Engineering education in a context of VUCA

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***Abstract*—Nowadays the world is very dynamic and thus we are faced with scenarios with a high degree of volatility, uncertainty, complexity, and ambiguity (VUCA). This reality affects engineering educators that need in many circumstances to promote more active learning approaches that transfer to the students the responsibility of learning. The aim is to allow students to get better prepared to face the market, after their studies. Such learning strategies encompass many challenges, both for educators and students. This manuscript discusses the major changes that have been introduced in a university course that promotes entrepreneurship in the field of software engineering. The promotion of entrepreneurship within universities asks for effective approaches that must be frequently evaluated and changed. The course is analyzed along two major VUCA angles: (1) how to adapt it to satisfy the students, and (2) how students can be stimulated to learn how to behave in VUCA contexts.**

Keywords— VUCA; active learning; technology stewardship; IT tools; entrepreneurship

I. Introduction

Currently, almost all organizations are faced with scenarios where Volatility, Uncertainty, Complexity and Ambiguity (VUCA) are present. The organizations (i.e., their employees and collaborators) need to be able to react to any unexpected problem that may arise. VUCA scenarios require innovative strategies that can be adopted to handle any situation. The VUCA dimensions are an excellent opportunity for teachers and students to develop effective and flexible approaches to learning. In particular, VUCA constitutes a good background to learn how to behave in unpredictable situations.

Active learning approaches fit well in VUCA scenarios, because they transfer the responsibility of learning to the students. As discussed in [1], active learning presents several challenges to both teachers and students. Generically, it involves students in two ways: doing things and thinking about the things they are doing [2]. Active learning approaches require students to read, discuss, and engage in the solution of complex and poorly-structured problems. Specifically, students should be involved in higher-order thinking tasks such as analysis, synthesis, and evaluation.

Today, universities are forced to respond and adapt to a rapidly changing environment as a result of learning, adaptation and development [3]. In particular, universities face many uncertainties due the chaotic, vibrant and rapidly changing educational environment of our day [4]. These factors require educators to constantly reformulate the courses for which they are responsible, to make them more attractive to their students.

Entrepreneurship education constitutes a good environment to prepare students for the VUCA dimensions of the world. Adaptability and flexibility are necessary qualities in many working contexts [5]. In fact, entrepreneurship education is a growing area of engineering education, more specifically in software engineering [6, 7]. Entrepreneurship education demand approaches that must be efficient and effective [8]. This implies a permanent adaptation and evolution of the best practices. The courses that address entrepreneurship need to be continuously reshaped; otherwise, they quickly become inadequate and obsolete.

This main aim of this manuscript is to discuss the evolution of a course (Project in Software Engineering - PSE) that promotes entrepreneurship for engineering students. The changes were driven by the idea of adapting the course to better achieve its goals and better meet students' expectations.

This manuscript is structured as follows. Section II presents a brief state of the art. In section III, the main ingredients of the PSE course are described. Section IV presents the major changes that were introduced in the course due to the need to adapt it to different circumstances. Section V discusses the impact, limitations, challenges and opportunities of such changes. Finally, the main conclusions and opportunities for further research are presented in the last section of the manuscript.

II. State of the Art

A. VUCA

The world is currently undergoing a serious transformation and presents more and more signs of what is described by the concept of VUCA: volatility, uncertainty, complexity and ambiguity [9]. VUCA is a catchphrase and an often-discussed topic for today's adaptive leaders during annual strategy meetings [10]. The notion of VUCA was introduced by the U.S. Army War College to describe uncertain, complex, and ambiguous, in a multilateral world which resulted from the end of the Cold War.

Rapid changes in the political, economic, social and technological fronts are making the organizational world increasing VUCA. The multiple increases in the rate of change in the VUCA world place new challenges [11]. In fact, organizations are forced by external factors to move from the SPOD world (Steady, Predictable, Ordinary, Definite) to this new paradigm [12]. These factors, which are contributing to the increase in turbulence in the global higher education world include, among others, the rise of the digital economy, connectivity, trade liberalization policies around the world, increased global competition and innovation [13].

Engineers were traditionally faced with the problems that required speed, analysis and uncertainty to be solved; nowadays, the challenges demands patience, sense making and an engagement with uncertainty instead [14].

The four dimensions of VUCA are the following:

Volatility The speed, volume, magnitude and dynamics of change are all high, which imply that the scenario is unstable and has an unpredictable duration.

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Uncertainty The lack of predictability of issues and events that results in a substantial change.

Complexity Some information regarding the nature of complexity is available or can be predicted. However, the sheer volume and the nature of the problem could prove to be overwhelming. The complexity of a phenomenon depends not only on the number of its parts, but essentially on the way they interact among themselves.

Ambiguity The situation is unprecedented and one must brace himself to face the unknown. The occurrence of ambiguity means that there are two or more possible interpretations for a sentence.

Students need to acquire several skills to be prepared for VUCA contexts. For instance, the dispositions and skills required for the VUCA work environment are as following as indicated in [15]: communications skills, self-management, ability to learn independently and in trans-disciplinary ways, ethics and responsibility, cross-cultural competency, teamwork in real and virtual ways, social intelligence, flexibility, thinking skills and digital skills.

Thus, universities must prepare their students to address the new challenges surrounding us, which are sufficiently complex, typically ill-defined and interdisciplinary in nature [16]. Students must be provided stimulating opportunities to improve their skills, like the capacity to evaluate new inputs and perspectives, build new capacities and strengthen autonomy.

In the context of higher education, volatility refers also to the ease and speed in which teaching and learning best practices change. The mission of global higher education is being shifted by volatility. Currently, universities must ensure that their students are able to adapt to changes in the global labor markets and continue to be employable [17].

Teaching is becoming increasingly uncertain for the educators, because they are never sure about what their students understand, whether the misunderstandings come from inadequate content or incomplete understanding of difficult concepts. There are also doubts about how the classroom practices can be improved, since it is not straightforward to select the most successful teaching approach for a particular group of students. To address these issues, interesting examples and experiences can be adopted. For example, the UNIS-X approach encompasses in a single course four principles (project-based learning; close collaboration between faculty and external partners; interdisciplinarity; and active mentoring) [18]. The findings obtained in discussions with focus group indicate that the effectiveness of the UNIS-X pedagogy in stimulating the cognitive, interpersonal and intrapersonal competencies of the students is positively assessed by them.

B. Teaching of entrepreneurship in an active learning context

The quality of the software products and services developed for commercial purposes is highly dependent on the competencies of the software engineers, whose previous education should favour interdisciplinary skills, practice experience, communication skills, ability to continue education, and professionalism [19]. In fact, the success or failure of software products and services depends on an excellent alignment of technology, market needs and business model. The issue here is that this alignment occurs in markets and domains that are volatile, uncertain, complex and ambiguous. The software development processes must provide, in a world that progressively more competitive, globalized and digital, profitable products and services that meet the needs of all stakeholders (i.e. clients, customers and users). The challenges are thus enormous.

Active learning is an educational approach that focuses the responsibility of learning on students. It is especially adequate and effective for exploring VUCA contexts and to prepare students for them. Among several active learning educational strategies, approaches and tools, project-based learning (PBL) is well known in higher education institutions. Whenever PBL is followed, students perform a set of tasks within a concrete project typically based on a real or market situation, thus gaining knowledge, experience and skill.

PBL approaches are the vehicles that universities can use (1) to move from more traditional teaching and learning approaches to more active ones, and (2) to redefine their academic offers in engineering to include innovation, entrepreneurship, creativity and marketing.

Moving from traditional approaches to PBL entails many challenges and issues. Five aspects are indicated in [20]: (1) critical involvement and input of stakeholders external to the course design team; (2) need to adapt PBL for institutional, discipline and cohort fit; (3) importance of preparing the student cohort to cope with the inherent tensions of PBL; (4) managing their potential demands for additional control; (5) clarification of opportunity and resource costs that arise from implementing PBL.

Entrepreneurship is particularly important for exploring the opportunities offered by VUCA contexts. It can be promoted using active learning approaches, notably PBL. Entrepreneurship is highly connected to change, since it is a phenomenon associated with the change process and entrepreneurs are expected to be agents of change. Additionally, an entrepreneurial perspective fits well in the software domain, as software products and service have the potential to be highly profitable [21].

The promotion of entrepreneurship in engineering education, more specifically in software engineering is getting significant attention. In particular, it is evident that entrepreneurship requires active educational approaches, so that students learn new skills and reflect on what they have learnt and how they can benefit from and apply those skills. There are some examples. The use of game-inspired exercises to address all the relevant topics of software engineering is presented in [22]. The multidisciplinary, active, and collaborative approaches used in teaching requirements engineering is described in [23]. In [24], the authors discuss the insights on how providing students the opportunity to explore their entrepreneurial skills has an impact on students' action capability towards entrepreneurship.

III. TEACHING ENTREPRENEURSHIP IN THE SOFTWARE DOMAIN: A CASE STUDY

The "Project in Software Engineering" (PSE) course follows a PBL approach to teach entrepreneurship in the field of software engineering. It is offered since 2009/2010 to final students of the Master Degree in Computer Engineering at UMinho. This one-semester course aims to stimulate students to combine their "natural" technical vision with a business

perspective, a combination that is not common in the education of software engineers.

The ideas described in [25] are followed within the PSE course. Those ideas assume that any topic at any level of education is achieved more effectively when the students are faced with the whole issue of that topic, instead of isolated parts. The authors also describe the advantages for students when they acquire competencies and technical knowledge while developing a real-world artefact, using the tools and the best practices that are common in industrial scenarios.

The two main activities that students should accomplish are related to (1) the development (requirements, design, construction, testing and management) of a software product or service, and (2) the analysis of the business model of that product/service. This context allows students to acquire several skills, which often were not previously considered, but that the industry is clearly looking for. Among those skills one can include: leadership, team management, requirements elicitation, interaction with customers and users, product design, software testing, communication and presentation, marketing, documentation, entrepreneurship, business [6].

Students are organized in teams with from 6 to 10 elements to develop the software product. The evaluation, which is always a critical aspect, is based on three main criteria: (1) the quality/scope of software product, (2) the respective business model, and (3) the pitch delivered by the students.

IV. Major Changes Made in the Course

The success and achievement of the objectives of a curricular unit with these characteristics require a permanent effort of adjustment and a continuous improvement effort. Courses should correspond to the expectations of the students, the institution and the society, recognising that these expectations are changing more and more rapidly and profoundly nowadays because the VUCA context. The PSE course has been adapted and has evolved over the last ten editions to meet these expectations and also to optimise its management. In fact, the management itself of the course is also a big challenge to the coordinators and teachers considering the focus on real problems with a significant interaction with the industry and potential market in classes with a growing number of students because course's attractiveness.

Over the last 10 years there were several drivers that drove and justify the changes promoted in the course. These drivers are presented and succinctly explained in Table 1.

A. Teams' Size

The attractiveness of the course and the increasing number of students taking the software engineering degree has considerably increased the number of students in PSE. Managing larger classes is more complicated and requires additional effort. In the case of this course, it should be added that the course, based on a PBL approach, is developed around projects to be carried out in groups, with teachers playing the role of coaches who follow the projects throughout the semester and the support of mentors from industry, invited guests who give seminars and opinion about the projects, etc. The role of teachers is important but should not intrude too much on the autonomous work and initiative of the students. Above all, it is intended that the projects are developed from the beginning of the semester without major mishaps, delays and with conditions to obtain a minimum viable product (MVP) at the end of the semester. However, the increase in the number of students per group and the variability induced by increases and decreases in this number creates difficulties in managing the discipline and requires different approaches that need to be adjusted in each edition. Generically, we can increase the number of students per group and increase the number of groups. In this case, both were done. In addition, the number of hours of support per group, the number of groups supported by each teacher, the interaction in the preliminary stages with the students, etc., also had to be adjusted and decreased with the increasing number of students.

Our experience has shown that big groups do not show much better results. In a working group, the marginal benefit of more students increases significantly up to 6 students, decreasing from that number onwards and may be negative for more than a dozen students. Therefore, and in line with the literature, the optimal number of members per group should be a number between 6 and 9 students. In all the editions of the course, several problems and challenges for the course management have been detected when the number of members per group is high. One of them is the obvious risk of some of the students contributing too little to the project but there are also problems of entropy, too much partition of the tasks to be carried out and more easily personality and leadership clashes.

In the different editions, the teaching team involved has not changed significantly and on average there are five teachers in every edition, two of them having been linked to the course since the first edition. The number of students has been around one hundred and two hundred turning the work of the teachers very demanding.

B. Leadership and Project Management

In group work there is a risk of free-reading situations, which are independent of the number of students but are more frequent and more damaging in large groups. The centralised management of the project and the control of the activities developed by the students in the various tasks allows reducing this risk and mitigating the negative impact of these situations. There are various instruments and tools that can be used for this purpose.

TABLE I. Major Changes Made in the Course

Change	Description
Teams' size	Number of team members changed (groups composed by 6 to 9 elements).
Leadership and project management	The team work is managed with the contribution and help of a team leader and project management tools and software.
Diversity of projects	Different types of projects: students' own projects or projects proposed suggested by companies.
Interaction with external elements	Students present their ongoing work to external elements (e.g. specialists in innovation and business design, managers) to get early feedback.
Market analysis and feedback	Searching for data and feedback directly from the market and potential business partners or clients.
Empowering students in the evaluation process	Peer assessment is used to involve and compromise students in the process of evaluation and to turn the team work more effective and valuable.
Developing business skills	Presentations to an external audience, development of business cases, pitches and economic evaluation.

As it is stated by [26], the use of project and software management tools is very important in courses based on PBL approaches contributing to a more effective and coordinated participation of individual activities. This contribution is more significant when dealing with a high number of students.

How groups are formed is also important. It is relatively common to choose friends or colleagues with whom there is a strong affinity. Friendship and previous knowledge contribute positively to good teamwork. But it is also important to promote the opportunity to work with new people to develop teamwork skills. On the other hand, a balanced team composed of people with different skills should also be promoted. It was found strong evidence that role of the leader is fundamental for the good functioning of the group.

Teachers play an important role in the composition of the teams. Firstly, the total number of students in the course defines to some extent the size of the groups and the number of groups, mainly for practical reasons of course management. In the PSE course the number of students per team has varied between 6 and 10 elements and the number of groups between 10 and 15. The number of elements in each team depends on the number of students enrolled in the course. It is suggested, without too much intrusion, that the groups should include members who know each other, but also new colleagues and above all balancing different competences should be considered in the selection of group elements. It is suggested that it should be avoided to include in the same group people with a history of conflict or with personalities that could generate conflict.

C. *Diversity of Projects*

Throughout the various editions we have seen a considerable improvement in the projects both in technical and market-oriented quality (more information can be found in [6]). The example provided by the projects of the previous editions and the experience of the teachers, collaborators and guests may explain this improvement observed in the projects of the last editions. The course is also already very well known by the students and many start the semester with very clear ideas and very motivated.

However, as the number of students exceeded one hundred and approached two hundred students, the diversity of students' expectations increased considerably. To meet these expectations and for curricular unit management reasons, it was decided to create two types of projects: proposals presented by the students and proposals presented by partner companies of the course.

The own projects have the support of teachers, guests and mentors. The projects proposed by companies have the support of teachers and of the proposing companies. In the latter, neither the development of a business plan nor an active interaction with the market are requested.

D. *Interaction with External Elements*

Throughout their academic experience, university students undertake mainly academic work with little interaction with industry and real problems. Academic assignments offer teachers greater control and security and allow them to direct their work towards the subjects and approaches that need to be highlighted in the discipline. But, the comfort and security of this approach also applies to students who find it difficult to deal with real problems and are not comfortable interacting beyond the university walls. However, in engineering in general and in projects of new product development in particular, contact with the outside world is fundamental. Therefore, a course like PSE offers students the opportunity to experience challenges that they will soon have to deal with in companies. On the other hand, it instils in them a new or increased sensitivity towards business issues such as price versus costs, profitability, expenses and investment, return on investment, marketing and strategic issues, etc.

Thus, we promote the participation of elements from outside the course, e.g., teachers from other courses and other departments, experts in technical and business areas and company managers with high experience in software products development. In the 2014/2015 edition there was an increase in these collaborations, contacting a high number of companies that still continue to collaborate with the course.

The opinion of external elements is very important and useful during the product development process that takes place throughout the semester and also exposes students to the scrutiny and opinions, not always convergent, of other people who have a different vision of the project being developed. Knowing how to absorb positive and negative criticism, managing different opinions, defining and maintaining a consistent direction for the project is a difficult task in which teams pass with greater or lesser distinction. It is an important challenge and a learning process provided by the development process of the projects influenced by the contributions of external elements. In fact, there are students who almost uncritically and immediately follow any and all suggestions they receive, without analysing the impact and logic of these suggestions in the project. The lack of critical spirit and a lower self-confidence in the potential of the project is reflected in zigzagging paths that delay and even compromise the completion of the product. Therefore, it is necessary not to accept all the suggestions, in some cases because they are not good and in others because, even though they may be relevant, they would imply significant changes for which there is no more time or which put the success of the project at risk. This is an important learning outcome: to know how to listen and retain good advice, but also to remain firm and confident in the strategy outlined for the product.

E. *Market Analysis and Feedback*

The teams that choose to develop their own projects need to have some feedback from the market – what is called “the voice of the customer” which complements and validates the personal ideas and beliefs of the team, usually not fully aligned to what the market real needs or wants. Such market rule is not intuitive for engineering students and results in a very important lesson learned. The opinion and support of external elements (explained in section D) is very useful in this process but it is not enough. It is necessary to know the potential market and to have a mentor to support the project. The mentor can be an expert in that particular market, a potential customer of the product, a supplier of competing products or services, etc. Teachers instruct the teams to seek a mentor for the project from the very beginning of the semester and in some cases they actively participate in this process by helping the teams to have the support of a mentor. The mentor allows the validation of the value proposition and provides valuable information about the product, customers and market. The mentor can help in the proof of concept and the testing of the minimum viable product. The mentor is not supposed to follow the project on a weekly basis, but only to give quick and punctual feedback on issues that need to be

validated about the product – what she/he can do easily. The coaching role is performed by the teachers despite the time constraints due to the high number of teams.

F. Empowering Students in the Evaluation Process

In teams there are usually different levels of work and contribution to the project. In large teams these differences can be considerable. However, in a project of this nature, it is difficult to adequately differentiate the members of each team according to their individual contributions. And, we need to recognize that less effort and time dedicated to the project can be compensated with more relevant and sharper contributions or indispensable management and leadership tasks that contribute decisively to the results of the project. The easiest evaluation model is to evaluate the team performance and assign the same evaluation to all students. However, it is important to highlight the individual work of each element especially if the contributions are very disparate. In this way students can choose to request a differentiated assessment if the team agrees. Students are more qualified than teachers to make a differentiated assessment of the performance of each element of the team.

Almost 100 teams have participated in the ten editions of the course under evaluation, and only once has a team not been able to reach a unanimous decision. The individualized evaluation process is supported by a peer assessment [27, 28] which is already commonly used in several teaching projects.

In PSE, students have to submit information on the peer assessment at three different moments throughout the semester. The reallocation of grades is a zero-sum game. The indication of the students must be given before the announcement of the collective grade.

G. Developing Business Skills

Developing a complex project in a team implies producing a significant amount of documentation at different moments also to make possible feedback in an iterative process (i.e., following the SCRUM approach for software development).

In the first years of the PSE the tendency was to add requests to the students in terms of documents to be presented at the end of the semester, e.g., requirements documents, installation guides for the software products, user manuals, business plans, recorded presentations, product promotional material, posters, websites, etc. The type of material requested varied from edition to edition depending on the number of projects, external audience for the final presentations, suggestions from the students and teachers, etc. The existence of groups with larger elements also induced the idea that it was necessary and possible to request more documents. The students, in turn, were increasing the size of the documents.

However, it became clear that it is not desirable to ask for too much documentation, because it diverts the students from the work they have to do, which is essentially the MVP. On the other hand, it is unaffordable for teachers to assess a lot of material in a timely manner.

It was also felt that the business plan may be too much and only a more succinct business case is requested. However, students tend to prefer to submit a more traditional business plan because they find ample support and examples on how to make a business plan. Abandoning the business case or the business plan is not appropriate because it is important for engineering students to develop the analysis from the business perspective which represents a new competence that they have not yet explored during their academic path. The decrease in the number of deliverables was compensated with a greater focus on different ways of communicating the project to different audiences (e.g., potential customers, business partners, investors, experts, administrators of business accelerator programmes or incubators).

In this context, short and incisive presentations (i.e. pitches) with careful communication and graphic presentation have gained great relevance in the last editions. At this moment, the teams have to present results in three moments along the semester. The first deliverable comes right at the beginning of the process, after 3 to 4 weeks, asking for a presentation of the value proposition (which will be validated and improved over the following weeks). In the second moment, what occurs much later, two weeks before the end of the project, the teams have to present the project to the teachers in a pitch format. The third and last stage takes place after the end of the project and consists of a presentation of the product and its business model to an audience of experts. These presentations are a very important moment in the entire process and have taken place outside the university (e.g., auditoriums of large companies, business incubators) which gives them a very special atmosphere. The press of the university and also newspapers have followed these events and news are published every year about the event valuing the work developed by the students. The invited panel is very impressed with a good part of the projects presented. In this final stage, the lack of quality of some projects may justify that they are not presented to the external panel but this decision has been taken mainly because the number of projects is too big and it is necessary to select the best ones.

The final presentation is the culmination of the whole process and contributes greatly to the final evaluation assigned to the projects. This importance has been recognised and is evident in the increase in the rating given to it in the evaluation scheme used. Initially, the final presentation contributed only 10% of the final mark, but in recent years this value has risen considerably to 50%. Thus, communication skills and the quality of the final product are particularly valued (i.e. both content and form are highly valued). Nowadays, communicating correctly and efficiently is a fundamental competence for an engineer. Students are made aware of these issues and of the importance of soft skills understanding that the success of a new product or a startup depends a lot on a good presentation which is usually between just 3 to 7 minutes! The PSE course allows students to be confronted with this reality and to acquire these skills or at least to become aware of it.

V. DISCUSSION

The PSE experience highlights a set of pedagogical issues that are important to discuss and understand, namely in the VUCA context that characterizes the current world. There is a set of lessons that can be used to continue the effort of continuous improvement in the course and that can be considered in other courses promoting entrepreneurship in engineering students.

The constant adaptation of the PSE course responds to the challenge of [29] and the need to adjust the curricular units to their context (students, general environment, etc.) to make the teaching-learning process more effective. Teachers are asked to prepare their students for the future and therefore they have to understand and anticipate trends. On the other hand,

teachers have to understand their students in order to enhance their learning. The PSE course has evolved to accommodate these various aspects and with the aim of enhancing students' motivation to contribute more to the course objectives and get more out of the work done.

The alignment with real problems and the needs of the market and industry is also important and allows students to initiate a transfer from the controlled and predictable academic world to the more unstable, uncertain, competitive world of business. - in short, the VUCA world. Universities need to prepare the professionals of tomorrow's companies with high qualifications, modern mindsets, advanced and disruptive knowledge and effective tools.

A. External Environment

The possibility to interact with external elements and throughout the semester gives a very relevant experience to the students and contributes to increase the success of the product development in both technological and business perspectives. This interaction allows the product to be developed under the best conditions to be placed on the market. If this does not happen, the team has gained from the lessons they have learned about the limitations the product may have in not being marketable. In most cases, students report that this interaction is very positive and allows them to improve the products throughout the semester. On the other hand, the challenge of presenting almost every week the idea and the product to different people results in an important exercise and in the development of relevant communication skills. Besides these moments, the groups have to be competent in the pitches they need to make (which are 3 throughout the semester) in different situations.

The contact with external elements and the presentations are not easy tasks for these students who generally do not develop them in their traditional courses. But students can adapt to this context very quickly and the improvements achieved throughout the semester are evident. The experience of the PSE course with the developed project is extended later with the development of startups in the worked area or in other areas and with other products. The project can be developed after the PSE course by participating in business acceleration programs, for example, or directly with the launch of a business. These situations have occurred throughout the various editions of the course. During the financial crisis period, there was a greater availability or will to continue with the project after the course than now. Probably, because at that time there was a greater incentive to self-employment due to the lower demand in the labor market and currently the opportunity cost of launching one's own project instead of working in a company is higher, particularly for computer engineers.

However, it seems clear that there is a link between the VUCA context and entrepreneurial skills and the contribution that a course like PSE can give in this domain.

Finally, it should be mentioned that there are a large number of PSE students who are already working. Their participation is very important because they bring experiences and knowledge that complement the competences of the remaining colleagues of the group. A good balance of group elements working in the industry and elements who still just students in the university is very important for the success of the project and to enhance the learning of new skills by all.

B. Personal Aspects

Most of the projects developed by the students are proposed by themselves and represent an attempt to create a software product with the potential to be launched in the market. In fact, in a course like this, preferably, the ideas should be proposed by the teams, so that the levels of motivation and commitment, but also the technical skills are much higher.

It is important to propose ambitious projects but also not overly so. In fact, a realistic project allows to simulate with high verisimilitude what happens in companies or when someone decides to launch a new product. Being feasible allows for the effective exploration of viable development alternatives during the available time, which is reduced (just a few months), and if it goes well, it promotes the personal satisfaction of the team members. On the contrary, both a more modest or overly ambitious product idea will not work well and causes frustration in the team.

An idea that is weak technologically or without market potential will not be entirely successful. In every edition there are teams that change significantly the initial ideas, because they feel that the idea does not represent a sufficiently interesting challenge technologically and from a market perspective. Both teachers and external elements warn about these issues, with the groups being more sensitive to the external advice when it comes to abandoning an idea because it does not have enough potential.

In this context, students are confronted with VUCA and are challenged to make some dramatic decisions such as abandoning a project and starting a new one after more than half the semester has passed. These situations are not common but they do occur.

However, different types of projects that combine technology risk and market risk differently are welcome. The challenges and demands are different and it is up to the teachers to make the alert preparing the students for the assessment they can get at the end. A product with a business model or approach to the market with little innovation and reduced complexity and technological risk has to explore other aspects of (e.g. good market analysis, good economic evaluation, good handling of non-functional requirements). On the other hand, a project with a disruptive business model and a high technological risk is promising but requires a lot of competence and ability from the team to achieve the objectives. The demanding nature of the work also requires good leadership and good project management. However, a more modest project very well executed may be preferable to an ambitious project with more modest results.

Therefore, an important lesson the students get is that during project development, it is important to know how to manage the effort of planning and executing the project. Starting to develop the project too early, based on an insufficiently elaborated idea, absence of a clear value proposition, among other common mistakes compromises the success of the project. However, it is also necessary to avoid spending too much time thinking about the idea and then lacking time to develop and test a good product. Balancing these various aspects is essential. In this sense, it is proposed that students use an iterative approach, with constant validation and incorporation of feedback from experts and market knowledgeable until the final validation through the proof of concept or MVP.

The methodology followed in the course is based on the "Lean Startup" methodology. In the wake of agile product development methodologies, the execution of short development cycles and the development of successive minimal versions of the product are promoted.

VI. Conclusions

The PSE course allows the development of entrepreneurial skills in computer engineering students. In order to keep the course highly challenging and motivating for students and manage it properly, several changes were promoted throughout the various editions of the course. This continuous improvement effort made it possible to make the course an important vehicle to introduce students to the so-called VUCA world. In this article we analyse the changes made in the PSE course that kept it interesting for the students, made it easier to manage (specially to deal with a growing number of students and projects) and gave the students more skills to succeed in the VUCA context that is a reality in companies nowadays and that will be even more evident in the future.

Therefore, the main modifications introduced in the course and the drivers of those changes were highlighted, namely: the increase in the number of students per team, the need for an effective leadership and management of the project, the increase in the diversity of projects (own projects versus projects proposed by companies), the reinforcement of the contact with elements external to the course, the need to seek information and support outside the university to know about the real needs of the market and obtain feedback about the product, a greater participation of the students in the evaluation process through the use of peer-assessment, and a development of competencies and skills in business and communication. The experience and lessons learnt from the work carried out in the PSE course can be applied in other similar courses and even in other domains where we want to promote technical and entrepreneurship skills in university students considering the VUCA context.

The three main lessons learned relate precisely to the key concepts that underline this manuscript: software engineering, entrepreneurship, and VUCA.

Traditionally, education in engineering in general, and software engineering in particular, promotes the more technical or technological competencies, but nowadays these skills are not enough. Soft skills and particularly entrepreneurial characteristics are very relevant and even fundamental for most engineers.

On the other hand, students typically solve controlled and predictable academic problems and are not confronted with the difficulties, challenges and inconsistencies of real problems or the solutions they develop are not usually tested against the market or the opinion of elements external to the university. Engineering students must recognise that they must develop products that are technically correct, but for which there is also market demand. It is a recurrent problem when products are developed at the university for which there is no market because they have not been sufficiently validated with feedback from the market at an early stage. Sensitising to these issues is very important to be able to deal with the demands of the VUCA world.

In fact, companies are only sustainable if their products are profitable. The profitability of products depends on several aspects: technical and business-related. A good product needs an adequate business model and new, innovative and possibly disruptive products require a higher investment in market analysis and business model design according to their characteristics. The development of software-based products requires taking all these aspects into consideration. Computer engineering graduates must be prepared for these challenges that they will soon encounter when they join companies. The PSE course contributes to give these skills to the students.

Engineers with only technical skills cannot fully contribute to the development of software products. And this is particularly evident in a VUCA context.

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