A new method for developing interactive courses in smart textiles

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ABSTRACT – REZUMAT

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This paper presents the essential aspects of the impact of intensive learning materials using online interactive courses and mobilities for learning organised in the ADDTEX Erasmus+ project for involving students in transnational cooperation-based working groups for smart textile prototype development. The e-learning tools and methods (interactive videos, quizzes and smart prototype development), in both asynchronous and synchronous formats, used in the framework of the ADDTEX Erasmus+ project revealed a successful acceptance of the end-users (students and young researchers) attending the online courses through the ADDTEX platform providing Massive Open Online Courses (MOOCs) and hackathons organized in comparison with classical teaching methods without digitilased courses and practical prototype development. Also, the on-site summer school organised in Prato, Italy, came with the possibility of working in transnational teams and contributing to the documentation and creation of prototypes and appropriate business plans. At the end of this activity, the students presented the prototypes and business canvas model developed in teams and received rigorous feedback from smart textile industry specialists. The asynchronous learning format allowed students and young researchers to familiarise themselves with green and digital transitions and smart textiles in the EU context. The synchronous e-learning organised in the hackathon format allowed students to interact with companies and clusters and solve the challenges proposed by the industry. The lesson content on ADDTEX MOOC has been delivered in an attractive format using interactive videos, graphics, animation and videos with digital teachers explaining the course.

Keywords: *green, digital, smart, transition, e-learning, textile*

O nouă metodă pentru dezvoltarea cursurilor interactive pentru textile inteligente

Această lucrare prezintă aspecte esențiale ale impactului cursurilor interactive pentru învățare intensivă online și mobilitățile de învățare organizate în cadrul proiectului ADDTEX Erasmus+ implicând studenți în grupuri de lucru bazate pe cooperare transnațională pentru dezvoltarea de prototipuri de textile inteligente. Instrumentele și metodele de e-learning (videoclipuri interactive, chestionare și dezvoltarea de prototipuri inteligente), atât în format asincron, cât și sincron, utilizate în cadrul proiectului ADDTEX Erasmus+ au arătat o acceptare cu succes din partea utilizatorilor finali (studenți și tineri cercetători), care au participat la cursurile online prin intermediul platformei ADDTEX, care oferă Cursuri Online Masive Deschise (MOOC), și hackathon-uri organizate în comparație cu metodele clasice de predare, fără cursuri digitalizate și dezvoltare practică de prototipuri. De asemenea, școala de vară organizată în Prato, Italia, a adus posibilitatea de a lucra în echipe transnaționale și contribuie la documentarea și crearea unor prototipuri și planuri de afaceri adecvate. La finalul acestei activități, studenții au prezentat prototipurile și planurile de afaceri utilizând modelul business canvas dezvoltate în echipe și au primit un feedback riguros din partea specialiștilor din industria textilă. Formatul de învățare asincronă le-a permis studenților și tinerilor cercetători să se familiarizeze cu tranziția verde și digitală și cu textilele inteligente în contextul UE. Învățarea online sincronă organizată în format hackathon le-a permis studenților să interacționeze cu companii și clustere și să rezolve provocările propuse de industrie. Conținutul lecțiilor de pe MOOC-ul ADDTEX a fost livrat într-un format atractiv, utilizând videoclipuri interactive, grafică, animație și videoclipuri cu profesori care au explicat cursul.

Cuvinte-cheie: *verde, digital, inteligent, tranziție, e-learning, textile*

INTRODUCTION

The technical textiles industry in the EU-27 is crucial, contributing about 30% of the total textile turnover and experiencing a notable 27% increase in overall textile production. To support this industry, current and future employees should enhance their knowledge by taking courses in technical textiles. This includes learning about the development of smart textiles and utilising digital, green, and smart specialisation. These educational opportunities can be accessed through MOOCs, digital assessments, and short intensive learning events such as bootcamps and hackathons.

In general, MOOCs (Massive Open Online Courses) provide access to online courses for learners, offering flexibility for students and citizens without requiring formal registration at an institution. This approach facilitates knowledge sharing within civil society. The online courses are open-licensed, free of charge, and allow open entry, meaning attendees do not need to provide any prior information about diplomas or certificates. The ADDTEX MOOCs developed are sustainable because future learners can choose specific

study programs related to smart textiles in the context of digital and green transitions.

"Bootcamp" is frequently used in ICT programming and focuses on developing digital skills. It represents a specialised, intensive training program centred on high-impact educational courses [1]. These courses aim to equip students with practical, job-ready tech skills within a short timeframe [2], with the ultimate goal of enhancing participants' technical knowledge and soft skills [3]. The benefits of participating in such a bootcamp include an immersive learning experience, tailored guidance for prototype development, opportunities for students to network with industry professionals, and access to career coaching and support [2]. Interestingly, the concept of a bootcamp originated from the U.S. Army forces that intensively train troops to achieve optimal performance within a short time [3].

The main objective of the ADDTEX Erasmus+ project was to develop a Massive Open Online Course (MOOC) platform that offers innovative training and learning materials in advanced textile materials. This platform is intended to enhance technicians, graduates, engineers, managers, and mentors' knowledge of advanced textiles, particularly in smart, digital, and green manufacturing. The project involved learners – students and employees – in various activities such as online courses, hackathons, a mobility program, and bootcamp to achieve this goal. Additionally, a new ADDTEX hub was established to facilitate industry upskilling.

The ADDTEX Erasmus+ project offered online interactive courses and a Summer School bootcamp to provide a holistic learning experience for participants, including trainees, teachers, and experts. The project employs various e-learning tools and methods, catering to both asynchronous and synchronous formats. The goal of the ADDTEX mobility (bootcamp) was to enhance students' and young researchers' green, digital, managerial, and communication skills in the creative industries, particularly in producing smart textiles. Students gained skills to develop smart prototypes addressing sustainability, safety, and societal needs. Furthermore, the on-site Summer School, held in Prato, Italy, offered a unique opportunity for participants to engage in transnational collaboration, contributing to developing prototypes and business plans. The culminating presentations of these prototypes provide students with invaluable feedback from specialised professionals in the textile industry. The asynchronous learning format within the project serves as a platform for students and young researchers to immerse themselves in the intricate facets of green and digital transitions and smart textiles within the context of the European Union.

On the other hand, synchronous e-learning, mainly through the hackathons format, facilitates direct interaction with companies and industry clusters, enabling students to address and resolve real-world challenges proposed by the industry. In addition, the ADDTEX MOOC is designed to deliver engaging lesson content, incorporating a myriad of multimedia elements such as videos, graphics, animations, and comprehensive explanations provided by educators. This approach ensures that participants are thoroughly engaged and empowered throughout their learning journey within the project.

COURSE DEVELOPMENT

In the framework of the ADDTEX project, INCDTP was involved in the development of courses from smart and digital transition categories. The smart transition courses for Managers and Mentors contain seven lessons, from which INCDTP developed 1 lesson related to Innovations linked to smart, intelligent textiles. From smart transition courses, INCDTP developed the module "Innovations linked to smart (figure 1), intelligent textiles" for different levels (e.g. Managers and Mentors, Engineers and Professionals, respectively Technicians and Graduates). To assess the knowledge gained from the digital materials, students completed quizzes consisting of a maximum of five questions within 15 minutes. Upon finishing the online lessons and demonstrating their knowledge through the assessment, the ADDTEX MOOC platform automatically generates a certificate confirming the successful completion of the course (figure 2).

The learning module developed by INCDTP for Managers and Mentors is elaborated to provide a comprehensive understanding of cutting-edge innovations in smart textiles. These innovations encompass a wide array of applications, including but not limited to health monitoring, rehabilitation, protective equipment for various industries, military applications, augmented human capabilities, and sophisticated devices such as supercapacitors and harvesting devices. Furthermore, the module also contains the intricate integration of advanced software and hardware, equipping participants with a thorough understanding of the technological landscape in this domain. Smart textiles for health state monitoring refer to developing advanced fabric-based materials with embedded sensors to monitor various biomedical parameters continuously. These textiles are knitted garments, and the integrated sensors can track vital signs such as heart rate, body temperature, and movement, providing real-time data for health monitoring purposes. This innovative technology has the potential to revolutionise healthcare by allowing for non-invasive, continuous monitoring of an individual's health status, leading to early detection of health issues and more personalised medical interventions. (figure 3).

In the context of rehabilitation, textile-based systems integrating actuators have proven to be instrumental in facilitating the recovery of impaired body functions. These systems encompass a variety of innovative technologies, each designed to address specific rehabilitation needs. These technologies include smart gloves [5] equipped with advanced sensor and actuator technology, allowing for precise and targeted rehabilitation of hand and finger movements. Arm exoskeletons, integrating textiles with rigid mechanical

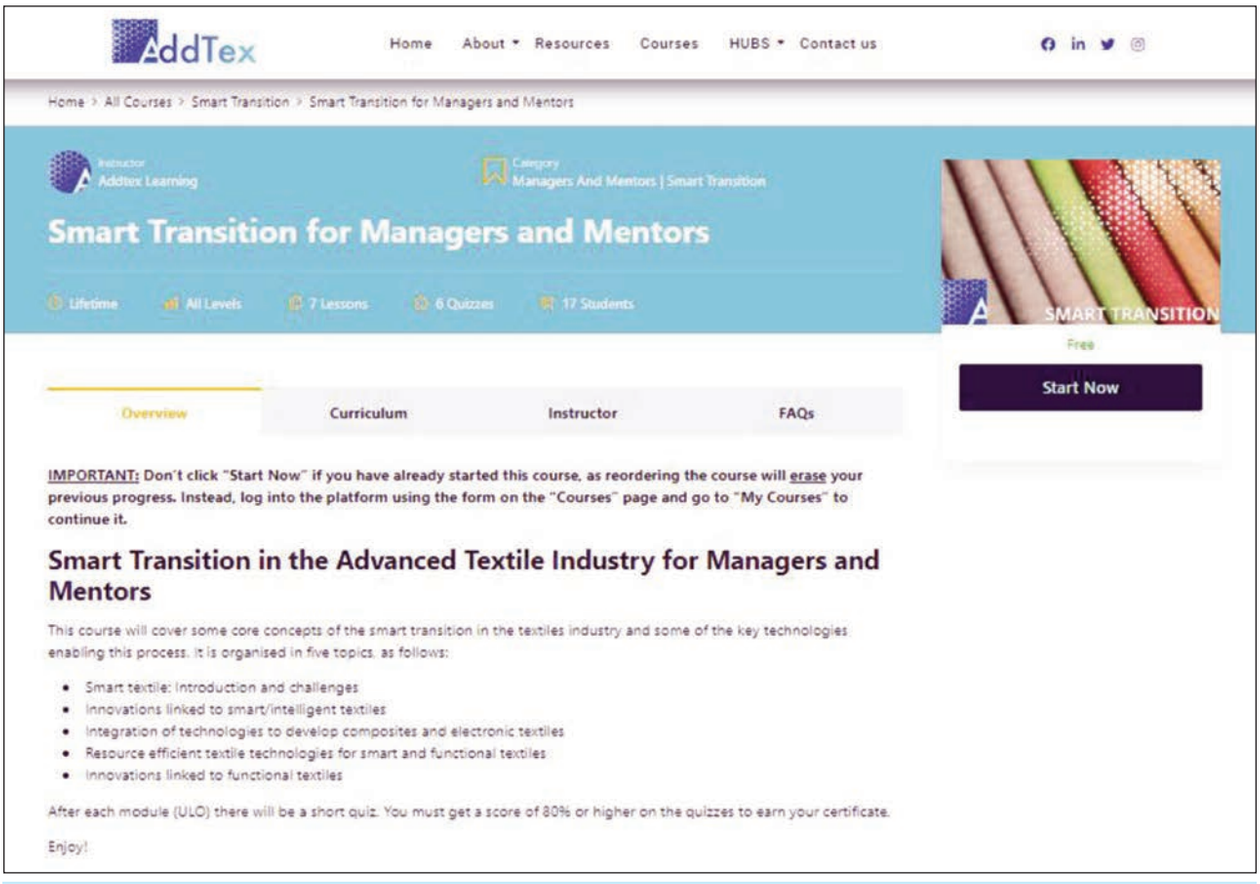

Fig. 1. Smart transition for Managers and Mentors

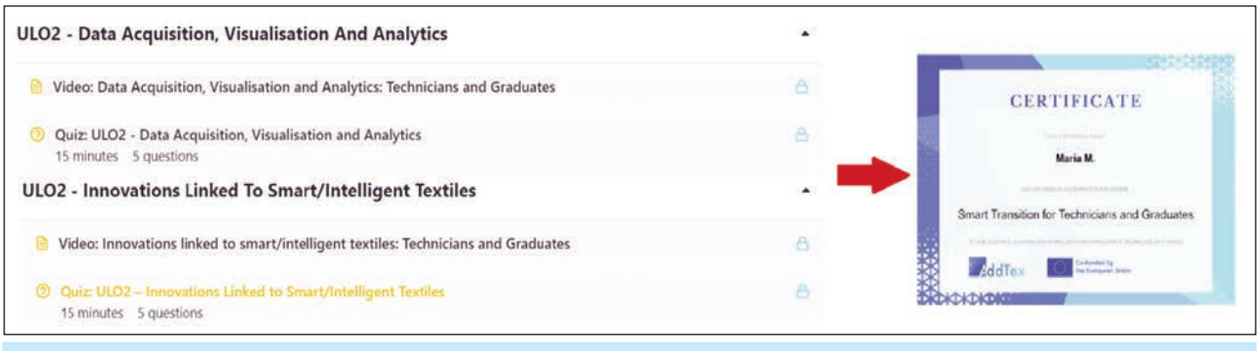

Fig. 2. Testing and certification of course completion

Fig. 3. Smart shirt with integrated ECG for heart monitoring, oximetry, respiration and temperature [4]

and electronic components [6], offer comprehensive support for upper limb rehabilitation, providing assistance and resistance as needed. Furthermore, the ExHand exoskeleton actuator [7] explicitly targets hand and finger movements, offering a tailored approach to rehabilitating fine motor skills. These advanced textile-based systems underscore the evolving landscape of rehabilitation technology, offering promising solutions for individuals seeking to regain lost functions (figure 4).

Smart textiles for personal protection (figure 5) are a groundbreaking innovation integrating advanced technology into protective uniforms. These textiles are designed with sophisticated sensors continuously monitoring vital signs such as pulse, temperature, and humidity. Additionally, they are equipped with GPS technology to track the wearer's location and

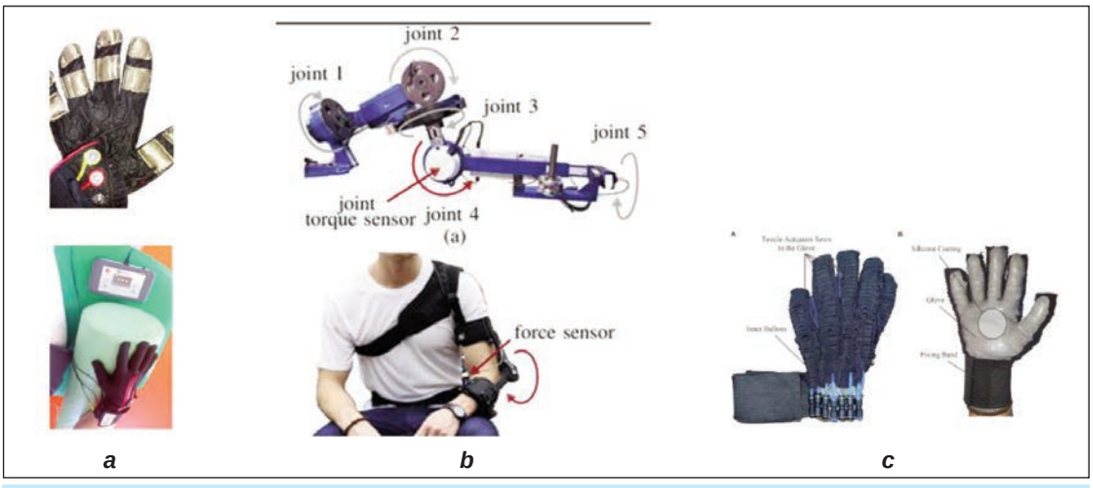

Fig. 4. Graphical representation: *a* – histogram; *b* – box plot graph of the reflection variable (colour variant M1)

Fig. 5. Smart textile for protection [8]

movement. Moreover, the textiles can detect toxic and combustible gases, providing advanced protection. In case of exposure to a hazardous environment, such as a fire, these textiles are equipped with alert systems that promptly notify the wearer and relevant authorities, ensuring swift and effective response to potential dangers. This advanced technology makes these textiles suitable for high-risk applications such as firemen's personal protection equipment [8].

The smart textile for military applications comprises intelligent uniforms seamlessly integrated with state-of-the-art sensors. These sensors are embedded within CORDURA® fabric, comprising 60% cotton and 40% nylon 6,6. The integration of these smart textiles has undergone rigorous testing by soldiers to assess their effectiveness and practicality, as detailed in the referenced study [9]. This development marks a significant leap forward in the evolution of military attire, with the potential to revolutionise the capabilities and safety of military personnel. The collaboration between the U.S. Army and the Massachusetts Institute of Technology (MIT) has yielded groundbreaking advancements in smart clothing fibres (figure 6, *b*), creating a revolutionary technology capable of transforming standard uniforms into wearable autonomous computing systems. These innovative smart uniforms offer many cutting-edge features, including the ability to self-power, provide digital camouflage, and monitor (figure 6, *a*) a wide range of biomedical parameters [10–13]. Researchers at the prestigious Institute for Soldier Nanotechnologies at the Massachusetts Institute of Technology (MIT) have significantly advanced in developing fibre prototypes. These innovative prototypes are constructed using polymer fibres intricately embedded with hundreds of tiny silicon microchips (figure 6, *b*). Upon electrification, these microchips demonstrate a remarkable capability to sustain a digital connection spanning impressive distances of tens of meters. This breakthrough in nanotechnology holds promising implications for various applications, particularly in advanced communication and connectivity technologies [10].

Smart textiles used for augmented humans (Human 2.0) serve a significant purpose in several domains, including medical rehabilitation, enhancement of soldiers' performance, and augmentation of human capabilities through soft exoskeletons [11]. This necessitates the integration of various technologies such as textiles, robotics, software (AI, data analytics), and hardware (electronic components). An example of this integration is the use of force sensors based on QTSS (Quantum Technology Supersensor) ink printed on fabric to develop wearable prosthetic sockets for amputees [12].

A recent study introduced a new type of flexible supercapacitor. These supercapacitors have a CNT-textile anode and a MnO2/graphene textile cathode. They operate at a potential of 1.5 V and have an energy density of 12.5 Wh/kg [14]. The study also mentioned that a polyester-based textile structure can be coated with graphene nanosheets and MnO2. The study highlighted that these supercapacitors are well-suited for energy storage in flexible electronics [15]. The seamless integration of software and hardware components enables the development of a sophisticated and versatile smart monitoring

a *b*

Fig. 6. Smart textiles for military: *a* – Smart uniform used by soldiers in training activity [13]; *b* – knitted sleeve from polymeric fibres containing hundreds of tiny silicon microchips [10]

platform that leverages textile support or tiny sensor-based fibres, knit, woven, or nonwoven structures. As an illustration, the innovative garment integrates ECG leads through screen printing on a knitted structure, serving as the soft component. This garment should also contain a robust hardware unit, which serves as the complex component, facilitating communication and efficient data storage for subsequent in-depth analysis. By harnessing the power of AI technologies such as expert systems, neural networks, fuzzy logic, and genetic algorithms [16], it becomes possible to create an intelligent garment that is not only capable of real-time monitoring but also facilitates predictive sensor data analysis, thereby enhancing overall functionality and utility.

CONCLUSIONS

Smart and intelligent textiles refer to integrating advanced electronic components into textile products, eventually also software components based on artificial intelligence (AI), to improve the quality of life for wearers. These textiles are designed to collect data from various sensors integrated into the fabric and then use AI algorithms to analyse and interpret this data. The potential benefits of such technology include enhanced comfort, performance, and even health monitoring for the wearer.

Despite the potential advantages, the current landscape shows that many of these prototypes are still in the validation stage within laboratory settings, designated explicitly as Technology Readiness Level 4 (TRL 4). This level indicates that while the concepts have been demonstrated in a lab environment, they have not yet advanced to a stage where they are ready for widespread commercialisation. The maturity and refinement required for these innovations to be truly groundbreaking and market-ready have not yet been achieved. This highlights the ongoing challenges in translating promising technological concepts into practical, consumer-ready products within the smart textiles industry.

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