Guide for the Final Year Project Assessment in Telecommunications and Computer Engineering

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***Abstract*— This paper presents an efficient and objective procedure for the competence-based assessment of engineering final year projects (FYP). The procedure, consisting of 6 steps, can easily be customized for different engineering curricula. A User Guide has been developed to help institutions create their own FYP assessment system. Actually, the Guide is not the teaching / evaluation guide of the FYP, but it defines the framework that each institution can use to define its own guide for the FYP. Particularly, a set of FYP-oriented observable descriptors for Tuning competences was defined. The final products of the proposed assessment procedure are a set of assessment forms that the evaluation agents must fulfil at each milestone, marking the level reached by the student at every descriptor. These marks are then gathered together in an overall assessment report showing, for every competence the evolution along the assessment milestones of the level reached by the student at any descriptor. All assessment agents use the same list of descriptors and the same definition of the levels of acquisition, thus improving the consistency, traceability and global quality of the assessment process.**

I. Introduction

Engineering curricula both at bachelor and master levels include the development and assessment of a final year project (FYP). The FYP represents the culmination of the student learning process, where s/he must put into use their previously learned engineering and personal skills. The FYP is a complex undertaking, and its assessment has a major influence on decisions regarding the student's readiness to graduate.

In our country (Spain), FYP students are assessed in most schools on the basis of a final written report of the work done plus a public defense in front of an academic board composed of several experienced professors. Unfortunately, this approach presents serious drawbacks:

- It is not in line with the education and accreditation processes [1], [2], [3], so the assessment has to mandatory shift to an outcome-based approach.
- Assessment via a unique final milestone clashes directly with the formative purpose of assessment.
- Assessment is highly dependent on the subjective criteria of academic board.

In December 2007, the AQU[1] and the MICINN[2] launched a program for the development of a User Guide for the competence- (or outcome-) based assessment of engineering FYP. Six universities[3] from Catalonia took on the task of developing this User Guide.

This paper summarizes the results of the program and the contents of the User Guide [4]. It describes how the Guide is applied step by step, and presents a possible teaching / evaluation guide for FYP that has been obtained by using the proposed framework.

II. The User Guide

The User Guide is aimed at the academic authorities that have to define syllabuses for FYP, and it provides them with a strategy for making an assessment of the FYP. It contains a series of guidelines to help each Faculty or College to produce its own evaluation procedure.

The User Guide proposes a process based on 6 stages that Faculties and Colleges could follow to define their own procedure of assessing the FYP:

1. Definition of (i) the competences or learning outcomes associated with the FYP, and (ii) a set of objective descriptors for each of them;
2. Definition of (i) the assessment moments or milestones, (ii) the specific assessment actions that must be performed at each milestone, and (iii) the agents that will carry out the assessment;
3. Assignation of descriptors to each assessment action;
4. Definition of the levels of compliance for each descriptor, clearly and objectively establishing the level of competence that the student must demonstrate that s/he possesses;
5. Preparation of the assessment reports.

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6. Definition of the marking criteria to be used to assign the final mark of the FYP on the basis of the results reflected in the final assessment report.

III. Example of Application of the User Guide

In this section, we follow the six steps above in order to prepare an example of the teaching / evaluation guide for the FYP in Telecommunications / Computer Engineering degree. The example has been done while keeping in mind the expected level at a Bachelor, but the result is essentially also valid for Master projects after small modifications in the definition of the levels of compliance (step 4). In the following, we briefly describe each of the steps and present the result of applying them at the example.

A. Definition of Skills and Descriptors

The first step in the process consists in establishing which skills the students must demonstrate during their FYP. The specific (technical) skills change significantly depending on the specific studies, but the transversal (generic) skills of any engineer are probably very similar, regardless of the speciality. In our case, we take the specific competences officially defined in Spain [5] for bachelors in telecommunications engineering together with some additional ones introduced by the UAB in the degree. Those official competences are the ones that students must acquire during the degree so that, once graduated, they can become chartered technical engineers of telecommunications. The transversal competences are those defined by the Tuning project [6].

Table I shows all possible specific and transversal competences and the ones we have selected in the example. The chosen selected competences constitute only an example, and a different set may be appropriate depending on the objectives of the FYP. It is worth noting that not selecting a competence does not mean that it is not important for our graduates. In general, all competences are relevant but it is necessary to make an effort to focus the evaluation on a small subset in order not to dilute the effort by trying to cover everything. Moreover, the small subset probably covers aspects present in other competences given that there is some degree of redundancy between them.

TABLE I
Selection of Specific and Transversal Competences

COMPETENCES SELECTION	
SPECIFIC COMPETENCES	Selection
Drafting, developing, and signing projects in the field of Telecommunications engineering, whose purpose is, according to the specifications, the design, development or operation of networks, telecommunication services and applications, and electronic systems.	
Implement the applicable legislation during the development of the Telecommunications engineering profession, and comply with technical specifications, regulations and mandatory standards.	
Learn new methods and technologies based on fundamental previous knowledge, with great versatility to adapt to new situations.	
Manage projects in the field of telecommunications.	
Perform measurements, calculations, assessments, and appraisals; provide expert opinions, studies, reports, task planning and similar activities in the field of telecommunication systems.	
Analyze and evaluate the social and environmental impact of technical solutions.	
Apply basic principles of economics and human to the organization and planning of projects.	
Analyze components and specifications for communications systems based on guided and free-space propagation at microwave and optical frequencies.	
Select, analyze and conceive algorithms, circuits, subsystems, or systems for wireless or wireless communication in order to comply with a set of specifications.	1
Apply deterministic and stochastic signal processing techniques to the design of communication subsystems and data analysis.	2
Design and dimensioning of multiuser communication using communication theory principles and taking into account the specifications and the need to provide quality service.	
TRANSVERSAL COMPETENCES	Selection
Ability to apply knowledge in practice	
Ability to conceive, design and implement projects using the inherent tools of engineering	3
Knowledge of the field of study	
Troubleshooting	
Ability to set reasonable goals based on the analysis of the problem and the resources available	
Analysis and synthesis capability	4
Ability to learn independently	
Ability to work independently	
Information management	
Ability to develop professional work in accordance with law and regulations	
Drive for quality	
Organization and planning capability	5
Teamwork	
Decision taking	
Initiative and entrepreneurial spirit	
Ethical commitment	
Drive for self-improvement	
Interpersonal skills	
Ability to adapt to new situations	
Oral and written communication in English	
Critical thinking and self-criticism	
Oral and written communication in the mother tongue	6
Ability to work in multidisciplinary teams	
Communication with experts from other fields and not experts	
Creativity	
Leadership	
Research Skills	

In order to be able to evaluate these skills, it is needed to define a set of objective descriptors that make it possible to evaluate the level of acquisition of the skills by the student. For each skill, a file was created that (i) describes the skill from the point of view of the FYP, and (ii) defines descriptors for its assessment. Both the surveys of skills and the definition of descriptors are matters that have been dealt with on numerous occasions (see e.g [7], [8]), but what is new about this study is that it is centred on the assessment of skills in the context of FYP. Among all the possible descriptors for the selected competences, which are defined in the User Guide, we select the ones that we want to evaluate in the our example of FYP guide (see Table II).

TABLE II
Selection of Descriptors

DESCRIPTORS SELECTION
COMPETENCE 1: Select, analyze and conceive algorithms, circuits, subsystems,

or systems for wireless or wireless communication in order to comply with a set of specifications.	
Descriptors	*Selection*
D1.1. Select antennas, analogue circuits and subsystems for radiofrequency communications and radar systems.	
D1.2. Select circuits and subsystems for optical communications.	
D1.3. Select digital circuits and subsystems for radiofrequency communications and radar systems.	X
D1.4. Perform link budgets.	X
D1.5. Use software packages for the development and exploitation of networks, services and applications based on radio and optical communications.	
D1.6. Evaluate the pros and cons of different technologies for the deployment of optical networks.	
COMPETENCE 2: Apply deterministic and stochastic signal processing techniques to the design of communication subsystems and data analysis.	
Descriptors	*Selection*
D2.1. Apply principles of estimation and detection theory to the design of communication receivers.	X
D2.2. Design and implement adaptive filters.	
D2.3. Apply multichannel signal processing algorithms to the design of fixed and mobile communication systems.	X
D2.4. Extract information from data series.	
D2.5. Develop Matlab routines and Simulink schemes for the simulation of transmitters, receivers and channels.	X
COMPETENCE 3: Ability to conceive, design and implement projects using the inherent tools of engineering.	
Descriptors	*Selection*
D3.1. Choose the most adequate tools and methodologies to analyze, design and implement the project.	X
D3.2. Analyze, design and implement the project in accordance with the most adequate methodologies.	X
D3.3. Find a solution to the proposed project that can be carried out considering the inherent resources of Telecommunications / Computer Engineering.	
D3.4. Use correctly the selected tools.	X
COMPETENCE 4: Analysis and synthesis capability.	
Descriptors	*Selection*
D4.1. Identify the fundamental parts of the project; describing their relationships with a block diagram.	X
D4.2. Critically assess the results of the project, comparing them with similar results coming from other sources and identifying the new contributions, if any, to the state-of-the art.	X
D4.3. Identify the knowledge required to solve the different problems posed by the project, either coming from the telecommunications / computer engineering area or others (i.e. capability to handle multidisciplinary projects).	X
D4.4. Rank the relative importance of the different parts of the project and the required knowledge.	
D4.5. Synthesize the gathered information and the previous knowledge into a global and structured review of the state-of-the-art.	X
COMPETENCE 5: Organization and planning capability.	
Descriptors	*Selection*
D5.1. Preparation of a GANT (or similar) diagram.	X
D5.2. Monitor the development vis-à-vis the GANT diagram, identifying the detected deviations and proposing corrective actions.	X
D5.3. Critically assess the final level of compliance with the GANT diagram, analysing the causes and consequences of the deviations.	X
COMPETENCE 6: Oral and written communication in the mother tongue.	
Descriptors	*Selection*
D6.1. Explain ideas and concepts in a clear way.	
D6.2. Tailor the vocabulary to the particular circumstances, making a proper use of the technical terminology when needed.	
D6.3. In oral presentations: keep eye contact with the audience, show empathy with the listeners, and use a correct volume and pitch.	
D6.4. Link together the arguments in an exposition.	X
D6.5. Write clearly and correctly.	X
D6.6. Document the work adequately.	X

B. Milestones, Actions and Assessment Agents

In the second step the control milestones need to be defined. Each milestone may consist of one or several actions, where different assessment agents may be involved. The result of this step can be easily summarized with a chart similar to that in Table III.

TABLE III
MILESTONES, ACTIONS AND ASSESSMENT AGENTS (T IS THE DURATION OF THE PROJECT)

M1. INITIAL MILESTONE	20% T
A1.1 Action: Initial report	
Agents: Advisor	
M2. 1st PROGRESS MILESTONE	35% T
A2.1 Action: Presentation	
Agents: Advisor and second professor	
M3. 2nd PROGRESS MILESTONE	60% T
A3.1 Action: Progress report	
Agents: Advisor and students	
M4. FINAL MILESTONE	100% T
A4.1 Action: Thesis	
Agents: Advisor and Board of examiners	
A4.2 Action: Oral defense	
Agents: Board of examiners	

C. Assignation of Descriptors to the Assessment Actions

Having reached this point, the descriptors defined for each skill have to be distributed among the assessment actions and agents. We advise against trying to evaluate more than 10 or 15 descriptors in a single action. Our example is shown in Table IV. As described above, we introduced the participation of a second professor and students (preferably working under the same advisor in related projects) in the second and third evaluation actions, respectively. However, we have not deemed appropriate that they evaluate all the descriptors assigned to these actions, whereas the advisor takes part indeed in all them. The reason is that other professors may not be aware of the technical details of the project. On the other hand, although the view of the students themselves is always enriching, they may have limited experience to evaluate some of the skills / descriptors which they are still acquiring. The removal of some agents from some actions and descriptors should be also reflected in the corresponding table, see e.g. Table IV, where we have preferred to use additional comments rather than create separate columns for each agent in order not to duplicate information in excess.

TABLE IV
ASSIGNMENT OF DESCRIPTORS TO ASSESSMENT ACTIONS. AN 'X' INDICATES THAT ALL AGENTS INVOLVED IN AN ACTION EVALUATE THE DESCRIPTORS. X(1) AND X(2) MEAN THAT ONLY THE ADVISOR EVALUATES THE CORRESPONDING DESCRIPTOR.

DESCRIPTORS	ACTIONS				
	A1.1	**A2.1**	**A3.1**	**A4.1**	**A4.2**
D1.3		X(1)	X(2)	X	X

D1.4	X	X		X	X
D2.1			X(2)	X	X
D2.3		X		X	X
D2.5		X	X	X	
D3.1	X	X(1)	X(2)		
D3.2		X	X(2)		X
D3.4			X(2)	X	
D4.1	X	X			
D4.2				X	X
D4.3		X(1)	X		
D4.5		X		X	
D5.1	X				
D5.2			X		
D5.3				X	
D6.3		X			X
D6.4		X		X	X
D6.5	X		X	X	
D6.6				X	

D. Level of Compliance with the Descriptors

For the assessment to be objective and independent of the evaluator there is a need to accurately define the level of compliance that is demanded to the student in each descriptor. Four levels of compliance are proposed for the descriptors. Level 1 corresponds to the minimum that the student must be able to demonstrate, and for a level below that (level 0) it is considered that the student does not comply with the descriptor. Level 2 is considered adequate for the FYP. Level 3 represents an excellent level.

E. Assessment Form

The assessment forms that must be completed by the assessment agents are constructed after assigning the descriptors to the assessment actions and defining the levels of demand. Two types of report are proposed: Assessment Forms, organized by milestones, and the Overall Assessment Report, organized by skills.

The assessment forms constitute the final product of the assessment milestones; they contain the set of descriptors to be assessed, a column for the mark (from 0 to 3) and the levels of compliance for each descriptor. These reports must be public and their result should be provided to the student as quickly as possible. It is important to include the description of the levels of compliance (defined in the previous step) in the report that will be filled by each agent. The objective is that agents have a very clear understanding at every moment about the meaning of each mark. Thus, consistency across agents and along time will be easier to maintain. A complete example of the form that has to be filled in by the advisor for the progress report of the third milestone is shown Table VI. The rest of assessment forms follow the same logic, but cannot be reproduced here due to the lack of space.

The results of these assessment actions are used to automatically complete the Overall Assessment Report. This report groups the set of assessments made, but now organised by competences, in such a way that it is easy to visualise the student's evolution over time. Table VII shows an example of this report (including also some plausible marks). The overall assessment report is the basis for the final grading, in view not only of the final level of acquisition of the skills associated to the work, but also their evolution over time.

F. Qualification

Finally, the Faculty or College must define the criteria to follow in order to determine the final qualification. These criteria must define minima, allowing for a certain freedom in the analysis of the overall quality of the work done. The overall assessment report in Table VI shows different ways to summarize information. For instance, if it is expected that the level of acquisition for each descriptor will have an upward trend and it is desired to give priority to the evolution of the student, we can take as final mark of the descriptor the maximum among the different actions / agents. On the other hand, we can decide to define relative weights for the evaluation actions / agents and take the average as the final mark. Both options are shown at the rightmost column of Table VII. It is also possible to set relative weights for the descriptors. Then, taking any of the two possible marks for each descriptor, the global mean can be computed, resulting in the value at the bottom right corner of the table. One could also follow an approach not based on averaging to such a large extent, but relying on the amount of "0", "1", "2" and "3" present in the whole table or in the final marks per indicator. To this goal, Table V can be useful. Then, one can decide for instance that the final qualification is "2" if there is at least one "3" and no more than two "1". Similarly, the criteria for a final qualification of "fail", "1" and "3" can be set.

TABLE V
SUMMARY OF THE OVERALL ASSESSMENT REPORT.

	Number and % of "0s"	**Number and % of "1s"**	**Number and % of "2s"**	**Number and % of "3s"**
Whole table		12 (16%)	46 (63%)	15 (21%)
Maximum per descriptor	0	1 (5%)	8 (42%)	10 (53%)

IV. CONCLUSIONS

The User Guide that has been developed provides an efficient and objective mechanism for the assessment of FYP. It is a flexible instrument that each centre must personalize in accordance with their objectives. The User Guide defines six steps to prepare a competence-based Assessment Guide of the FYP. The use of well-defined descriptors and levels of compliance will help increase the homogeneity of qualifications, the traceability of results, and the general quality of the assessing process of FYP based on competence learning.

ACKNOWLEDGMENT

Besides the five authors of this paper, all participants of the AQU-MICINN project have contributed to the guide. The participants have been: Elena Valderrama (UAB), Jesús Bisbal (UPF), Julián Carrera (UAB), Francesc Castells (URV), Fernando Cores (UdL), Jordi García (UPC), Laureano Jiménez (URV), Claudi Mans (UB), Tomàs Margalef (UAB), Asunción Moreno (UPC), Enric Peig (UPF), Julio Pérez (UAB), Jordi Pons (UAB), Mercè Rullán (UAB), Fermín Sánchez (UPC), Gonzalo Seco (UAB), Joan Sorribes (UAB), Javier Tejero (UB), Ramón Vilanova (UAB).

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TABLE VI

EXAMPLE OF THE ASSESSMENT FORM CORRESPONDING TO THE EVALUATION ACTION ASSOCIATED TO THE MID-TERM REPORT

M3. 2nd PROGRESS MILESTONE: Assessment report				
A3.1. Action: Progress Report				
Agent: Advisor				
Descriptors	*Score 0-3*	*Level 1*	*Level 2*	*Level 3*
D1.3. Select digital circuits and subsystems for radiofrequency communications and radar systems.	0-3	The student makes a selection based on typical or text-book examples. Although the desired functionality is achieved, there is a lack of particularization to the specific problem.	The student has a system-level view and is able to select circuits / subsystems that optimize global performance. S/he understands concepts not seen during the courses.	The student understands in depth the particularities of each system / subsystem and of the system as a whole. After a first selection, s/he is able to refine the design and justify all the decisions taken.
D2.1. Apply principles of estimation and detection theory to the design of communication receivers.	0-3	The student reproduces the basic schemes presented during the courses without a deep understanding. S/he needs continuous guidance from the advisor in order to solve day-to-day problems. The student has difficulties with the mathematical formulation.	The student understands the basic theory and is able to translate it to practical designs. Although the mathematical formulation of algorithms is understood, s/he is not fluent with it. S/he is able to relate the analogue and digital domains.	The student shows a good abstraction capability that allows her/him to link the practical problem to the theory. S/he is able to make modifications to existing algorithms. The student can predict the results that will be obtained in practice.
D2.5. Develop Matlab routines and Simulink schemes for the simulation of transmitters, receivers and channels.	0-3	The routines / schemes developed by the student are poorly structured and hardly flexible even though the basic functionality is achieved. Most of the routines are minor modifications of existing code. The development is not validated / calibrated (i.e. the student has not made sure that the software performs the function it is intended to do, without bugs).	The student shows a good command of the programming tools and has the abstraction capability needed to go easily from the code to the block diagrams. The student has developed a significant part of the code, but it is not fully validated. S/he has been able to decide when existing code could be reused and when code had to be developed from scratch.	The routines / schemes developed by the student are optimized in terms of memory usage, computation time, etc. and include advanced functionalities allowing for an evolution of the code. The code is well documented. The student has been able to debug and validate the code autonomously. It is close to a professional development.
D3.1. Choose the most adequate tools and methodologies to analyse, design and implement the project.	0-3	The student has defined a methodology to follow throughout the project and s/he is able to identify at least one tool for each part of the project.	The student has performed an analysis of the methodologies and tools that can be used for the problem, and s/he has reasonably selected the most suitable ones.	The student has critically evaluated the efficiency of the employed methodologies and tools, and s/he has proposed modifications to improve their performance.
D3.2. Analyse, design and implement the project in accordance with the most adequate methodologies.	0-3	The chosen methodology is applied with, possibly, minor modifications.	The correct methodology is applied with rigor.	Novel methodologies are employed at the same time as the concrete problems caused by their use are analyzed.
D3.4. Use correctly the selected tools.	0-3	The student uses correctly the selected tools, with an medium command of them.	The student shows a good command of the used tools.	The student uses latest-generation tools or, even, emerging ones at the same time that s/he analyzes the specific problem caused by their usage.
D4.3. Identify the knowledge required to solve the different problems posed by the project, either coming from the telecommunications / computer engineering area or others (i.e. capability to handle multidisciplinary projects).	0-3	The student identifies the subjects related to telecommunication / computer engineering and other disciplines involved in the definition and the solution of the problem.	The student analyzes the knowledge from the aforementioned disciplines needed to carry out the project.	The student identifies topics of the aforementioned disciplines that have not been covered during the courses. S/he analyzes whether those topics can be bypassed or the effort needed to learn them.
D5.2. Monitor the development vis-à-vis the GANT diagram, identifying the detected deviations and proposing corrective actions.	0-3	The student is able to identify the state of each task (behind schedule, ahead of time, on time).	The student identifies discrepancies from the established plan and proposes actions to resolve them.	The student proposes solutions for any deviations that are very reasonable and guarantee, as mush as possible, compliance with the project schedule.
D6.5. Write clearly and correctly.	0-3	The student does not make basic orthographic errors even though there may be a few minor ones (accents,…). Sentences are correctly structured and logically sequenced.	The student employs grammatical sentences, and s/he conveys ideas and concepts without trouble.	The student 's texts present ideas and concepts in a clear and concise way, at the same time texts are pleasant to read.
Comments: Signature: (Advisor)				

TABLE VII
EXAMPLE OVERALL ASSESSMENT REPORT

COMPETENCES & DESCRIPTORS	ACTIONS & AGENTS										
ACTIONS		**A1.1 Initial Report**	**A2.1 Presentation**	**A2.1 Presentation**	**A3.1 Prog. Report**	**A3.1 Prog. Report**	**A3.1 Prog. Report**	**A4.1 Thesis**	**A4.1 Thesis**	**A4.2 Final Pres.**	
AGENTS		**Advisor**	**Advisor**	**Second professor**	**Advisor**	**Student 1**	**Student 2**	**Advisor**	**Board of examiners**	**Board of examiners**	
Relative weight of each evaluation action and agent	**Descriptors' relative weight**	**5%**	**5%**	**5%**	**10%**	**5%**	**5%**	**25%**	**20%**	**20%**	**Weighted average / maximum**
COMPETENCE 1: Select, analyze and conceive algorithms, circuits, subsystems, or systems for wireless or wireless communication in order to comply with a set of specifications.											
D1.3	7%		1		2			2	3	2	2.2 / 3
D1.4	7%	2	2	2				3	3	3	2.8 / 3
COMPETENCE 2: Apply deterministic and stochastic signal processing techniques for the design of communication subsystems and data analysis.											
D2.1	7%				1			2	2	2	1.9 /2
D2.3	7%		1	1				2	3	2	2.1 / 3
D2.5	6%		1	2	1	3	3	2	2		1.9 /3
COMPETENCE 3: Ability to conceive, design and implement projects using the inherent tools of engineering.											
D3.1	5%	1	1		2						1.5 / 2
D3.2	5%		2	2	3					3	2.8 /3
D3.4	5%				2			2	2		2 / 2
COMPETENCE 4: Analysis and synthesis capability.											
D4.1	5%	2	3	2							2.3 / 3
D4.2	5%							2	2	2	2.0 /2
D4.3	4%		1		2	3	2				2.0 / 3
D4.5	4%		2	2				2	2		2.0 / 3
COMPETENCE 5: Organization and planning capability.											
D5.1	4%	1									1 / 1
D5.2	4%				2	2	2				2.0 / 2
D5.3	4%							3	3		3.0 / 3
COMPETENCE 6: Oral and written communication in the mother tongue.											
D6.3	4%		3	2						3	2.8 / 3
D6.4	5%		2	2				2	2	2	2.0 / 2
D6.5	6%	1			1	2	2	2	2		1.8 / 2
D6.6	6%							2	2		2.0 / 2
Average											**2.1 / 2.5**