the PCK and TPCK domains (Alzahrani, 2014). Secondly, and with respect to the role of the professor as the integrator of technology in the educational process, very few studies have been carried out despite the great differences in the teaching environments and the professional objectives set by university professors as opposed to primary and secondary teachers (Alvarez, Guasch, & Espasa, 2009; Kinchin, Lygo-Baker, & Hay, 2008). University professors, for example, first seek to gain a deep knowledge of their chosen subject and then acquire the teaching skills and knowledge required to teach students (Hanson, 2009; Lueddeke, 2003). Nevertheless, the research on TPACK and the role of the professor has been basically centred on appraising the kind of professional training that the teacher needs (Benson & Ward, 2013; Rienties, Brouwer, & Lygo-Baker, 2013) and in assessing the application of ICTs by the faculty (Lye, 2013).

The main focus of this article however is another set of studies which has begun to analyse the variables of the professor and her/his knowledge according to the TPACK model (Alzahrani, 2014; Blackburn, 2014; Knolton, 2014). To date, most of the findings in this field indicate that the level of TPACK knowledge is not related to the field of interest of the professor (Alzahrani, 2014; Lye, 2013; Rienties, Brouwer, & Lygo-Baker, 2013), that contradictory results were found when age and TPACK domains were analysed (Alzahrani, 2014; Blackburn, 2014) and that no significant differences were found when online teaching was compared with classroom teaching (Alzahrani, 2014).

As mentioned above, this study is centred on this question. So, our research questions would be: Is the TPACK model applicable and useful for higher education? In addition, what is the relationship between the variables of university professors and their degree of technological, teaching and content knowledge?

Methods

The study follows a descriptive quantitative methodological approach using a self-assessment survey.The sample was formed by 113 professors who teach in the faculties of Architecture, Engineering and Business Administration in a university in Barcelona over the academic year 2015–16. The questionnaire included questions relating to demographic data and teacher academic experience, in particular: the fields of knowledge which the professor teaches (27% Business Administration, 40% Architecture, 33% Engineering), the age of the teacher (6% between 25 and 30 years, 7% between 31 and 35 years, 17% between 36 and 40 years, 26% between 41 and 45 years, 21% between 46 and 50 years, and 23% over 50 years) and experience in online training (43% had experience, while 57% had not). The sample is considered representative of the 440 teachers who teach in the institution, both in the number of respondents and in terms of all the attributes of the teaching staff.

A self-assessment tool was chosen to carry out this study, specifically the most commonly used to measure TPACK developed by Schmidt et al. (2009). Internal consistency and discriminant validity were positively rated, as was flexibility, ease of application and its wide acceptance in various contexts. However, this instrument was created to evaluate the knowledge of primary and secondary teachers, and the questionnaire assessed CK, TCK, CPK and TPACK knowledge in the domains of mathematics, natural sciences and social sciences. Therefore, one modified version of the questionnaire by Chen and Jang (2014) for higher education teachers was adopted in which the questions cover a more general description of CK, PCK, TCK and TPCK and an increase in the number of questions in the areas of TCK and PCK.

The initial questionnaire included 35 items on the seven domains of TPACK with a Likert scale of 5 response options (Totally disagree, TD; Disagree, D; Neither agree nor disagree, N; Agree, A; Totally agree, TA). After its translation into Spanish, a pilot test

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was conducted with randomly chosen professors, with a subsequent interview on completion of the questionnaire. As a result of this pilot scheme, some aspects related to the translation were corrected and we decided to eliminate two questions which had generated confusion. The final result of the review of the study was a questionnaire of 33 questions distributed as follows: TK (7), CK (3), PK (7), PCK (4), TCK (3), TPK (4) and TPCK (5). The reliability was evaluated with the Cronbach Alpha test for the entire questionnaire and for each TPACK domain. An electronic questionnaire in Google Drive that was distributed by email was used to collect the data. The package of statistical programs of open-code R version 3.2.3 for Mac (R Core Team, 2015) was used for data management and analysis.The first step of the analysis was to carry out a descriptive analysis of the data to obtain the different values of the TPACK domains on the basis of the average of the items assigned to each variable.

The matrix of correlations with Pearson's correlation coefficient (r) was initially used to analyse the relationship between the different domains of the model and then we applied the MAPS – Minimum Average Partial Method (Velicer, 1976) – to analyse the factors and decide their final number of factors.The analysis of the influence of the characteristics of the professor in the TPACK model was performed using Student's t-test in the factors of two values and the analysis of variance (ANOVA) in those with more than two values, together with the Levene test to check the homogeneity of the variance in the two previous analyses. All this allows us to compare this research with other studies that have used the same validation of results.

Analysis and results

The reliability of the questionnaire was measured with Cronbach's Alpha test, obtaining .94 for the whole test and over .8 separately for all domains except CK, which obtained .7. This degree of reliability was considered acceptable as all values score between .7 and .91 (Lance, 2006), and are similar to those which validated the original tool (Schmidt et al., 2009), between .75 and .92.

To explore and validate the application of the TPACK model in higher education, first we calculated the correlation between the different domains and then carried out an exploratory factor analysis.

Table 1. Pearson correlation coefficients.

	TK	CK	PK	PCK	TCK	TPK	TPCK
TK	1.00						
CK	.25	1.00					
PK	.21	.48	1.00				
PCK	.23	.45	.84	1.00			
TCK	.59	.29	.46	.48	1.00		
TPK	.57	.38	.46	.51	.70	1.00	
TPCK	.56	.40	.45	.47	.69	.77	1.00

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Table 2. Loadings of TPACK factors.

Factor	1	2	3
TK1			.86
TK2			.86
TK3			.67
TK4			.55
TK5			.59
TK6			.81
TK7			.43
CK1			
CK2			
CK3		.53	
PK1		.74	
PK2		.83	
PK3		.77	
PK4		.66	
PK5		.55	
PK6		.69	
PK7		.72	
PCK1		.76	
PCK2		.67	
PCK3		.70	
PCK4		.59	
TCK1	.55		
TCK2	.51		
TCK3	.45		
TPK1	.72		
TPK2	.82		
TPK3	.50		
TPK4	.79		
TPCK1	.77		
TPCK2	.86		
TPCK3	.66		
TPCK4	.54		
TPCK5	.73		

There is a high (greater than .8) or moderate (around .7) correlation in several domains. These results coincide with the correlations published in applications of the model to primary and secondary school teachers (Cabero et al., 2015; Roig Vila et al., 2015), and might be seen as a first partial confirmation of the possibility of application of the model applied to university professors. An exploratory factor analysis was made with the matrix of correlations obtained (Table 1). The sample size in our study (n = 113) follows a ratio of 1 variable per 3.4 participants. Although a priori analysis could classify the sample size as low (Hair, Black, Babin, Anderson, & Tatham, 2010), the number of variables per factor (seven or more) and the high communality obtained allow us to consider a posteriori that the sample size was appropriate to apply this analysis (Heson & Roberts, 2006). The test was carried out with three factors, obtaining a minimum MAPS value of .02, and later with the application of a promax oblique rotation and obtaining an explained variance of 52% with a moderate adjustment indicated by a value of RMSEA .07 (Browne & Cudeck, 1992). Table 2 shows the weights

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Table 3. Scores on TPACK subscales.

Variables	Mean	SD	Median	Alpha
TK	3.86	.76	3.86	.91
PK/PCK	4.24	.53	4.25	.92
TCK/TPK/TPCK	3.87	.61	3.91	.92

Table 4. Analysis of professors of different subjects.

	Levene	Mean by group			ANOVA	
Factor	p	Arch	BA	Eng	F	p
TK	.17	3.61	3.80	4.22	7.43	.00*
PK/PCK	.07	4.28	4.23	4.20	0.25	.77
TCK/TPK/TPCK	.15	3.89	3.72	4.00	1.79	.17

of the items in the survey factor by factor on application of the rotation. In this table the results with a weight lower than .4 have been removed owing to their low significance with respect to the size of the sample (Hair et al., 2010).

As showed, the result of the factor analysis identifies three differentiated factors. The first factor is related to the application of technology in teaching (TCK, TPK and TPCK), the second is related to traditional teaching without technology (PK and CPK) and the third is directly related to TK. These results were compared with previous studies both in early stages of education and in the few studies in higher education.

Regarding previous studies in pre-service, in-service and high school teachers, after testing the seven domains they find three to five factors (Archambault & Crippen, 2009; Chai, Koh, Tsai, & Tan, 2011; Jang & Tsai, 2012; Koh, Chai, & Tsai, 2010). Compared with the reference for our questionnaire of Chen and Jang's (2014) research, our results fit with three out of four of their factors. CK does not appear in our study, probably because the university professor considers himself an expert in his area of teaching.

Regarding higher education studies, this research confirms previous results about the independence of technology knowledge (Benson & Ward, 2013; Blackburn, 2014), but does not confirm the relationship found between the CPK and TPCK domains (Alzahrani, 2014).

In the light of this comparison, we consider that the three-factor structure is acceptable as the result of our exploratory analysis and we move forward to analyse subsequent data. In the light of these results, this study adds evidence of the difficulty in separating out each of the domains of TPACK, and shows that the university professors perceive three separate areas of knowledge, namely their teaching knowledge, their technological knowledge and their teaching knowledge with technology.

The TPACK of a university professor

Table 3 shows the values of the average and the standard deviations obtained for the three factors calculated as the average of each category.

In the case of university teachers, the factor with the highest value would most probably be PK/PCK. This means that teachers have greater knowledge in the domains of the model related to teaching without technology. The knowledge related to technology, TK and TCK/TPK/TPCK gets a lower rating. These four domains of TPACK are the ones which incorporate technology into the educational process.

On completion of a joint analysis of the responses, the averages of the different factors were compared to study whether there were significant differences according to the professor classification factors in terms of area of study, age and participation in online teaching.

In reference to the area of knowledge taught by the professor, the results obtained in Table 4 show significant differences in the TK of the professor, but no significant differences in the other areas. Thus, the results provide us with two conclusions about the key variables of the teacher according to her/his specialist area. In the first place there is homogeneity in the self-perception of the TPACK domains related to teaching, confirming the studies carried out at an international level which gave similar conclusions (Alzahrani, 2014; Lye, 2013; Rienties, Brouwer, & Lygo-Baker, 2013), and secondly the results indicate a significant difference in the self-perception of technological knowledge and its relationship with the curricular content. Part of this might be explained by the nature of university schools, that is, engineering and architecture.

Table 5. Analysis of professors of different ages.

	Levene	Mean by group						ANOVA	
Factor	*p*	25-30	31-35	36-40	41-45	46-50	+50	*F*	*p*
TK	.16	4.22	3.77	3.96	3.71	4.11	3.66	1.52	.19
PK/PCK	.61	4.13	4.32	4.09	4.23	4.33	4.29	0.56	.73
TCK/TPK/TPCK	.83	3.76	4.15	3.75	3.88	3.94	3.87	0.56	.73

able 6. Analysis of professors with online teaching experience.

	Levene	Mean by groups		*t*-Student	
Factor	*p*	No online	Online	*t*	*p*
TK	.39	3.77	4.07	-1.93	.05*
PK/PCK	.17	4.18	4.38	-1.78	.07*
TCK/TPK/TPCK	.06	3.82	4.03	-1.69	.09*

Regarding the differences which may arise with professors of different ages, the results of Table 5 do not let us confirm that there are significant differences in the TPACK domains for any age group, that is to say, the self-perception of teachers on the use of technology in the educational process does not seem to be affected by the age group to which they belong. These results coincide with those obtained in the study that was carried out in the universities in the south of Spain (Marcelo et al., 2015) and with those obtained in the study conducted in the United States (Blackburn, 2014), but they contradict partially those obtained for university teachers in Saudi Arabia (Alzahrani, 2014), where age was a differential factor in some domains.

In reference to online teaching experience, Table 6 shows significant differences in the three factors among professors who had taught their subject online and those who had not. The values obtained could be due to the intrinsic use of technology in the online format as the professors have to design their course and adapt the contents to an online learning environment and this process itself improves their technological knowledge. These results confirm that the introduction of online content generates new relationships between technology, pedagogy and content (Sangra, 2005), but they differ from other studies which did not find significant differences between professors with online experience and those without (Alzahrani, 2014).

Conclusions and discussion

The TPACK model has been used extensively to explain the knowledge that teachers need to integrate technology into teaching. However, this application has focused on primary and secondary school teaching. This study is focused on extending the application of this model to the university environment and on providing a greater insight into the variables regarding academic experience of university professors and the differential characteristics that affect their technological, pedagogical and content knowledge.

The reliability indexes obtained in the translation and adaptation of the questionnaire used confirm that the model of TPACK can be applied to the environment of university teaching. However, this runs into difficulties when separating each of the domains, similar to those found from empirical studies of pre-service, in-service and high school teachers.

In reference to the general results obtained on the previous academic experience of university professors, there is a strong indication that their perception of general knowledge in the TPACK domains is high. The highest score obtained is the knowledge of the traditional non-technological educational domains, with the lowest scores in the teaching domains with technology. These values coincide with other studies conducted at university level (Benson & Ward, 2013; Blackburn, 2014) and are clearly differentiated from the studies with primary and secondary school teachers (Archambault & Barnett, 2010; Cabero et al., 2015; Chai et al., 2011; Roig Vila et al., 2015; Schmidt et al., 2009; Shinas, Yilmaz-Ozden, Mouza, Karchmer-Klein, & Glutting, 2013), which leads us to confirm that there are clear differences between the two groups of teachers. As a conclusion with regard to the idiosyncrasy of the university professors, this research shows that they perceive the necessary knowledge in three groups: knowledge on teaching without technology, knowledge on teaching with technology and separately the techno-logical knowledge they possess. This grouping enabled us to develop an explanation for the individual relationships found in the TPACK studies which have been carried out so far on university teachers.

This result has implications for the practical contribution of the study. As mentioned earlier, part of the research using the TPACK model focuses on being able to evaluate the necessary training of teachers (Benson & Ward, 2013; Rienties, Brouwer, & Lygo-Baker, 2013). It could be assumed that for the proper introduction of ICTs in the classroom, teacher training has to be in technology, but previous studies have already discussed that it might not be the best way (Smith, 2003). Centred on the university level, the results of this research confirm the indissolubility of technological knowledge from pedagogical knowledge, and although in higher education it is expected that a teacher has deep knowledge of the content, it is not so obvious that he or she will consider opportunities offered by technology (Lawless & Pellegrino, 2007). So this study also confirms and supports the need to train professors in all kinds of knowledge, something that has been already discussed in online programmes (Rienties, Brouwer, Carbonell, et al., 2013).

Regarding the variables of the teacher, and specifically the disciplines of his/her teaching, we have only found differences in their perception of the technological aspects of each subject, but not in those related to pedagogy or with the application of technology to teaching. This coincides with other studies (Lye, 2013; Rienties, Brouwer, & Lygo-Baker, 2013) and shows that the university professor has a homogeneous perception of the domains related to teaching irrespective of the discipline to which it belongs. We have also found significant differences between teachers with online experience and those without, contradicting partially the results found in a previous study on online experience (Alzahrani, 2014). However, it is expected that the progressive introduction of online content and its Integration into courses will bring about a significant change in the perception of university professors (Alvarez et al., 2009). Finally, we have not found significant differences in the perception of the domains of the model between teachers belonging to different age groups. Despite the fact that we could expect a greater perception in younger professors, our results and the studies carried out so far (Blackburn, 2014) do not give us reason to confirm this difference.

With regard to the limitations of this work, the TPACK model is not the only model which has been developed to show how teachers use technology. Alternative models have been proposed, although most tend to coincide in the theory that the application of these new technologies requires teachers to have different types of knowledge and that connections between the possibilities and limitations of new technologies for the transformation of the contents and the pedagogy must be established (Voogt et al., 2013). Furthermore, in reference to the model, prior investigations prove that TPCK is always framed and located in a specific context, and explicitly recognise that the effective use of technology is heavily influenced by the content that it is intended to impart and it is difficult to separate technology from contexts (Graham et al., 2009; Rosenberg & Koehler, 2015; Voogt et al., 2013). With regard to the sample, the survey has been conducted in a single university which has three specific areas of knowledge. Therefore, the characteristics of this centre could influence the results obtained or make it difficult to obtain more important differences. On the other hand, the sample size does not allow us to perform analytical studies of confirmatory factors.

An interesting line of research for the future would be to extend this study of the application of the TPACK model in higher education to a broader sample which would include more universities, expanding both the geographical areas and the number of areas of knowledge. It would also be interesting to investigate the relationship between the different domains of the TPACK model and how the university professors actually use technology in their teaching. Another future line of research could be developed around the adaptation of TPACK to the characteristics of online university teaching

This research has sought to contribute to fostering the knowledge of the application of the TPACK model, in particular in the area of higher education and with university teachers. The results obtained show that it is necessary to improve the development of technological and pedagogical knowledge, as well as the curriculum of university teachers, in order to adapt their teaching practices to the new challenges created by the implementation of technology in the classroom in today's increasingly digital society.

Disclosure statement

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Notes on contributors

Albert Cubeles is an associate professor at La Salle Campus Barcelona. He is interested in how to foster the knowledge and use of ICTs in teaching and learning, specifically in higher education.

David Riu is an associate professor at La Salle Campus Barcelona. He applies operational research to the fields of education and management at the research group Data Science for the Digital Society.

ORCID

Albert Cubeles http://orcid.org/0000-0002-6380-9435

David Riu http://orcid.org/0000-0002-2880-3230

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