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Integration of Teaching Activities for Training in Research Skills in Technical University of Madrid*

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Training researchers entails a process of social interaction that enables an advance in knowledge, know-how and attitudes. When engineering students of the Technical University of Madrid (UPM) enrol in an educational cycle consisting of research and post-graduate studies, they are confronted with a need to change the way they conduct their activities, and find themselves unfamiliar with the research methodology and the nature of the study objectives. The acquisition of research skills at this stage of education is not usually part of the teaching syllabus. The investigation conducted here is the action-research type, whereby a situation is studied from the point of view of the participants. It consists of a process of analysis, diagnosis, proposals for change and assessment before the process is re-initiated. The main aim of this experience is to develop the skills associated with research activities. The objective results of this experience show that the trainee researchers acquired the skills that were the object of this work. These skills were manifested by the subjects resolving a real problem, working as part of a research team, and preparing work for publication in a variety of channels for the dissemination of scientific output. The opinion of the experienced researchers was resulted in a very positive valuation of the aspects considered. This action may potentially have a significant impact on the new postgraduate programmes, as it demonstrates that the planning of joint works covering a variety of disciplines and with data corresponding closely to the actual situation not only provides high-quality academic results, but is also capable of generating results from real research projects. With the logical adaptations, it could also be applied in undergraduate courses.

Keywords: doctoral education; researcher training; scientific publications; teaching experience

1. Introduction

For Solé and Mirabeth (cited by Brunet and Belzúnegui [1]), training represents an ongoing process aimed at "improving students' technical and professional skills (...), enriching their knowledge, developing their abilities and teaching them to learn". Training researchers entails a process of social interaction [2] that allows them to advance their knowledge (the fact of knowing something), know-how (knowing *how* to do something), and attitudes (wanting to do something). These are all components of the skills and behaviours that link individual characteristics with the skills required to carry out the tasks involved in research.

As an activity, training is not a process that is done by an isolated individual. According to Vigotsky [3], the subjects, the objects of knowledge, the training actions and the research tools combine and interact to favour the ability of people trained in research techniques to integrate the problems and tasks that lead to the solution [4]. The knowledge of experienced researchers enhances the subjects' training. The teachers-researchers take on the role of advisers, and are responsible for guiding the trainees at decisive moments in the research training process [5, 6]. Aspects that must be considered in the training of PhD students are collected comprehensively in the work of American Academy of Health Behaviour Work Group on Doctoral Research Training [7].

The primary purpose of the Technical University of Madrid (UPM) is to train professional engineers [8]. When engineering students embark on an educational cycle consisting of research and post-graduate studies, they are faced with a change in the way they perform their activities. The students' preliminary exploratory activities in this cycle lack the necessary focus, as they are unfamiliar with the methodology required for research activities and the nature of the study objective [9]. Until two years ago, the doctoral courses offered by the UPM had a duration of two years. In the first year, the students completed their training as researchers, studying subjects that were complementary to their main areas of interest, for up to a total of 300 hours. The second year required them to specialise in a specific research subject, involving 120 hours of work and concluding with a research work to be defended before a tribunal of experts, which once approved, would entitle the students to receive their Diploma of Advanced Studies (DEA).

This plan was modified in 2011 [10] so that it is now necessary to have the official Spanish graduate

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qualification—or its equivalent—, and a Master's degree from the university in order to embark on an official doctoral program. A doctorate is understood as being the third cycle of official university studies, leading to the acquisition of the skills and abilities relating to front-line scientific research. The doctoral programs at the UPM are run by its departments or centres, and thus tend to be linked to a different set of qualifications. Until the academic year 2011–12, over 100 different programs were offered. Currently, there are 55 different Master's programs available.

The acquisition of research skills at this stage of education is not a part of the study plan. Most Master's degrees do not explicitly state the skills required (only 40.23%), and these tend to refer to the application of knowledge, with a wide diversity in their classification. Skills related to the research activity—such as: ''communicating conclusions'', ''formulating considered judgements'', ''integrating knowledge'' and ''originality''—are only found in 24% of the references found in the Master's courses [11].

The present work highlights an educational experience carried out during the 2009/2010 academic year with postgraduate students who were studying two subjects in different doctoral programs. The fact that there were common elements in the students' two subjects, in addition to convergence in some of the topics, and frequent cooperation between the teaching staff of both students, meant that a part of the teaching activity could be carried out jointly, focusing on the acquisition and assessment of skills associated with training in research.

The primary objective of the experience consisted in developing the skills associated with the research activity, namely: the search for solutions to real problems, the integration of knowledge, the ability to work in a team, formulating considered judgements, communicating conclusions and originality in presenting the results [12, 13]. These skills were assessed in a personalised manner, as a very small number of students were involved in the study.

2. Materials and methods

The action consisted of a training activity that integrated general and specific research skills in two subjects (''Statistical Techniques for Research'' and ''Geographic Information Systems as a research tool for Rural Planning'') during the 2010/11 academic year. This was the last year in which doctoral programs were offered in the departments where the subjects were studied prior to developing the work for the doctoral thesis.

2.1 Subjects

''Statistical Research Techniques'' is defined as an essential subject in the programs in which it is taught, and has a value of 4 ECTS. It is described in the subject guide [14], and the opinion of the participants is shown in the work of [15]. Specifically, the final part of the subject covers the development of stochastic processes (temporal series and geostatistics) for at least five theoretical-practical hours. At the time this experience was carried out, it was taught as part of the doctoral programs of ''Economics and Forestry Management'', ''Rural Projects and Planning'', ''Environmental Sciences'', and in joint doctoral courses in Environmental Engineering taught in conjunction with Latin America.

''Geographic Information Systems as a research tool for Rural Planning'' is classified as an optional and methodological subject in the Rural Projects and Planning program in which has been taught since the academic year 2007–2008, and has an estimated teaching load of 4 ECTS. The syllabus is divided into two parts: the first part which teaches specific skills related to the creation, handling and management of Geographic Information Systems, including certain widely-used commercial GIS applications; and a second part where the students are required to carry out a teamwork project, in which these systems are applied to research in a rural setting. The students are assessed according to the development and results of this final work.

2.2 Study population

A university strategy for the training of human resources in research consists of creating research groups comprising trainee researchers under the direction of an experienced researcher [16]. These groups can form research communities that work around specific projects of interest to the community, developing both vertical (trained researcher → trainee researcher) and horizontal (trainee researcher → trainee researcher) pedagogical relationships. The process of exchange and collaboration gives rise to an intertraining relationship which produces a space for constructive knowledge-sharing with a specific pedagogical value, as trainees have access to methodologies and experiences developed by other researchers, which favours the development of the necessary skills [17]. In this experience, a research group was formed comprising five trainers and three trainee researchers.

Most of the trainee researchers who are studying these subjects have an excellent technical training in the field of Nature Sciences. During the 2009/10 and 2010/11 academic years, the number of students in the doctoral programs assigned to the departments

had already dropped by up to 60% compared to previous courses. Three trainee researchers took part in this experience. They had previously studied to graduate level in the fields of Forestry Technician (UPM), Agricultural Technician (UPM) and Environmental Sciences graduate (at the Autonomous University in Madrid).

The researchers charged with the training work in this case were five teachers from the agroforestry area, three of whom were directly involved in teaching the subject in question, while the two remaining teachers described a real research problem that was unresolved, and provided the observed data that could lead to the solution.

The characteristics of the research group as a whole were very specific. 62.5% of the group consisted of trainers and only 37.5% were trainee researchers. 100% of the group was formed by women, 87.5% of whom are trained in forestry engineering. The members of the group belonged to two different research groups in the UPM at the time of the experience.

2.3 Methodology

Following the classification of Melo and Villalobos [18], the research was of the action-research type, whereby a situation is studied from the point of view of the participants. It consisted of a process of analysis, diagnosis, proposals for change and assessment before the process was re-initiated [19, 20]. The training experience involved the following stages:

1. Choice of a study problem related to both subjects: search for real data and discussion of possible solutions to the problem.
2. Outline of the starting hypothesis and the selection of research methodology.
3. Planning the teamwork.
4. Carrying out the research and obtaining results
5. compiling a report on the results.
6. Written, oral and graphic communication of the research work.

This work by the research group began after the necessary skills had been developed to tackle the problem, and required a significant proportion of the ECTS in each subject.

The task undertaken with this methodology was to estimate, by means of geostatistics, the dasometric variables (height and diameter) of a set of trees whose data could not be taken in the field. This information was used to supplement the data collected in actual research plots in a forest in Cercedilla (Madrid). The team studied and analysed several assessment methods and compared the results before selecting the method that provided the best results for this assessment. It was decided to display the work in different result transfer formats. One of these is shown in Fig. 1, which describes part of this work.

2.4 Assessment of the experience

Three formal aspects of the experience were assessed: the research methodology, the dissemination of the results and the opinion of the trainee researchers.

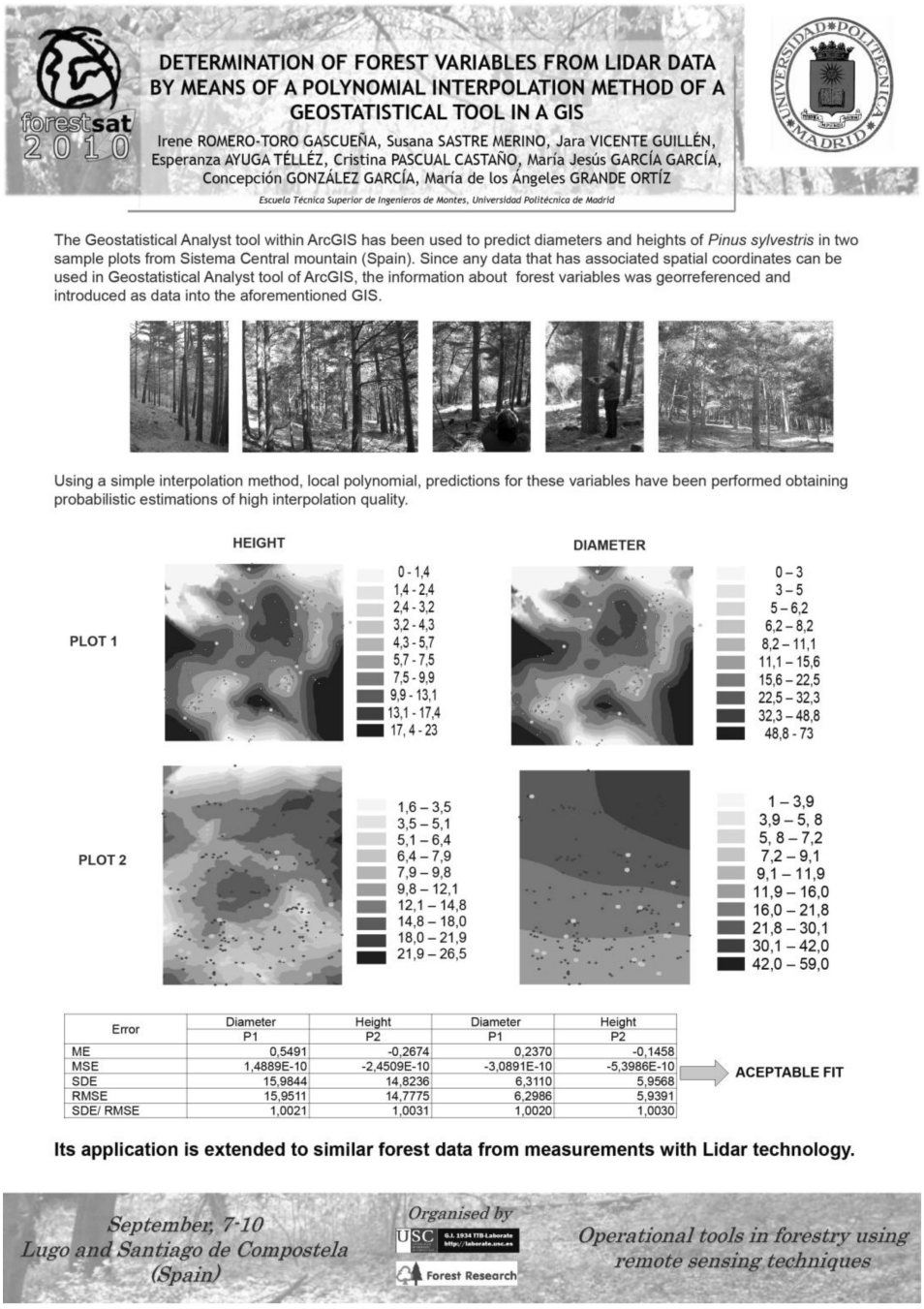
The fact of working with a single experience involving a reduced number of doctoral students required the teaching research to have a methodological focus which was partly very subjective [21]. The research methodology was assessed by verifying compliance with the 12 heuristic criteria proposed by Tillema et al. [22]. Self-assessment of compliance with the criteria makes it possible to avoid some of the problems that arise when carrying out specific research into teaching itself. The aim of this analysis was to control, or at least be aware of the objective processes of interpretation, which yields a greater overall knowledge of these aspects and avoids reaching premature conclusions.

The experience was also assessed according to the criteria used to evaluate the quality of the research [23] from the point of view of the dissemination of the results of the training activity. These results can be summarised according to the following criteria: the number of contributions to scientific meetings and the percentage of success in participation attempts, the number of contributions to scientific knowledge in international dissemination media and percentage of success, and the achievement of postgraduate degrees.

Several papers published recently have highlighted the importance of evaluating the knowledge achieved by assessment by expert researchers [24, 25].

The research also included a questionnaire on the participants' opinion of the experience, integrating the trainee researchers' individualised assessments by means of seven global operational indicators [18] as described below:

1. Formal aspects referring to presentation, scientific language and structure.
2. The themed content expressed within its framework of reference.
3. The formulation of the problem and the research objectives.
4. The methodological model used and the study subjects.
5. Importance of the results and their scope of application, as applied research or basic to educational development.
6. Contribution and importance to current pedagogical knowledge.
7. Achievement of the proposed objectives.



Error	Diameter P1	Height P2	Diameter P1	Height P2
ME	0,5491	-0,2674	0,2370	-0,1458
MSE	1,4889E-10	-2,4509E-10	-3,0891E-10	-5,3986E-10
SDE	15,9844	14,8236	6,3110	5,9568
RMSE	15,9511	14,7775	6,2986	5,9391
SDE/ RMSE	1,0021	1,0031	1,0020	1,0030

Fig. 1. Poster presented at the Forestat 2010 congress.

Each indicator was assessed with a Likert assessment scale [26] (Insufficient = 1, Sufficient = 2, Good = 3 and Excellent = 4). The three first indicators correspond to the overall assessment of the students' work, and the four last to the research into the methodological experience described.

3. Main results

After the conclusion of the theoretical developments necessary to tackle the geostatistical problems of variables in agroforestry research in the area of forestry engineering using GIS tools, an initial research group was created comprising the three trainers and the three trainee researchers. The objective was to formalise the research work for presentation at a scientific meeting.

The problem was posed by a trained researcher who was not involved in teaching the subjects studied. The research involved a series of variables observed in trees (geo-referenced specimens) in a scrubland, but for which several of the records

contained significant measuring errors; it was therefore necessary to find a reliable way of estimating these results. Observations of the same population were also available obtained with another measuring method and supplied by another trained researcher.

The GIS and the geo-statistical tools were the most suitable for resolving the problem; and the research group as a whole discussed the possible solutions, and established the starting hypotheses and the methodology to be used. All these stages were transacted smoothly and served as a training exercise for the researchers, inasmuch as they demonstrated the collective and systematic development of the research methodology.

Subsequently, the teamwork was planned; this entailed the search, using commercial GIS, for estimated values for the diameter and height variables for several tree specimens based on three different geostatistical estimation methods. The results obtained were compared by means of conventional statistical tools using field and satellite measurements. The trainee researchers conducted the research, each using a different interpolation method. The results were analysed as a whole.

The report on the results was drafted by the trainee researchers supervised by the experienced researchers, and then corrected in its different stages by the whole research group. The first stage was the presentation of the report in its written and oral form in order to grade the component subjects. The teachers of these subjects conducted a preliminary review at that time and found errors, mainly in the formal aspects of the drafting and presentation of the scientific work. These errors were insignificant. The component referring to consultation of the background literature and the updated review of the scientific knowledge was done correctly, but with room for improvement. Very good results were obtained in aspects of oral communication, development of the research, use of statistical techniques and GIS. The score obtained in these subjects was excellent for all three trainee researchers.

These deficiencies were corrected, and a part of the results was sent for peer review at a major international congress in the area of agro-engineering. The work was accepted and selected from among a number of others for oral presentation. A communication was compiled with another part of the results in poster format for a further high-profile international congress in the area of forestry, and was also accepted. This result signalled the achievement of the objective proposed in this experience.

The assessment of the experience with the proposed heuristic criteria leads to the conclusion that the results of the research agree and are compatible with the predicted objectives, even though the population on which the experience was conducted is insufficient to extrapolate the results to other different research groups. The conclusions and the objectives coincide, but in addition significant results have been obtained that are independent of the objectives proposed, such as the subsequent publications. These results are also presented in this work. The methods selected guarantee the conclusions and fulfil the object of the study in a consistent manner, as they show the results of the training in real scientific activities and are evaluated by a number of scientists in various formats. The methods do not overestimate the results or the objects of the study. There is consistency between the construct and the data, and the conclusions are based on the objective data. However, the research does not appear to guarantee the emergence of essential theoretical elements that are not considered a priori, although a detailed scrutiny reveals the construct. Therefore, only one of the 12 self-assessed criteria is not met, and it can be concluded that the research appears to be free from most of the problems of subjectivity inherent in this type of study.

The results of the experience include the two expected outcomes (100% compliance with the objectives established), in addition to further results that were not initially predicted, such as the publications by the group, and publications by some of the group's researchers in relation to the subjects described.

In total, three communications containing the direct results of the research work were presented to congresses. Two of these were international congresses. 100% of the works were accepted and published. Two of these works were pre-selected by international journals to be included in their publications. One of them was peer-assessed and published in an indexed journal. The other was assessed by three reviewers from a journal featured in the JCR. A negative assessment was obtained from one, indicating that changes should be made; specifically a recommendation for a greater number of measurements and that the analysis should include more valuation measurements. This work is proceeding extremely slowly due to the dispersal of the research group at the present time. It can be concluded that the success rate of the research group in these works is at least 50%.

As a result of the research training in the theoretical-practical developments of these subjects, all the trainee researchers obtained an excellent grade and succeeded in completing their studies for their master's degree or advanced diploma.

This work describes a scientific advance and demonstrates that the statistical method of Kriging

can be used to estimate dasometric variables such as diameter and height in the type of woodlands in the study, in an innovative approach that is used here for the first time.

They also produced additional scientific publications based on the training they acquired. The series of works prepared as a result of this experience and disseminated by means of scientific publications with sufficient quality indexes are shown in Table 1.

As can be seen in Table 1, five of the works were communications to congresses (four in poster format and one oral communication), one book, and two articles in indexed journals. There are six international and two national publications. The publications cover the period from 2010 to 2012. An additional publication is pending which is still in the process of development.

Finally, the five experienced researchers assessed the global operational indicators proposed. All the indicators scored good or excellent. Table 2 shows the assessments and the statistical indicators used for evaluating the scores.

Figure 2 shows the bar chart indicating the frequency of the valuation obtained by each indicator.

It can be seen that indicators 1, 4 and 7 were assessed by most respondents as excellent, while the rest were assessed as good. The importance of the research was the least valued indicator, as all the respondents assessed it as good.

4. Future issues

This action may potentially have a significant impact on the new postgraduate programs, as it demonstrates that the planning of joint works covering a variety of disciplines and with data corresponding closely to the actual situation not only provides top-quality academic results, but is also capable of generating real research results. We believe that this experience could also be applied in undergraduate courses, by adapting the work to the acquisition of graduate skills.

Methods for evaluating the experience can also be

Table 1. Scientific publications by researchers in the group in relation to the experience

Title	No. of experienced/ trainee researchers	Publication	Quality indications of the publication
Comparison of interpolation methods integrated into a GIS for the study of dasometric variables.	4/3	Presentation at int. Agroengineering congress in 2010	Peer reviewed. ISBN 978-2-85362-684-2
Validating a stream flow prediction model for ungauged watersheds in Spain.	1/1	Presentation at int. Agroengineering congress in 2010	Peer reviewed. ISBN 978-2-85362-684-2
Determination of forest variables from Lidar data by means of a polynomial interpolation method of a geostatistical tool in a geographic information system.	5/3	Presentation at int. ForestSAT congress 2010	Peer reviewed.
Use of geostatistical environmental teledetection tools for forestry planning and management.	4/3	Presentation at national congress CONAMA10	Peer reviewed. ISBN 978-84-614-6112-7
Comparison of Interpolation Methods for the Study of Forest Variables Using a GIS.	4/3	Journal of Agricultural, Science & Technology	Indexed journal
Influence of soil moisture on the curve number method for small ungauged watersheds.	1/1	Presentation at the 6th Iberian Agroengineering Congress	Peer reviewed. ISBN 978-972-778-113-3
Silvanet, Public Participation for Sustainable Forest Management.	4/1	Book, Ed. Fundación Conde del Valle de Salazar	Peer reviewed. ISBN 978-84-96442-36-8
Performance of a Monthly Streamflow Prediction Model for Ungauged Watersheds in Spain.	1/1	Water Resources Management	Journal index in the JCR

Table 2. Assessment and statistics for the score obtained in each indicator

Global indicator	Good	Excellent	Average score	Median score	Median deviation
1. Formal aspects	1	4	3.8	4	1
2. Thematic content	4	1	3.2	3	0.2
3. Problem formulation	4	1	3.2	3	0.2
4. Methodological model	2	3	3.6	4	2
5. Importance of results	3	2	3.4	3	0.4
6. Relevance	5	0	3	3	0
7. Achievement of objectives	0	5	4	4	0

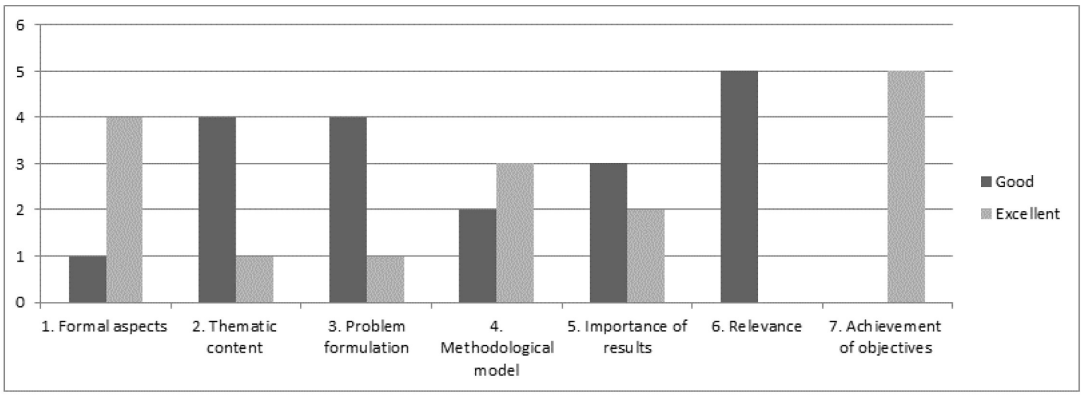


Fig. 2. Diagram of response frequencies to the valuation of the overall indicators of the experience.

extrapolated and used as useful indicators of skills in the future tracking of Master's programmes, especially those oriented to training researchers and for evaluating the level of training of doctoral students.

In cases where there are more researchers in training, other actions could be considered such as the use of the PDEODE method ((Predict-Discuss-Explain-Observe-Discuss-Explain) [27] and the evaluation of the students' degree of satisfaction [28].

5. Conclusions

The experience described in this work is primarily aimed at developing the skills associated with the research activity. The dissemination of the results shows that the trainee researchers acquired the skills that are the object of this work. These skills were developed by tackling a real problem, posed by an actual research project in progress at the time, which was successfully resolved. The experience involved integration in a research team, and several works were produced for publication in a range of dissemination channels for scientific research.

The mark obtained by the trainee researchers in the subject in question was excellent. All three passed the training stage in the Master's degree in research.

The series of works prepared as a result of this experience and disseminated through scientific publications with significant quality indexes are the quantifiable and objective results of the success of the experience.

The teaching research methodology was assessed in order to resolve the possible problems of subjectivity of the results, and the only issue detected was a lack of representativeness of the experience due to the low number of participants and the inability of the methodology to guarantee the detection of important issues not considered in the research.

Due to the reduced number of participants (students and teachers) the assessment system used was the verbal expression of the opinions of the trainee researchers, who demonstrated a high degree of satisfaction. The opinion of the experienced researchers was collected by means of a survey on the seven global indicators, and resulted in a very positive valuation of the aspects considered.

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