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Additional Information

Using an ANP Performance Management Framework to manage the development of transversal competences in University degrees

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Abstract

Organisations are concerned about measuring the performance of the product/service they deliver to their customers. In all types of organisations, if a proper performance assessment is to be developed, it should be measured in different dimensions. At University, the new study programs include the development and assessment of transversal competences due to their importance in enhancing the abilities and improving the employability of students. The achievement of transversal competences can be assessed in different levels/stages; for example, the 1st and 2nd years of a Bachelor's degree; the 3rd and 4th years of a Bachelor's degree and at Master's level. The purpose of this paper is to integrate the research into performance management in organisations to develop an approach consisting of four components (a methodology, a solid and integrated performance management framework, graphical diagrams and quantitative techniques) to assess and manage the achievement of transversal competences through the different levels of study using a consolidated approach. The proposal uses the Analytic Network Process (ANP) to model dependences and feedback among the elements of the competences.

Keywords: ANP, performance management, transversal competences, assessment, University degrees.

1 Introduction

Organisations are concerned about measuring the performance of the product/service they deliver to their customers. In all types of organisations, if a proper performance assessment is to be developed, it should be measured in different dimensions, such as productivity, quality, etc. in order to provide a complete overview of the performance status. Performance measurement is a key issue in public organisations due to their specific characteristics (Jablonsky 2016). In the Universities, the new study programs demand the introduction of transversal and specific competences to be achieved by students during their degree and state that these competences must be assessable. Furthermore, the accreditation process that the degrees have to follow aims (among other things) to find evidence of the implementation of systematic procedures with which to assess competences. Measuring how far this requirement has been satisfied is complex due to the nature of transversal competences.

The new programs at the Universitat Politècnica de València (UPV) include the development and assessment of transversal competences on Bachelor's and Master's Programs. For example, some of these competences are (UPV 2014): problem solving; effective communication; time planning; and critical thinking. González and Wagenaar (2003) indicate that *"specific competences are those skills related to the specific domain of knowledge while generic or transversal competences are those skills related to personal development that do not depend on a thematic or specific scope but they appear in all the domains of the professional and academic activity"*.

The main problem in assessing these competences is their novelty, as instructors are not experts in this field of domain. There is still a need to develop tools that aid the development and assessment of transversal competences as well as collect evidence for the overall assessment of students during the teaching-learning process. In order to deal with this issue, the UPV has introduced a University project called "UPV transversal competences" for the purposes of enhancing and guiding the assessment of the transversal competences of the degrees (Bachelor's and Master's degrees). In line with this UPV project, the researchers involved in the present study have developed two previous educational research projects (Verdecho et al. 2015) and (Gómez-Gasquet et al. 2018) for designing instruments for transversal competence assessment. Other instruments have been developed by Jonsson and Svingby (2007), Villa and Poblete (2007), AQSUC (2009), Blanco et al. (2009), García-García et al. (2009), Rodríguez-Gómez (2009), Ibarra (2010), Alsina (2013) and Sonseca et al. (2015).

It has to be noted that the year the student is in influences the degree of achievement of the transversal competences. So, for example, the UPV has defined three levels for every transversal competence. The first level should be developed during the first and second years of a Bachelor's degree. The second level should be developed during the third and fourth years of a Bachelor's degree. Finally, the third level should be developed during the Master's degree.

After finishing the two educational projects (Verdecho et al. 2015) and (Gómez-Gasquet et al. 2018), it was observed that there was a need to establish mechanisms with which to trace the consolidated degree of achievement when students pass from one year to the next. Thus, the different assessment instruments used to assess the different levels need to be coherent and consistent.

Performance Management Frameworks are systems that support the definition and implementation of the strategy of enterprises/supply chains and establish monitoring for performance. One of the most important performance management frameworks is the Balanced ScoreCard (BSC) by Kaplan and Norton (1992). The BSC was adapted for dealing with supply chain performance management by introducing different levels (supply levels and individual enterprise levels); for example, the studies developed by Bititci et al. (2005), Folan and Browne (2005), Alfaro et al. (2007), etc. These systems present different performance elements (levels, perspectives, objectives, key performance indicators, etc.). In addition, they integrate a path of performance elements definition from the strategic level to the operational, ensuring coherence in performance management. The authors of the present study believe that a similar structure should be adopted to consolidate the requirements/degree of achievement of each transversal competence through the three levels in University studies. Thus, the main purpose of this paper is to develop an approach consisting of four components (a methodology, a solid and integrated performance management framework, graphical

diagrams and quantitative techniques) to assess and manage the achievement of transversal competences through the different levels of study using a consolidated approach.

The structure of this paper is as follows. First, the global approach to the management of transversal competences composed of four components (methodology, performance management framework, graphical representation and quantitative techniques) is described. Second, the methodology component (consisting of five phases) is presented. Third, the performance management framework component is detailed. Fourth, the graphical representation component is shown. The performance management framework and the graphical representation deal with the first two phases of the methodology. Next, the rest of the phases of the methodology are described. Then, a quantitative technique, the Analytic Network Process (ANP), is used to develop a model to quantify and implement the approach. Finally, the conclusions are presented.

2 The approach to the management of transversal competences

The approach to the management of transversal competences is composed of four components (Fig.1): methodology, performance management framework, graphical diagrams and quantitative techniques.

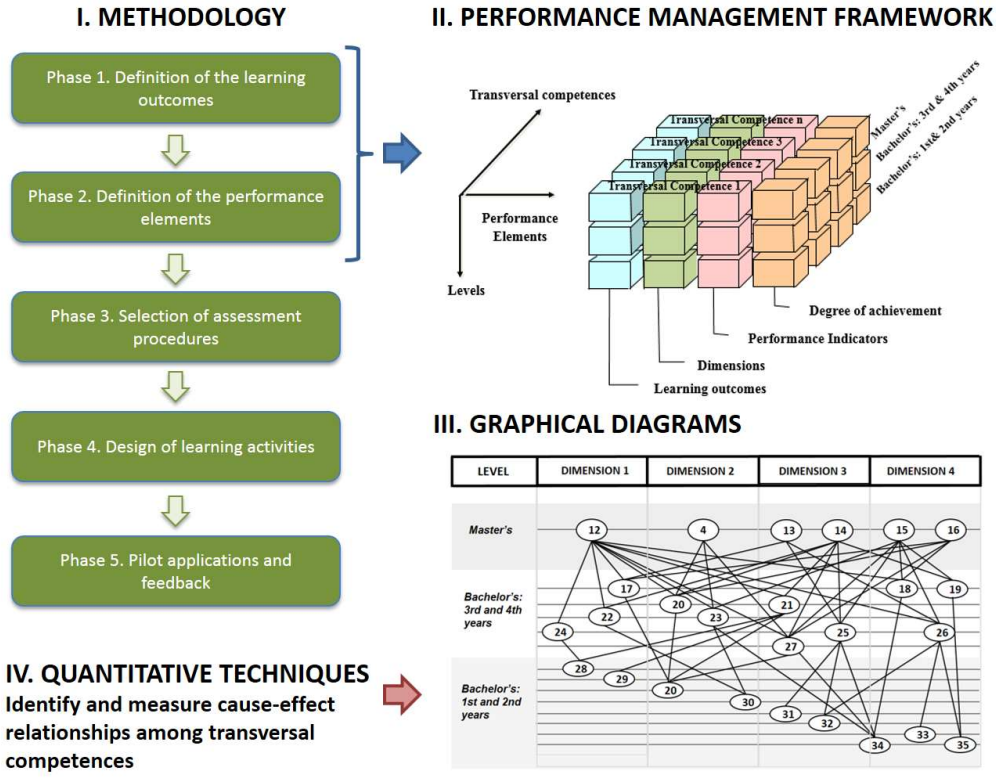

Fig. 1 Components of the approach to the management of transversal competences

The methodology consists of five phases. The first and second phases are related to the definition of all the elements of the performance management framework (blue arrow between both components). Once the performance management framework is defined, the graphical diagrams aid the visual representation of the relationships among its

performance elements. Finally, the fourth component is the selection and application of quantitative techniques to identify and measure the relationships among the performance elements. In this paper, we use the Analytic Network Process (ANP). The next sections develop these blocks in more detail.

3 The methodology for the management of transversal competences

There is a need for methods, instruments and procedures that establish the steps to be followed in order to manage the development and assessment of transversal competences through the years of study in University programs using a solid approach. The developed methodology consists of five phases (Fig.2).

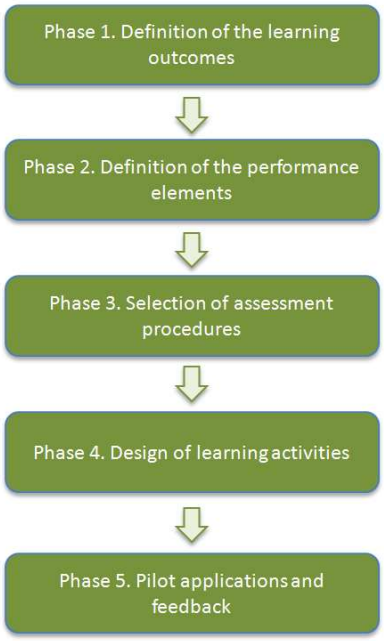

Fig. 2 Phases of Methodology

As shown in Fig. 2, the five phases are: 1) the definition of the learning outcomes for each transversal competence at each level of study (first level (the first and second years of a Bachelor's degree); second level (the third and fourth years of a Bachelor's degree); and third level (Master's degree)), 2) the definition of the performance elements with which to assess each learning outcome at each level, 3) the selection of assessment procedures, 4) the design of learning activities and 5) the pilot applications and feedback. The next two sections of this paper focus on developing the extent of phases 1 and 2 in more detail. After that, the remaining phases (phases 3-5) will be described.

4 The performance management framework

The characteristics of a management framework for assessing transversal competences comprise the needs that the framework must comply with to be coherent in its formulation. The proposed framework introduces these characteristics based on the performance management framework for networks developed by Alfaro et al. (2007). This framework should support the degree of development of each transversal

competence throughout the years the student spends at University. For that reason, the framework must consider three levels: the first and second years of a Bachelor's degree, the third and fourth years of a Bachelor's degree and, at Master's levels. All three levels should be aligned to maintain a coherent definition between the elements of the framework.

The starting point of the framework is the definition of the learning outcomes for each transversal competence (phase 1 of the methodology). These learning outcomes are different for each level, and it is very important that the level of requirement of each level be incremental with regard to the previous level (e.g. higher in the third and fourth years than in the first and second years) and that it should be achievable by students with a medium degree of effort. This logic is applicable for all levels and competences. Fig. 3 shows the composition of the performance management elements within the framework.

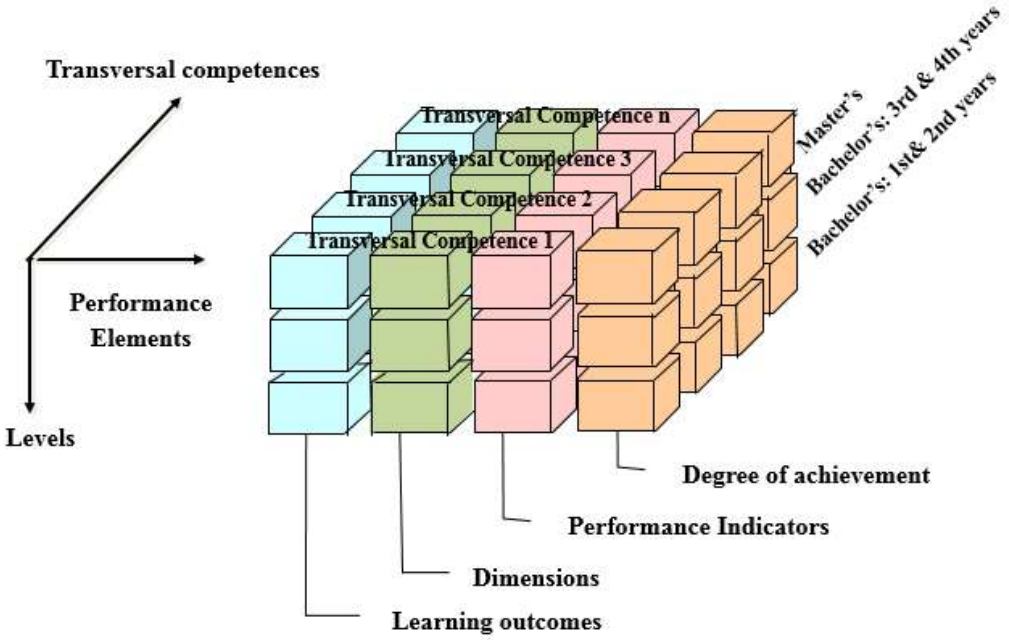

Fig. 3. Performance management framework to assess transversal competences

Once the learning outcomes are defined for one transversal competence, phase 2 comprises the definition of the rest of the performance elements for assessing this competence in this order:

I. The definition of the dimensions of the transversal competence to assess the learning outcomes. The dimensions defined for each competence will be defined according to the best method of measuring and managing them. For some competences, it may be sufficient to define a single dimension but, for others, it might be necessary to establish more dimensions in such a way that they complement each other. The idea is to provide a broad and global vision of all the aspects that will be measured and managed later when defining performance indicators. For example, the transversal competence "effective communication" can have two basic dimensions: oral and written. In turn, each of these dimensions can be decomposed into other specific sub-dimensions.

II. The definition of the Key Performance Indicators (KPIs) to measure in each dimension of the transversal competence. Although it is important to define quantitative KPIs for measuring each dimension, this is sometimes not possible due to the specific nature of the dimension, so qualitative KPIs may also be used. On the other hand, the KPIs must be easy to collect, calculate and interpret, and it is advisable not to use too many KPIs per dimension. If the total number of KPIs is very large, their management becomes more complex and their interpretation may be difficult. It has to be said that many times one dimension comprises only one KPI.

III. The definition of the degrees of achievement of each KPI to assess the student's capability in each transversal competence. In most cases, it is sufficient to distinguish three (high, medium and low) or four (excellent, attained, in development and not attained) degrees of achievement of each KPI, but it is also possible to use the numerical scale (e.g., 0-10). The important point is not only the degree achieved in each KPI but also the degree achieved in each transversal competence, which is not always equivalent, since a certain competence can have several dimensions and each dimension may have one or more KPIs. Another thing that should also be noted is the evolution in the degree of achievement of each competence throughout the different levels (the 1st and 2nd years of a Bachelor's degree; the 3rd and 4th years of a Bachelor's degree and a Master's). If we monitor the evolution through the training process, we can take the appropriate actions to enhance the weaker transversal competences in those students who need it.

All these elements are defined for all the transversal competences. These elements help to structure performance measurement and present cause-effect relationships. For this reason, the next section presents a graphical diagram that helps to visually represent the deployment of relationships among the performance elements of the transversal competences.

5 The graphical diagrams for the deployment of transversal competences

Once all the performance elements are defined, it is important to note that consolidating the degree of achievement of one transversal competence within the bottom level (the 1st and 2nd years of a Bachelor's degree) helps to achieve other transversal competences. We can distinguish three types of impacts that can be derived from the achievement of one transversal competence (Fig. 4):

- Type 1. The impact on the degree of achievement of other transversal competences in the same level. This type of impact is shown in Fig. 4 with red arrows. When a certain degree is reached at a certain level in a transversal competence, it can influence the achievement of other transversal competences. This impact is important because the efforts made to reach that degree in a competence have a beneficial impact on others; therefore, they present synergies, which can help to better plan the improvements that the students have to make for their development. An example of this type of impact would be the influence between the transversal competences "Time management" and "Problem solving".

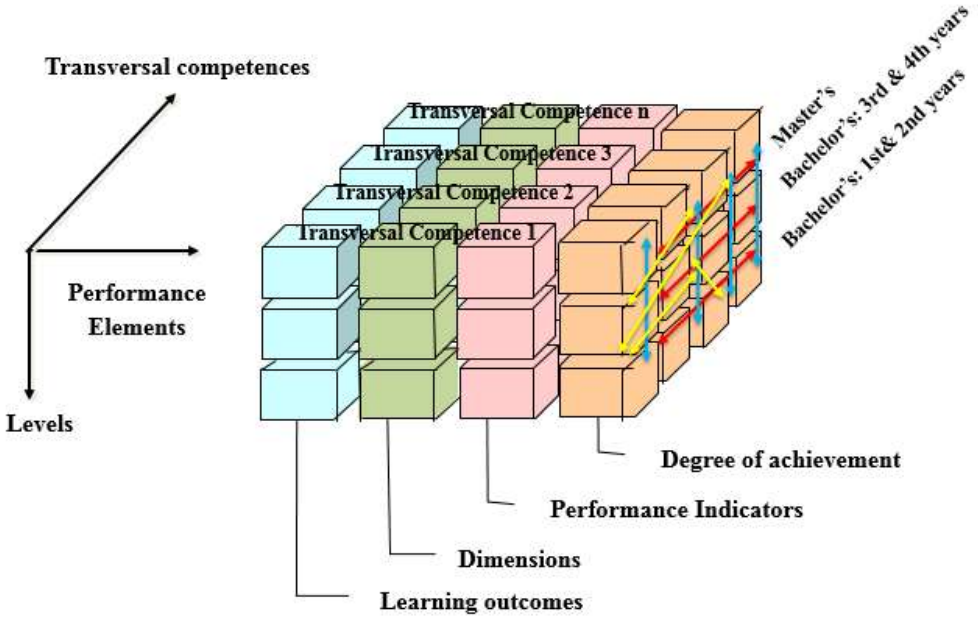

Fig. 4. Types of impacts derived from the achievement of one transversal competence

- Type 2: The impact on the degree of achievement of the same transversal competences in higher levels. This type of impact is shown in Fig. 4 with blue arrows. Fig. 5 presents a visual representation of the Type 2 impacts of a transversal competence that comprises four dimensions. Thus, achieving the competence in different dimensions (dimensions 1-4) at the first level (the 1st and 2nd years of a Bachelor's degree) impacts on the achievement of the different dimensions in the second level (the 3rd and 4th years of a Bachelor's degree). Similarly, the achievement of the competence in different dimensions at the second level has an impact on the achievement of the different dimensions at Master's level. A similar analysis can be carried out for the other two types of impacts, obtaining a map of impacts (cause-effect relationships) within the different transversal competences. Using this map, we can see that the degree of achievement in one transversal competence is not only based on the activities performed to develop this competence but also on the work done on other competences. It is important to highlight that each transversal competence may have a different number of dimensions to assess. However, it is convenient that the number of dimensions in each transversal competence be maintained between the three levels (the 1st and 2nd years of a Bachelor's degree; the 3rd and 4th years of a Bachelor's degree; and a Master's). In this way, it is easier to maintain traceability between levels. On the other hand, the number of performance indicators used to measure each dimension of a transversal competence can be different, and it is not necessary to keep all the performance indicators used in a given dimension for all levels. This is because the method of measuring a certain dimension of a transversal competence can vary when the student is at one level or another.

- Type 3: The impact on the degree of achievement of other transversal competences at higher levels. This type of impact is shown in Fig. 4 with yellow arrows. This type of impact is similar to Type 1, the difference being that sometimes the impact of the achievement of a transversal competence at a specific level influences the degree of achievement of another transversal competence but at a different level. Continuing with the same example used previously, achieving a standard degree of the transversal competence "Time management" at the first level (the 1st and 2nd years of a Bachelor's degree) can make it easier to achieve a high degree of competence in "Problem solving" at the second level (the 3rd and 4th years of a Bachelor's degree).

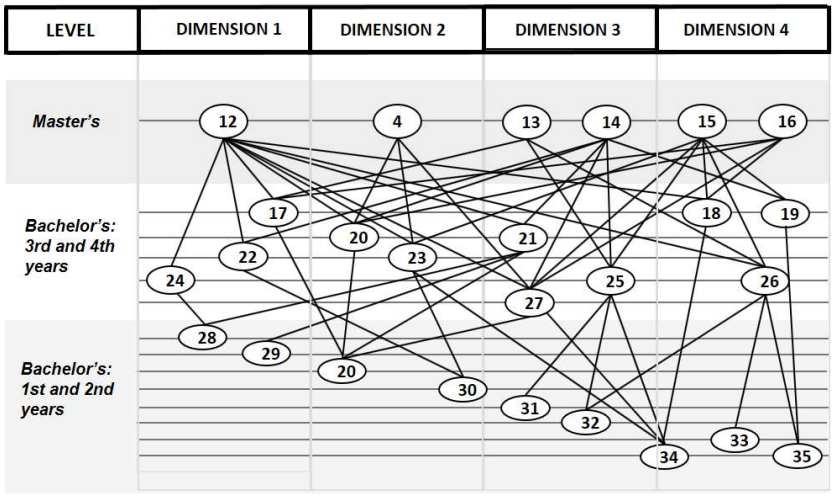

Fig. 5 Impacts of the achievement of a transversal competence on the achievement of higher levels of the same transversal competence

6 Selection of assessment procedures

Once phase 2 of the methodology is completed, the performance elements for the development of the transversal competences are defined. So, phase 3 consists of the selection of assessment procedures for each transversal competence. Although different assessment procedures can be used, it is advisable to use active assessment procedures, such as self-assessment or co-assessment (both instructor and students assess the competence). This will provide students with an active role, increasing their implication and motivation.

7 Design of learning activities

After phase 3, phase 4 comprises the design of learning activities. In this phase, three types of activities may be used (alone or combined) to develop the transversal competences depending on the required degree: theoretical understanding, practical understanding and real application of the competence.

In the case of theoretical understanding, the instructor should provide the students with materials describing the transversal competence. This activity should be complemented with an assessment activity that provides the student with feedback regarding how well the transversal competence has been understood. For the practical understanding of the competence, practical case studies can be developed to show the different degrees (e.g. not reached, reached, and outstanding) of a specific transversal competence. Finally, the real application of the competence involves the student in an activity applying the competence; for example, submitting an assignment, doing a presentation, performing a simulation in groups, etc.

8 Pilot applications and feedback

In the last phase, the actual learning activities take place, after which the student obtains the assessment and feedback on the degree of competence reached (the current degree of achievement) (see Fig. 6). For the assessment, the instructor should have developed an assessment instrument (e.g. rubric, assessment list, etc.) that should be explained to students in advance. If students do not reach the required degree of achievement, an action plan can be defined. For that purpose, it is important to review the degree reached in each dimension of the competence so that training can be focused on the specific dimensions that are at the lowest level. Then, it is important to define the degree of achievement required (target level to achieve) and subsequently implement the actions that must be followed in order to increase the degree of achievement . Depending on which dimensions have to be developed, these actions serve to further exercise the learning activities previously defined: theoretical understanding, practical understanding and real application of the competence. The student will have the opportunity to work on the transversal competence from different perspectives in order to consolidate the level of achievement. Afterwards, the assessment takes place, which could be repeated in the same year or different ones within the same level (the 1st and 2nd years of a Bachelor's degree; the 3rd and 4th years of a Bachelor's degree and a Master's), thus monitoring how the development of the competence is progressing.

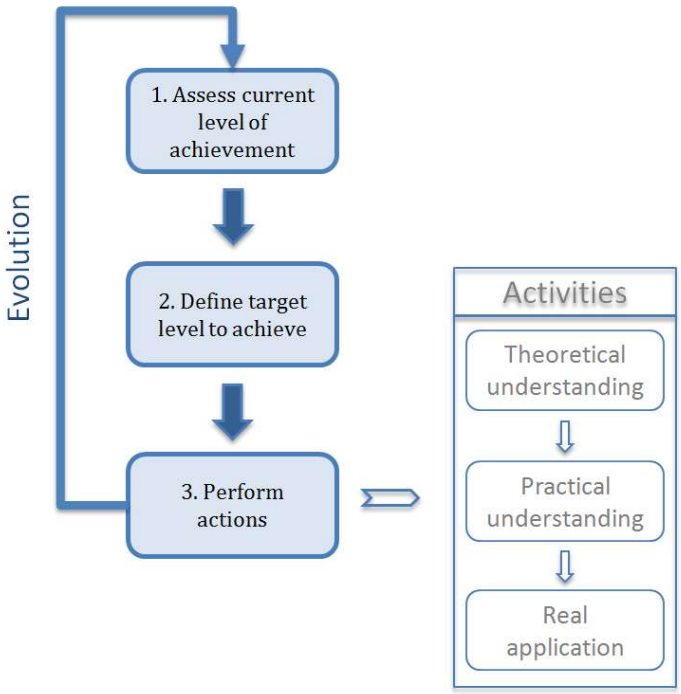

Fig. 6 Pilot application and feedback

9 The ANP model to implement the approach

ANP is a multi-criteria technique developed by Saaty (1996) and used in a wide variety of applications. Some interesting literature reviews of ANP models are: Ho et al (2010), Iglin and Gupta (2010), Diaz-Balteiro et al (2017) and Rodrigues Lima-Junior and Carpinetti (2017). ANP permits the modeling of complex problems with a network structure, integrating interdependences and feedback among their elements (Saaty 1996). Thus, it is an adequate technique to address problems with interrelationships among decision levels and different elements within each level. In the last two decades, ANP has been used in many decision-making applications from different sectors (Yang et al. 2008; Seyhan and Mehpare 2010, Verdecho et al. 2012, Boateng et al. 2015, etc.). Recently, some applications using ANP have been implemented in the education sector. Begičević et al. (2010) use ANP as a multiple criteria decision-making methodology to solve project selection problems in higher education institutions. Kadoić et al. (2018) develop a new method for strategic decision-making in higher education based on the characteristics of the ANP and social network analysis. Tang (2018) applies DEMATEL-based ANP as a decision-making tool to conceptualize an emerging leadership competence model for further prioritizing school leadership training needs. Choi and Jeong (2019) develop a quality evaluation model using the ANP approach for multimedia contents of e-learning systems.

As we have previously stated, the different transversal competences present cause-effect relationships. The achievement of one competence may impact on the achievement of another/other competence/s. This network of influences is highly important as it can modify both the weights associated with each KPI and the results obtained in the assessment of the competence.

The network of influences can be represented and computed using an ANP model (Fig 7). At the top of the model is the cluster containing the learning outcomes to be achieved for each competence. In this case, the cluster contains four learning objectives (Learning Objective 1 (LO1), Learning Objective 2 (LO2), etc.). So, there are three levels (Master's level, 2nd level and 1st level) for each competence. In this example, at each level, there are three competences. The different competences are represented by clusters at each level: cluster of competence 1, cluster of competence 2, and cluster of competence 3. Every cluster of competences is composed of dimensions (three or four dimensions in this example) and every dimension comprises one or more Key Performance Indicators (KPIs). Many times a dimension is measured with a single KPI. The KPIs are named KPI i-j-k, where i is the competence, j is the level of the competence ("3" Master's level, "2" the second level of the degree and "1" the first level of the degree), and k is the KPI number in that specific cluster. For instance, Cluster of competence 1 at Master's level includes four KPIs (KPI 1-3-1, KPI 1-3-2, KPI 1-3-3, KPI 1-3-4). The clusters present two types of relationships: internal and external relationships. Internal relationships occur among the KPIs of the same cluster (e.g., impact between KPI 1-3-1 and KPI 1-3-2) and are represented in the figure with a circular arrow on the right-hand side of each cluster. External relationships take place among the elements (Learning outcomes and/or KPIs) of different clusters and are represented with lineal arrows. External relationships (types of impacts) have been explained in section 5. Then, clusters are linked by external relationships (lineal arrows) that represent the impacts of the achievement of one LO/KPI on another LO/KPI.

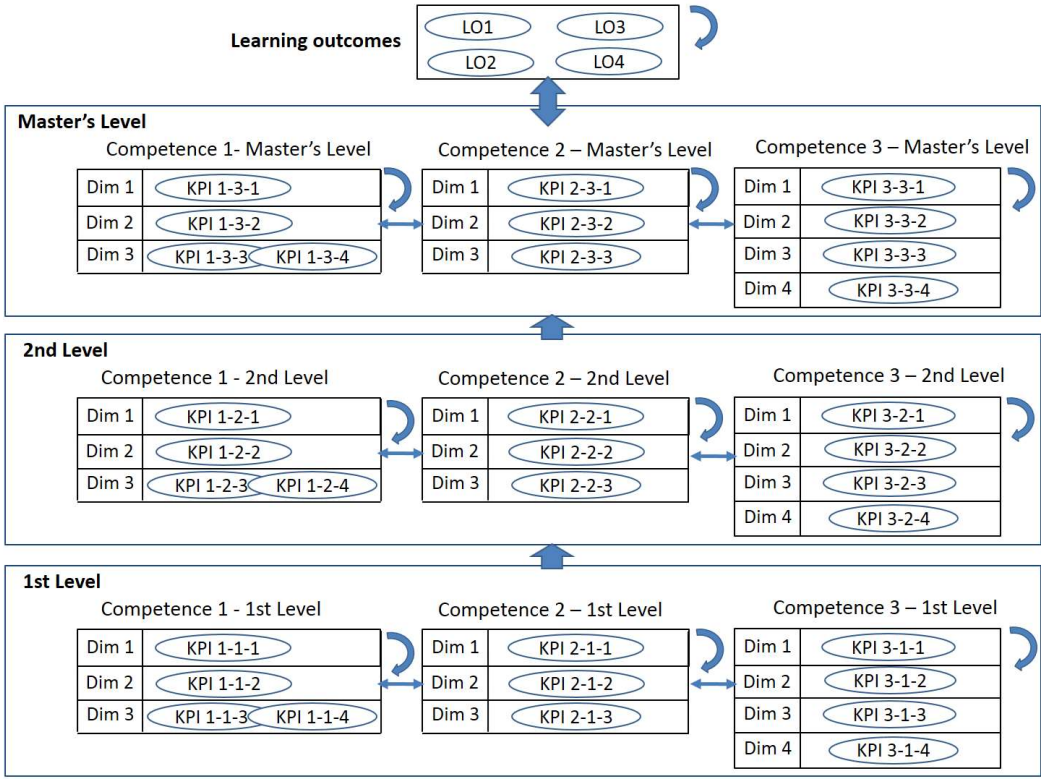

Fig. 7 ANP model for assessing transversal competences considering their cause-effect relationships

The methodology to implement the model consists of the following steps:

Step 1. Build the ANP model following Saaty (1996). This step comprises the identification of all the competences, KPIs, etc. as well as their relationships.

Step 2. Fulfil the pairwise comparison matrices of elements using Saaty's relative scale (1980). The scale varies from 1 to 9. 1 means that two elements in the pairwise comparison are equally important. 3 means that one element is moderately more important than the other element. 5 means that one element is much more important than the other element. 7 means that one element is very much more important than the other element. 9 means that one element is more important than the other element by a long way. In addition, the pairwise comparison matrices should comply with the axiom of reciprocity: if one element is n times more important than another (n is a number from Saaty's scale), then the other element is 1/n times more important than the first one.
In this step it is also sometimes useful to provide a questionnaire for the experts and, afterwards, responses are translated into Saaty's numerical scale.
After obtaining each pairwise comparison matrix, the priority vector is computed and the consistency of judgments is checked (Saaty, 2001).

Step 3. Elaborate the unweighted supermatrix using the priorities from step 2.

Step 4. Fulfil the pairwise comparison matrices among clusters (if it is necessary to assign different priorities to the different competences) following step 2. Elaborate the cluster matrix with the priorities computed.

Step 5. Obtain the weighted supermatrix by multiplying the cells of the cluster matrix by the corresponding columns of the unweighted supermatrix.

Step 6. Calculate the limit matrix. Then, the limit priorities are obtained.

Step 7. Analyse results.

10 Example

In this section, four transversal competences are assessed at the three levels of University studies: Master's level, 2nd level and 1st level. This example has been developed by a group of four associate professors with between ten and twenty years of experience teaching on University degrees and eight years researching transversal competence development.

Step 1. Build the ANP model. Following the ANP method (Saaty 1996), competences and KPIs are elements that can be structured into clusters. The four competences are: Critical Thinking (CT), Problem Solving (PS), Oral Communication (OC), and Time Planning (TP). The definition of the learning outcomes and elements of the competences have been performed using the studies (Villa and Poblete 2007; ICE 2015).

The first cluster is composed of the four learning outcomes as shown in Table 1. LO1 corresponds to the CT competence, LO2 corresponds to the PS competence, LO3 corresponds to the OC competence and, LO4 corresponds to the TP competence.

Table 1. Learning outcomes of the four competences. Cluster of learning outcomes

LO1	Argues the relevance of judgments made in complex approaches
LO2	Solves problems individually and/or as a team in different contexts and in depth using different approaches
LO3	Is persuasive in the speech, adapting the message and the media to the characteristics of the situation and the audience
LO4	Plans and temporarily manages individual or group projects

The other clusters will contain the KPIs to assess each competence at each level. Tables 2, 3, 4 and 5 present the KPIs for the four competences according to the assessment level. For the purposes of assessing each competence, there will be three clusters, one per level; that is to say, one cluster containing the KPIs for the Master's level, one cluster containing the KPIs for the 2nd level, and one cluster containing the KPIs for the 1st level (see Fig. 8).

Table 2. KPIs of CT competence

Master's level	
CT31	Verifies the conformity of an approach with respect to a standard
CT32	Argues judgments based on external criteria
CT33	Extrapolates models and arguments to new situations
2nd level	
CT21	Values the judgments of others
CT22	Elaborates judgments based on own criteria
CT23	Assesses the implications of a proposal
1st level	
CT11	Shows a critical attitude to reality
CT12	Detects inconsistencies in speech
CT13	Distinguishes between facts and opinions

Table 3. KPIs of PS competence

Master's level	
PS31	Analyses the causes and effects of problems from a global approach
PS32	Organises the work for decision-making
PS33	Evaluates the possible solutions according to the scientific-technical feasibility
2nd level	
PS21	Identifies a complex problem and its parts
PS22	Uses a resolution methodology efficiently and in a justified manner
PS23	Chooses the best solution using justified criteria
1st level	
PS11	Defines the most important aspects of a problem
PS12	Uses the resolution method learned to solve the problem

PS13	Analyses the coherence of the solutions

Table 4. KPIs of OC competence

Master's level	
OC31	Shows an ethical attitude in communication
OC32	Masters the presentation and debate
OC33	Adapts the organization of the content to the audience and keeps to the time
OC34	Adapts non-verbal language to the message
2nd level	
OC21	Shows a positive attitude to communication
OC22	Makes interesting presentations and answers the questions properly
OC23	Performs a prepared and structured presentation in the allocated time
OC24	Adapts non-verbal language to the audience
1st level	
OC11	Shows a positive attitude to communication
OC12	Presents relevant information
OC13	Structures the information in a coherent manner in the allocated time
OC14	Transmits calm through non-verbal language

Table 5. KPIs of TP competence

Master's level	
TP31	Defines the general and specific objectives to be met
TP32	Determines the phases and the individual and group activities to be carried out to achieve each objective
TP33	Allocates time to the individual and group activities and keeps to it
2nd level	
TP21	Defines the objectives to be met in the short and medium term
TP22	Defines the activities to be carried out and their hierarchy according to their importance
TP23	Allocates time to the activities and keeps to it
1st level	
TP11	Identifies short-term activities
TP12	Makes a hierarchy of short-term activities based on their importance
TP13	Performs the activities in the allocated time

Once the elements have been identified, the next task is to identify the relationships (internal and external relationships). For that purpose, the group of experts defines the Coherence matrix (Table 6). In this matrix, if a KPIi influences the achievement of another KPIj, then the intersection cell aij (where i is the row and j is the column) is marked with an "X". Otherwise, the cell is "0".

Table 6. Coherence matrix

	LO1	LO2	LO3	LO4	CT31	CT32	CT33	…
LO1	0	X	X	0	X	X	X	…
LO2	X	0	X	X	X	X	X	…
LO3	X	X	0	X	0	0	0	…
LO4	0	X	X	0	0	0	0	…
CT31	X	X	0	0	0	X	X	…
CT32	X	X	0	0	X	0	X	…
CT33	X	X	0	0	X	X	0	…
PS31	X	X	0	0	X	X	X	…
PS32	X	X	0	0	X	X	X	…
PS33	X	X	0	0	X	X	X	…
OC31	0	0	X	X	0	0	0	…
OC32	0	0	X	X	0	0	0	…
OC33	0	0	X	X	0	0	0	…
OC34	0	0	X	X	0	0	0	…
TP31	0	X	X	X	0	0	0	…
TP32	0	X	X	X	0	0	0	…
TP33	0	X	X	X	0	0	0	…
…	…	…	…	…	…	…	…	…

Then, the elements (clusters and KPIs) and relationships from the Coherence matrix are modelled using *SuperDecisions* software (Fig. 8). The cluster of the TP competence at the 1st level is called *alternatives* in the software model .

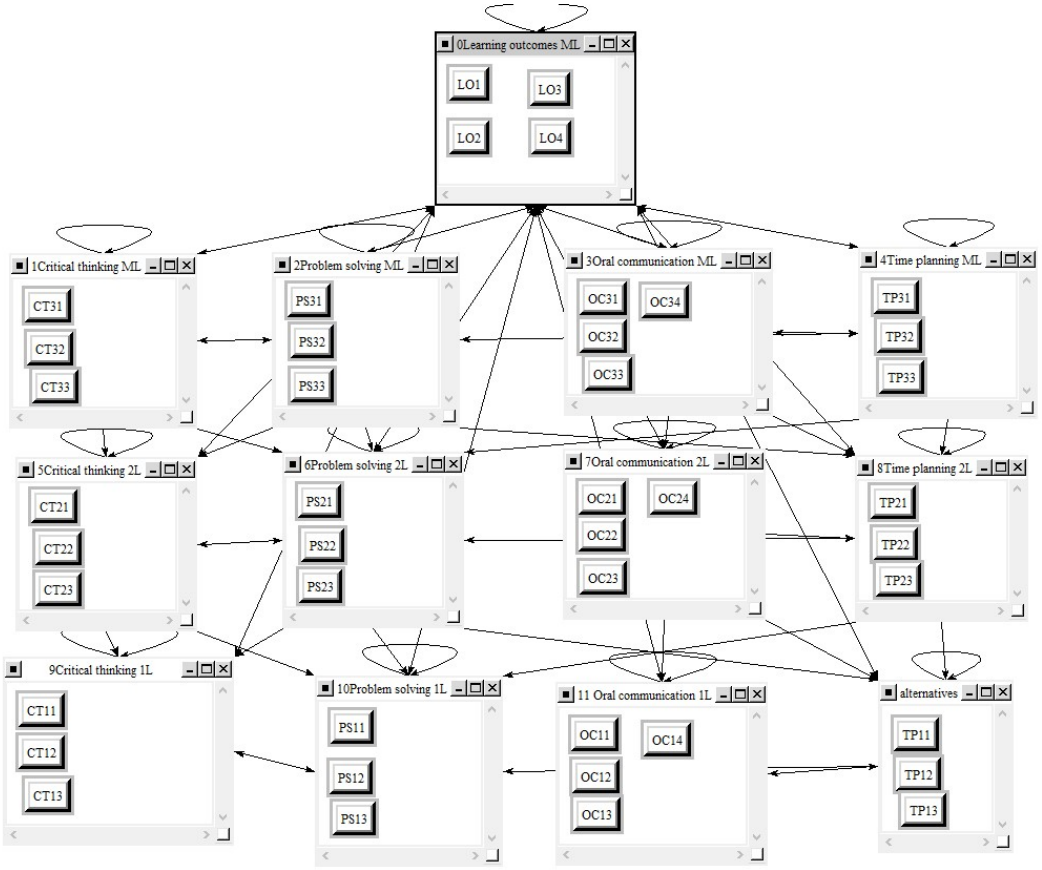

Fig. 8 ANP model for transversal competence assessment

Step 2. Fulfil the pairwise comparison matrices of elements. For that purpose, a questionnaire was filled out by the group of experts. Pairwise comparison matrices in this case are established by consensus although there are other methods that can be applied for group decision-making, such as aggregation of individual judgments or voting (Saaty 1980; Aczél and Saaty 1983; Saaty 1996; Forman and Peniwati 1998).

Table 7 shows the pairwise comparison matrix of the KPIs for the critical thinking competence at Master's level (1Critical thinking ML cluster) with respect to LO2.

Table 7. Pairwise comparison matrix of KPIs for 1Critical thinking ML cluster with respect to LO2 element

	CT31	CT32	CT33	Eigenvector
CT31	1	1	1/3	0.2000
CT32	1	1	3	0.2000
CT33	3	1/3	1	0.6000
			C.R.	0.0000

The eigenvector indicates the importance of each KPI. The CT33 has the highest eigenvector weight with 0.6 while CT31 and CT32 both weigh 0.2. In addition, the consistency ratio (CR) is checked to verify that the experts have been consistent when making their judgments.

Step 3. Elaborate the unweighted supermatrix. The summary of weights from the pairwise comparison matrices of step 2 is shown in the unweighted supermatrix (Table 8).

Table 8. Unweighted supermatrix

	LO1	LO2	LO3	LO4	CT31	CT32	CT33	…
LO1	0	0.7143	0.3333	0	0.8750	0.8750	0.8750	…
LO2	0.8750	0	0.3333	0.8333	0.1250	0.1250	0.1250	…
LO3	0.1250	0.1429	0	0.1667	0	0	0	…
LO4	0	0.1429	0.3333	0	0	0	0	…
CT31	0.2000	0.2000	0	0	0	0.1667	0.1667	…
CT32	0.6000	0.2000	0	0	0.8750	0	0.8333	…
CT33	0.2000	0.6000	0	0	0.1250	0.8333	0	…
PS31	0.6370	0.1429	0	0	0.2067	0.7143	0.4869	…
PS32	0.1047	0.4286	0	0	0.0581	0.1429	0.0778	…
PS33	0.2583	0.4286	0	0	0.7352	0.1429	0.4353	…
OC31	0	0	0.0956	0.1250	0	0	0	…
OC32	0	0	0.2867	0.1250	0	0	0	…
OC33	0	0	0.3943	0.6250	0	0	0	…
OC34	0	0	0.2234	0.1250	0	0	0	…
TP31	0	0.1562	0.1429	0.3333	0	0	0	…
TP32	0	0.6586	0.1429	0.3333	0	0	0	…
TP33	0	0.1852	0.7143	0.3333	0	0	0	…
…	…	…	…	…	…	…	…	…

Step 4. Fulfil the pairwise comparison matrices among clusters and elaborate the cluster matrix with the priorities computed. Table 9 shows the pairwise comparison matrix of the clusters with respect to 1Critical thinking ML cluster.

Table 9. Pairwise comparison matrix of the clusters with respect to 1Critical thinking ML cluster.

	0Learning outcomes	1Critical thinking	2Problem solving	5Critical thinking	6Problem solving	Eigenvector
0Learning outcomes	1	1/5	3	1/3	3	0.1303
1Critical thinking	5	1	5	5	5	0.5348
2Problem solving	1/3	1/5	1	1/3	1	0.0652
5Critical thinking	3	1/5	3	1	3	0.2044
6Problem solving	1/3	1/5	1	1/3	1	0.0652
					C.R.	0.0780

The summary of all weights from the pairwise comparison matrices of step 3 is shown in the cluster matrix (Table 10).

Table 10. Cluster matrix

	0Learning outcomes ML	1Critical thinking ML	2Problem solving ML	3Oral communication ML	4Time planning ML	…
0Learning outcomes ML	0.3261	0.1303	0.0945	0.1244	0.1525	…
1Critical thinking ML	0.1049	0.5348	0.0498	0	0	…
2Problem solving ML	0.1049	0.0652	0.3332	0	0.0786	…
3Oral communication ML	0.1049	0	0	0.4782	0.0763	…
4Time planning ML	0.1049	0	0.0375	0.0553	0.3394	…
5Critical thinking 2L	0.0445	0.2044	0.0375	0	0	…
6Problem solving 2L	0.0445	0.0652	0.4204	0	0.0353	…
7Oral communication 2L	0.0445	0	0	0.2838	0	…
8Time planning 2L	0.0445	0	0.0270	0.0584	0.3180	…
9Critical thinking 1L	0.0192	0	0	0	0	…
10Problem solving 1L	0.0192	0	0	0	0	…
11 Oral communication 1L	0.0192	0	0	0	0	…
Alternatives	0.0192	0	0	0	0	…

Step 5. Obtain the weighted supermatrix by multiplying the cells of the cluster matrix and the corresponding columns of the unweighted supermatrix (Table 11).

Table 11. Weighted supermatrix

	LO1	LO2	LO3	LO4	CT31	CT32	CT33	…
LO1	0	0.2801	0.1639	0	0.1140	0.1140	0.1140	…
LO2	0.4303	0	0.1639	0.4098	0.0163	0.0163	0.0163	…
LO3	0.0615	0.0560	0	0.0820	0	0	0	…
LO4	0	0.0560	0.1639	0	0	0	0	…
CT31	0.0316	0.0252	0	0	0	0.0891	0.0891	…
CT32	0.0949	0.0252	0	0	0.4679	0	0.4457	…
CT33	0.0316	0.0757	0	0	0.0668	0.4457	0	…
PS31	0.1007	0.0180	0	0	0.0135	0.0466	0.0318	…
PS32	0.0166	0.0540	0	0	0.0038	0.0093	0.0051	…
PS33	0.0408	0.0540	0	0	0.0480	0.0093	0.0284	…
OC31	0	0	0.0151	0.0198	0	0	0	…
OC32	0	0	0.0453	0.0198	0	0	0	…
OC33	0	0	0.0624	0.0988	0	0	0	…
OC34	0	0	0.0353	0.0198	0	0	0	…
TP31	0	0.0197	0.0226	0.0527	0	0	0	…
TP32	0	0.0831	0.0226	0.0527	0	0	0	…
TP33	0	0.0234	0.1130	0.0527	0	0	0	…
…	…	…	…	…	…	…	…	…

Step 6. Calculate the limit matrix. The weighted supermatrix is normalized and raised to powers until it converges, thus obtaining the limit supermatrix. Table 12 shows the limit priorities (LP) of learning outcomes and KPIs.

Table 12. Limit priorities

Learning outcomes							
LO1	0.0660	LO2	0.1046	LO3	0.0395	LO4	0.0520
KPIs							
CT31	0.0095	TP31	0.0157	OC22	0.0082	PS12	0.0655
CT32	0.0238	TP32	0.0202	OC23	0.0115	PS13	0.0218
CT33	0.0220	TP33	0.0128	OC24	0.0057	OC11	0.0347
PS31	0.0158	CT21	0.0160	TP21	0.0240	OC12	0.0128
PS32	0.0096	CT22	0.0187	TP22	0.0283	OC13	0.0212
PS33	0.0169	CT23	0.0132	TP23	0.0127	OC14	0.0213
OC31	0.0037	PS21	0.0144	CT11	0.0183	TP11	0.0237
OC32	0.0084	PS22	0.0257	CT12	0.0204	TP12	0.0306
OC33	0.0116	PS23	0.0122	CT13	0.0223	TP13	0.0107
OC34	0.0082	OC21	0.0073	PS11	0.0586		

Step 7. Analyse results.

In order to provide an overall prioritization of the KPIs, limit priorities are normalized (Table 13). Thus, we obtain the normalized limit priority (NLP) and the accumulated normalized limit priority (ANLP). The KPIs with the highest priority (those accumulating up to 50% of ANLP) are: PS12, PS11, OC11, TP12, TP22, PS22, TP21, CT32, TP11, CT13 and CT33. Six out of eleven KPIs belong to the 1st level competences (PS12, PS11, OC11, TP12, TP11 and CT13), which makes sense as success in developing the 1st level competences supports the development of the 2nd level and Master's level competences. Three out of eleven KPIs belong to the 2nd level competences (TP22, PS22 and TP21). Finally, two KPIs (CT32 and CT33) belong to the Master's level. It can also be observed that three out eleven KPIs belong to the CT competence (CT32, CT13, and CT33), three out of eleven belong to the PS competence (PS12, PS11 and PS22), one KPI belongs to the OC competence (OC11) and four KPIs belong to the TP competence (TP12, TP22, TP21 and TP11).

The assessment of these KPIs is the most relevant for two reasons. First, the fact they carry the greatest weight makes them the most influential ones in the assessment. Second, the weight of these KPIs accounts for around 50% of the global weight.

Table 13. KPIs ordered according to priority weight

KPI	LP	NLP	ANLP
PS12	0.0655	0.0887	8.87%
PS11	0.0586	0.0794	16.81%
OC11	0.0347	0.0471	21.52%
TP12	0.0306	0.0414	25.66%
TP22	0.0283	0.0383	29.49%
PS22	0.0257	0.0348	32.97%
TP21	0.0240	0.0325	36.22%
CT32	0.0238	0.0322	39.45%
TP11	0.0237	0.0321	42.66%
CT13	0.0223	0.0303	45.69%

CT33	0.0220	0.0299	48.68%
PS13	0.0218	0.0295	51.63%
OC14	0.0213	0.0289	54.52%
OC13	0.0212	0.0287	57.39%
CT12	0.0204	0.0277	60.16%
TP32	0.0202	0.0273	62.89%
CT22	0.0187	0.0254	65.43%
CT11	0.0183	0.0247	67.90%
PS33	0.0169	0.0229	70.19%
CT21	0.0160	0.0217	72.35%
PS31	0.0158	0.0214	74.50%
TP31	0.0157	0.0212	76.62%
PS21	0.0144	0.0196	78.58%
CT23	0.0132	0.0179	80.37%
TP33	0.0128	0.0173	82.10%
OC12	0.0128	0.0173	83.83%
TP23	0.0127	0.0173	85.55%
PS23	0.0122	0.0166	87.21%
OC33	0.0116	0.0158	88.79%
OC23	0.0115	0.0155	90.34%
TP13	0.0107	0.0144	91.79%
PS32	0.0096	0.0131	93.10%
CT31	0.0095	0.0128	94.38%
OC32	0.0084	0.0113	95.51%
OC34	0.0082	0.0111	96.63%
OC22	0.0082	0.0111	97.73%
OC21	0.0073	0.0099	98.72%
OC24	0.0057	0.0077	99.49%
OC31	0.0037	0.0051	100.00%

In order to provide students with feedback during their studies, it is necessary to assess the degree reached by students at each level and in each competence. For example, Table 14 shows the assessment of two students at the first level of their studies. The limit priorities of the 1st level competences, previously obtained, are normalized. Thus, we obtain the 1st level normalized limit priority (1st level NLP) and the 1st level accumulated normalized limit priority (1st level ANLP). The KPIs with the highest priority (those accumulating around 50% of 1st level ANLP) are: PS12, PS11, OC11 and TP12. It is important to focus on the development of these 1st level competences as they support the development of the 2nd level and Master's level competences. In the table, the assessments of two students are shown. In the Degree cell there appears the degree of achievement of the KPI for this specific student. Then, the overall assessment for this level is obtained by multiplying the weight of every KPI (given by the 1st level NLP) by its corresponding degree and then adding their value for all the KPIs. Next, it is important to verify the degree of achievement of the high priority KPIs as they are the most important in the assessment. This assessment is calculated by multiplying the weight of every high priority KPI by its corresponding degree and then adding their value for all

the high priority KPIs. The value obtained is then divided by the percentage of the 1st level ANPL for the high priority KPIs. In the table, for example, Student 1 has a higher value of high priority assessment than Student 2, but lower overall assessment. This will provide information about the activities to be performed by students in order to develop their competences successfully.

Table 14. Overall and High priority assessment of 1st level competences

				Student 1	**Student 2**
KPI	**LP**	**1st level NLP**	**1st level ANLP**	**Degree**	**Degree**
PS12	0.0655	0.1810	18.10%	8	7
PS11	0.0586	0.1619	34.29%	9	5
OC11	0.0347	0.0960	43.89%	7	7
TP12	0.0306	0.0844	52.33%	6	6
TP11	0.0237	0.0656	58.89%	5	7
CT13	0.0223	0.0617	65.07%	7	7
PS13	0.0218	0.0602	71.08%	6	9
OC14	0.0213	0.0590	76.98%	7	9
OC13	0.0212	0.0585	82.83%	6	9
CT12	0.0204	0.0565	88.48%	5	9
CT11	0.0183	0.0505	93.53%	9	9
OC12	0.0128	0.0353	97.05%	8	9
TP13	0.0107	0.0295	100.00%	5	9
		Overall assessment		7.13	7.29
		High priority assessment		7.80	6.22

The specific competence assessment for each competence at every level can be performed as shown in Table 15 for Student 1. For example, the assessment of the Critical thinking competence at 1st level is obtained by normalising the weights of the CT KPIs and then multiplying each weight by the degree reached and adding the results for all three KPIs.

Table 15. Assessment of 1st level individual competences for Student 1

Competence	KPI	LP	1st level NLP	Degree	Competence assessment
Critical thinking	CT11	0.0183	0.0505	9	6.93
	CT12	0.0204	0.0565	5	
	CT13	0.0223	0.0617	7	
Problem solving	PS11	0.0586	0.1619	9	8.10
	PS12	0.0655	0.1810	8	
	PS13	0.0218	0.0602	6	
Oral communication	OC11	0.0347	0.0960	7	6.91
	OC12	0.0128	0.0353	8	
	OC13	0.0212	0.0585	6	
	OC14	0.0213	0.0590	7	
Time Planning	TP11	0.0237	0.0656	5	5.47
	TP12	0.0306	0.0844	6	
	TP13	0.0107	0.0295	5	

To sum up, the development of this ANP model contributes to the approach in several ways. First, it helps to identify the relationships among different competences through the relationships among the KPIs used to measure each competence so that the results from the assessment are more reliable as dependences and feedback among competences are considered. Second, after solving the model, it is possible to focus on KPIs that have the greatest impact (highest weight/limit priorities) on the assessment of the transversal competences. With these results, it is possible to develop materials/activities that are more geared towards improving the achievement of these KPIs. Third, it helps to operationalise the assessment tool as it assigns weights to the different KPIs in order to obtain the global assessment of the competences. Thus, the assessment tool is refined by introducing the weights given by the experts' opinions (the instructors of the course). Fourth, the results from the use of the assessment tool may be used to develop teams (groups of students) that have reached the same degree of development of a given transversal competence or are at a complementary degree, which enables them to work together.

11 Conclusions

The importance of developing the transversal competences of students during their University years for the purposes of enhancing their abilities and improving their employability has led to the introduction of training in and assessment of these competences in the University degrees. It has to be noted that there are different levels of achievement of these competences, depending on the year the student is in. Thus, for example, UPV has defined three levels for every transversal competence. The first level should be developed during the first and second years of a Bachelor's degree. The second level should be developed during the third and fourth years of a Bachelor's degree. Finally, the third level should be developed during the Master's degree. However, there is still a need to develop coherent and consistent tools with which to align the management of all three levels . This paper has presented an approach, based on the performance management literature of organizations, consisting of four components (a methodology, a solid and integrated performance management framework, graphical diagrams and quantitative techniques) to assess and manage the achievement of transversal competences throughout the different levels of study using an ANP consolidated approach.

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