ENGINEERING STUDENTS' PERCEPTION ON DEVELOPING COMPLEX PROBLEM-SOLVING SKILLS

Remus LUNGU, Adriana SAVA, Simona NOVEANU, Sorin ȘUTEU, Violeta FIRESCU

Abstract: The present paper aims to present the results of testing ProCESS methodology by identifying, analyzing and discussing the implications of a group of 6 workshops on developing the sensorial, emotional and spiritual skills of 16 students from TUCN, which were organized during the second year of ProCESS project's implementation. Based on a qualitative research, the results emphasize the value of developing some soft skills to use along with rational thinking for both students' personal development and for increasing efficiency and effectiveness of organizations in general and in leadership in particular.
Key words: Engineering challenges, soft skills, qualitative research, complex problems, engineering education.

1. INTRODUCTION

In recent years, the development of technologies in the field of engineering comes with a need for competitive production which requires multidisciplinarity [18, 4]. This means that knowledge from different professional fields is needed for solving multifaceted problems. In this case, engineers need to be adept at integrating diverse perspectives and methodologies [5]. As engineering continues to evolve in response to global challenges, the integration of multidisciplinarity and soft skills becomes paramount. This ensures that solutions are not just technically sound but also socially responsible and adaptable to rapidly changing contexts [16]. The current world characterized by volatility, uncertainty, complexity and ambiguity – VUCA world – requires additional skills for engineers, such as collaboration, enhanced communication, debating, empathy, balancing, creativity, critical and analytical thinking, problem-solving abilities and so on [1; 13]. Companies are looking for engineers which can solve complex real-world problems, with a deeper understanding of various aspects in a dynamic field of innovation so they need to step "out of the box" and have flexibility and adaptability [19]. In a rapidly transforming global ecosystem, engineers work in tandem with experts from other domains and their solutions must be technically robust, socially conscious, and globally adaptable. As a result, technical prowess alone no longer defines the efficacy of an engineer and soft skills need to be added for success.

In this context, the article aims to present a research based on the experience the team from the Technical University of Cluj-Napoca (TUCN) had during the second year of implementing Erasmus+ ProCESS project, focusing on the aspects related to the involvement of TUCN students in this project.

The paper is structured into six parts. Following the introduction, the second section consists of literature review and problem description, emphasizing the need for engineering students to develop soft skills to complement their technical competences. ProCESS project and its relevance in this context are also presented in this section. The third part details the methodological dimension of the conducted research, whereas the main research results are presented in the fourth part. The article concludes with two sections dedicated to discussing the results and highlighting the conclusions.

2. BACKGROUND AND PROBLEM DESCRIPTION

2.1 Literature review

Technical skills have always been essential for success in engineering careers. However, recent years have brought many significant changes that emphasize the importance of soft skills as well for those working in technology-related fields. Globalization, rapid advancement of technology, including the increasing reliance on automation and artificial intelligence, complexity of workplaces nowadays – all these factors contribute to an engineering landscape that requires engineers' technical competences to be augmented by their soft skills, for increasing individual and ultimately organizational performance [9].

Within the context of rapid technological advancements, technical or hard skills are subject to change, but soft skills remain relevant for the entire duration of one's career, including in the engineering field, mainly because these soft skills are relevant, transferable from one working context to another and enhance an individual's employability [2].

The need for engineers' soft skills is further emphasized by the emergence of Industry 5.0, the next industrial revolution, which has a human-centric focus and is centered around the collaboration between humans and robots, thus underlining the essential role of the human factor [13].

The engineer of the 21st century should therefore possess a strong set of soft skills in addition to his technical multidisciplinary competences. Soft skills become more valuable than ever as there are still tasks that cannot be performed by robots and ultimately, engineers are working for and with people [9]. Therefore, the soft skills that were previously considered "nice to have" by employees in technology-related fields are now moving to the "must have" area [9].

An important research thread in the literature review focuses on identifying various sets of soft skills based on bibliographical studies and empirical research surveys.

One study in this direction revealed that the soft skills considered most critical by business executives were, in order, integrity, communication, courtesy, responsibility, social skills, positive attitude, professionalism, flexibility, teamwork, and work ethic, but it drew attention to the importance of hard skills as well (technical and knowledge) and emphasized that the two categories of skills, hard and soft, "must complement each other" [15]. In another study [12], highlighting the importance of soft skills in leadership and teamwork, the authors proposed a set of main soft skills to be developed in employees (communication, problem solving, teamwork, creativity, leadership, strategic thinking, customer service, innovation management) and reached the conclusion that weak soft skills lead to poor organizational performance.

Soft skills gained a special focus in the context of increasing employability as well. According to a study of Ruiz (2015), as cited in [3], which explored skills that are considered essential for an individual to be hired, meaning that the applicant is unlikely to be hired if he is not highly skilled or knowledgeable in this area, the most essential skills to be hired were teamwork/ collaboration, problem solving, ability to work with others of diverse backgrounds and critical thinking, whereas science, technology, engineering and mathematics (STEM) skills and technical skills were considered much less important. Similar results are revealed by Chinotti (2015), as cited in [3], showing that the skills employers required the most when hiring new employees were working in a team, competences related to decision making and problem solving, processing information, data analysis, technical knowledge, computer skills, written communication ability, ability of influencing the others.

Turning now to the impact of soft skills on individual and organizational performance, studies attest significantly higher percentages, between 75% and 85% in the favor of soft skills over hard skills, whose contribution to performance is limited to 15% - 25% (Tang, 2018; Klaus, 2010; John, 2009, as cited in [6]). Moreover, El-Tabal's study [6] completes the range of impact factors on organizational creativity identified in previous studies (the ability to generate new ideas, sensitivity to problems, risk tolerance, acceptance of change),

by adding the following soft skills: critical thinking, self-management, problem-solving, communication, teamwork, individual innovation.

2.2 Problem description

In this context, soft skills have become necessary for university students and graduates that are entering the labor market as well. Engineering education programs need to support engineering students to further develop these skills, such that they become more employable and better equipped for tackling the challenges and solving the complex problems of the 21st century.

2.3 ProCESS project

ProCESS (Processing Complexity with Emotional, Sensorial and Spiritual capacities) is an Erasmus+ educational project that addresses the problem above, as it advances an innovative method for training students on how to solve complex organizational problems, based on the development of a specific sub-category of soft skills, namely Sensory, Emotional and Spiritual (SES) skills. The project proposes an innovative methodology to deal with complex management cases by alternating sequences of mobilization of sensory, emotional and spiritual (SES) intelligence, in addition to rational capacities and to test this methodology on real business cases [7, 17].

In the context of ProCESS project, SES skills are considered a sub-category of soft skills. When these skills are trained, they lead to increasing awareness, alignment and connection to oneself, to others and ultimately to something greater than us [14]. By developing these skills, the project aims to support students, future managers, to not just better understand the complex problems they are facing in business life, but also to feel and sense these challenges [10].

Nine organizations from four different countries – France, Finland, Latvia and Romania – are taking part in the project: four higher education institutions (HEIs) and five partner companies. Four of the partner companies prepare complex business cases to be analyzed by students and the fifth one is a soft skills evaluation company which assesses students' SES skills [7, 10, 17].

Over a three years period, starting with 2021, the four company partners prepare 12 complex management case studies based on their current business challenges and a total of 192 students from the four HEIs take part in solving these cases, using their SES skills in addition to their rational capacities for this purpose.

3. METHODOLOGY

3.1 Testing ProCESS approach on engineering students

Students' activity of analyzing complex management cases is structured in three rounds, one per year. This means that every year each of the four partner companies advances one complex case study to be solved by 64 students, 16 from each of the four partner HEIs.

Projects' activities and results based on the first round of students solving complex case management studies have been previously published [7, 17, 19]. Therefore, this paper focuses on the experience the team from TUCN had during the second round of complex company case analysis, in the fall semester of 2022.

The 16 students from TUCN that took part in the second round of the project were students of the *Faculty of Industrial Engineering, Robotics and Production Management*, ten of them being bachelor students and the remaining six master students. All the Romanian students were students in the *Engineering and Management* field of study, being registered in one of three programs: *Industrial Economic Engineering* bachelor program, *Entrepreneurship* or *Business Management and Engineering* master programs.

The 16 students were divided into groups of four students and each group was assigned one of the four company cases to analyze. Each company presented its complex case to students during enterprise meetings that took place in October 2022. The students next attended a series of six SES skills workshops organized in TUCN, between October and December 2022, which were facilitated by local SES skills trainers, who are authors of the present paper. In accordance with ProCESS methodology, the goal of these workshops was to support students to develop their SES skills and to actively use

them for solving the company cases they were working on. Various artistic tools were used during the workshops – music, dance, movement, poetry, drawing, collage, plasticine modeling and other types of artistic creation, with the aim of encouraging students to explore and use more their emotional, sensorial and spiritual sides and to develop out of the box solutions and recommendations for the company cases.

In addition, students' SES skills were tested by the partner company specialized in soft skills assessment at three different time points: before the beginning of SES skills workshops, after the first three workshops and after the last one. Students were also asked to provide their feedback regarding the six workshops.

Following all the mentioned above phases, each student team prepared a report regarding its own analysis of the complex case, following a required structure: (1) Summary of the company's main features, case and previous plans for action; (2) Presentation of key features of SES skills workshops; (3) Global contribution of workshops on case treatment; (4) Final plans for action. Finally, the students presented their main solutions and recommendations for the companies during a winter school in Riga, Latvia, in January 2023.

3.2 Research design
This subsection presents the main coordinates of the qualitative research that was conducted based on the four student reports mentioned above with the aim to discover to what extent the ProCESS approach was successful.

According to Strauss and Corbin methodology [20], the core of the qualitative research relies on an elaborate coding approach. In doing so, the researcher is searching from the outset for possible categories answering a certain research question. These categories, along with their proprieties and dimensions, are subject of a refining approach and of identifying relationships among them, aiming to conceive a narrative with explanatory value for a social phenomenon.

In line with the above general methodology, the authors, after a first reading of each of the four reports of the students, in order to identify their general structure, searched in a first stage for possible categories related to the development of the sensorial, emotional and spiritual skills, starting with a pre-defined set of key words, as but not exclusively, (I/we) learned [what/ how/ why/ etc.], developed, increased, enhanced, discovered, realized, become, understood, and so on.

In a second stage, the authors analyzed students' answers on a pre-defined set of questions the students had to answer, that allowed a more in-depth insight on several topics, as: (1) how the SES skills workshops led them to discovering oneself; (2) the practical meaning of SES skills in daily life; (3) the contribution of SES skills for a better dealing with case studies; (4) how are SES skills related to business organizations; (5) SES skills as a supporting mean for effective leadership.

In a third, and last stage, the authors propose a rational for understanding if, how, and to what extent developing SES skills by the ProCESS methodology may add value to developing efficiency and effectiveness on an individual, group, organizational and leadership level.

4. RESULTS

Of the four sections of students' reports on the complex cases, only two were relevant for the purpose of present analysis: presentation of the key features of the SES skills workshops and the global contribution of the workshops on case treatment.

For facilitating the review and analysis, and ensuring both a good balance among the groups and confidentiality, the authors coded the four reports corresponding to the four student teams as groups A, B, C and D.

4.1 Engineering students' perception on practical meaning and impact of SES skills
In students reports' section related to workshops' contribution to case treatment, students had to answer a set of five predefined questions, which were reformulated during the analysis process, to gain a more concise structure, as: (1) How SES skills workshops led to discovering oneself; (2) The practical meaning of SES skills in daily life; (3) The contribution of SES skills for a better dealing with case studies; (4) How are SES skills related

1. The participation of students on the set of the workshops was to a large extent beneficial for all the students, their reports stating it explicitly, as presented above.

2. Both qualitative and quantitative research results, based on the analyzed reports and students' overall feedback, prove the relevance and certain benefits of developing SES skills for both personal development and for organizational life, including more effective leadership.

3. Comparing the soft skills identified in the students' reports as being gained during the six workshops, we conclude that many of these skills are in line with those emphasized in the literature review, in both bibliographical and empirical studies, as better communication, opening toward teamwork, problem solving ability, enhanced emotional intelligence, to name just the most frequent ones. All these skills are related by many studies to aquiring not only higher degrees of employability, career development and succes, but also to increasing organizational performance.

As soft skills become more and more required on the labor market, including in engineering field, engineering educations programs should encourage students to develop and use their sensory, emotional and spiritual intelligences, as a sub-category of soft skills, in addition to their rational capacities, in order for students to become more employable and better prepared for solving the increasingly complex engineering problems and challenges.

The results presented in this paper have limited scope, as they are based only on the second year of ProCESS project's implementation in TUCN. However, these results are encouraging and confirm the ones obtained after the first round of the project, one year before [17]. As the third and final round of the project will take place between October 2023 and January 2024 and will involve other 16 engineering students from TUCN, the near future will enable the authors to get a more in-depth perspective on the usefulness of SES skills for engineering students, based on the entire three years duration of the project and on the experience of a total of 48 engineering students from TUCN.

8. REFERENCES
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[1] Caeiro-Rodríguez, M. et al., *Teaching Soft Skills in Engineering Education: An European Perspective*, in IEEE Access, vol. 9, pp. 29222-29242, 2021.

[2] Castrillon, C., *Why Soft Skills are More in Demand Than Ever,* 2022. *https://www.forbes.com/sites/carolinecastrillon/2022/09/18/why-soft-skills-are-more-in-demand-than-ever/*

[3] Cimatti, B., *Definition, development, assessment of soft skills and their role for the quality of organizations and enterprises*, International Journal for Quality Research 10(1) pp. 97–130, ISSN 1800-6450, 2016.

[4] David J., Mc Laughlin, *Applied electrical engineering fundamentals: Multidisciplinary engineering design*, University of Massachusetts Amherst Libraries, http://openbooks.library.umass.edu/funee/, 2023.

[5] Dowdall, S. et al., *Multinational, Intercultural, Multidisciplinary & Intensive, Methodology to Enrich Soft Skills Development in Computer Science Students*, Informatics in Education, Vilnius University, vol. 20, no. 3, pp. 391–420, 2021.

[6] El-Tabal, A.A., *Soft skills and its impact on an organizational creativity-A field study*, Journal of Business and Retail Management Research 14, no. 3, pp.78-87, ISSN 2056-6271, 2020.

[7] Eskola, A., Zoccoli, M., Korhonen, A., Hundal, S., *Activation methods for leadership in complex environments*, From Globalization to Regionalization in a Time of Economic, Socio-Political, Competitive, and Technological Uncertainties: Current Issues and Future Expectations. Twenty Ninth World Business Congress, June 12-16,

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