

Pedagogy in Engineering: A proposal to improve the training of Chilean engineers

Hanno Hortsch¹, Diego Gormaz-Lobos¹, Claudia Galarce-Miranda¹, Steffen Kersten¹, Nancy Calisto², Patricia Maldonado², Richard Lagos³, Marcela Romero⁴, Jorge Hinojosa⁵, Paul Fuentes⁵, Pablo Rojas⁵, Guillermo Schaffeld⁶, Michelle Paulete⁷, Cristián Millán⁸

¹ Technische Universität Dresden, Dresden, Germany.

² Facultad de Ingeniería, Universidad de Magallanes, Punta Arenas, Chile.

³ Facultad de Ciencias, Universidad de Magallanes, Punta Arenas, Chile.

⁴ Facultad de Filosofía y Educación, Universidad Metropolitana de Ciencias de la Educación, Santiago, Chile.

⁵ Facultad de Ingeniería, Universidad de Talca.

⁶ Facultad de Ingeniería, Universidad Autónoma de Chile, Santiago – Talca - Temuco, Chile.

⁷ Facultad de Educación, Universidad Autónoma de Chile, Santiago – Talca - Temuco, Chile.

⁸ Facultad de Administración y Negocios, Universidad Autónoma de Chile, Santiago – Talca - Temuco, Chile.

Email: {Hanno.Hortsch, Diego_Osvaldo.Gormaz_Lobos, Claudia.Galarce_Miranda, steffen.kersten }@tu-dresden.de; {nancy.calisto, richard.lagos, patricia.maldonado}@umag.cl; marcela.romero@umce.cl; {jhinojosa, pfuentes, pabrojas}@utalca.cl; {guillermo.schaffeld, michelle.paulete, cristian.millan}@uautonoma.cl

Abstract

This paper presents the results of a survey focused on the interests and needs of academic training related to the different pedagogical aspects that influence the training of engineers in the engineering faculties of Chilean universities, seeking to improve the quality of teaching and the academic training.

The research was organized in the frame of the "Pedagogy in Engineering in Chilean Universities" project, led by the Technische Universität Dresden (TUD) of Germany, funded through of DAAD and consisting of a group of academics from engineering faculties of three Chilean universities: Universidad Autónoma de Chile (UA), Universidad de Magallanes (UMAG) and Universidad de Talca (UTALCA). The objective of the project is to develop tools to determine the training needs of trainers of engineers in the pedagogical field.

Methodologically, an instrument was developed for the assessment of needs, based on specific theoretical concepts of the engineering training as well as the experience in research projects of the TUD in this area. In the gathering of information, 114 Chilean academics participated, distributed among the different specialties that the engineering faculties of the three participating universities impart, among which stand out: chemical engineering, mechanical engineering, computer engineering, electrical engineering, construction engineering, industrial engineering and commercial engineering.

Among the main results obtained, it is worth noting that more than 90% of the respondents stated their interest in improving the pedagogical area focused on the training of engineers, but they present time constraints to participate in a training and to attend this type of activities. At the same time it is possible to point out that the main areas of interest to receive training are: evaluation, ICTs and methodologies of teaching learning.

Based on the description given by the results of the surveys, we are currently working on the design, implementation and evaluation of an on-line training course aimed at teachers and academics at engineering faculties of Chilean universities.

Keywords: Pedagogy in engineering higher education Teacher training Pedagogy for professionals Pedagogical skills.

1 Introduction

Engineering Pedagogy, as a branch of Engineering Education, was originated in Germany more than 60 years ago. Also, a society for this discipline, Die Internationale Gesellschaft für Ingenieurpädagogik (IGIP) exists for more than 40 years. These endeavors demonstrate the importance that has been granted, worldwide, to

the improvement of the teaching methods, theoretical and practical, for the training and education in the technical and engineering fields, to satisfy the needs and expectations, both of students and employers.

The PEDING Project is a binational university effort – Germany and Chile - with the purpose to study and to develop a didactic methodology focused on the training of engineering lecturers and instructors at higher education engineering schools of Chilean Universities.

This initiative is relevant at present times, because it is the product of the concern of higher education institutions about the pedagogical specialization and training of engineering schools faculty, training that should have a positive impact in the reduction of academic failure and dropout of many, given that the lecturers would be knowledgeable in pedagogical and didactic principles, teaching and learning methodologies, and evaluation methods specially aimed to the formation of engineers through the Engineering Pedagogy approach.

In this context, three Chilean universities: Universidad Autónoma de Chile, Universidad de Talca y Universidad de Magallanes in collaboration with TU-Dresden, and DAAD support and funding, host this initiative, and gather and analyze the pedagogical needs of these institutions, to enhance the quality of the teaching process at the engineering schools.

1.1 Theoretical aspects

In 1951, Prof. Hans Lohmann, in his quest to systematize and to professionalize at an institutional level the teaching and research in engineering, founded the Engineering Pedagogy Institute (Institute für Ingenieurpädagogik) at The Dresden Technical University (Technische Universität Dresden, TU Dresden). Lohmann specifically concentrated his work in the relationship between the “Technique” (Technik) and the “the teaching of the Technique” (Technicklehre). Thus, establishing with this concept the foundations of Engineering Pedagogy, whose aim is no other than the conformation of teaching and learning processes that are specific for the technical and technological spheres. During time, along with new demands on business and Industry and the development of new technologies which have generated increasing training requirements in the field of engineering education, they also bring with them the development of social and communication skills of engineers, allowing them to have an improved performance in the production structures of modern societies. Dr. Steffen Kersten (2015), a Professor at TU Dresden and general Coordinator of the “Engineering Pedagogy in Chilean universities” (PEDING) Project, proposes a scheme that describes the factors that influence and condition engineering education: The economic and production sectors of a country, engineering sciences, society and culture of the country, and the individuals who study engineering (see Kersten, Simmert, Gormaz, 2015).

Research in engineering education and didactic led by “The Institute for Didactic for the professional en technical formation” at TU-Dresden, in charge of Prof. Dr. Hanno Hortsch (General Director PEDING and President of IGIP) show numerous contributions that can deliver systematic training offerings in engineering pedagogy for faculty and instructors of engineering schools at universities in different countries: These training is specifically targeted to the needs of modern engineering in order to allow an improvement in the quality of teaching and the education of engineering students at engineering schools, thus, distinguishing itself from the generic pedagogical training that are usually offered in many higher education institutions, training that does not consider the specific needs of each discipline and profession.

Under this perspective, the PEDING Project Chile, which central objective is the design, implementation and evaluation of a training course for instructors and academics belonging to Chilean faculties of engineering. At this point It is important to highlight that this project was prepared and elaborated in a collegial way, voluntarily and collaboratively, by the researchers of the three Chilean regional universities and TUD, and proposed, by the researchers, to the senior academic authorities of their respective institutions. At the same time, teachers belonging to each of the Chilean engineering faculties were invited to participate voluntarily in the process of raising the pedagogical needs. Moreover, the format of the course (Bi-learning) was adopted considering the requirements of the teachers surveyed, regarding the importance of flexibility, and finally, the teachers who take the course will also do so voluntarily, motivating them to register in it by granting a certification on the completion of an international training program. Also, horizontal collegiality was

manifested among the TUD researchers and those of the Chilean universities, since the former agreed to adapt the original model to the particularities of the Chilean university culture.

Firstly, an instrument was generated for collecting information about the academic interests and needs in the scope of engineering educación. In the framework of this Project, Dr.(c) Diego Gormaz designed a questioner to gather data on the training requirements of lecturers at engineering faculties from the results of the research in this matter[†] carried out by TU Dresden in Saxony (Germany). This study revealed the following needs: Didactic foundations of planification, implementation and analysis of academic teaching, design, selection and utilization of didactic media, design of communicative processes in academic teaching, design and implementation of control and evaluation processes, and the structuring of courses and syllabi (vase Köhler, Umlauf, Kersten, Simmert 2013, p. 17-18). The results of this research created the bases of a training course offered in 2012, modeled from the learning module structure according to IGIP (International Society for Engineering Education). Through an analytical adaptation of the results of this study and the module structuration of the training course, Gormaz (2014) systematized in clusters the following categories and indicators/aspects (see Table 1), which later were used in the recollection instrument on teaching needs of the engineering faculty of the three Chilean universities (see Gormaz, 2014).

This instrument and indicators seek to obtain information about: **i)** characteristics of lecturers (years of experience, subject matter, etc.), **ii)** experience and needs related to engineering didactic fundamentals, **iii)** requirements for the structuration of Teaching - Learning forms in a university context, and the setting of objectives and contents of an engineering degree, and, **iv)** identification of strengths and weaknesses, together with the conditions to enroll in a training course. It is important to highlight that the results about the needs in PEDING were used in the development of the training modules.

Table 1. Instrument Indicators.

I. ENGINEERING DIDACTICS FUNDAMENTALS	
Category	Indicator/Aspect
I.1. Design of teaching-learning processes	I.1.1. Psychological foundations of the work and action of teaching and learning
	I.1.2. Theoretical and practical bases of engineering didactics and learning
	I.1.3. Didactic Principles
	I.1.4. Organisation of the teaching – learning processes for the training in engineering sciences
	I.1.5. Structuring of the teaching – learning processes for the training in engineering sciences
I.2. Didactic media for teaching in engineering	I.2.1. Concepts and classification of didactics media
	I.2.2. Functions of didactic media and technological tools
	I.2.3. Field of action of didactic media
	I.2.4. Elaboration of didactic media
I.3. Communication	I.3.1. Design of communication processes
	I.3.2. Monologic and dialogic Communication procedure in education
	I.3.3. Conflict identification and resolution
I.4. Control and Evaluation of the learning outcomes in engineering education.	I.4.1. Registration and evaluation of the learning outcomes at universities
	I.4.2. Operalisation of Learning outcomes
	I.4.3. Procedures for the registration of learning outcomes.
	I.4.4. Evaluation of the learning outcomes.
II: FORMS OF STRUCTURING THE TEACHING – LEARNING PROCESSES IN UNIVERSITY CONTEXTS	
II.5. Lectures (theoretical courses)	II.5.1. General structure of a University course planning
	II.5.2. Preparation of a university course
	II.5.3. Execution of a university course
	II.5.4. Feedback in a university course
II.6. Laboratory practicum/ self-study	II.6.1. Laboratory training
	II.6.2. Experiment functions in the teaching – learning processes
	II.6.3. Exercices and self – study planning
II.7. Engineering internships, written reports, research colloquium	II.7.1 Engineering Internship preparation and research preparation
	II.7.2 Support systems for internships and for autonomous research
	II.7.3. Intrenship analysys and research activities analysis
III: DETERMINING THE OBJECTIVES AND CONTENTS OF ENGINEERING STUDIES	
III.8. Determination of the	III.8.1. Analysis of the activities in engineering

[†] Project "Ingenieurdidaktik an Sächsischen Hochschulen, e-Didact 2010-2012"

Study programme objectives	III.8.2. Analysis of the activities related to an university engineering study programme III.8.3. Analysis of social aspects in engineering III.8.4. Analysis of personal aspects in engineering
III.9. Determination of the Study programme contents	III.9.1. Fundamentals for the determination of contents of an engineering Study programme III.9.2. Contents determination of an university sudy programme with regard to the academic activities III.9.3. Contents determination of an university sudy programme with regard to the societal activities III.9.4. Contents determination of an university sudy programme with regard to the personal activities

2 Methodology

To conduct a research study with a greater dynamic, a "cross – focus" strategy was applied, as proposed by Lincoln and Gubba (2000), given the need to integrate the opinions of the participants with the assessment of pedagogical teaching needs and interests, that are most required for the education of engineers. Thus, in this way, it was called upon a mixed research design of the concurrent execution type, *i.e.* without a sequence and in parallel, for integrating the obtained data (Onwuegbuzie y Johnson, 2006).

2.1 Population and available sample

The sample of this study was composed by 144 academics of the Faculties of Engineering of the three universities, considering the indications of Hulland (Hulland et al., 1996), who suggest using a minimum sample of 100 individuals. The final sample consisted of 54% of lecturers belonging to Universidad Autónoma de Chile, 26 % to Universidad de Magallanes, and 20 % to Universidad de Talca.

2.2 Instrument

With a view to identify the training needs and interests in the pedagogical aspects requirements of major importance for the formation of engineers, an opinion poll type instrument, with open and closed questions, was applied. The characteristics of this instrument is described in point 2.1 above, and it was oriented to identify the perceptions about the teaching needs of different pedagogical aspects related to the engineering subjects at universities. Table N°2 presents the dimensions and conceptual categories of the instrument.

Table 2. Dimensions of the instrument items.

DIMENSION	ITEM GENERATING CONCEPTUAL CATEGORIES
Fundamentals from the point of view of Education Science	Knowledge about the procedures for the recollection and measurement of learning outcomes. Knowledge about the effective design of learning outcomes measurement Evaluation and assessment of learning outcomes. Knowledge about the fields of action of the didactic media and ICT Knowledge about the design of didactic media for the teaching – learning process.
Engineering didactics	Knowledge for determining teaching contents in engineering for the personal, technical and social activities of engineers. Structuring of teaching – learning processes for the scientific education of engineers. Theoretical and practical knowledge about didactics for the teaching and learning in engineering. Didactic principles for the teaching – learning process in engineering. Fundamentals for determining the technical contents within de engineering field. Knowledge about special teaching-learning strategies at university level. (Case study, observations of learners, among others). Knowledge and Skills for the preparation, execution and feedback of teaching. Knowledge about the design of teaching-learning processes for laboratory work. Analysis of specific topics about the concrete activities of engineers and specific knowledge from the engineering sciences. Organisation of the teaching – learning processes for the scientific education of engineers

Source: Results report, Projekt-ID: 57060070. March 2015. Pedagogía en Ingeniería para Universidades chilenas, DAAD

2.3 Procedure

The instrument was individually applied, considering the ethical aspects according to the Chilean social sciences research criteria. Once the data were gathered, the research process had to phases. Phase (T1), corresponded to information collection of the closed questions carried out by the research teams of the three universities. The statistical analysis applied was exploratory-descriptive with the aim to raise problems.

The second phase of the study (T2) examined the open questions of the sample through a textual content analysis by codifying the discourse of each of the 114 academics, based on the item generating conceptual categories.

3 Characterization and obtained results

The characterization and the results obtained with the surveys applied to the academics of the Faculties of Engineering of the three Universities are presented below. These results were analysed in three dimensions: (1) Characterization of the group surveyed / general information of the academics, (2) Perception and needs in pedagogy in engineering, and (3) Open questions.

3.1 Characterization of the sample / General information of academics

The selected sample of academics that participated in the survey in each university was approximately 30% of the total number of academics attached to each of the Engineering Faculties. In total, 117 academics were gathered (62 AU, 33 UMAG, 22 UTAL) with 23% women (15 AU, 11 UMAG, 1 UTAL) and 77% men. Of the total respondents, 64% were engineers by profession (56% UA, 67% UMAG, 81% UTAL), the rest had similar professions that help to complement the total training of the future engineers. As for the respondents' ages, more than 40% of survey participants are between 30-40 years old and approximately 11% are over 60 years old. In relation to years of teaching experience, over 75% is between 1-20 years (79% UA, 76% UMAG, 72% UTAL). Of the total number of participants, 70% have been trained in university teaching (74% UA, 55% UMAG, 81% UTAL) and approximately 39% (32% UA, 36% UMAG, 64% UTAL) have participated on graduates/magister programs in the area of university teaching.

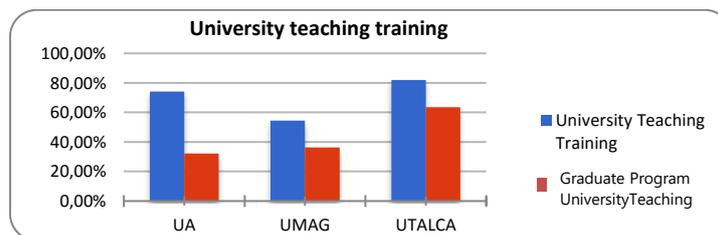


Figure N°1: Percentage of participants with university teaching training and diploma or teacher in university teaching, separated by university.

3.2 Perception and needs in engineering pedagogy

In this section, the results about the perception of the respondents regarding the need for different skills and pedagogical tools for university teaching in engineering careers are presented. It was asked "How necessary do you consider the following aspects of engineering pedagogy in relation to your teaching experience?" For this section, 28 aspects were considered based on the indicators of Table 1, being the most relevant those related to the evaluation methods, among which stand out with more than 90% of the preferences aspects such as: "Evaluation and assessment of achieved learning" and "Knowledge about design for effective measurement of achieved learning". Then with more than 85% of the preferences are "Structuring of teaching-learning processes in the scientific training of engineers", "Use of didactic resources and information and communication technologies (ICTs). For instance: support elements such as projector, blackboard, materials, etc.", "Knowledge about procedures of collection and measurement of achieved learning", "Knowledge about collection procedures and measurement of achieved learning" and "Knowledge about the preparation and valuation of professional practices and research activities".

Among the aspects considered less relevant (less than 70% of the preferences) were found: "Psychological foundations for teaching and learning" and "Dialogic and monologic communicative processes for teaching". It is important to note that all aspects had at least 60% relevance for the respondents.

The results by university do not suffer major modifications (Figure 2). But it is observed that for the participants of the UTALCA, there are three aspects that obtain preferences less than 60%: "*Dialogic and monological communicative processes for teaching*", "*Knowledge about strategies to support professional practices and independent research activities*" and "*Analysis of the personal scope of engineering in Chile*". One possible explanation for these percentages is that the majority of the UTALCA participants have training in university teaching and also due to the institutional model that has been implemented for some time, so that the needs in that institution are not reflected with these aspects.

Some discussed aspects present a great difference between the institutions. In 3 aspects, the UA has preferences above 85%, while UMAG and UTALCA are under 66%: "*Recognition and resolution of conflicts within the classroom*", "*Planning of activities for individual study*" and "*Analysis of the personal scope of engineering in Chile*". Another aspect where there is a marked difference is "*Knowledge about strategies to support professional practices and independent research activities*" where the UA and UMAG have preferences over 81% while UTALCA does not reach 55%. These differences may be due to the different programs given at each University, as well as to the institutional and social context and to the training given to the participants.

By grouping the participants by gender (Figure 3), the female participants (27) have 100% preferences on aspects 4: "*Structuring of teaching-learning processes in the scientific training of engineers*" and 14: "*Evaluation and assessment of achieved learning*". In the case of men (90), the aspects 12: "*Knowledge about the design for effective measurement of learning achieved*" and 14: "*Evaluation and assessment of learning achieved*" have preferences of 92% and 91% respectively.

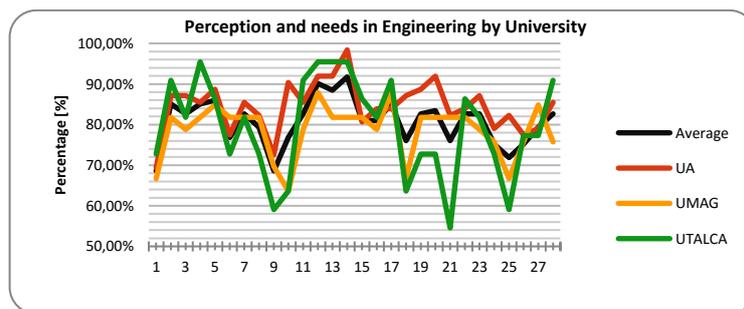


Figure N°2: Relevance of the different aspects consulted about perception and needs in Engineering by University.

The worst evaluated aspects by the female gender correspond to the 7: "*Knowledge about the design of didactic means for the teaching-learning processes*" and 9: "*Dialogic and monological communicative processes for teaching*", both with 70% of preferences, while for males the worst evaluated aspects correspond to 1: "*Psychological foundations for teaching and learning*" and 9: "*Communicative dialogic and monological processes for teaching*" with 66% and 69% of preferences.

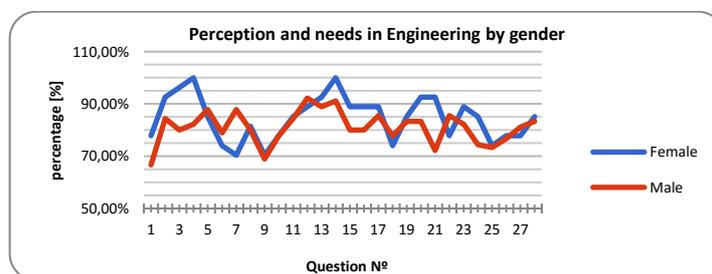


Figure N°3: Relevance of the different aspects consulted about perception and needs in Engineering by gender.

With respect to the results obtained in the 11 questions about strengthening of teaching methods (Figure 4), respondents considered all aspects with relevance over 70%. Among the aspects considered, the most relevant are: "*Use and development of new didactic means in the training of engineers*", "*Design, choice and use of didactic means*" and "*Planning and structuring of teaching-learning processes at university level*", all of them with more than 80% of preferences. The aspects with the lowest relevance were the aspect 3 "*Realization of communicative processes for teaching at university level*", 6 "*Planning and materialization of*

evaluation and evaluative processes" and 10 "Curriculum development for academic training at the university level".

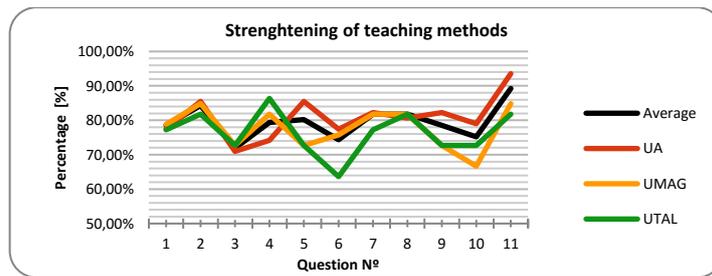


Figure 4: Relevance of the different aspects consulted on the strengthening of teaching methods.

Analysing the results by university, aspect 5 "Resolution of specific problems on the design of instruments for the assessment of teaching-learning processes" appears as one of the worst evaluated in both the UMAG (72%) and UTALCA (72%) while in the UA is one of the most relevant (85%).

3.3 Open Questions

In this part of the survey we asked about 4 aspects: (1) strengths in engineering pedagogy; (2) aspects to be improved in the teaching task; (3) interest and availability to train in the engineering pedagogy area; and (4) conditions necessary to attend a training in engineering pedagogy

Regarding the strengths of the teachers in the sample, the five most relevant results are grouped in strengths associated with: The *fundamentals for the determination of technical contents within the engineering area* (20.9%); the *organization of teaching-learning processes in the scientific training of engineers* (15.69%); the *knowledge for the determination of contents of teaching in Engineering in relation to personal, technical and social fields of the work of Engineers* (13.77%); the *structuring of teaching-learning processes in the scientific training of engineers* (12.68%) and the *analysis of specific subjects of the specific engineering activity and knowledge from the engineering sciences* (11.30%) (see Figure 5).

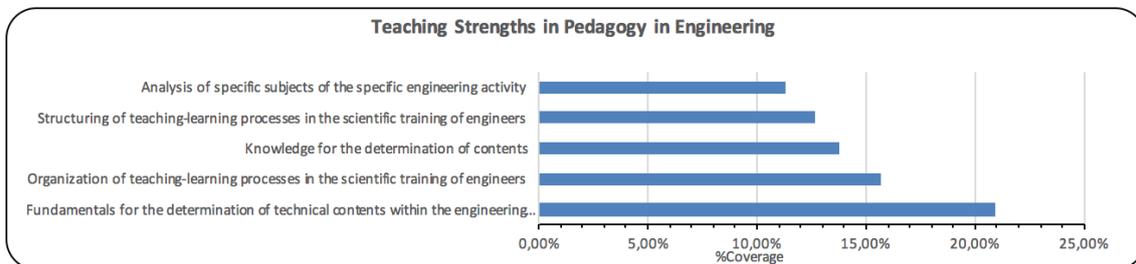


Figure N°5 Teaching Strengths in Pedagogy in Engineering

With respect to the aspects to be improved in teaching, the five most relevant categories are grouped based on: *Fundamentals for the determination of technical contents within the area of engineering* (35.03%), *Evaluation and assessment of achieved learning* (18.77%), *Didactic principles for teaching-learning in Engineering* (12.70%) and *Knowledge and skills for the preparation, execution and feedback of teaching* (12.22%) (See Figure 6). In this review emerge two relevant categories associated to the improvement of the infrastructure and the time for preparing the teaching.

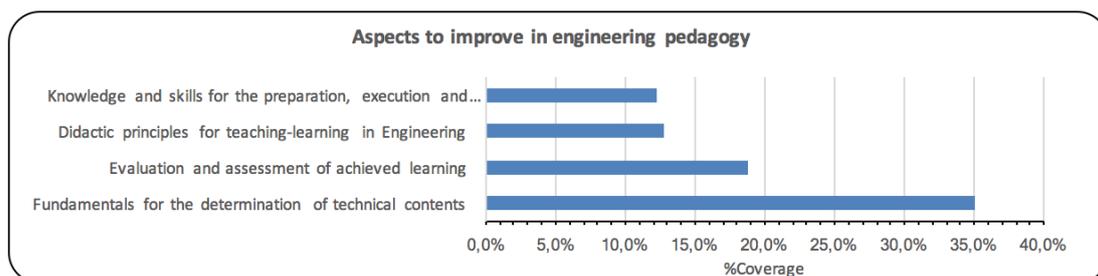


Figure N°6. Aspects to improve in engineering pedagogy

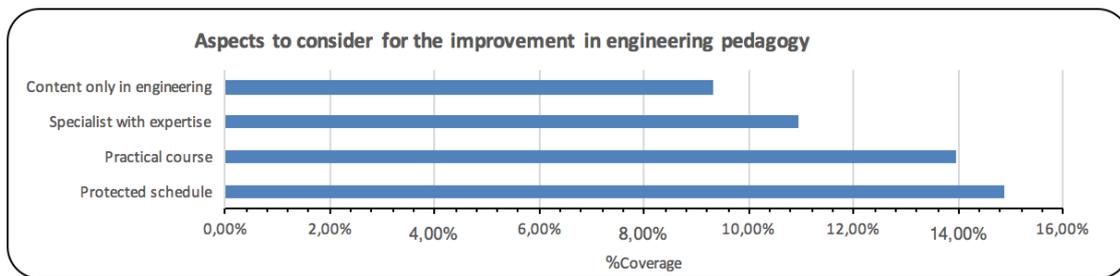


Figure N°7. Aspects to consider for the improvement in engineering pedagogy

Regarding the interest in training, 83.44% would be willing to improve and only 8.06% would not. These results are mainly associated with lack of time, however they are available to review associated material, without having to attend formal courses. Finally, in response to the question related to the necessary conditions to attend an engineering pedagogical training, the results indicate that the schedule is a factor (6.95%), and in that sense the 14.86% indicate that a fixed and protected schedule for full-time teachers, and a weekend or evening (3.34%) for part-time teachers (4.78%) should be considered. Another condition indicated is that they should be certified courses (4.17%) and part of the remuneration (1.62%). They also consider it important to have a practical course (13.96%), dictated by a specialist with expertise on the contents (10.95%) and ideally be a course dictated by engineers, with content only in engineering 9.31%) (See Figure 7).

4 Conclusions

This work aimed to show the pedagogical and didactic needs found in the academics who teach in the engineering faculties of three Chilean universities (two public and one private), based on the knowledge and experiences in the field of Engineering Pedagogy of the TU-Dresden.

From the results obtained it is possible to conclude, that the academic communities of the engineering faculties studied, tend to converge on the pedagogical capacities that are required to train the future engineers. It can also be observed that, both public and the private universities, there is a need to update and refine the methods currently used to deliver and evaluate knowledge, taking advantage of the available technological advances and tools.

The main relevance of this joint work was to show that Chilean academics from different engineering faculties are willing to train and incorporate systematic knowledge and skills, based on the tools of Engineering Pedagogy, to enhance the skills they already possess and thus improve the strategies and methods of teaching directed to its students. As shown on the results, the academics consider a priority to be trained in: (1) Evaluation and strategies of results measurement, (2) design of teaching processes, and (3) design of learning resources, among others. To meet these and other needs, teacher-training modules were developed and subsequently implemented. With these actions it is expected to increase the academic success of the engineering students of these universities; and to develop an improvement line in the area of engineering pedagogy for teachers of engineering faculties, using the results obtained in this project. In this context, it is observed that the participation of these academics would be conditioned mainly by the time involved and the ease on the part of the universities, to reduce the amount of hours that the academic has in teaching and academic management, while doing the training.

5 Acknowledgements

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