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Research article

Use of Technology to Increase the Quality of Collaborative Learning Experiences for Engineering Students in the Post-Pandemic Period

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Abstract

This paper focuses on the changes made to the design and delivery of course materials and lab sessions for an Engineering module in the post-pandemic period – aiming to keep a balance between hands-on experience and use of digital technology as part of the students' socio-emotional learning (SEL) experience and development of emotional intelligence, employability skills required by Industry 4.0. The flipped classroom approach facilitated the students' engagement in authentic and valuable learning experiences as active partners in the process of sustainable knowledge creation enabling the development of their growth mindset in constructive, active, intentional, cooperative, and authentic ways. The practical lab sessions aimed to develop the students' manual dexterity and soft skills while preparing the lab work technical reports enabled the improvement of their creative and critical thinking skills through inquiry and reflective writing.The problem-oriented project work (where students examined and provided creative and innovative solutions for real-life situations through collaboration and problem-solving experiences) has increased their motivation, engagement, performance, persistence, and their capacity to give and receive constructive feedback by positive engagement with online discussion forums. The continuous cumulative assessment encouraged students to reflect on their performance and refine their learning practices to become career-ready engineering practitioners. The efficiency of the proposed approach was evaluated by conducting semi-structured interviews with students, analysing student's academic performance and lecturers' observations while engaging in classroom-based research. In conclusion the weaving of academic grace into the fabric of hybrid engineering courses has increased the quality of collaborative learning experiences for students.

Keywords:
blended learning; engineering education; growth mindset; problem-oriented project work.

Zusammenfassung

Dieser Artikel zeigt die Änderungen, die an der Gestaltung und Bereitstellung von Kursmaterialien und Laborsitzungen für ein Ingenieurmodul in der Zeit nach der Pandemie vorgenommen wurden – mit dem Ziel, ein Gleichgewicht zwischen praktischer Erfahrung und der Nutzung digitaler Technologie als Teil der sozio-emotionalen Lernerfahrung der Studierenden und der Entwicklung emotionaler Intelligenz zu wahren. Dabei handelt es sich um Beschäftigungsfähigkeitskompetenzen, die für Industrie 4.0 erforderlich sind. Der Flipped-Classroom-Ansatz erleichterte den Schülern die Teilnahme an authentischen Lernerfahrungen als aktive Partner im Prozess der nachhaltigen Wissensbildung und ermöglichte die Entwicklung ihrer Wachstumsmentalität auf konstruktive, aktive, zielgerichtete und authentische Weise. Die praktischen Laborsitzungen zielten darauf ab, die manuelle Geschicklichkeit und die Soft Skills der Studenten zu entwickeln, während die Erstellung der technischen Laborberichte die Verbesserung ihrer kreativen und kritischen Denkfähigkeiten durch Nachforschungen und reflektierendes Schreiben ermöglichte. Die problemorientierte Projektarbeit (bei der die Studierenden durch Zusammenarbeit und Problemlösungserfahrungen kreative und innovative Lösungen für reale Situationen untersuchten und lieferten) steigerte ihre Motivation, ihr Engagement, ihre Leistung, ihre Beharrlichkeit, ihre Fähigkeit, konstruktives Feedback zu geben und zu erhalten durch positives Engagement in Online-Diskussionsforen. Die kontinuierliche kumulative Bewertung ermutigte die Studierenden, über ihre Leistungen nachzudenken und ihre Lernpraktiken zu verfeinern, um berufsbereite Ingenieurpraktiker zu werden. Die Effizienz des vorgeschlagenen Ansatzes wurde durch die Durchführung halbstrukturierter Interviews mit Studenten, die Analyse ihrer akademischen Leistungen und die Beobachtungen der Dozenten während der Durchführung von Forschung im Klassenzimmer bewertet. Zusammenfassend lässt sich sagen, dass die Einbindung akademischer Qualität in die Struktur hybrider Ingenieurkurse die Qualität kollaborativer Lernerfahrungen für Studierende verbessert hat.

Schlüsselworte:
Blended Learning; Ingenieurausbildung; Wachstumsmentalität; problemorientierte Projektarbeit.

1. Introduction/ Statement of problem

Nowadays humanity is living in a time of massive transformation, major upheavals and the dawning of a beautiful new era with extraordinary evolutionary possibilities. This VUCA world is characterized by Volatility, Uncertainty, Complexity and Ambiguity and VUCA education (LearnLife, 2021) means embracing change and welcoming it so the educators and students are able to thrive in the technologically transformed workplaces of tomorrow.

The lecturers are required to create technology-infused learning experiences in virtual and physical teaching environments that build future-ready skills for students. So the educators evolve from being adapters of technology to becoming the leaders of learning experiences then catalysts of creative and confidence and finally being the mentors of upgraded mindsets and innovation (Intel, 2023).

There are several technologies used in Industry 4.0 (known as the fourth industrial revolution) – Internet of Things, big data analytics, additive manufacturing, engineering simulation – so the engineers need to be agile and proactive and able to integrate new technologies into existing manufacturing lines without long downtimes and disruptions of the product development process and take actions to lower the environmental impact.

Islam (2022) classified the employability skills required by Industry 4.0 in two categories: technical skills (programming, virtual collaboration, quantitative, data interpretation, data visualization) and business skills (critical thinking, complex problem-solving, cognitive flexibility, adaptive thinking ability, communication skills). Singh and Tilak (2020) proposed a framework for Higher Education with flexible learning structure aiming to adapt to fast changes within industrial companies and their requirements from Engineering graduates because there is a skills gap between the employers' requirements and engineering graduates' skillset (Institution of Engineering and Technology IET, 2021).

Rouvrais et al (2020) presented suggestions for the development of transversal and versatile 5.0 skills (human-centered IT soft-skills) in engineering graduates based on two Erasmus projects (DAhoy and EASTEM).

The impact of the pandemic on Higher Education (HE) research, teaching and learning, and community/societal engagement was significant (Grodotzki, Upadhya, Tekkaya, 2021, International Association of Universities, 2022). The educational institutions were forced to use towards a complete online system of education during lockdown and less social interaction with lecturers and other students led to increased levels of anxiety and stress for students.

These days the HE system is recovering from the challenges and influences of pandemic period and adapting to the new normal by resuming or reforming actions (Abdrasheva et al, 2022, Munir, 2022).

This paper focuses on the changes made to the design and delivery of course materials and lab sessions for an Engineering module in the post-pandemic period – aiming to keep a balance between hands-on experience and use of digital technology in the educational processes.

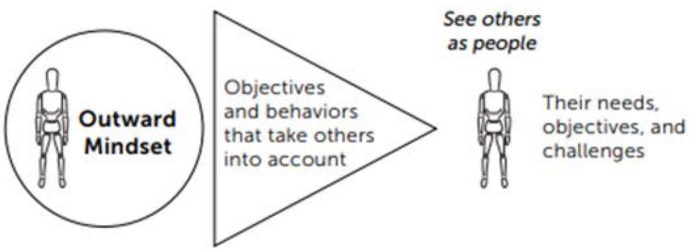
Section 2 presents the HE challenges during pandemic period observed by the authors as practitioners of learning (Miller, Cunha, Allwirght, 2022) and change agents (Van der Heijden, 2015) and as conclusions of literature review. Section 3.1. explains the design and delivery of course materials and practical lab sessions for an Engineering module based on the recent results of engineering education research.

Section 3.2. describes the problem-oriented project work and the continuous cumulative assessment approach based on the research into student experience including educational effectiveness, student wellbeing, widening participation and outreach. Section 4 presents the conclusions and proposals for future work.

2. Theoretical foundation

The unexpected, unplanned, and sudden shift from place-based learning to remote learning during this period required many lecturers to adopt the five-stage model for creating and structuring productive online encounters (Salmon, 2002) containing e-tivities related to access and motivation, online socialization, information exchange, knowledge and development stage where participants confidently build on each other's contributions and display kindness and compassion to ensure psychological safety within teams (Edmonson, 2019).

Figure 1. The outward mindset and others (Arbinger Institute, 2016)



Psychosocial impact of lockdown has emphasized the importance of open-mindness (Arbinger Institute, 2016), cultural awareness in human interactions (including educational activities) and the role of gratitude and wholesome habits (see Figure 1), sense of belonging and identity in building true wealth (inner happiness).

Lecturers and students have discovered the power to be vulnerable (Brown, 2012) which is the most accurate measure of courage and birthplace of belonging, creativity, empathy, and innovation. Many publications presented the results of neuroscience research – like the role of sensory neurites (brain-like cells located within the human heart) in creating personal resilience and emotional agility (Braden, 2015), use of Reticular Activation System to turn off the "worry" centers of the brain (Waldman, Manning, 2017) and focus on your goals and success (Lipton, 2008, Robbins, 1992) and on spiritual solutions for real-life problems (Dwyer, 2003).

Many educational institutions started to use PERMA model (Seligman, 2011) for the design and delivery or learning activities aiming to enable students to feel happy, content, and confident (see Figure 2) by combining traditional education principles with the science of well-being and happiness and alchemy of pain into power.

Figure 2. PERMA model (Seligman, 2011)

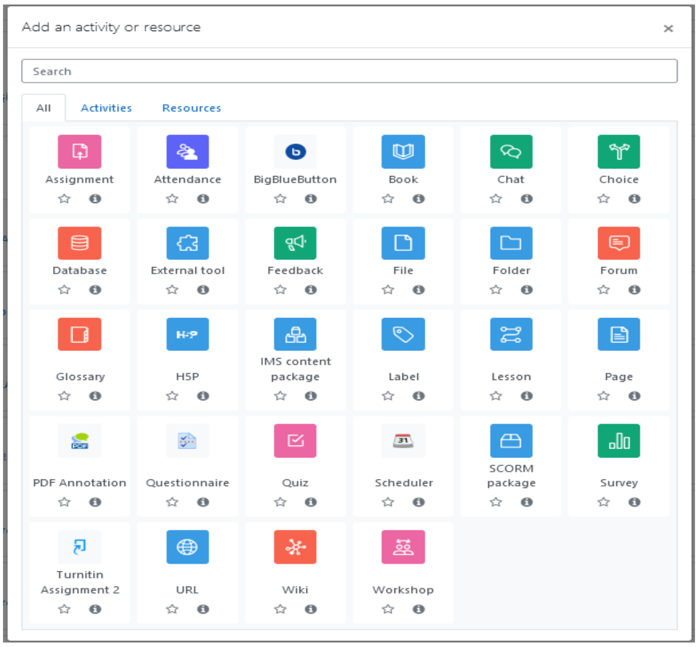
There is a link between positive emotions and good academic performance (Fredrickson, 2001), multiple intelligences, cognitive flexibility, resilience and engagement (Guillen, Tirado, Sanchez, 2022), enhanced creativity and development of valuable mental and social resources (Fredrickson, 2013).

Positive emotions broaden mental repertoires and encourage novel, exploratory thoughts, and actions (Hawkins, 2020) and a calm attitude, emotional agility, self-acceptance, loving-kindness, mindful composure, appreciative joy and compassionate clarity while processing the past, accepting the present time and creating the future where actions align with personal values in this VUCA world.

The students and staff from Transilvania University Brasov Romania have used exclusively the online learning platform (https://elearning.unitbv.ro) during pandemic period (see Figure 3).

It has been challenging for some members of staff and students who lacked access to laptops/PCs with the required specifications or access to high-speed internet with sufficient bandwidth/ data (Kenan, Pislaru, Elzawi, 2014).

Figure 3. Snapshot of Engineering module online content



They had to develop digital skills to articulate ideas and contrasting viewpoints, express themselves, and formulate opinions within computer-mediated communication exchanges. There were unexpected educational challenges instigated by the broad pivot to online learning and unprecedented opportunities to investigate the instructional, mental health, wellbeing and equity needs of staff and students who were used with in-person instruction before pandemic period.

3. Research methodology

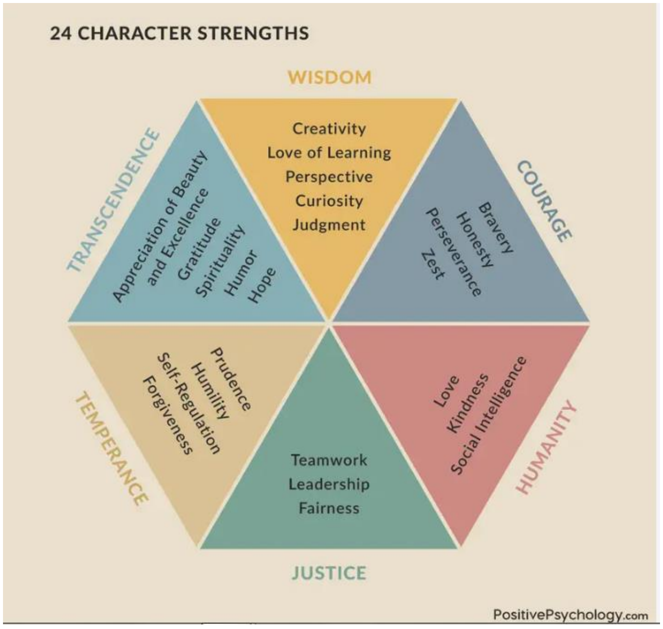
The authors of this paper have collected data via semi-structured interviews and researcher observations. The students preferred face-to-face teaching and lab sessions and remote live lectures over recorded ones. Majority of respondents agreed that virtual laboratories can be efficient tools for involving in authentic learning experiences (Mishra, Barrans, Pislaru, 2009), stimulating self-paced learning and overcoming the spatial and temporal constraints of scheduling practical labs. However, concern areas were reduced interaction in online classes and virtual lab sessions; diversity, equity, inclusion, and belonging (DEI&B) requirements; limited experiential learning experience; lack of specialized equipment and manual dexterity interactions - which influenced students' lack of interest, personal motivation, and engagement with educational activities. Also, all respondents emphasized the need for people-focused approach and physical human interaction with students and staff.

The successful practical applications carried out by Engineering students in lab sessions and project work help them become more confident about their knowledge and industry-based skills and their capability to solve real-world applications.

3.1. Design And Delivery Of Course Materials and Practical Lab Session For An Undergraduate Engineering Module In The Post-Pandemic Period

Generally Engineering courses are often delivered with a harmonious combination of lectures, laboratory sessions and project work. The design and delivery of course materials and practical lab sessions and the problem-oriented project work during the semester aimed to build and develop various character strengths (see Figure 4) and multiple intelligences (i.e., social, interpersonal, verbal-linguistic, logical-mathematical, intrapersonal). The learning strategy focused on the improvement of individual and group performance of learners by boosting knowledge, confidence, and commitment, honing skills, and offering opportunities to give and receive constructive feedback facilitating the creation of more personalized learning experiences (Peterson, Seligman, 2004).

Figure 4. Classification of character strengths (Peterson, Seligman, 2004)



The case study was conducted at Transilvania University Brasov Romania for Materials in Electrical Engineering module (Helerea, Calin, 2015) in academic year 2021-2022.

The course material was presented during in-person teaching sessions and the concepts of flipped classroom and hybrid learning (Othman, Pislaru, Impes, 2013) were applied for the practical lab sessions. There were three stages in preparing and delivering in-person lab sessions:

Stage 1 – pre-lab activities - The lecturer uploaded the lab sheets on virtual learning environment (VLE) platform (https://elearning.unitbv.ro) for students to read before the practical lab session. Students' engagement was enforced by online support for students before the experiments, clear signposting about the experiment and lab set-up.

Stage 2 - During in-person lab sessions - the lecturer assisted the groups of students as they performed the practical experiments using physical equipment to illustrate engineering principles, gained practical skills and had to deal with the non-ideal characteristics of real-world systems. Co-operation, teamwork, peer learning and collaboration were promoted as students worked together on experiments, analysed the experimental data collected in their practical labs, and applied the calculations and equations learned in class. Teaching strategies for active learning (including group discussions concerning conducted experiments, problem solving, case studies, formative assessment with reflection, feedback) were employed.

The lecturer made some notes about student engagement during experiments and provided guidance for writing the lab reports and encouraged students to reflect on their learning.

Stage 3 – post-lab activities – the lecturer uploaded on VLE platform some examples of lab reports prepared by students in previous years. The intended aim was for students to learn how to draft a technical report, formulate a line of argument, and reflect on options and choices in experiments. Then the drafts of the lab reports prepared by students were discussed with the lecturer during progress meetings focused on feedback and formative assessment.

The final reports described the preparation of the experiment, doing the experiment, and evaluating and reflecting on the results. Additionally, the reports included reviews of empirical literature related to the experiment set-up. The final lab reports focused on reflecting students' conceptual understanding, connecting in-class learning with practice-based experiences and transferring from theory to application in the practical lab.

The final lab reports contained a reflective writing component where they explored and explained the conducted experiments and measured results. The students looked at possible causes of errors and weaknesses, as well as strengths and successes and how they planned to improve in the future. So they ‘reflected back to the past’ and ‘reflected forward to the future’. This reflective practice equipped graduates effectively for professional practice and preparation of applications for professional registration status (like Chartered Engineer, Eur Ing Engineer). The ability to reflect on learning events (that confirmed or contradicted their prior knowledge, theories or understanding) enabled the students to view their projects, life choices, social interactions in a more positive light (when looking at the big picture) and increase their confidence in making decisions to act differently in the future so they can achieve a more positive outcome (Socha, Razmov, Davis, 2003).

The organization of the practical lab sessions focused also on the development of research skills (such as ingenuity, critical thinking, objectivity, etc.) among undergraduate Engineering students which supported and increased student motivation and engagement with theoretical knowledge and practical experiments. The students were involved in knowledge creation rather than receiving knowledge from the instructor in this process of active learning.

The final lab reports served as a form of summative assessment of students’ knowledge of mathematical equations and their understanding of experimental procedure and ability to accurately analyse and describe experimental results. The reports were graded and counted toward the students’ final course grade.

3.2. Problem-Oriented Project Work and Continuous Cumulative Assessment Approach

Constructivism, social learning, situated cognition and communities of practice are used in problem-based inquiry environments (Hmelo-Silver, Eberbach, 2012) in which students creatively resolve complicated problems in real life situations.

Socio-emotional learning (SEL) is an integral part of education and human development (see Figure 5). The learning environments and experiences are established through school-family-community collaborations, so students develop healthy personal identities, regulate their emotions and achieve personal and collective goals.

Figure 5. CASEL wheel (Collaborative for Academic, Social, and Emotional Learning (CASEL), 2023

The students were divided into groups and assigned various projects which enabled them to develop design, teamwork and leadership skills when solving real-life problems. The learners (majority Gen Z students) enjoyed the challenges of being a part of this fully immersive educational experience and learning how to make a difference in the world by challenging, questioning, adapting and applying knowledge in new ways with a sense of purpose and ambition.

The group learning activities helped the students to build positive interpersonal relationships and prepare for their future careers by learning how think creatively, make decisions independently when necessary, and freely navigate the world of rapidly changing information.

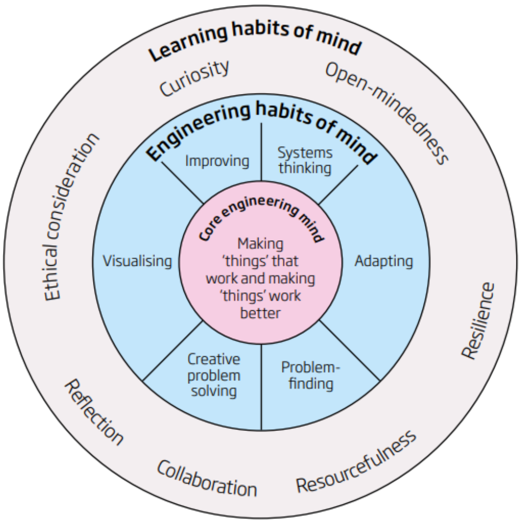
Also, various learning activities were designed and implemented for two purposes:

- development of healthy group climate and a sense of cohesion – students develop skills like mutual trust, personal accountability, openness, patience, empathy, support, respect, deal productively with conflict, etc.
- establishing effective group processes – students exhibit skills like personal accountability; giving and receiving constructive feedback; management and organization; diplomacy; problem solving; reliability; knowledge of individual roles within the team, etc.

Students gained experience in solving realistic problems, and emphasis was placed on using communication, cooperation, and resources to find solutions and develop thinking skills.

The Royal Academy of Engineering from UK has published a report (Royal Academy of Engineering, 2014) about the set of thinking characteristics, skills and attributes of engineers required by industry (see Figure 6).

Figure 6. Engineering habits of mind (Royal Academy of Engineering, 2014)



The students harnessed their collaborative genius by creating a culture of teamwork and holding regular team meetings (formal and informal) and through peer mentoring activities (Pislaru, 2016) aiming to regulate communication, address conflict management agile practices, promote understanding, acceptance, respect and increase positive perceptions on team cohesion, performance, and team learning. The written and verbal communication was one of the factors which gave their team a competitive edge.

The opportunities for face-to-face group meetings enabled them to improve their communication skills and apply empathic and positive communication patterns, politeness in language, asking questions, opening communication, maintaining manners, being responsive and responsible, active listening, building a resilient stress threshold etc.

The group project activities enabled the students to remain curious and open-minded, develop critical thinking skills, ability to clearly state their ideas in a creative and collaborative way so they were better equipped to succeed in the engineering world.

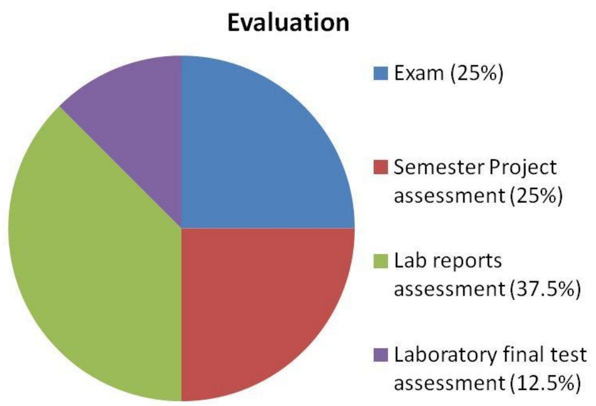
In their future workplace, the Engineering graduates will be required to work within collaborative and interdisciplinary teams to ensure integrated development of products and the creative engineers are designing and producing items which improve the way we live and work as creativity often spurs innovation.

The grading scheme of the group work contained several components: performance (group, individual), assessment (process, final product), peer evaluations, team evaluation, self-evaluation. The performance criteria were clearly articulated so the students understood the expectations and standards. The dynamics of student groups was observed by the lecturer during the semester and reflected by three types of evaluations provided by students (formally and informally):

- group evaluation – each student evaluated the dynamics of the team as a whole.
- peer assessments - each student evaluates the contributions of his/her teammates.
- self-evaluations - each student kept a reflective journal documenting and evaluating one's contributions to the team.

The components of the summative assessment for the undergraduate Engineering module are presented in Figure 7.

Figure 7. Components of the summative assessment for the undergraduate Engineering module



4. Conclusions

The academic performance of students was increased in comparison with previous academic years and the results of semi-structured interviews showed that the level of student satisfaction is noticeably high, and students valued the self-paced learning opportunities, so it can be concluded that the flipped classroom and blended learning approach for delivering the lab sessions, has been well received. So, the students perceived that they had made progress in their learning and competencies development.

The students mentioned the benefits of working in group projects which enabled them students to develop their skills related to time management, give and receive feedback, develop stronger communication skills and other teamwork skills such as leadership, creativity, practicality, and diplomacy. The relevance of the challenges included in the learning experience within group project, the greater was the motivation, involvement, and self-assessment of the students regarding their skills development.

The students considered that the combination of various learning activities was very useful both for understanding the overall subject and for the preparation work for the exam. The results of this study will be used for the design of new learning experiences considering the influence of learning activities and students' interest, and motivation on the development of employability skills for future engineers.

The authors of this paper observed that the students preferred to receive constructive feedback about lab reports and group projects based on the Gen Z innate characteristics such as shorter attention span, demand for transparency and plea for direct in-person communication and receiving precise action plans with sustainable schedules and strategy sessions to follow-up the progress frequently. The students have unique learning needs, experiences, and motivations, aspirations, attitudes, communication preferences, values and prefer to learn from socially conscious curriculum that bridges the gap between academia and industry flawlessly.

In conclusion it is beneficial to keep a balance between hands-on experience and digital transformation learning activities in experiential learning spaces for engineering education and development of emotional intelligence, creativity, grounded cognition, innovation, interpersonal skills, and employability skills required by Society 4.0. (informational society) and Industry 4.0.

Authors note:

Marius-Daniel Calin (Member IEEE from 2010) is Senior Lecturer at Transilvania University of Brasov, Romania. He published over 30 scientific papers and concluding over 10 research contracts following the collaboration with economic and industrial partners of Research-Development Institute, Transilvania University (https://icdt.unitbv.ro/en/). His main research areas are focused on advanced materials for electrical engineering, electromagnetic compatibility between technical systems and Engineering education.

Crinela Pislaru has over 20 years experience of teaching in Higher Education (in UK and Romania) and research on elearning, hybrid learning, control applications in rail and manufacturing industry, digital transformation, growth mindset in Engineering education. She has a PhD in Control Engineering and graduated MSc in Multimedia si E-learning from University of Huddersfield, UK. Crinela has published over 130 publications (including 3 books and 25 journal papers) and worked in several EU rail projects and education projects (Tempus, Leonardo da Vinci, Erasmus).

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