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DEVELOPING CURRICULUM AND COURSE CONTENT FOR HYBRID AND ELECTRIC VEHICLE (HEV) EDUCATION USING VIRTUAL AND AUGMENTED REALITY (VR/AR) TECHNOLOGIES

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Abstract: *This study focuses on the development of a framework for training content and Virtual Reality (VR)/Augmented Reality (AR)-supported digital training materials (DTMs) for Hybrid and Electric Vehicles (HEVs) education. As part of an ongoing EU Erasmus+ Strategic Partnership Project, the research adopts a multidisciplinary design-based methodology to enhance teaching and learning outcomes in HEVs maintenance and service-related topics within Vocational Education and Training (VET). Recognizing the challenges of establishing uniform educational infrastructure across VET institutions, VR/AR-supported DTMs aim to provide accessible and equitable education solutions. The study outlines methodologies and results for designing content and curricula tailored to hybrid and electric vehicle technologies, guiding the development of HEVs training course pedagogy and curriculum. The outputs of this project are anticipated to significantly benefit a diverse range of learners, from vocational high school students to engineering faculty graduates and professionals in the workforce, fostering global accessibility and inclusivity in HEVs education.*

Key words: *STEM education, automotive training, immersive learning, virtual reality, augmented reality*

1. INTRODUCTION

In parallel with the widespread use of hybrid and electric vehicle (EV) production in the world and reaching a significant market share, the training needs of all relevant stakeholders, especially maintenance and service operations, are increasing rapidly, in addition to the routine vocational training of these vehicles.

Fechtner H. et al. [1] investigating new methods in electric vehicle education, it is emphasized that the increasing diffusion of electric vehicles causes a new challenge and program development needs for the education sector. For example, applying a high-voltage system to automobiles creates a new potential for danger to working people, necessitating a new and specialized training program. To meet this need, this study presents a student-centered model with a modular approach in which different technologies and occupational safety concepts are integrated.

In another study, Fechtner H. et al. [2] investigated the training needs of employees in areas such as technicians and firefighters on electric vehicles, including occupational safety risks. An approach to the development of a unique training program for working on electric vehicles is also presented in this paper. This training program focuses on improving the learning process with a learning concept blended with a modular approach.

Arslan et al. [3], studied a comprehensive training needs analysis was conducted to determine the vocational education and training needs of those working in the field of hybrid and electric vehicle technologies, and the findings were evaluated. In the study, 30 questions on a 5-point Likert scale were applied to the participants, which were structured under the headings of perception, knowledge, skills, and expectations about hybrid and electric vehicle education. 54 sector representatives, 650 students, and 652 vocational high school teachers and administrators participated in the

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surveys. Interestingly, in the needs analysis results, all three groups provided a similar response in all questions; that is, they stated the exact needs. Therefore, the training programs to be developed based on these results will meet all three priority stakeholder groups' hybrid and electric vehicle training needs.

Karahan et al. [4] studied the infrastructure needs analysis findings were made to determine the Vocational Education and Training needs of employees in the hybrid field. Electric vehicle technologies were evaluated and aimed to provide infrastructure for training programs in line with these needs, thereby strengthening the existing education infrastructure.

Beside these, many researchers and institutions are working to develop Virtual reality (VR) applications as a cheaper and more accessible solution to the high cost of physical workshop/laboratory setup and equipment supply for Hybrid and Electric vehicles (HEVs) training. For example, Perdikakis, A et al. [5] reported an Augmented Reality (AR) application they developed for electric vehicle training and the results of the application in pilot training. The evaluation results suggest that the AR application is reasonably successful for the users and trainees and that the scenarios they have developed should be expanded further with a systematic method. Another study Luo, H., [6] states that there are still some problems in the diagnostic system of purely electric vehicles and that the current diagnostic system needs to meet the needs of consumers. To overcome this problem, it focuses on the development of the electric vehicle diagnostic system with the use of VR fusion technology. The study discusses how the fault diagnosis and detection of the vehicle will be much easier by developing an integrated VR application with the existing engine management system software and how to develop the fault diagnosis system of the electric vehicle based on VR fusion technology. The study discusses how the fault diagnosis and detection of the vehicle will be much easier by developing an integrated VR application with the existing engine management system software and how to develop the fault diagnosis system of the electric vehicle based on VR fusion technology. In this study, content and curriculum development methodologies and outputs to develop the VR/AR supported digital training materials in the field of hybrid and electric vehicle technologies detailed.

2. PROJECT OF DIGITAL TRAINING MATERIALS DEVELOPMENT FOR HEVS

This research is part of the project ‘Development of Virtual and Augmented Reality (VR/AR) assisted digital training materials for Hybrid and Electric vehicles’ funded under EU Erasmus+ Strategic Partnership. The aim of the project is to develop training content and Virtual Reality supported digital training materials (DTM) using multidisciplinary design-based research methodology to improve the teaching/learning performance of HEVs maintenance and service-related topics in Vocational Education and Training. Due to the difficult to set up the educational infrastructure for all VET institutions, VR/AR supported DTMs will contribute to equal opportunities and easily accessible in education. This document aims to provide information that will guide for HEVs Training Course Pedagogy and Curriculum Development works.

In the frame of the project studies, basic and advanced standards and principles used in HEVs and EVs education and training are aimed to transfer to virtual/augmented reality VR/AR environment so that students and employees at all levels can use V/AR applications to understand these topics more easily in three-dimensional environment. For this purpose, in the context of the HEVs manufacturing and servicing sector; the project consisted of certain stages including, the needs analysis carried out to identify the most critical subjects and knowledge; the determination of content based on the results of the need analysis; the transfer of the determined contents to the virtual reality environment; and pilot study of the training modules. The study was carried out in four stages. These stages are the following:

1 - **Needs analysis:** Determining the priority training topics that are needed in the field with the stakeholders by employing survey methodology and statistical analysis.

2 - **Content development:** Developing a training curriculum with content and objectives in line with the determined needs from the field. New curriculum and scenario development studies and based on VR applications studies will be carried out.

3 - **Teaching Material development:** Developing V/AR applications on prioritized topics and skills in accord with the objectives and content determined in the curriculum. Digital training material DTM development. It consists of the stages of preparing a content design, animation, and digital VR/AR apps.

4 - **Piloting Implementation:** Evaluation of the results by administrating the developed V/AR applications. Pilot trainings performance measurement and dissemination activities.

The expected results of the project will consist of new HEVs and EVs course content especially focused maintenance and service subjects with the support of suitable for VR/AR equipment's that will be developed. Development VR and AR applications for HEVs and EVs education and training and development of Teaching/Learning guidebook, user manuals, interactive website and supporting materials for training.

3. MATERIAL AND METHODS

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3.1 Stakeholder Analysis

The curriculum development process systematically organizes what will be taught, who will be taught, and how it will be taught. To determine methods of development process and to find true answer for these curriculum development questions the stake holder analysis should be done. Stakeholder Analysis will be conducted to consider the opinions of all parties associated with the HEVs training in order to determine the expectations correctly in the selection of the content and products to be developed within the scope of the project and to ensure participation, which is one of the basic elements of the planning. In the first stage of stakeholder analysis, the answers to the following questions were sought to determine who the stakeholders are:

- Who are the Hybrid and Electric vehicle trainers and practitioners in the field?
- Who are directors of these trainings, activities and services?
- Who gets trainings HEVs offered by the institutions?
- Who are those affected by the training activities and services provided by the institutions and who affect these activities and services?

During the determination of the stakeholders, three different methods will be followed and the groups forming the common denominator will be identified as stakeholders.

- The first method is national and international literature review,
- The second method is interviews with the representatives of the sector and non-governmental organizations (NGOs),
- The third method is a mini workshop conducted by the program development commission with university faculty members, teachers and trainers in the sector.

As a result of these studies stakeholders will be determined for needs analysis about Hybrid and Electric vehicle training. The result of prior studies and draft version of stakeholders are given in Table 1. Stakeholders are sorted according to their roles as clients/ getting service, main partners, and service providers and according to the status of stakeholders as internal stakeholders, external stakeholders, and customers. The stakeholders identified in this preliminary stakeholder analysis are also the ones to be collaborated on to evaluate any improvements in the participants' competencies as a result of the material to be developed in the project. The most significant group of stakeholders is undoubtedly the students, as they are the primary beneficiaries of educational initiatives and institutional policies. Following them, the second largest stakeholder group consists of service providers, primarily educators, who play a crucial role in shaping the learning experience and delivering quality education. This hierarchy of stakeholder importance is both expected and consistent with previous research findings [7-9], as educators directly influence student outcomes through curriculum development, instructional

strategies, and mentorship. Their involvement is essential in ensuring that educational objectives align with student needs and broader institutional goals.

Table 1

Stakeholders and Distribution by Priority

Stakeholders	How	Why	Priority
Students	Internal	Base Beneficiary	1
Sector Employees	Internal	Beneficiary	2
Lecturers	Internal	Teaching and developing	3
Teachers	Internal	Teaching	4
Universities	External	Teaching and developing	5
Vocational High Schools	External	Teaching	6
Sector managers	External	Strategic stakeholder	7
Governmental staff	External	Base stakeholder	8
NGOs	External	Beneficiary and Strategic stakeholder	9

3.2 Needs Analysis

Methodology of Needs Analysis

The need is the gap between the current situation and the desired situation. In a way, it is the difference between "*What*" and "*What should be?*" It is a process that would be followed to reveal the difference between the current situation and the desired situation to develop a curriculum and teaching materials to be achieved consisting of four stages. This process provides a rationale to set priorities and use resources productively.

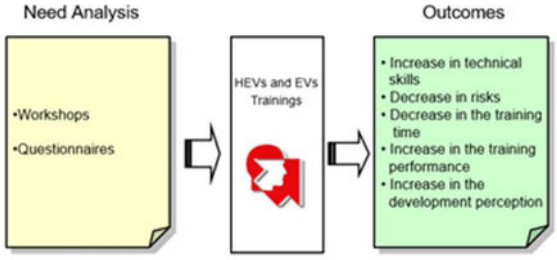

Fig. 1. Goals of the Needs Analysis

The needs analysis and basic outputs can be seen in Figure 1. The data in Needs Analysis will be collected from a sample of stakeholders and as a result of the data analysis the main subjects and topics that a need for content and material development is required will be identified. The needs analysis questionnaire is also administrated to evaluate training methods and educational technology in these trainings. Thus, a roadmap of teaching material development will be established based on the survey results. The questionnaire and how it is administered, and the data analyzed is explained under the heading of evaluation.

Statistical Analysis

The questionnaire that will be used in the needs analysis consists of 25 questions of five-point Likert types. The first five items seek HEVs perceptions, and the second 15 items test knowledge, skills and abilities, and last five items scrutinize expectations about digital education technology. The draft survey is given in Appendix 1. Having three different factors allows having different evaluations in the analysis including correlations between level of education and knowledge and skills competencies, differences between institutions or countries etc.

The questionnaire form that developed as five-point Likert scale without any judgmental items will be uploaded to Google Forms and submitted to all stakeholders. The five-point Likert scale items range from '1' (Strongly disagree) to '5' (Strongly agree).

3.3 Learning/Teaching (L&T) Methods

Higher education institutions have raised some concerns on the difficulty of teaching and learning abstract and complex topics. There is growing evidence that simulations/animations along with AR technologies can improve learners' engagement, competence, and skills; especially when compared to traditional didactic methods. However, there is also the argument that in education, and in particular the overall teaching and learning experience happens within a complex system that could dictate the

requirements needed for an AR application to cover user expectations and in consequence to be fully embraced in such complex systems. Higher Education institutions have the challenge of developing new and appropriate T&L tools and methods that will be used in a complex system where lecturers and other stakeholders involved in the learning process have the great challenge to ensure students are equipped with knowledge and skills to meet the demands of both academia and industry [10].

The decline in technical skills and understanding of essential principles and the conventions that underpin complex and abstract topics represent a challenge for HE institutions and poses an even greater challenge to traditional teaching strategies [11]. There are many traditional and more modern teaching and learning (T&L) approaches and methods. Some may consist of conventional lectures, tutorials or laboratory-based sessions. Others incorporate real-life concepts, experiences, technologies [12]and project-based work. However, these are usually isolated from each other [13].

VR/AR has become a popular technology, and it is widely used in educational settings offering many advantages, it no longer requires expensive hardware or sophisticated equipment, the technology now can be used with computers or mobile devices, and it has been used already in every level of training. VR/AR helps students engage in explorations and increases motivation, but; how are the elements that create this motivation being considered? This brings an important question into the development of VR/AR applications; who is the user? And what do they need? Students have different learning styles, some may be more visual or perhaps more logical than the rest of the cohort; if that is the case then; How VR/AR developments can consider these different learning styles? And give students a variety of options when learning a particular content. Additionally, VR/AR developments may need to consider the students' different levels of support as their concentration and abilities change due to personal circumstances, environment, age, among other factors. The overall effect of augmented reality-based methods and tools on the teaching and learning experience has been deemed positive [14].

T&L is a complex task, and purely technology driven developments may not foster student's learning [15] and some topics (e.g. HEVs training) require an interactive dialog and co-operation between lecturer and students to facilitate the construction of knowledge. This interaction may occur in a variety of media types, forms of interaction and contexts. Hence, a purely software-technology driven approach may not provide an opportunity to fully address the relevant needs for a successful teaching and learning experience. Therefore, an integration of a human-centred approach that combines pedagogy and technology can provide better considerations for the addressing of learning difficulties to enhance the impact or VR/AR applications in educative environments [16].

The rationale behind a human-centred approach for the development of a VR/AR-based application with pedagogic purposes, is the search for the right balance between the many teaching methods and learning styles, as well as the stakeholders involved in the T&L experience and the context where this experience happens. In the quest of this balance, the teaching methods and relevant topics should be appropriately matched with the different learning styles and scenarios where the T&L occurs to deliver an enhanced learning experience (see Fig. 2).

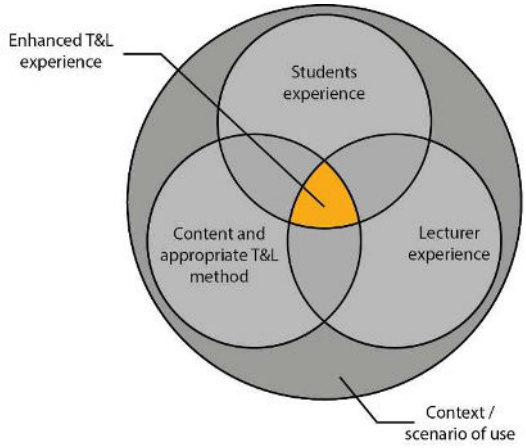

Fig. 2. Elements for a balanced and enhanced T&L experience [10]

While the project curriculum and content development team determine the pedagogical

infrastructure and method of the content to be developed, they will decide which content should be delivered with which technological infrastructure and which learning outcomes should be delivered with what L&T method.

Once the issue is defined, the curriculum team is formed, the needs assessed, analysed and prioritized, the next step is to refine and restate the issue, if needed, and develop the intended outcomes or educational objectives. An intended outcome states what the learner will be able to do because of participating in the curriculum activities.

After the content is selected, the next step is to design activities (learning experiences) to help the learner achieve appropriate intended outcomes.

3.4. Curriculum Development Methodology

The common HEVs training courses and course contents have been examined in detail and their shared learning outcomes constitute the basis of the curriculum development stage of this project. The stages in the process of curriculum development can be seen in Figure 3.

Fig. 3. Stages in the Process of Curriculum Development

Throughout the curriculum, content and scenario (storyboard) development process, the program development team, consisting of project members, academics and stakeholder representatives, supported by scientific data will be designed that maintained its up-to-datedness currency by considering national and international criteria. In the teaching of some subjects, instead of covering the whole content, the method of teaching the related module is adopted. The following sorted modules were identified to develop VR/AR supported content based on draft project proposal.

- Module 1: Introduction to hybrid and electric vehicles
- Module 2: Battery and energy storage systems
- Module 3: Automotive Electronics
- Module 4: HEVs and EVs diagnostic

3.5 Content Development Methodology

The curriculum development team determined the necessary criteria for the course by considering the following specifications:

- A structure to meet the basic demands of the sector;
- Compatibility with continuous development;
- Flexibility in timing and educational structure and a modular approach.

Handling all priority issues, the program development team has initially sorted them out according to their fields and results of the needs analyses; the process of integration of the issues has started. In the terminal stage, modular structure and course contents have been formed by taking into consideration the contents of the similar courses or the contents of the training in the vocational education institutions.

The fact that the individuals who would be attending the course had different backgrounds in terms of knowledge and skills makes it difficult to prepare content suitable for everyone. However, the general philosophy of the training program is based on competence so an individual completing a course should master the required knowledge and skills in that module. This priority was specifically considered when planning the course content and the details of theoretical and practical training classes. To this end, the training course was designed to be brief, competency-based, target-oriented, and student-centered.

Following the determined basic criteria and methodology, the stage of determining main projections for the content, priority, time and material development forecasts were passed. At this stage, the process was carried out as follows:

- Determining the learning outcomes by examining the content of the HEVs training courses

- Determining the main and sub-topics of the training modules,
- Determining an appropriate VR/AR method to teach according to modules outcomes
- Determining the content and class hours of the module

The development of an AR/VR application to support the T&L of HEVs learners in education and industry. Using a multi-disciplinary design-based research methodology (Figure 4), this European (Türkiye, Romania, Bulgaria) funded research project combines pedagogy and technology to approach HEVs education problems; and to develop an AR/VR education solution to address learning difficulties within the different critical HEVs categories will be identified.

This development is based on findings from an international study in three different categories covering the perception of HEVs education, assessing of HEVs knowledge and ability, and expectations of HEVs education. This research project also covers the difficulties and good practices of multi-disciplinary teams for developing HEVs and VR/AR contents where the approaches to T&L may differ between practices.

Developing Modules, Course Content and Learning Outcomes

During the module development phase, a multi-national curriculum development commission will be established under the leadership of academics among the project team who have expertise in the field of HEVs training. Content and learning outcomes will be determined in line with the basic criteria given in the method section (meeting sector expectations, compatibility with continuous development, flexibility in timing and educational structure, and modular approach.) and because of the priorities that were revealed from the needs analysis.

4. DEVELOPED CURRICULUM AND CONTENTS

Within the scope of the project, the content development team consisting of 16 academicians from three different countries (Türkiye, Romania and Bulgaria) participated in the work package work and produced content for the following four different modules presented within Table 2.

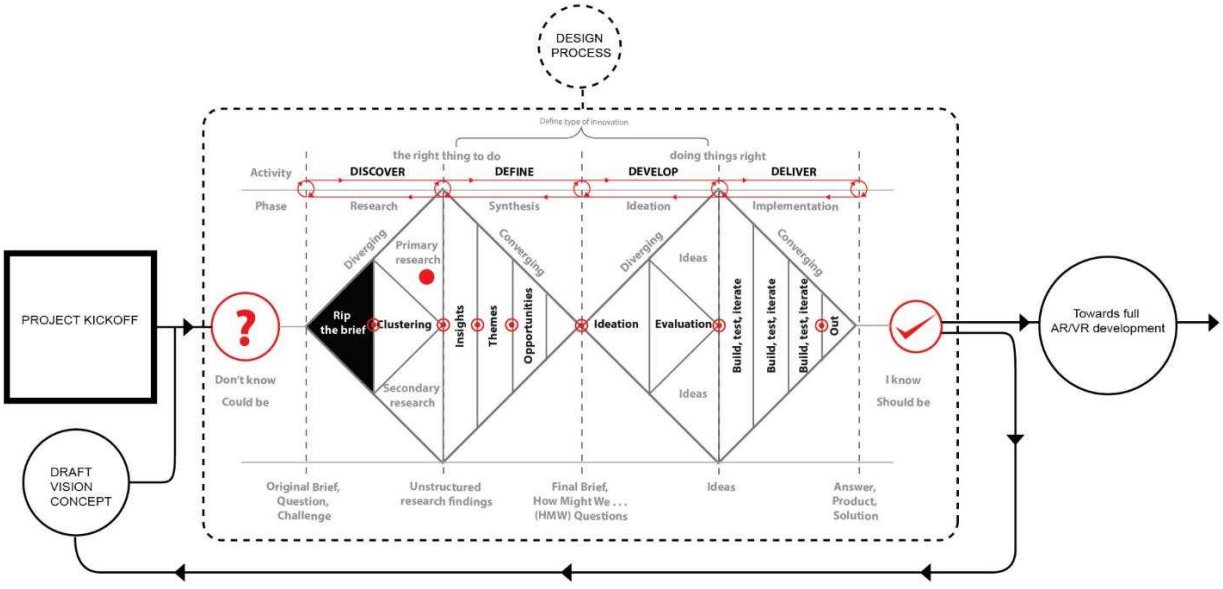

Fig. 4. Multi-disciplinary design-based research methodology

Table 2

The overview of the modules and the leading partners

Module Code	Module Title	Leading Partner
Module 1	Introduction to Hybrid and Electric Vehicles	Technical University of Sofia

Module 2	Battery and Energy Storage Systems	OIB Vocational High School
Module 3	HEVs/EVs Electric and Electronics	Technical University of Cluj
Module 4	HEVs and EVs Diagnostic	Bursa Uludağ University

In this process, each partner led the development of a module. After completing each module, the entire team finalized the program and contents with an international and multidisciplinary approach. Additional information regarding the content of each module is available on the project website at www.vrforev.org [17].

5. CONCLUSION

The comprehensive development of the curriculum and VR/AR-supported educational materials for HEVs training represents a significant step forward in addressing the diverse challenges of vocational and technical education. By systematically handling priority issues, the program development team successfully integrated findings from needs analyses and aligned course content with the requirements of vocational education institutions and industry standards. This modular and adaptive approach ensures compatibility with existing educational frameworks while allowing flexibility for future updates.

A notable challenge during the development process was accommodating the varying knowledge and skill levels of potential learners. The training program was, therefore, meticulously designed to prioritize competency-based learning, ensuring that individuals completing the course acquire the essential skills and knowledge required in their respective modules. The student-centered and target-oriented approach enhances the accessibility and practicality of the training, catering to a broad spectrum of learners, from vocational students to industry professionals.

Through a systematic process, the program development team achieved the following:

- Clearly defining learning outcomes tailored to HEVs training needs.
- Structuring training modules around key topics and sub-topics identified through rigorous analysis.
- Selecting appropriate VR/AR methods to optimize the teaching and learning experience based on specific module outcomes.
- Establishing the duration and structure of each module to align with both theoretical and practical training requirements.

The integration of AR/VR applications into the training process introduces an innovative solution to overcome traditional educational barriers. By leveraging a multi-disciplinary design-based research methodology, the project effectively combines pedagogy and technology to address the unique challenges of HEVs education. This approach ensures that learning difficulties within critical HEVs categories are identified and resolved, enhancing both the effectiveness and engagement of the educational experience.

The findings of this project, derived from an international study spanning Türkiye, Romania, and Bulgaria, provide valuable insights into the perception, knowledge, and expectations of HEVs education. The project also highlights best practices and challenges associated with multi-disciplinary collaboration in the development of AR/VR-supported content, which may vary across educational and industrial contexts.

A dedicated curriculum development commission, led by academics with expertise in HEVs training, has played a pivotal role in shaping the content and learning outcomes. This team has ensured that the curriculum meets sectoral expectations, supports continuous professional development, and remains flexible and modular. By adhering to these principles, the program provides a scalable and sustainable model for future educational initiatives in the field of HEVs.

In this process, all partners achieved significant gains, and a very dynamic cooperation process was demonstrated, especially in the preparation of the academic infrastructure of the outputs and the product development phases. It is expected that the project outputs will benefit students who receive H/E Vehicles training at all levels, from the first year of vocational high school to the final year

of engineering faculty, and individuals who need it in business life. These developed contents form the basis for VR/AR supported digital educational materials that will be developed in the second phase of the project.

The anticipated long-term impact of this project is profound. Upon completion, the digitalized HEVs training outputs will be freely accessible worldwide in four languages, democratizing access to high-quality vocational education. The VR/AR applications developed as part of the project are expected to serve individuals in both public and private sectors, significantly enhancing the competencies of professionals engaged in HEVs maintenance and service operations.

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Dezvoltarea Curriculumului și Conținutului Cursurilor pentru Educația aferentă Vehiculelor Hibride și Electrice (HEV) utilizând tehnologii de Realitatea Virtuală și Augmentată (VR/AR)

Rezumat: Acest studiu este axat pe dezvoltarea unui cadru pentru conținutul de formare și a materialelor de instruire digitale (DTM) susținute de Realitatea Virtuală (VR)/Realitate Augmentată (AR) pentru educația vehiculelor hibride și electrice (HEV). Ca parte a unui proiect de parteneriat strategic al UE Erasmus+, în curs de desfășurare, cercetarea adoptă o metodologie multidisciplinară bazată pe proiectare pentru a îmbunătăți rezultatele predării și învățării în întreținerea HEV-urilor și a subiectelor legate de servicii în cadrul educației și formării profesionale (VET). Recunoscând provocările stabilirii unei infrastructuri educaționale uniforme în instituțiile VET, DTM-urile susținute de VR/AR urmăresc să ofere soluții educaționale accesibile și echitabile. Studiul evidențiază metodologii și rezultate pentru proiectarea conținutului și a curriculei adaptate tehnologiilor vehiculelor hibride și electrice, ghidând dezvoltarea pedagogiei și curriculum-ului cursurilor de formare pentru HEV. Se anticipează că rezultatele acestui proiect vor beneficia în mod semnificativ o gamă diversă de cursanți, de la studenți de liceu profesional la absolvenți ai facultăților de inginerie și profesioniști din forța de muncă, promovând accesibilitatea globală și incluziunea aferent[instruirii digitale aferente vehiculelor hibride și electrice.

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