






Trends on Gamification, Generative AI, Multidisciplinary Technological Resources, Engineering Education, New Trends in Mechatronics, Diversity Gap in STEM, Laboratories in STEM Education at TEEM 2023

Joan Arnedo-Moreno¹ (✉), Carina González-González², Marc Alier³,
María José Casañ Guerrero³, Daniel Amo Filvã⁴, Juan A. Juanes Méndez⁵,
Samuel Marcos Pablos⁶, Joaquim Armando Jorge⁷, Clara Viegas⁸, Natércia Lima⁸,
María Isabel Pozzo⁹, José Gonçalves¹⁰, José Lima¹⁰, Paulo Costa¹¹,
Alicia García-Holgado¹² , Carina Soledad González-González¹³ ,
Angeles Dominguez^{14,15} , Arcelina Marques^{8,16}, Gustavo Alves^{1,2},
and Juarez Bento da Silva¹⁷

¹ Universitat Oberta de Catalunya, Barcelona, Spain
jarnedo@uoc.edu

² Universidad de la Laguna, La Laguna, Spain
carina.gonzalez@ull.edu.es

³ Universitat Politècnica de Catalunya (UPC), Barcelona, Spain
⁴ La Salle (URL), Barcelona, Spain

⁵ University of Salamanca, Salamanca, Spain
jajm@usal.es

⁶ Pontifical University of Salamanca, Salamanca, Spain

⁷ School of Engineering of the University of Lisboa, Lisbon, Portugal
jorgej@tecnico.ulisboa.pt

⁸ Polytechnic Institute of Porto – School of Engineering, Porto, Portugal
mcm@ipp.pt.pt

⁹ National Technological University, Rosario, Argentina
pozzo@irice-conicet.gov.ar

¹⁰ Polytechnic Institute of Bragança, Bragança, Portugal
{goncalves,jllima}@ipb.pt

¹¹ Faculty of Engineering of the University of Porto, Porto, Portugal
paco@fe.up.pt

¹² GRIAL Research Group, Instituto Universitario de Ciencias de la Educación, Universidad de
Salamanca, Salamanca, Spain
aliciagh@usal.es

¹³ Instituto Universitario de Estudios de las Mujeres, University of la Laguna, Tenerife, Spain
cjgonza@ull.edu.es

¹⁴ Tecnológico de Monterrey, Monterrey, Mexico
angeles.dominguez@tec.mx

¹⁵ Universidad Andres Bello, Santiago, Chile

¹⁶ CIETI – Center for Innovation in Engineering and Industrial Technology, Porto, Portugal

¹⁷ UFSC – Universidade Federal de Santa Catarina, Santa Catarina, Brazil

<https://ror.org/02f40zc51>

Abstract. This document presents the Tacks summary of Trends on Gamification, Generative AI, Multidisciplinary Technological Resources, Engineering Education, New Trends in Mechatronics, Diversity Gap in STEM, Laboratories in STEM Education at TEEM 2023, which was held in Bragança (Portugal) from October 25–27. These sessions were held as tracks of the International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM’23).

Keywords: Education · Learning · Gamification · Generative AI · Multidisciplinary Technological Resources · Engineering Education · Mechatronics · STEM · Laboratories

1 Gamification and Games for Learning (GamiLearn’23)

1.1 Introduction

Raph Koster once famously said in his book ‘A theory of fun for game design’ that “*fun is just another word for learning*”. Games teach you how aspects of reality work, how to understand yourself, how to understand the actions of others, and how to imagine”. Including game experiences in the design of learning materials has positively motivated students. These experiences are introduced in courses by considering game design principles in the course structure layout (gamification, gameful design) or directly using games as discrete learning resources (serious games). This endeavor is especially challenging when considering how technology can improve such approaches.

To celebrate games and their potential, the First International Workshop on Gamification and Games for Learning (GamiLearn’17), was born in 2017 and has been held yearly. This event was organized by two Spanish institutions: Universitat Oberta de Catalunya (UOC) and Universidad de La Laguna (ULL), with contributions from all kinds of researchers, practitioners, and industry stakeholders about the impact of gameful approaches in learning environments. Since 2020, the event has been incorporated as a special track in the TEEM (Technological Ecosystems for Enhancing Multiculturality) conference, which in the current edition was held in the nice town of Bragança, Portugal.

The symposium welcomed submissions from diverse aspects of gameful and playful approaches for learning, including but not limited to the following topics:

- User studies.
- Design frameworks.
- Techniques and strategies.
- Methodologies.
- Tools and applications.
- Technological ecosystems.
- Processes of analysis.
- Processes of assessments.
- Personalization approaches.
- Systems integrations.
- Data management.
- Interaction.

Each submission was anonymously submitted and evaluated following a double-blind review by up to three international program committee members. This process was based on the guidelines provided by the general conference and relied on overall evaluation and reviewer confidence scores, as well as a comment section that provided insightful feedback to the authors.

1.2 Contributions

The symposium received 14 manuscripts from different countries, such as Spain, Finland, Mexico, Portugal, Tunisia, Netherlands and Colombia. After a peer review, 11 were accepted for publication according to their originality and quality. Some of the main topics discussed were:

- Use of simulations or Virtual Reality (VR) in learning scenarios.
- Educational escape rooms.
- Digital tools for gamification design.
- “Unplugged” vs. “plugged” gamification design.
- Gamification as a tool to reach an older population.
- Studies on local gamification industries and the application of good practices.

1.3 Conclusions

Despite the common link between games and education, the selected papers encompassed a wide breadth of insightful topics. We look forward to this edition of GamiLearn, where it can be evidenced again that games have all kinds of fields of application beyond pure entertainment.

1.4 Acknowledgments

Of course, we cannot end without thanking all the PC members, volunteers and authors who have helped make GamiLearn possible.

2 Managing Generative AI in Educational Settings

2.1 Introduction

Generative Artificial Intelligence (AI) is a subset of AI that is able to create original content, such as text, images, and sound. Generative AI models use techniques such as machine learning and natural language processing to create new and unique content based on input data. One example of a generative AI model is a language model like OpenAI’s ChatGPT, which is able to generate human-like text based on the input prompt given to it. Additionally, models like GPT-3 can also be used for tasks such as text completion, translation, and summarization. Generative AI has the potential to be used in a wide range of applications such as content creation, language education, and as a tool to support student learning. The use of generative AI in educational settings is becoming increasingly popular, and this track aims to explore the management and

integration of these models in the classroom, including the challenges, opportunities and ethical considerations. It will focus on how to effectively utilize AI capabilities to enhance learning experiences, and how to use generative AI as an assessment tool and for providing feedback to students. It also covers the impact of AI tools on academic integrity, and how to maintain academic standards. Additionally, best practices for managing and monitoring AI models in educational settings, and ensuring the originality and authorship of AI-generated content will be discussed. This track aims to explore the management and integration of generative artificial intelligence (AI) in educational settings. It will focus on the challenges and opportunities that arise when implementing generative AI in classroom instruction and curriculum development, as well as the ethical considerations and best practices for managing AI models and data in an educational setting. One of the main challenges when incorporating generative AI in education is ensuring that the technology is aligned with the learning objectives and instructional goals. This requires the development of effective strategies and resources that can effectively utilize AI capabilities to enhance learning experiences. Additionally, the use of generative AI as an assessment tool, and providing feedback to students using AI-generated content are addressed. The track also covers the impact of AI tools on academic integrity and how to maintain academic standards. Additionally, the track will explore the ethical implications of using AI models in the classroom. Topics such as bias, transparency, and data privacy will be discussed. Additionally, best practices for managing and monitoring AI models in educational settings will be discussed.

Topics

- Aligning AI models with learning objectives and instructional goals
- Developing strategies and resources for incorporating generative AI in education
- Using generative AI as an assessment tool and providing feedback to students
- Integrating AI models into existing curriculum
- Creating educational resources for generative AI Ethical considerations for using AI in education
- Best practices for managing and monitoring AI models in educational settings AI-generated content in education
- Examples of AI in practice in education
- Data privacy and security in AI education
- Generative AI in adaptive and personalized learning
- Generative AI in language education
- Maintaining academic integrity in AI-assisted education
- Ensuring the originality and authorship of AI-generated content

3 Multidisciplinary Technological Resources Applied to Health Sciences

As has been demonstrated in recent decades, the development and use of new technological advances in the areas of prevention, diagnosis, and patient recovery directly impact health outcome indicators and the safety of health care processes. Although more and

more technological advances are being introduced in health and care settings, many of the technological developments are still not built from an end-user-centered perspective, and others are mere proofs of concept. Therefore, this track provides an excellent opportunity for the promotion and sharing of innovative experiences in both biomedical education and clinical practice.

In the paper entitled “Application of digital Video-capillaroscopy in clinical practice and teaching” discusses the use of digital video-capillaroscopy as a technique for studying the periungual microcirculation. The authors highlight its importance in evaluating patients with Raynaud’s phenomenon and its diagnostic utility in scleroderma and other rheumatic diseases. The paper explores the advantages of video-capillaroscopy compared to previous techniques, emphasizing its potential for routine clinical practice and teaching.

The work “Technology development for dynamic learning in virtual reality environments” discusses a technological development aimed at teaching human anatomy using 3D digitalization techniques and virtual reality (VR) glasses.

The paper “Impact of Robot-Assisted Surgery and 3D Vision Systems with Virtual Reality on Medical Training” explores the influence of robotic surgery and virtual reality on medical education. The study discusses how robotic devices used in surgical interventions have revolutionized surgical training by providing three-dimensional virtual anatomical models for practice, reducing the dependence on patient involvement.

In “Major trends in health-centered nursing professional education and complex thinking” is a research paper that explores the use of virtual reality (VR) and serious games in nursing education. It discusses the potential benefits of incorporating VR and serious games into nursing education to enhance learning experiences and improve student engagement.

“Proposal and Definition of a Novel Intelligent System for the Diagnosis of Bipolar Disorder based on the use of Quick Response codes containing Single Nucleotide Polymorphism data” presents a proposal for an intelligent system to improve the diagnosis of Bipolar Disorder (BD).

The paper “Degree of satisfaction of nursing students with the flipped classroom methodology in simulation scenarios” explores the degree of satisfaction of nursing students with the flipped classroom methodology in simulation scenarios. The School of Nursing at Zamora University in Spain implemented simulation as a form of learning in several subjects.

“Updating the Anatomical Understanding of Carpal Tunnel using State-of-the-Art Imaging Techniques” provides an overview of the advancements in imaging techniques for studying the anatomy of the carpal tunnel. The authors discuss the use of various imaging modalities such as plain radiography, computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI) to obtain a comprehensive understanding of the carpal tunnel’s structures.

The paper titled “Optimizing Data Entry Management in Healthcare: Leveraging HCI to Enhance Medical Decision Accuracy” presents the findings of a study that aimed to evaluate the impact of text-generator technology on the accuracy of medical reports.

Authors describe in “Design and Development of an Intelligent Decision Support System applied to the Diagnosis of Patients Susceptible to Heart Failure” the development and evaluation of an intelligent clinical decision support system for the diagnosis of heart failure. The system utilizes machine learning techniques and clinical data to predict the risk of severe heart failure in patients.

In the paper “Use of Intuitionistic Fuzzy Numbers to Prioritize Patients Suspected of Obstructive Sleep Apnea on the Cardiorespiratory Polygraphy Waiting List – A Novel Multi-Criteria Approach” authors describe the design and development of a prioritization tool for patients suspected of having Obstructive Sleep Apnea (OSA).

In “Comparative Study on the Performance of an Ultrasonic Sensor and a Laser Sensor for Detecting Obstacles of Different Materials in an Assistive Navigation Application for Visually Impaired Individuals” authors present a study comparing the performance of two distance sensors: the HC-SR04 ultrasonic sensor and the VL53L0X laser sensor. The study aims to determine which sensor is more suitable for a robotic prototype designed to assist visually impaired individuals with obstacle detection during navigation.

“Clinical competence acquired through digital and face-to-face courses during the COVID-19 pandemic in Dentistry” discusses the impact of the COVID-19 pandemic on dental education and the acquisition of clinical competence.

The paper titled “Semantic web in health: what is the goal?” discusses the potential impact of semantic web platforms on the organization and search for health information.

The work “Design and prototyping of personalised in-ear headphones with advanced digital methodologies” discusses the design and customization of headphones with an appealing surface model and ensuring proper fit and assembly of internal electronic components. The design of the audio canal is optimized to minimize physical interference and adapt to the curvature of the user’s ear canal.

In “Models, Metamodels and Transformations for Medical Informatics Ecosystems” the authors present an approach to creating technological ecosystems in the medical domain using Model-Driven Development (MDD) concepts. The main objective is to address information integration challenges in healthcare by characterizing components with meta-models and using transformations to adapt information between them.

The paper “Management and application of AI to DICOM image processing: A systematic mapping literature review.” presents a systematic mapping review focused on the application of Artificial Intelligence (AI) algorithms to Digital Imaging and Communications in Medicine (DICOM) images. The document also cites several relevant research papers and studies that have contributed to the advancement of AI applications in DICOM image analysis.

The work titled “Getting to know me: Web application for mood screening in infants” presents a research aimed to propose alternatives for approaching emotional issues in students, particularly depression, using ICT. The study focuses on a vulnerable population belonging to the flexible educational model ‘Learning Acceleration’ in Bogotá, Colombia.

4 Engineering Education: Approaches to Technology Education and Multiculturality

4.1 Introduction

Engineering education shifted from a traditionally approach, centred in developing knowledge and technical skills, to a more human-centred approach in recent years. This included incorporating social skills development into attention. Communication, multiculturalism embracing or teamworking has become very important issues to address along with the technological education [1–4]. Taking into account the characteristics the current Higher Education (HE) students, which belong to *Generation Z*, born in a digital era, with natural competences in technology and combining with the global society in which they grew, education no longer can maintain traditional standards.

The selection of teaching and learning methods to embody transferable skills as well as incorporating multiculturalism is important, as allows students to develop a deeper understanding of the impact of technology on society as well as develop the interpersonal skills necessary to succeed in a rapidly and changing technological landscape [5].

In a time where sustainability concerns are emergent, more than ever, HE institutions must support the needs and demands of their community and society. The more open professionals are to interdisciplinary, diversity and multicultural contexts, the more adaptable and resourceful they become to deal with the problems they encounter. By sharing these experiences and good practices with other HEIs and professionals, we may globally disseminate them among more disfavoured regions.

Accordingly, this track is dedicated to share reflections on issues in engineering education concerning technology education and multiculturalism [1–4]. Certainly, education in technology cannot be carried out separated from the society in which it takes place; in fact, it is traversed by conditions which are specific to each context. Assuming a situated technology education, there are numerous cultural crossovers that, far from resulting in cultural homogeneity, show a multiculturalism in different senses. As examples (not exhaustive), we can refer to working in multinational companies, with personnel of different nationalities and located in different regions of the planet; the design of technological products that respond to local needs, with the consequent reflection on the specificities of each place; communication with colleagues and bosses of different origins, the possibility of participating in training internships in different areas and countries, with the consequent enrichment from different perspectives,

On the other hand, telecollaboration, also known as “online intercultural exchange” [6], allows two geographically distant classes of students to be brought into contact with each other through online communication tools with the purpose of developing communication skills and intercultural competence [7]. In turn, the forced virtual education that occurred with the pandemic fostered links between groups of students and colleagues from all over the world, bringing us closer to diverse problems and divergent responses to common problems.

In this plethora of multicultural situations (and its desirable turn towards the inter), technology education -and much more within the framework of engineering education- needs to reflect on this dimension, which pays attention to the more human side of the machine and the consequent training needs [8]. Within this framework, this track

comprises different approaches in a broad sense: research work in this field based on qualitative, quantitative, or mixed analyses, compared studies, works describing good educational practices, liaisons with the industry, students' competences gaps, etc., that can be helpful to teachers and students to be prepared as competent professionals.

4.2 Engineering Education Papers in TEEM 2023

This year's contributions addressed Engineering Education from a perspective of teachers' concerns regarding students' abilities and how they may use them to motivate and promote their competences. From experiences using TIC, technology, and social media, to accounts where laboratories, teamwork and PBL are used to promote STEM education.

"Categorizing 4.0 Technologies within the Context of Education 4.0" brings us a categorization of these technologies considering its relevance in Education. This categorization can help designers and educators to understand how to better integrate those in the context of Education.

"Technopreneurship to foster skills in Education 4.0" presents the Technopreneurship model, as well as three case studies with industrial allies that solve a real problem based on technological integration. In the former case studies, industry has obtained value from the ideas generated from the academy and the academy also benefitted from the contact with real problems.

"Engineers, STEM education and multiculturalism: an online, open access approach" provides a set of case studies, supported by the open access digital repository MERLOT, that can be used for assignments or open discussions issues within the frame of any STEM educational program. It is clear an asset both for teachers and students.

"Social networks in higher education: a tool for sharing and coordination. Case of closed groups of distance learning" illustrates the use of Instagram groups to support teaching and sharing experiences and knowledge in technology distance education. They consider this digital tool can be a motivating system.

"In Search of an Efficient Assessment Method for Laboratory Activities" brings us the iterative approach of a teacher regarding how to make the best laboratory assessment, not only regarding equity but also equality in the procedures. This is particularly important when there are several teachers involved.

"Predicting Student's Performance with Machine Learning: Challenges, Opportunities, and Future Directions" also addresses students' performance, but using different tools: machine learning algorithms. The prior goal is to help students improve their learning and teachers to timely adapt their teaching towards the major students' struggles.

"Evaluation of Teamwork Competence in Universities, Statistical Analysis Report" identifies knowledge, frequency, and perception of teamwork competence of students from different universities and majors. Although they have a high level of teamwork competence, applying procedures and tools still need to improve.

"An Instrument to Characterize the Cognitive Process associated with Computational Thinking skills for Engineering students" describes an instrument aimed to promote computational thinking skills. After its development, the authors used it with elementary school students and university students and teachers of mechanical engineering, with high level of satisfaction.

“Smart Supermarket Cart – An EPS@ISEP 2023 Project” presents a smart user-centred designed shopping trolley to make the shopping experience more efficient and comfortable. It is equipped with a touch screen for real-time information on products and their location, cameras for product identification, an audio assistance system, a refrigeration chamber, and a mobile app interface for the customer.

“Cattle Monitoring Blimp – An EPS@ISEP 2023 Project” describes a PBL initiative developed during the 2023 edition of the European Project Semester (EPS) at ISEP, Portugal. It complies students working in groups where the diversity of nationalities and expertise allows them to develop social competences, and embrace a multicultural experience while working out the solution for a practical problem.

“Effective Solution Based Learning – Report of the experimental results” consists in a Project-Based Learning applied to solve real problems. Besides measuring effectiveness, a greater involvement and commitment on the part of students is taken into account as crucial factors for dropouts reduction and an increase in approved students.

5 New Trends in Mechatronics Engineering Education

This track focuses on new trends in mechatronics engineering education, through its several learning stages, from secondary school experiments, to the development of industrial applications, that require different robustness requisites and inevitably different implementation skills. Mechatronic applications are common in Automation, Control and Robotics, being these topics the focus of the proposed track, although mechatronics is not exclusive of these areas. Educational robotics can play an important role in mechatronics engineering education, due to the inherent multi-disciplinary concepts that are involved, motivating students to technological areas. It also plays an important role in research and development, because it is expected that the outcomes that will emerge here, will later be transferred to other application areas, such as service robots and manufacturing. Having in mind that the cost is always a key indicator, in addition to the application performance. Each application has its own requirements that must be fulfilled at the lowest possible cost, without having a performance compromise. Different methodologies and technologies allow for cost reduction in the development and deployment of mechatronic applications, and these different approaches must be researched and disseminated.

Topics

- Mechatronics Engineering Education
- Cost Oriented prototyping
- Mechatronic Applications
- Educational robotics
- Control
- Automation

6 Facing the Diversity Gap in STEM in Education and Working Spaces

6.1 Introduction

Diversity is one of the intrinsic characteristics of the societies in a globalized world. People from different ethnics, genders, religions, sexual orientations, socio-economical and cultural backgrounds share living and working spaces around the world. However, there are many problems related to diversity across the regions and countries. For this reason, the Sustainable Development Goals (SDG) consider inclusion and equality among their specific objectives, such as the SDG 5, gender equality, or the SDG 4, quality education, which are focused on reducing the diversity gap to improve the opportunities of diverse people.

In this context, science, technology, engineering and mathematics (STEM) fields have specific problems related to gender and diversity gaps [9–11]. The 50% of the population is not represented in the processes and mechanisms to solve the problems of the society. According to the World Economic Forum, the role that these areas have in the economic development during the next decades will be higher [12] and the jobs related to STEM are expected to grow in significance and scope in the future [13]. Moreover, the last Global Gender Gap Report, 2023 [13], indicates that “women make up almost half (49.3%) of total employment across non-STEM occupations, but just 29.2% of all STEM workers”. These figures are worst if we introduce intersectionality, considering women and ethnics, sexual orientation or sexual orientations. Moreover, this problems in STEM also occurs with other diversity factors.

The “Bridging the diversity gap in STEM” track aims to provide an open space to share actions, studies and other types of initiatives focused on breaking the traditional roles and stereotypes and work for equality and equity in education and labour market in STEM. Over the last four editions, since 2019, authors have shared experiences developed in different regions such as United States, Morocco, Mexico or Spain.

6.2 Contributions to the TEEM 2023 Bridging the Diversity Gap in STEM

Eleven papers have been accepted in TEEM 2023 focused on bridging the diversity gap in STEM. The papers covered different topics related to diversity in STEM, including actions for early childhood education, primary and secondary education, initiatives in higher education and some actions at professional level (Fig. 1). The works were developed in different Latin American and European countries, including Mexico, Colombia, Ecuador, Peru, Italy and Spain.

We have classified the works into two macro-categories. The first category clusters papers related to actions in preuniversity education. These projects and studies focused on increasing motivation in STEM topics through different approaches, such as training teachers, enhancing spatial ability or introducing computational thinking at early educational stages:

- Development of inclusive tools through digital fabrication for chemistry learning in students with and without visual impairment.

of hands-on labs to cyberspace, creating online (virtual and remote) labs has gained momentum with the COVID-19 pandemic, as evidenced by Fig. 1. This trend and the value of experimental skills in STEM education is once more addressed in track 7, “Lab-based Education in STEM”, as part of the 11th TEEM conference edition, which seeks to attract contributions dealing with this thematic (Fig. 2).

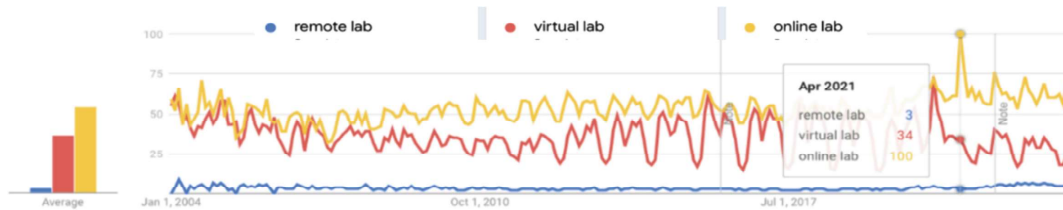


Fig. 2. Popularity of the search expressions “remote lab”, “virtual lab”, and “online lab”, from Jan 1, 2004, till Sep. 30, 2023.

7.2 Brief State of the Art

Two recent contributions, i.e., a chapter entitled “Online Laboratories in Engineering Education Research and Practice” and published at the International Handbook of Engineering Research (IHEER) [16], plus a special issue of the European Journal of Engineering Education entitled “Online Laboratories in Higher Engineering Education: Solutions, challenges, and future directions from a pedagogical perspective” [17], are worth being highlighted here as the current state-of-the-art on how online laboratories are being used to complement the acquisition of experimental skills in STEM courses. These two most recent scholar contributions provide an actual, in-depth view of the laboratory role in engineering education and how such role can be accomplished through different modalities, i.e., on-campus, online or hybrid. We encourage any researcher interested in obtaining a quick overview of this thematic to read them first and then appreciate the contributions accepted for presentation at track 7 “Lab-based Education in STEM”.

7.3 Brief Presentation of Each Paper

7.3.1 From Users to Technological Mediators: Experiences of Pre-service Teachers Incorporating VR and AR Technologies in Their Initial Teaching Strategies

This work presents a study, using the procedures of Grounded Theory, to explore the impact on teaching quality, benefits of using technology to teach, according to students’ perspective, with pre-teachers incorporating virtual reality (VR) and augmented reality (AR) in their teaching practices during their supervised internships. Apart from describing this experience for the first time in designed learning strategies, it was important to identify the intervening conditions for a successful implementation and analyze assumptions, and beliefs of pedagogy students as they transition from being users to becoming technological mediators. Results demonstrated that technology integration is not easy and requires specific training, in the absence of which, learning quality is compromised

and technology misbelief increases. On the other hand, it also represents an additional stress to teachers whenever the conditions for the implementation process are not adequate. This study shows interesting conclusions and can be used to devise indicators for teachers' technology introduction in the classroom.

7.3.2 Considerations on the Implementation of a Non-traditional Laboratory for Rock Characterization Tests

This work aims to answer the following question: "Are non-traditional labs as effective in achieving learning outcomes as traditional labs?" Conducting a cross-analysis of some of the main differences between the non-traditional laboratories (virtual, and remote or hybrid), their strengths and weaknesses, all experimental rock characterization tests, and the associated learning objectives, will allow an informed choice of the best suited type of non-traditional laboratories. Authors state that this practice in engineering degrees has proven to be effective in learning as presented in literature, mainly during COVID-19 emergency teaching practices, and intend to verify it, in the case of geotechnical engineering. In conclusion authors state that a well-designed non-traditional laboratory can be as practical as a traditional hands-on laboratory when measuring content knowledge. Some essential issues still need to be adequately addressed, such as operation and maintenance costs affecting the non-traditional laboratory choice.

7.3.3 Statistical Reasoning Levels When Solving Realistic Problems with Technology Support

This work explores the levels of statistical reasoning achieved by students when using two different simulators (Huitla-sim and Sim-manlift) to analyze data and applying the knowledge obtained in solving problems involving risk situations. Structure of the Observed Learning Outcome (SOLO) taxonomy was applied within this study to classify the reasoning levels. The major sticking result from this study was observing that students' initial proposed solutions were observed to change, as the activity progressed. Presenting each team's outcomes and discussing arguments among the group, enabled students to fortify their arguments and reckon with further aspects which they may not have considered previously, therefore showing higher statistical reasoning capability.

7.3.4 UVMove – Disinfection Robot

This work has been developed in the framework of an interdisciplinary course integrated in Biomedical Engineering Degree curriculum, at Polytechnic University of Porto. This work describes the development of a disinfection autonomous system, capable of recognizing the area to move and adapt their disinfection trajectories. Authors describe the project and development process. The final prototype was tested, and future developments and improvements were presented.

7.3.5 HANDCARE: Post Stroke Upper Limb Rehabilitation Device

In this work, authors present the project and development of a system to help people's upper limb rehabilitation after some kind of disability situation like a stroke. The work is

developed by a group of students enrolled in the Biomedical Engineering degree program, at Polytechnic University of Porto – School of Engineering. With this development, students developed transversal soft and hard skills, since the project development is performed adopting a task-oriented methodology. The goal was achieved, and future developments and improvements were presented.

7.3.6 Competency-Centered Taxonomy Focus on VISIR Remote Experiment

The primary contribution of this work lies in the development of a competency-centered taxonomy specific to identify remote labs competencies, namely using VISIR, which is a remote experiment platform for electrical circuit practices. Authors want to establish connections between the remote experiments and pedagogical contents and identify competences needed or developed during remote experimentation. They identify three categories: technical, analytical, and digital competences. Authors conclude that although remote laboratories are well established tools, there is a growing need for a deeper understanding of pedagogical aspects to which this work contributed.

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