Integral and Transformative Engineering Coursework in Formative Research for Undergraduate Curricula

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***Abstract*— At several private Peruvian universities, formative research was not included in the curricula design. Here the problem to solve was the small number of undergraduate dissertations in Engineering. First, the coursework design and tutoring were reviewed and reformulated. The former proposal was based on the triangle of Peñaloza Ramella [1], in this study, this view was extended to a double triangle. The proposed extension uses an inverted triangle in order to compensate for the insufficient preparation in high school. Second, problems were identified comparing current outcomes against the desired undergraduate dissertations. The design used a mix of the transformative research ideas at US education institutions [2] and the triangle's formulation of Peñaloza-Ramella [1], where the first triangle is to assure student preparation for different ways of formative research and the second one is to adapt the coursework to the original triangle to get more specific results each semester. Furthermore, several aspects in the use of resources were promoted (e.g. use of IEEE Xplore databases). In the first year, results have shown (1) acceptance by former students (before academic semester 2014-2) of these changes, generating 12 dissertations, (2) a change in few courses in formative research clearly enhanced at semesters II, III and VII, (3) an increase in the number of undergraduate dissertations during coursework, (4) first works accepted and presented in a Peruvian Student Competition Congress (5) all alumni with professional degrees have completed their undergraduate dissertation. Finally, in the next four years, a new generation of students is going to emerge with a significant improvement of their quality and their reasoning skills.**

Keywords*— *Formative Research; Dissertation; Integral Formation; Transformative Research; Plagiarism.

I. INTRODUCTION

In the current context of university education, there are several levels in the curriculum system. Van der Akker used four levels for different curricular activities: country or society in a macro-level, institution in a meso-level, classroom in a micro-level, and individual in a nano-level [3]. Looking at engineering programs in the world, for example in the USA, the most successful engineering programs, in terms of formative research, were designed for postgraduates: Harvard University with 14,500 postgraduates and 6,700 undergraduates [14]. In contrast, in European programs, master's programs were designed as a continuation of undergraduate programs, e.g. Telecommunications in Spain consider coursework in four years plus two years for master's degree [15]. In Peru, universities are predominantly undergraduate institutions. However, formative research in Peruvian undergraduate universities generated papers that in few cases appeared in conferences indexed in Scopus [16].

Formative research is a research activity used at the beginning of a project carried out to gain insight into the subject, and it guides the whole process until the solution of the problem is reached [23]. In this case, it was utilized to address the undergraduate dissertation problem

The *Universidad de Ciencias y Humanidades* (UCH) is one of the eleven universities that provide undergraduate Electronic Engineering in Lima [9], where more than 9 million inhabitants live. Improving the current curriculum was the main concern at UCH, and here the focus is on the improvement of formative research. Other universities such as the *Universidad Nacional de Ingenieria* (UNI) and *Pontificia Universidad Catolica del Peru* (PUCP) allows degrees with Professional Sufficient Work and also few students obtain their undergraduate degrees based on their graduate dissertations from abroad translated into Spanish. According to data extracted and processed from PUCP Webpage in the 1993 to 2015 period [22], there were 1,576 undergraduate alumni with a professional degree, 802 having completed their undergraduate thesis, 771 taking a course to obtain their professional degree and 3 submitting a professional report.

Since its inception in 2008, the UCH has followed the idea of Integral Curricula from Peñaloza-Ramella. Peñaloza-Ramella developed a university system based on five dimensions: cognitive (i.e. coursework), research, sports and arts, pre-professional practice, and tutoring [1]. Thus, in the research dimension all the undergraduates were encouraged to formulate and implement their own plans for formative research. Unfortunately, there was not an adequate control of this development, courses did not provide clear indicators to support this plan, and there were an insufficient number of full time professors. A clear sign of this problem was the output at the beginning of 2014: there were three groups of undergrads without any of them having completed the final dissertation. In these three groups there were 53 students and the main problem was not only their dissertations but also the dissertations of all the upcoming students. This was supported by the previous University Law, which allowed students to finish their

undergraduate studies without the final undergraduate dissertation.

César Germaná in 2002 pointed out some key points to guide the improvement of the university: Public University Quality, Governmental Education System, University Education, University Research, Financing, Teacher Quality and Accreditation. A good description of these points was mentioned and even what functions they should have, but not how to generate them. For example, Germaná mentioned that an economic incentive will help improve teacher quality but he did not discuss details of these incentives. He also emphasized that knowledge development and the University in Peru require teachers and students to explore new paths, but he did not detail the process [5]. In this way, a second problem arose: how to improve the quality of research professors if none of them holds a doctorate.

In addition, the new University Law encourages lecturers not only to focus on coursework but also in research [8]. However, at the Electronics Program, there was only one full time lecturer compared to 22 part time lecturers. The part time professors worked for other universities during the day or in other full time jobs.

Therefore, three parts in the undergraduate scenario in engineering programs in the UCH were used as the main context for the three main problems identified, i.e. not enough undergraduate dissertations, not clear formative research areas, and not enough lecturers according to the new university law. Therefore, these problems are used to redesign and reformulate the coursework to improve the formative research for the university, giving specific options for the students.

II. Theory and General Design

A. *Triangle's formulation of Peñaloza-Ramella*

Peñaloza-Ramella reviewed the organization of some public universities and suggested a model for a university based on the five dimensions reviewed in the introduction and not offering only professional coursework. An interesting approach was that he saw the complication occurring when the previous semester of General Studies was added with one or two professional courses whose content was basic and administered by the "General Studies" department. This leads, as a rule, to conflicts between departments, because they do not look at the consistency with the guidance that motivates the continuation of General Study's courses. All these problems and conflicts disappear when the number of courses offered by General Studies and Undergraduate Coursework creates a "triangle" (highlighted in green, in Fig. 1) is conducive to the general coursework. In conclusion, Peñaloza-Ramella formulated a careful analysis from a practical point of view and much more in harmony with the meaning of the General Education whose subjects must be addressed by the students throughout their careers [1]. This model is being implemented in few SouthAmerican universities in Venezuela, Colombia and Peru.

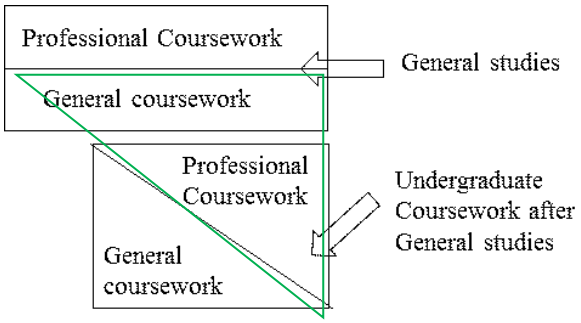

Fig. 1. Undergraduate studies at UCH following Peñaloza-Ramella model, Adapted from [1].

B. *Theoretical Project Management Choice*

Having the problems and the environment described in the introduction, it was strategic to implement a better program to produce knowledge. This was the first step about the facilitation of the new program to formulate and implement the project. In a project, usually one is given the options of "Fast" (the time required to deliver the product), "Good" (quality of the final product), and "Cheap" (total cost of designing and building the product) [4]. The typical triangle reflects how the three properties of a project are interrelated, and the difficulty to optimize all three. Therefore, depending of the particular project, it usually takes two variables.

In a later version of the project management triangle, Collin Harman added the usual "free" axis that extends the "cheap" view [19]. This vision would agree with some cases in the electronics and computer sciences. In the project development a modified version of Fig 1 was chosen. In the UCH, there is no expensive infrastructure and full time professors do not have many lecturer hours. Therefore, the long term project that seeks for "cheap" and "great" quality development may assure a better work with most of the students. This long term choice allowed UCH to start in semester I and finish in most of the cases in semester X.

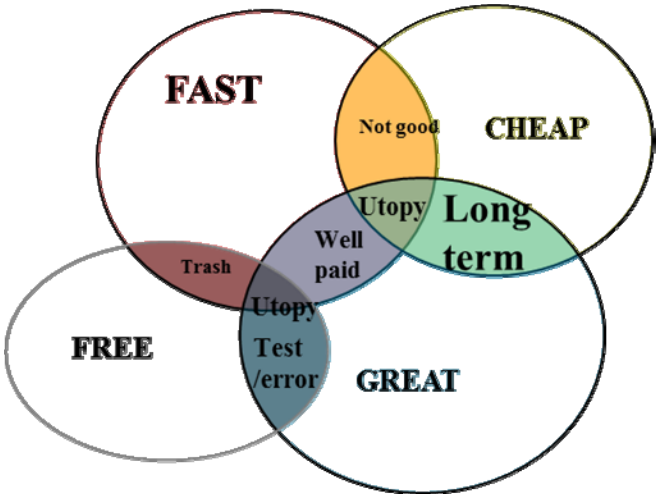

Fig. 2. Updated "Project Management Triangle" of the long term realization of the individual Undergraduate Dissertations, Adapted from [19].

C. General Design of Coursework to improve Dissertations

It is known the relatively long time needed to have the design of each undergraduate research with high quality and cheap. Therefore, it was decided to use the complete time in undergraduate coursework, i.e. the five years of undergraduate studies in Peruvian universities.

At the beginning of 2014 the formative research in the UCH was followed by five courses: University Work Methodology (MTU) in the first semester, Scientific Research Methodology (MIC) in the fourth semester, Pre-professional Practice (PPP) in the eight semester, Workshops for Thesis 1 in the ninth semester, and Workshops for Thesis 2 in the last semester, as shown in Figure 2. Therefore, the main problem was that the gaps between the first three courses were 3 and 4 semesters. This should be a cause for the lack of dissertation outcomes.

Due to the insufficient preparation of the students in the Peruvian high schools, the program looks first for the increase of the skills and the diversification of student's knowledge in the first 2 years. This means an inverted triangle is used, compared to the one proposed by Peñaloza-Ramella (see red triangle in Figure 3), i.e. the program increases the number of works read and interpreted by every student.

After that increase, the number of works analyzed decreased gradually, following the triangle of Peñaloza Ramella [1] (see yellow triangle in Figure 3).

Following the program, the formulation of the project is done almost as a sink funnel, where all skills and knowledge developed in the first 7 semesters are used (see green line in Figure 3).

Finally, continuing with the sink funnel (see green line in Figure 3), every student dissertation has an advisor for at least the last two semesters and the results will be the consequence of all the study and formulation previously done. Moreover, to assure the quality of the dissertation, students are encouraged to present their works in student competitions in the Peruvian National Congresses: INTERCON, CONEIMERA and COMTEL (see blue arrows in Figure 3).

All of this was going to be labeled as the "double triangle with the sink funnel design". In this way the design considers meso-, micro- and nano-levels of the curriculum implementation.

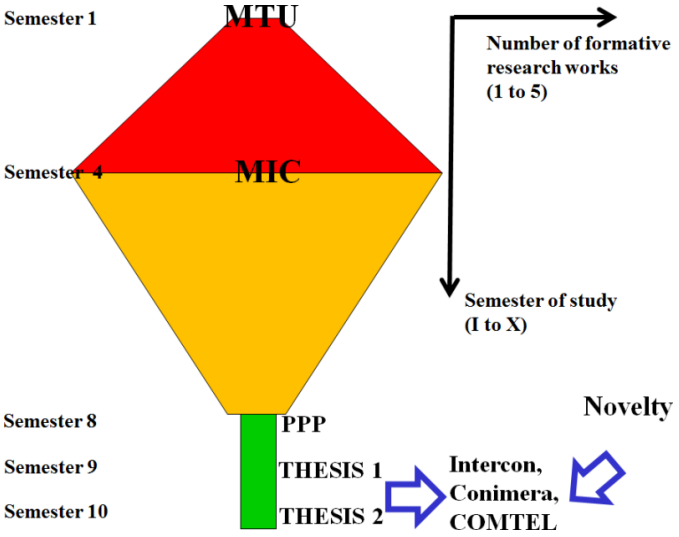

Fig. 3. Theoretical Design of the Project Management for Each Student Dissertation Work.

III. Design and Methods

Bearing in mind all the previous design, the three problems identified were included for this specific design.

Having selected the long term period of the undergraduate project, we needed to define the Design of the Undergraduate Formative Research Plan. First, we focused on the necessary skills and knowledge of the student to formulate the project at the time he/she was in semester VIII. This part was thought in order to facilitate the solution of the first problem.

This proposal is in line with the other 4 specialties of UCH and seeks to highlight the creative thinking based on scientific criticism of students and professors. The specialty of Electronic Engineering is sensitive to future interdisciplinary collaboration for students with greater sensitivity to modern research.

The accreditation implementation research within the undergraduate courses and laboratories has been considered similar to universities seeking excellence through programs aimed at transformative research at the undergraduate level [2] in a decade time and also it is largely in the planning of Integral Curricula Training [1].

The frame of the "Proposal on Formative Research Area of Electronic Engineering" considers four phases, as listed in Table 1 and explained in the following subsections.

A. Initial Formation: Semesters I to IV

The reports of students and teachers are used as indicators (see Table 1). The student work items are papers and book chapters in Spanish. In this case the assignments were considered in courses whose technology changes across the board in several technology sectors. Therefore, there are articles in Spanish which are chosen with no more than five years gap. This choice is due to the fact that new theories tend to be documented in various languages within about 10 years,

but article reviews are suggested to work in this Initial Formation.

B. Diagnostic Training: Semesters IV to VII

The reports of students and teachers are used as indicators. The work items are in English; in part, because of the improvement of student's second language skills is required as the student goes further in the average Peruvian university curriculum. English is necessary in these semesters because between the fifth and sixth semester courses it is acting as a "lever" to more advanced courses. Given the current technological change in electronic engineering, depending on the field, it is appropriate for the student to speak English, Korean or Chinese. Of these languages, English is adequate and gives no more than 2 years lag on average. New theories at early implementation are common practice and tend to be documented within around 2-3 years in the so called "Trends", There are also revisions and patents or other diagnostic technology sources.

TABLE I. DESIGN PHASES ON THE RESEARCH AREA OF UNDERGRADUATE ELECTRONIC ENGINEERING

Program	*Semester*	*Indicators Per Student*	*Indicators Per Lecturer (2014-2)*
Initial Training	I to IV	Trials of Objectives: in 50 words, Methods: 400 words, Results: 400 words and Comments: 200 words	3 works selected for collection at DACINV
Diagnostic Training	V	Items in English. Trials of goals: 50 words, methods: 400 words, results: 300 words and 1 item of discussion: 300 words	3 selected works
	VI	Items in English. Trials of goals: 50 words, methods: 300 words, results: 300 words and 2 items of discussion: 600 words	2 selected works
	VII	Trials of goals: 50 words, methods: 300 words, results: 300 words, 2 items of discussion: 600 words, and 1 problem on the basis of the 3 articles: 200 words	2 selected works
Formulation of the Project	VIII	Dissertation project: motivation, state-of-the-art, formulating problems and specific objectives (OEs) and theoretical framework	75% of students with projects in registry
Execution and Completion of the Dissertation	IX	Dissertation with 50% of the old OEs of the project	70% of projects with 50% of OEs
	X	Dissertation with 100% of the old OEs of the project	65% of projects 100% of OEs

C. Formulation of the Project: Semester VIII

The Project Draft is the indicator that is presented formally for qualification of the undergraduate dissertation to the UCH. The formulated problems should be recollected after or within pre-professional practice. The previous two phases have trained the student to make a diagnosis according to where he/she did the pre-professional practice or another strong professional interest. In addition to the individual or group work, each teacher must fill out an evaluation form.

D. Execution and Completion of the undergraduate dissertations: Semesters IX and X

The typical feedback of the advisors was considered in the formative research of students. Feedback should increase throughout the semester as the thesis advisor gains experience. This is important for faculty development that would help to solve the second problem

E.A.P. Electronics Engineering developed the first format of assessors Assessment Thesis for academic semester 2014-1 (March-June). This specific format gradually changed in the following semesters. This part was thought in order to make it easier to see where the optimal solution of the second problem is.

Other specific parts of the implementation were addressed in order to give continuity to some projects started by lecturers with different groups of students. This was done putting different professors in charge of different groups through different semesters. Specifically, few Projects that started in semesters II, III and VIII were followed by the same lecturers at the immediately next semesters. This part was thought in order to facilitate the solution of the third problem.

It was suggested to encourage students to participate in student projects presented at INTERCON, Coneimera and COMTEL.

E. Students that have finished coursework in academic semester 2014-1

Here, as shown in the introduction, past senior undergraduate students needed to reformulate their dissertations. Therefore, the work of the second full time professor started completing this important part, in order to get the best dissertations

F. Students that have finished coursework earlier than academic semester 2014-1

Reviewing, in the UCH the formative research design, two calls were scheduled for professors to explain what was required from them and the gradual implementation. The coursework implementation considered from two to five courses for semesters I to IV, decreasing gradually from 4 to 2 courses from semesters V to VII and 1 course in the last semesters (Figure 3).

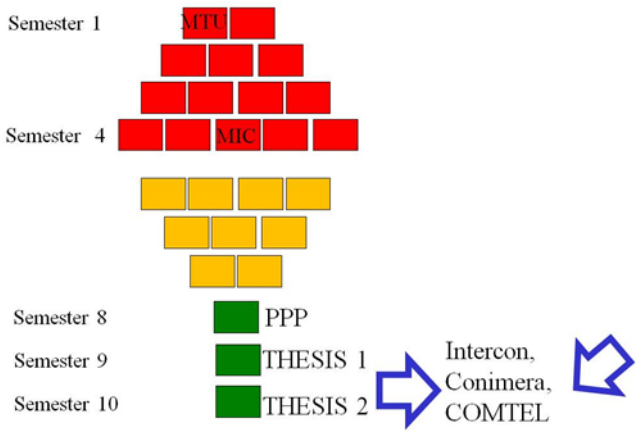

Fig. 4. Implementation of Formative Research in the following years in order to get more undergraduate dissertations.

IV. Results of the First Year of Implementation

A. *Work of all the students from semesters I to VIII*

This formative research was required since 2012 as a 30% of the grade in each course, but it was not applied in any course. The project was worth 30 % of grade 1 and 2 and it is contained within the system change in the Intranet. It was used the week before partial and final exams: week 7 and week 14. This was implemented since academic semester 2014-2

Although original written was found in the students at semesters II and III (between first and second year), unfortunately, plagiarism was detected in most of the works in students at semesters VI and VII, see numbers highlighted in Table II. These works were encouraged to be done in groups, but the groups of students supplied the same information available in the Internet which was contrasted with the online software of plagiarism detection "Duplichecker" [18]. Plagiarism decreased in 2015-1 as expected, e.g. from 8 to 0 in Control Engineering I and 4 to 0 in Optical Fiber, groups at different semesters (VI and VII).

The results shown in Table II do not clearly match with neurodidactics, but here it was shown how to improve learning through daily events (e.g. Physic III at semester III) groups at different semesters (VI and VII) and possibly playing with affection as reported in other contexts [11]. This work help students to Formulate the Project having a greater percentage of students 17 of 29 in 2014-1 and 19 of 25 in 2014-2

Initially, all these changes were not well received by all the students, because now they needed to finish their undergraduate dissertation to finish the degree. Therefore, in order to popularize their studies a Technology Workshop on week 15: 2 shortlisted projects for each course. Professors and students having the two best works received a reward. Currently, an increasing support for students is being finding.

Research areas for each professor: Based on link/continuity of these formative research works. Three professors started with a research line, a direct contribution to the third problem.

When academic semesters 2014-2 and 2015-2 are compared (Table II) the increasing trend is made not only in the time spent by the students in their works and assignments. It is believed that the process of learning outside the lectures but also the teacher attitude and synergy with students, assure the successful process of this implementation to happen [13].

TABLE II. Coursework Design and Results of Academic Semesters 2014-2 and 2015-1 on the Research Area of Undergraduate Electronic Engineering

PROGRAM	SEMESTER	COURSES	RESULTS	
			2014-2	*2015-1*
Initial Training	I	MTU,	App	App
		Mathematics 1	0	0
		Mathematics II	0	0
	II	Instrumentation I	11(**0^{p}**)	9(**0^{p}**)
		Physics II	0	0
	III	E (Instrumentation II)	2	7
		Electrical Circuits Analysis I	0	0
		Mathematics III	0	0
		Physics III	3(**0^{p}**)	11(**0^{p}**)
	IV	MIC	App	App
		E (Formulation and Project Investment)	0	0
		Digital circuits	0	0
		Electrical Circuits Analysis II	0	0
		Electronic devices	0	0
Diagnostic Training	V	Digital Signal Processing I	0	0
		Digital systems	0	0
		Telecommunications I	0	0
		Numerical methods	0	0
	VI	Microprocessors	0	0
		E (Telematic networks)	0	0
		Control Engineering I	**8^{p}**	**0**
	VII	**Optical fiber**	**4^{p}**	**7(0^{p})**
		Microwave	0	0
Formulation of the Project	VIII	Pre-professional Practice	17(**0^{p}**)	19(**0^{p}**)
Execution and Completion of the Dissertation	IX	Workshop of Thesis I	6(**0^{p}**)	11(**0^{p}**)
	X	Workshop of Thesis II	2(**0^{p}**)	9(**0^{p}**)

^{p} Number of Works with plagiarism

B. *Students that have finished coursework from academic semester 2012-2 to 2013-2*

These students had finished before 2014 without a complete undergraduate dissertation. During academic semesters 2014-1

and 2014-2, four calls were made: April, June, August, and October. Each student worked with a professor and received a feedback on their dissertation. Finally 11 dissertation works were made under this scheme, each one of these students received between four and eight corrections on their dissertations, giving a direct contribution to the first problem.

C. *Students that were finishing coursework in academic semester 2014-1*

During the last semester of their coursework (academic semester 2014-1) they were advised by some professor and extra hours for tutoring were provide in order to achieve the best work for undergraduate dissertations. Of special importance for administrative purposes, this was done without spending more money. Two calls were done after they had finished: September, and December. Finally, two dissertation works were made under this scheme; they received three and five corrections in the overall dissertation. This gave a direct contribution to the first problem.

D. *Students that were finishing coursework in academic semester 2014-2*

During the last two semesters of their coursework (academic semesters 2014-1 and 2014-2), students were advised by two professors and extra hours for tutoring were provided. Again, this was done without spending more money and moreover, the money spent was around 10% less than previously. No calls were made after they had finished. Finally, nine dissertation works were made under this scheme, giving a direct solution to the first problem and facilitating changes in the program.

E. *Overall result in the "double triangle with the sink funnel design"*

Reviewing the results in formative research after the first year of implementation, the requirement was partially fulfilled in most of the semesters as was stated in Table 2. The implementation was colored when the professor collaborated actively with the assignments (Figure 5). In addition, two student's works were presented at INTERCON 2015, which highlighted the improvement of quality work as assessed by external referees. In addition, two professors started rotating between courses to follow their students.

The indicators were considered meso-, micro- and nano-levels of the curriculum implementation. In the UCH, it is hoped that professors will consider these figures to motivate students to make it work in the future. The administration is also collaborating by hiring two new full time professors; one of those will have at least half of his time for research.

It is also expected that the UCH are going to improve their use of science databases such as IEEE Xplore in the future. This could be measured by the next Peruvian National Poll in Education, as it was done in 2010 [12].

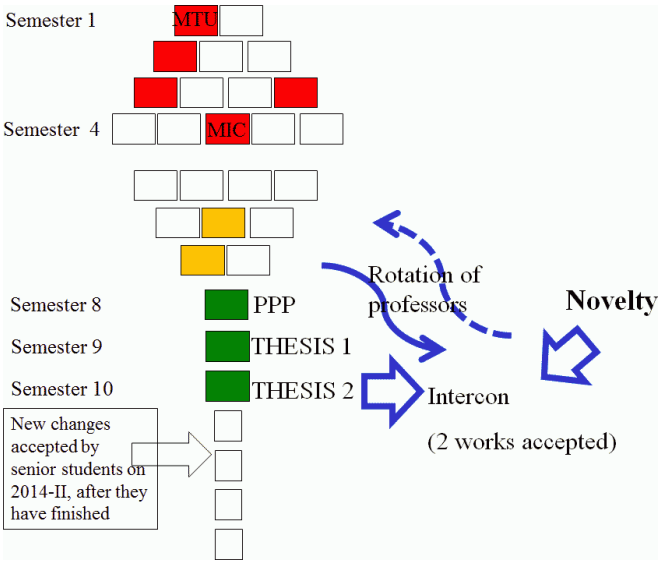

Fig. 5. Implementation of the Project Management for Each Student Dissertation Work in the following years.

Results in terms of percentage were good for UCH, having only Professional Undergraduates by Undergraduate Dissertation. Therefore, comparing with local universities, in Fig. 6 for example PUCP got a similar program that started at 2003 and got 100% of the results in 2014.

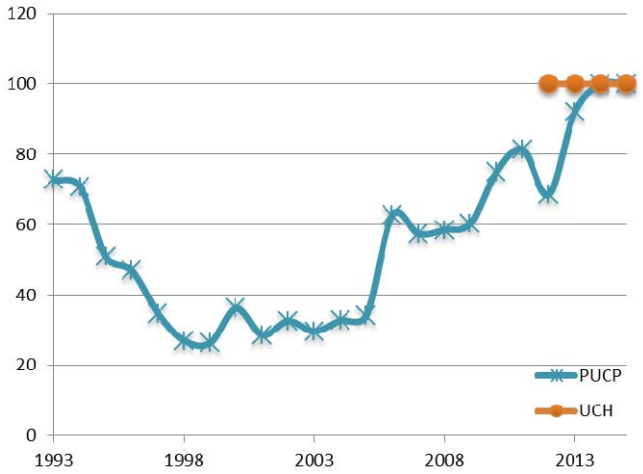

Fig. 6. Percentage of Professional Undergraduate with Undergraduate Dissertation in UCH and PUCP

V. Discussion

In the present study formative research was designed and implemented to solve the following problems in the long term. (1) increasing from 0 to 22 undergraduate dissertations, (2) adapting coursework in the last 3 semesters and reformulating the coursework between semesters I and VII, (3) starting research lines with 2 part time lecturers, (4) hiring two full time professors with doctorate abroad and (5) no undergraduate alumnus with professional degree should remain without an undergraduate dissertation. Nowadays, due to the current University Law [8], it is believed that similar implementations would be a trend in Peru. It is not only about including

disciplines related to scientific planning and science and engineering writing in both public and private universities; it was also about the necessary significance of the naturalistic or social views of undergraduate formative research work in the first semesters.

One important problem was the plagiarism found in most of the students in few courses, which was giving not only a direct contribution to the second problem in terms of indicating the students their weak point, but also highlighting a problem of plagiarism observed even in Harvard University [17]. Different to the typical case of identical answers on final-exam questions in Harvard, the groups of UCH students supplied the same information in the assignments when they were contrasted with the online software of plagiarism detection (Duplichecker).

In the South-America region, there is an increasing interest in the relationship between education and learning. For example, Ecuador has improved recently not only for students themselves (in electronics and computer programming) but also for working in groups in order to expand search tasks and capabilities [10]. Here, it was believed that learning should be studied in detail for future research in this kind of curricular designs to improve the relationship between neuro-informatics and education. Having these changes in Electronics Engineering will give UCH a good position in the future, by implementing computer science changes in Systems Engineering.

Therefore, the proposal is in agreement with Standard 24 of CONEAU: The subjects of the curriculum incorporate the results of research in career [7]. Moreover, it takes Van der Akker's thoughts about curriculum level [3]. Work on the coursework is being partially successful at the first year of this implementation. At meso-level in the university, the final project work (dissertation) in electronics engineering was used to fit with the direct implementation of the design. At micro-level in every course in classroom as the design was implemented (see Table II). At nano-level an advisor was provided for every individual dissertation. All improvements at these levels should be seen in the next Peruvian University Census. In the 2010 census, regarding the use of databases, the undergraduate UCH student obtained: 15% in IEEE, 7% in Hinari and 19% in ScienceDirect [20]. This suggests that the average Engineering student was using scientific database 4% less than the average UCH student. Moreover, it showed 7% less than the average Engineering student in Peru.

Other ways of viewing the curriculum were not addressed; e.g. Bonafe mentioned the four powers that have a role in college: Military, Energy, Economic and Media. Then he explored "the speech" for the political project of public education. Later on he mentioned the problem of knowledge and the notion of curriculum in the crisis of the university. Finally, he discussed the relationship between critics Epistemology and researchers and teachers. In these reflections he reminded that there is not a debate between knowledge and research without the "dialogic desire" [6]. In regards to this point, Germaná called "the exploration of new roads" [5] or what Bonafe called "the dialogic desire" [6], in the light of the results, more than wishful thinking is needed for a broader implementation. This means that the commitment of all administration staff, professors and students involved, will bring needed changes in the curriculum levels at UCH and ultimately at other universities. Overall, the long term project management requires a university system working with people to reach the goal. In this way, university authorities should lead these formative research changes invoked. For example, in the UCH, there is no clear scheme in regards to the five dimensions of Walter Peñaloza's comprehensive curriculum. Although in each specialty there is an academic coordinator, a research coordinator, a tutor or counselor, and a cultural center university coordinator. However, there was not a clear head for each one of these five dimensions. In this context, the commitment of the authorities is not clearly reflected in the university management. Therefore, it is believed that these changes will happen slowly in the university system. Consequently, the level of undergraduate dissertations will improve slowly, but the results of the first year suggested that the change is happening.

Limitations of these results, especially in Fig. 6, were the implementation of only one year and the number of students and years of graduation were less in the UCH, but this looks promising for the next years.

The long term formative research is necessary for a good implementation of the program. In addition, it is expected to gradually encourage current students and UCH engineering students to succeed in writing their final dissertations. The benefits include: a) Students can be employed in better jobs and be prepared to continue their graduate level studies, b) The department itself increases its prestige within the institution and within the country as it produces better quality students, and c) A department with better prestige attracts better lecturers and staff, who have the skills to supervise students writing their dissertations. Therefore, this issue may be a topic for a further research in around 5 years.

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