Engineering education in a context of VUCA

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***Abstract*—We live in contexts of higher volatility, uncertainty, complexity, and ambiguity (VUCA). In such contexts, higher education must promote active learning approaches where the responsibility of learning is focused on students, enhancing their competencies and ability to be competitive in the market, after their studies. But, such educational strategies encompass many issues, questions and challenges, both for teachers and students. This article presents and discusses the main changes that have been introduced in a course that promotes entrepreneurship in the field of software engineering. The promotion of entrepreneurship within universities requires effective teaching paradigms which need to be constantly adapting and evolving particularly in the current VUCA context. The PSE course is analyzed according to two distinct VUCA angles: (1) how the course can be adapted to satisfy the expectations of students, and (2) how the course can provide opportunities for students to learn how to behave in a VUCA context.**

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

I. Introduction

Volatility, uncertainty, complexity, and ambiguity (VUCA) all describe the conditions under which organizations, corporations, and institutions operate in the world today. As there is no predictability for every issue that may arise, it becomes necessary to plan and react for any issue. The VUCA world calls for innovative strategies and processes that can be used to cope with in any given situation, and, if treated right, the VUCA world can be an opportunity for teachers and students to learn and develop effective, agile and flexible strategies. VUCA is a way of assessing and providing for the changeability of general situations and events that are completely unpredictable.

Active learning is an educational approach that fits this context of VUCA, focusing the responsibility of learning on students. It basically engages students in two aspects: doing things and thinking about the things they are doing [1]. All active learning approaches suggest that in order to learn, students must read, write, discuss, or be engaged in solving relatively complex and ill-structured problems. Specifically, students must be involved in higher-order thinking tasks, like analysis, synthesis, and evaluation. Active learning encompasses many challenges, both for teachers and students, as discussed in [2].

Nowadays, universities face many uncertainties, due to VUCA and the chaotic, vibrant, and rapidly changing educational environment of our days [3]. These external factors demand from professors a constant and quick reshaping of the courses they are responsible for, so that they are more attractive to their students. Higher educational institutions are forced to reshape, respond to and adapt to a rapidly changing environment, as a result of learning, adaption, and development [4].

Additionally, entrepreneurship education is a good context for preparing the students for the VUCA side of the world. Indeed, work factors such as adaptability and flexibility are necessary [5]. Thus, entrepreneurship education is among the fastest growing fields of education. The promotion of entrepreneurship in engineering education, more specifically in software engineering, is getting significant attention (e.g., [6, 7]).

Nevertheless, training for entrepreneurship requires approaches that need to be simultaneously and continuously efficient and effective [8]. This implies a permanent adaptation and evolution of good practices and a continuous reshaping of the courses, where those topics are considered. Otherwise, pedagogical practices quickly become inadequate and obsolete.

This manuscript is focused on describing and discussing the evolution of a course (Project in Software Engineering - PSE) since its inception. The changes were fuelled by the idea of adapting the course to better achieve its objectives and of better satisfying the expectations of the students.

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

VUCA is a catchphrase in the corporate arena and an often-discussed topic for today's adaptive leaders during annual strategy meetings [9]. 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.

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 [10]. The multiple increases in the rate of changes in the VUCA world place new demands on people, processes, technologies, structures, and systems where conditions are created for the education of a personality, for the development of a mobile, vibrant and adaptive style of thinking [11].

Indeed, according to [12], organizations have been pushed to move from the SPOD world (Steady, Predictable, Ordinary, Definite) to this new paradigm.

There are additional factors that also contribute to the increase in turbulence in the global higher education world

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including: the rise of the digital economy, connectivity, trade liberalization policies around the world, increased global competition and innovation [13].

Rapid changes taking place in political, economic, social and technological fronts are making the organizational world increasing VUCA [9].

We are moving from a world of problems, which demands speed, analysis and uncertainty to solve, to a world of dilemmas, which demands patience, sense making and an engagement with uncertainty [14].

Volatility The speed, volume, magnitude and dynamics of change are all high. The situation is unstable and may be of an unpredictable duration.

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.

Ambiguity The situation is unprecedented and one must brace himself to face the unknown.

If the challenges surrounding us are highly complex, often ill-defined and interdisciplinary in nature, universities should prepare students to tackle these challenges by providing them opportunities to hone skills such as the ability to evaluate new inputs and perspectives, build new capacities and strengthen autonomy that are critical for 21st century life and work [15].

Thus, students need to learn about and to be competent in several skills. For example, in [16] the authors identify the dispositions and skills required for the VUCA work environment as following: 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.

Indeed, in the 21st century, volatility has shifted the mission of global higher education to ensuring that everyone is able to adapt to changes in the global labor markets and continue to be employable [17].

In the context of higher education, volatility refers also to the ease and speed in which teaching and learning best practices change. Teaching is very uncertain for the teachers because they have never been sure about what their students understand, whether the misunderstandings come from inadequate content or incomplete understanding of difficult concepts. There is also uncertainty about how the teachers can improve their own classroom practices because no one can be sure of the teaching approach that is the most successful for a particular team of students.

Nevertheless, there are recent interesting examples and experiences. For example, the UNIS-X approach encompasses four principles (project-based learning; interdisciplinarity; close collaboration between faculty and external partners; and active mentoring) in a single course [18]. The findings from focus group discussions indicate that students shared positive feedback on the effectiveness of the UNIS-X pedagogy in developing their cognitive, interpersonal and intrapersonal competencies. Students were positive about their UNIS-X experiential learning journey.

B. Teaching of entrepreneurship in an active learning context

Active learning is an educational approach that focuses the responsibility of learning on students thus, particularly suitable and relevant in a VUCA context and to prepare people for such environment.

Among several strategies, approaches and tools, project-based learning (PBL) is an active learning educational approach relatively well known in higher education institutions. Through PBL, students gain knowledge and skills by performing a set of tasks within a concrete project typically based on a real or market situation.

The change from traditional approaches to PBL is not free of challenges and issues that should be considered. Five aspects are highlighted in [19]: (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.

PBL approaches are, thus, important to help universities to move from more formal traditional teaching and learning and to redefine their institutional mission to include innovation, entrepreneurship, creativity and marketing.

Entrepreneurship is particularly important in this context of VUCA that can be promoted using active learning particularly, PBL approaches. It is closely linked to the concept of change, i.e. entrepreneurs are agents of change and entrepreneurship is the phenomenon associated with the change process. Furthermore, the fields of software and ICT are especially attractive to be exploited in an entrepreneurial perspective [20].

The quality of the software is a direct consequence of the quality of software engineering education that should include interdisciplinary skills, practice experience, communication skills, skills on continuing education and professionalism [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 multidisciplinary, active, and collaborative approaches used in teaching requirements engineering is described in [22]. The use of game-inspired exercises to address all the relevant topics of software engineering is presented 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.

Indeed, the success or failure of software-based products is highly dependent on a good alignment of technology, market needs and business model in very volatile, uncertain, complex and ambiguous (new) markets and industries. Students must to understand that software development processes should meet the needs of all stakeholders (i.e. clients, customers and users) and result in profitable products and services in the actual very competitive globalized and digital-oriented world.

III. Teaching Entrepreneurship in the Software Domain: A Case Study

The "Project in Software Engineering" (PSE) course, offered since 2009/2010 to final students of the Master Degree in Computer Engineering at XXX, is a project-based course to teach entrepreneurship in the field of software engineering. In this course, students combine a technical vision with a business perspective. This combination is still unusual in the training of software engineers.

The main objective of PSE is to enable students to acquire a set of skills related to (1) the development (analysis, design, implementation, testing and management) of a software product as a team and (2) the analysis of the business potential of that product. Students are organized in relatively large teams (from 6 to 10 elements) to carry out the project during an academic semester. Students are evaluated based on three main aspects: (1) the software product that they develop, (2) the respective business model, and (3) the pitch of the product.

Students are evaluated with respect to the quality of the product that they have developed, the process they follow, and the pitch that they deliver.

In this course, students acquire several skills, which in most cases are not properly explored in their previous academic path, but that are clearly valued by the market. This set of skills includes: leadership, team management, requirements elicitation, interaction with customers and users, product design, software testing, communication and presentation, technical documentation, marketing, business, entrepreneurship [6].

PSE follows the philosophy advocated in [25] in the book "Making Learning Whole", which argues that any topic at any level of education can be achieved more effectively if students were confronted with the whole issue of this topic, instead of isolated parts. Perkins also describes the benefit that results for students when they learn skills and concepts in the context of creating a real-world artefact, using tools and best practices from the professional world. At the same time, students learn the academic subjects required for this level of software engineering.

IV. The Need of Change, Adaptation and Evolution

A course with these characteristics needs itself to be continuously adapted and changed, according to the conditions that surround us. In the actual world qualified as VUCA, the modern professor needs to rapidly adapt his/her courses according to the reality and the expectations of the society particularly, organizations and students. We analyse in this manuscript the main changes that we, as professors, have introduced in the last 10 years in the PSE course, either as an attempt to make it more appealing to the students or as a reaction to the outside conditions that surrounded us.

The main factors that have induced change in the PSE, as verified throughout its editions, are presented in Table 1 and discussed below.

A. Number of Students per Team

Every year, the number of students that attend PSE varies. Since the course is oriented towards team-based project development, the task of the professors is to act as mentors/coaches of the teams, in order to guarantee that the projects progress as smoothly as possible. This variable number of students implies that either the number of teams also varies accordingly, or we have to change the number of students per team, if we want to fix this number of teams. In both cases, the associated challenges are appreciable.

A high number of elements reduces the capacity of the team to deliver good results. The marginal benefit of having more elements is decreasing from the optimal number of elements that could be between 6 and 9 people.

There are some challenges for the professors when the number of students in each team is relatively high. One of them is the risk that some of the team members have a very reduced (or even null) contribution to the project development.

Throughout the various editions, the number of professors involved has remained relatively stable, generally five, with two professors having been linked to the course since the first edition.

B. Project Management and Leadership

In a team-based work, free-riding strategies are common, independently of the dimension of the team. Thus, in order to mitigate this problem, the use of a centralised project management tool is mandatory. In this mechanism, the contribution of each student can be controlled.

TABLE I. Major changes

Change	Description
Number of students per team	Variation in the number of members of each team (in general, between 6 and 9).
Project management and leadership	The use of a centralised project management tool is mandatory and each team has a leader.
Different types of projects	Students can develop their own projects or projects proposed by partner companies of the course.
Contact with external elements	Interaction between students and external elements to receive feedback and suggestions about the business potential of the idea.
Go out of the building	Searching for mentorship, getting feedback from the market.
Accountability of students in the evaluation process	Empowering students in the evaluation process through the implementation of a peer review mechanism.
Focus on business and communication	Developing a proper business plan and a persuasive pitch.

We share the opinion in [26] that online platforms used within PBL courses are powerful tools to improve the attitude of students with respect to continuous work and individual participation in the activities of the team. This is of paramount importance whenever the number of students is high.

Leadership is also important in this context. Choosing friends makes sense, but it can be equally as important to work with people one does not have much confidence. A balanced team is a factor that has a very high impact on the success of the projects. It is also important to have a leader who knows how to manage the team in a calm but determined way.

The composition of the teams is discussed with the professors. In principle, the number of elements in each team depends on the number of students enrolled in the course. Typically, this number varies between 6 and 10. It is suggested to choose students with different backgrounds, for the team to include members with different skills. It is also a good idea to exclude people on the same team who have conflicts with each other or whose personalities foster some sort of antagonism.

C. *Different Types of Projects*

There has been an increasing number of products developed by the teams and remarkable progress in technical complexity and in the level of sophistication of the solutions as presented in [6]. The quality of the value propositions underlying the products developed has also improved considerably.

Nevertheless, with big classes, i.e., larger than 100 students, the diversity of the expectations of the students is high. Thus, at some point, in PSE we decided to allow students to choose between projects proposed by themselves or by partner companies.

The projects proposed by companies are monitored on a weekly basis by the respective proponents, which should provide some alignment between what is expected and what is achieved.

D. *Contact with External Elements*

In many universities, the students within their academic activities have very limited or no interaction with people from industry. In engineering, this contact is fundamental so that students can experience during their academic path the challenges associated with having a more business-oriented approach.

We followed a strategy that promotes the participation of external, whether from other departments of the university or from companies. In 2014, the contribution of these elements was reinforced, by increasing the number of companies that regularly collaborate with the course.

The feedback and suggestions provided by these external elements are very useful in general and expose students to the scrutiny of business experts and managers, such as CEOs, CTOs, etc, which is a new experience for them. However, sometimes students follow immediately all the suggestions that are provided by the experts, without carefully analysing the impacts of those suggestions in the project and without the necessary critical spirit and self confidence in the potential of the project whatever others' ideas. This is not a reasonable approach, since often those suggestions, even if relevant, imply significant or even drastic changes, which may put in risk the success of the project.

E. *Go Out of the Building*

The students that develop their own ideas have to align their products with the market. As already indicated in D, the contact with experts allows the products to be improved in that dimension. This is promoted essentially asking each team to search a mentor for the project. The mentor can be a potential first client, a business partner, an investor, someone with a good knowledge of the market or the industry. This contact is important to validate the value proposition, to help in the proof of concept and test of the minimum viable product that should be designed and evaluated with feedback from the market till the end of the semester. The role of the mentor is to give some advice and feedback and not coaching the project.

F. *Accountability of students in the evaluation process*

Whenever there are many students in a team working together, it is always a challenge for the professors to decide how to differentiate the members of each team, according to the individual contributions. In many cases, the easiest solution is to evaluate the collective performance of the team and assign that evaluation to all its members. However, this may be quite unfair in many cases, as students contributed very differently to the final outcome. Thus, we suggest students within the same team to be allowed to decide how to differentiate their individual marks, if they find it appropriate. In fact, providing this power to the students is adequate, since they are the ones best entitled to make a fair evaluation of the performance of each team member.

Transferring this responsibility for the students make sense, since they should be able to collectively arrive to a consensual decision. In the various editions of the course, for almost 100 teams, only once a team was not able to arrive to a unanimous decision. This evaluation process is accomplished through the implementation of a peer evaluation mechanism [27, 28].

Students provide regular feedback (three times in a semester) to the teachers regarding the peer assessment. At the end, they indicate for each student the delta that should be summed to the collective mark in order obtain his/her individual mark. The total of the deltas should sum up to zero. The indication of the deltas should be given before the collective mark is announced, otherwise students are invited to artificially assign the deltas to total of the marks.

G. *Focus on business and communication*

Developing a complex project in a team entails producing a significant volume of documentation in different moments also to turn possible feedback and an iterative process (e.g., following the SCRUM approach for the development of software). In the initial editions of PSE, students were asked to produce many deliverables, like requirements documents, user’s manuals, installation guides, and business plans.

It is now clear that requesting such amount of documentation is excessive, because it deviates the students to artefacts that are now not considered as primary. Currently, the focus is on developing a proper business plan, since it forces engineering students to shift from a technical perspective to a business-oriented one. Students are, thus, asked to justify how their technical product is aligned with a proper business plan.

Reduction in the number of deliverables allows also students to be requested to put more effort on communication issues.

Thus, now, pitching is a crucial element of the project, so students are requested to put great care on it. Three pitches are formally performed throughout the semester. The first pitch takes place at an early stage of the project (after 3 weeks). The second pitch takes place when the project is near the end (two weeks before the end). The third and final pitch takes place when the project is finished and aims to present the product and its business model to a panel composed of specialists external to the university. In the final pitch, all teams are expected to participate, but some can be removed if the product is not of sufficient quality.

This implies that the final pitch is a very important moment in the overall project (and with a higher impact in the final evaluation of the projects). Initially, the pitch accounted for 10% of the final mark, but in the last editions this weight raised to 50%, highlighting the idea that being able to communicate properly and efficiently is a very crucial skill for a modern engineer. Students understand this idea because a big percentage of the success of the project is dependent on a 7-minute pitch.

V. Discussion

In this section, we discuss the pedagogical issues related to the ingredients of the PSE course and how its design and application reflects the concerns with the context of VUCA in the world in general and in the universities in particular.

The effort to regularly change the PSE course follows the challenge indicated in [29] that understanding the context and the mentality of the new generations is important. Professors must understand their audience, their way of reasoning, their culture, their dreams, and their typical reactions. PSE evolved in order to enhance students' motivation. This is a relevant challenge for educators, because a conquered students audience participates in a more active and enthusiastic way. Furthermore, both, professors and students, must be aligned with the actual world. Universities must prepare people to deal with the future where unskilled people, old fashion mentalities, obsolete knowledge and ineffective tools have no room.

A. External Issues and Motivation

Interaction between students and external elements and business experts throughout the project raises the chances that the project has potential to be a real product and that there is a better fit between the business idea and its potential market. In general, this interaction is positive, because the students can improve their products. Additionally, this interaction allows students to improve their communication skills, since they need to be able to align their messages to the different styles/backgrounds/interests of the experts with whom they discuss.

An additional feature of PSE that promotes the development of skills to deal with the world outside the academia is the focus on pitching. The final pitch should take place in installations outside the university (e.g., in an incubator, in a company) and the session is open to the general public. The presence of some media has already happened in some editions.

The contact with external elements means the absence of the typical academic guidelines and common manipulated academic problem, substituted by VUCA. Students must learn to deal with such experience and to learn from it. It is not an easy task and mostly of our students does not like it. But, students adapt themselves very quickly. During the years of the financial crisis the availability to continue with the project after the course was higher than now. VUCA and entrepreneurial skills appears to be linked.

Furthermore, given the significant number of students who workers who attend the PSE, it is important to mention that their involvement is encouraged, as their experience in business contexts can bring added value to their teams.

B. Personal Issues and Motivations

The choice of the product ideas to be developed is an extremely critical aspect. Preferably, ideas should be proposed by students, who will thus be much more motivated to develop them.

A good idea (i.e., with some business potential) allows the team to work with a realism similar to that experienced in a business context. It is also a motivating factor, as it allows exploring viable development alternatives and promotes the personal (and professional) satisfaction of the team members. Contrarily, a weak product idea causes frustration in the team and does not allow the technological development to advance, as it is not particularly stimulating to develop something that has no commercial interest. In some editions, some teams have changed their ideas, after 5 or 6 weeks, exactly because they feel frustration (or little interest) in developing a project in which they did not see any potential.

Students learn to deal with VUCA when decide about the type of project and inherent trade-offs, particularly, in terms of technological and business characteristics. A project with little technological risk and with a classic business model implies that the team has to explore other aspects much more deeply (e.g., excellent user experience, solid market validation, systematic treatment of non-functional requirements, detailed financial analysis). In contrast, a project with a high technological risk or involving a disruptive business model may require a greater focus on the team in these aspects, which may justify a lower investment in others.

During project development, it is important to manage and balance the effort between planning and building. Starting to develop too early, but based on a poorly supported idea, is not recommended. However, thinking too much about the idea and then not having time to develop a professional product does not work either. Knowing how to manage this balance sheet is essential. In this sense, using an iterative and incremental approach, with regular interaction with users, usually proves to be the right decision.

It is recommended for the students to frame their effort according to the 'Lean Startup' development cycle. The goal is to run short development cycles, adopting a combination of experimenting with the product's value assumptions, using minimal versions of the product for that purpose. Thus, many validation cycles are performed until a valid value proposal is reached. Again, contacting potential customers/users of the product should be carried out to address this validation.

VI. Conclusions

This manuscript presents and discusses the main changes that have been introduced to the PSE course, whose aim is to promote entrepreneurship in the field of software engineering. PSE is here analysed in two different VUCA perspectives: (1) how the course is adapted to satisfy the students and (2) how the course provides opportunities for students to learn how to behave in a VUCA context.

The discussion is focused on the main factors that have induced change in the PSE course: number of students per team, project management and leadership, different types of projects, contact with external elements, go out of the building, accountability of students in the evaluation process, and focus on business and communication. We believe that some of the ideas discussed in this paper can be adapted and experimented in similar course that try to promote engineering and entrepreneurship in a VUCA context.

With the analysis of this course, some aspects can be highlighted and some lessons can be learned. These lessons are the following and are related to the three major keywords of this manuscript: software engineering, entrepreneurship, and VUCA.

Firstly, software engineering education tends to be focused on the technological/engineering issues, but this is always not enough. This is particularly not enough nowadays. Skills related to business and entrepreneurship are very relevant in any engineer.

Secondly, students must know how to build products that are useful and valuable respectively for users and clients. A common mistake is to develop products that were not previously and properly validated by the market. This sensitiveness is greatly important in the competitive markets and companies that face a globalized competition. This validation needs to be repeated regularly, to address the VUCA characteristics of the world.

Thirdly, companies exist to make money. Product and services are sustainable if they are profitable. Profitability is a function of the characteristics of the product in terms of price, quality and functionality, but also of the revenues models and these should be consistent with the firm's business model. Software-based products must be designed in accordance with the firm's characteristics and stakeholders' strategies

Fourthly, people with only technical profiles cannot support software development. In fact, successful software products must incorporate business knowledge and, in general, software engineers do not possess such knowledge. Therefore, the inclusion in the development process of business experts and specialists that have knowledge in the application domain is crucial for the correct development of the product.

ACKNOWLEDGMENT

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

REFERENCES

[1] C. Bonwell and J. Eison. Active learning: Creating excitement in the classroom. ASHE-ERIC Higher Education Report No. 1, 1991.

[2] E. Saalman. Implementing active learning: a challenge to teachers and students in higher education. Active Learning for Engineering Education (ALE), 2009.

[3] R.E. Waller, P.A. Lemoine, E.G. Mense, C.J. Garretson, and M.D. Richardson. Global Higher Education in a VUCA World: Concerns and Projections. Journal of Education and Development 3(2):73–83, 2019. DOI 10.20849/jed.v3i2.613

[4] H.C. Woodard, S.S. Shepherd, M. Crain-Dorough, and M.D. Richardson. The globalization of higher education: Through the lens of technology and accountability. I-manager's Journal of Educational Technology 8(2):16–24, 2011.

[5] S. Diefenbach and T. Deelmann. Organizational approaches to answer a VUCA world. In "Managing in a VUCA world", Springer, 197–208, 2016.

[6] J.M. Fernandes, P. Afonso, V. Alves, V. Fonte, and A. N. Ribeiro. Promoting entrepreneurship among informatics engineering students: Insights from a case study. European Journal on Engineering Education 37(2):167-177, 2016. DOI 10.1080/03043797.2016.1197891

[7] A. Järvi, V. Taajamaa, and S. Hyrynsalmi. Lean software startup – An experience report from an entrepreneurial software business course. 6th Int. Conf. on Software Business (ICSOB 2015), pp. 230–244, 2015. DOI 10.1007/978-3-319-19593-3_21

[8] A. Hamouda and L. Colman. Investing in entrepreneurial skills: Creating an entrepreneurial mind-set amongst engineering graduates. 3rd Int. Conf. of the Portuguese Society for Engineering Education (CISPEE 2018), Aveiro, Portugal, 2018. DOI 10.1109/CISPEE.2018.8593471

[9] R. Raghuramapatruni and S. Kosuri. The straits of success in a VUCA World. IOSR Journal of Business and Management 7(2):16-22, 2017.

[10] T.L. Friedman. The flat world: Brief history of the XXI century. Publishing House AST, 2007.

[11] W. Bennis and B. Nanus. Leaders: Strategies for taking charge. Harper Business, 1997.

[12] T.V. Korsakova. Higher education in VUCA-world: New metaphor of university. European Journal of Interdisciplinary Studies 5(2):31–35, 2019.

[13] R. Brodnick and S. Gryskiewicz. Using positive turbulence for planning and change. Planning for Higher Education, 46(4):27–40, 2018.

[14] K.K. Das and A. Ara. Leadership in VUCA world: A case of Lenovo, International Journal of Current Research 6(4):6410–6419, 2014.

[15] C.L. Scott. The futures of learning 2: What kind of learning for the 21st century. UNESCO Education Research and Foresight, Paris, 2015.

[16] A. Bates. Teaching in a digital age: Open Textbook project. Press Books, 2014.

[17] C. Ansell. Turbulence, adaptation, and change. In "Governance in turbulent times", Oxford University Press, pp. 77–104, 2017.

[18] P.S. Seow, Pan, G., and Koh, G. Examining an experiential learning approach to prepare students for the volatile, uncertain, complex and ambiguous (VUCA) work environment. International Journal of Management Education 17(1):62–76, 2019.

[19] Y. Delaney, B. Pattinson, J. McCarthy, and S. Beecham. Transitioning from traditional to problem-based learning in management education: the case of a frontline manager skills development programme. Innovations in Education and Teaching International 54(3):214–222, 2017.

[20] A. Szirmai, W. Naudé, M. Goedhuys (eds.). Entrepreneurship, innovation, and economic development, Oxford University Press, 2011.

[21] S. Mishra, N.E. Cagiltay, O. Kilic. Software engineering education: Some important dimensions. European Journal of Engineering Education 32(3):349–361, 2007. DOI 10.1080/03043790701278607

[22] D. Rosca. Multidisciplinary and active/colla-borative approaches in teaching requirements engineering, European Journal of Engineering Education 30(1):121–128, 2005. DOI 10.1080/03043790512331313886

[23] N.E. Cagiltay. Teaching software engineering by means of computer-game development: Challenges and opportunities, British Journal of Educational Technology 38(3):405–415, 2007. DOI 10.1111/j.1467-8535.2007.00705.

[24] B. Johannisson, H. Landstrom, and J. Rosenberg. University training for entrepreneurship: An action frame of reference, European Journal of Engineering Education 23(4):477–496, 1998. DOI 10.1080/03043799808923526

[25] D. Perkins. Making learning whole: How seven principles of teaching can transform education, Jossey-Bass, 2010.

[26] C. Cunha and J. Morgado. What about using a project management Agile methodology supported by online platforms in the classroom? 3rd Int. Conf. of the Portuguese Society for Engineering Education (CISPEE 2018), Aveiro, 2018.

[27] N. van Hattum-Janssen and J.M. Fernandes. Peer-assessment in projects: An analysis of qualitative feedback. 3rd Int. Symp. on Project Approaches in Engineering Education (PAEE 2011), Lisbon, Portugal, pp. 51–57, 2011.

[28] J.M. Fernandes and N. van Hattum-Janssen. Peer feedback: Quality and quantity in large groups. 40th SEFI Annual Conf. (SEFI 2012), Thessaloniki, Greece, 2012.

[29] I.C. Teixeira and J.P. Teixeira, Challenges of engineering education in a global world. 1st Int. Conf. of the Portuguese Society for Engineering Education (CISPEE 2013), Porto, 2013. DOI 10.1109/CISPEE.2013.6701962