Competency-Based Instructional Design for Microelectronics Training: ECoVEM Project

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***Abstract*—Microelectronics is an essential component of virtually all aspects of our daily lives. The microelectronics sector in Europe is responsible directly 200,000 and indirectly 1,000,000 high-skilled jobs and the demand for new skills is increasing. In this scenario, ECoVEM project, European Centre of Vocational Excellence in Microelectronics, is a continuing work, based on an existing model for business-education collaboration of the Knowledge Alliance MECA and Sector Skills Alliance in Microelectronics, both targeting tertiary education. The ECoVEM project platform targets vocational excellence on all levels of European Qualification Framework. This project aims to establish a transnational cooperation platform of Vocational Excellence in Microelectronics to tackle the challenges of the: digitalization, artificial intelligence, green technologies, gender equality, and integration of migrants among others. One of these mechanisms is based on develop innovative VET curricula through Massive Open Online Courses. professional online courses serve as catalysts for individual and collective growth, driving innovation, sustainability, and inclusivity within our workforce. They empower individuals to adapt to new challenges, seize opportunities, and contribute meaningfully to their fields, ultimately fostering a more dynamic and resilient workforce for the future.**

Keywords—Microelectronics, ECoVEM, Open Educational Resources, Vocational Training, MOOC,

I. INTRODUCTION

Microelectronics stands as one of the most rapidly advancing sciences, serving as the cornerstone of the e-economy and e-society [1]. It becomes imperative forging new partnerships between education and industry fostering a synergistic relationship between academia and the professional sphere. This synergy is essential for nurturing the competencies, technological prowess, and soft skills required for emerging roles within the realm of microelectronics.

Professional online courses play a pivotal role in enhancing the skills, competencies, and knowledge of individuals within our workforce [2]. They serve as a gateway to continuous learning, enabling professionals to stay abreast of industry trends, advancements, and emerging technologies. By engaging in these courses, individuals not only expand their expertise but also foster a deeper understanding of sustainable practices and greener electronic technologies. Furthermore, online courses facilitate greater inclusivity and diversity within the workforce by providing accessible and flexible learning opportunities for individuals from diverse backgrounds. They break down barriers to education, allowing people to acquire new skills and advance their careers regardless of geographical location or socioeconomic status, promoting a more equitable and inclusive workforce [3].

This paper outlines the pilot implementation of blended Massive Open Online Courses (MOOCs) developed by UNED

within the European Centre of Vocational Excellence in Microelectronics (EcoVEM). These courses extend and adapt the Vocational Educational Training (VET) model utilized within the European Union [4], [5], with a particular focus on the results obtained in Spain . The primary objective is to enhance the skills of existing workers and attract new talent to the microelectronics and technical sectors. This initiative aligns with the European Skills Agenda [6], a comprehensive five-year plan aimed at fostering the development and integration of enhanced skills among individuals and businesses [7], [8].

II. ECoVEM Project

ECoVEM aims to establish a transnational cooperation platform of Vocational Excellence in Microelectronics to tackle the challenges of the: digitalisation, artificial intelligence, green technologies, gender equality and technology, integration of migrants. The specific objectives within ECoVEM project are:

1. Networking of centres of VET, companies, regulatory agencies and social partners to share ideas, methodologies and experiences towards vocational excellence in microelectronics sector.
2. To develop innovative VET curricula for EQF 3 to 8 in collaboration with companies, polytechnics and social partners.
3. To disseminate the achievements of microelectronics in digitalisation, green energy, robotics, space technologies and medicine to raise the attractiveness of microelectronics VET through open days, international schools and competitions.
4. To ensure sustainable governance at national and EU levels through involvement of policy makers in VET and employment, social partners, chambers of commerce and companies for lifelong teacher training and stimuli; for raised teacher's qualification; for implementing the other countries best practices and approaches to excellence in VET; for efficient financial models for VET including work-based and apprenticeship and for investment in VET and applied research.
5. To tackle non-discrimination and social inclusion in VET focusing on the gender dimension of employability in the sector and VET for immigrants.

The ECoVEM project unites vocational education centers, polytechnics along with their research departments, SMEs, industrial associations, and social partners to create a European cooperation platform for Vocational Excellence in Microelectronics. This initiative aims to address key challenges such as digitalization, artificial intelligence, green technologies, gender equality in technology, and the integration of migrants. ECOVEM will leverage the strengths of national VET systems in more advanced regions while also supporting less advanced areas to achieve vocational education and training excellence.

ECoVEM is composed of representatives of the entire ecosystem for the microelectronics sector embedding VET providers at EQF levels from 3 to 8, industrial partners with their associations, chambers and science parks, regulatory bodies and associations at local, national and European levels (some included as associated partners). This collaborative network aims to foster synergies between education and the workforce, promote innovation, and address the evolving needs of society. The members of the consortium include:

- **Vocational education and training (VET) providers from higher educational institutions**: Technical University of Sofia from Bulgaria, Technical University Berlin from Germany, and Universidad Nacional de Educación a Distancia (UNED) from Spain.
- **VET providers from vocational training institutions**: Student Computer Art Society (SCAS) from Bulgaria, J-ArtEck Jugendbildungsstätte e.V. from Germany, IAL Innovazione Apprendimento Lavoro Friuli Venezia from Italy, Institut National d'Energie Solaire, INES-Formation from France, and Cyprus Productivity Centre from Cyprus.
- **Microelectronics sector companies**: Romit Ltd and MASHO EOOD from Bulgaria, EXOLAUNCH GmbH from Germany, and Pôle SCS (Secured Communicating Solutions) from France.
- **Industry or sector representatives**: Bulgarian Industrial Association from Bulgaria, SEMI Europe GmbH from Germany, COMET Scrl from Italy, Asociación de Industrias de Conocimiento y Tecnología del País Vasco (GAIA) from Spain (replacing Confederación Española de la Pequeña y Mediana Empresa, CEPYME, in 2023), and Cyprus Chamber of Commerce and Industry from Cyprus.
- **Intermediary agents for VET/industry/social**: Asociación Nacional de Centros de Formación con Certificado de Profesionalidad (ANCFCP) from Spain, Associazione Cimea (CIMEA – Centro di Informazione sulla Mobilità e le Equivalenze Accademiche) from Italy, European Center of Women in Technologies from Norway, and Cyprus Productivity Centre from Cyprus.

ECoVEM aims to implement innovative instructional approaches to foster lifelong learning, self-regulation, and the development of both hard and soft skills, using ecosystem-based theoretical models and performance support systems. Additionally, ECoVEM will contribute to sustainable VET governance at both national and EU levels by engaging policymakers in vocational education and training, employment sectors, social partners, industrial associations, and companies:

- for lifelong teacher training and stimuli for raised teacher's qualification;
- for implementing the advanced countries' best practices and approaches to excellence in VET into less advanced regions;
- for efficient financial models for VET including work-based and apprenticeship and for investment in VET and applied research;
- for raising the role of VET in Smart Specialisation Strategies [7].

III. Results and Analysis on Pilot Test

UNED leads WP3, focusing on the Design and Development of Innovative Vocational Education and Training (VET), with the Technical University of Sofia and Romit as key partners contributing significantly to course development and deployment [10].

The specific objective 2 of the ECoVEM project is focused on the development of innovative VET curricula for EQF levels 3 to 8, in collaboration with companies, polytechnics, and social partners. These curricula are designed to be:

- modular, for flexible delivery, adjustable for blended learning with open educational resources and/or in a dual VET system with apprenticeship and job-related projects;
- for iVET, cVET, for training, re-training and up-training on the job;
- aligned with ESCO, EQF and EQVET principles of quality and relevance and integrated with the National Qualifications Frameworks of the partner countries to ensure transparency and recognition across EU;
- including open educational resources in the Microelectronics cloud system.

This objective targets the needs of innovative and multidisciplinary approaches to teaching and learning in the interdisciplinary sector of micro- and nanoelectronics and the needs of closer cooperation between VET and business using the infrastructure, technology of partners' companies and universities and expertise of practitioners.

A. *UNED Courses*

At this stage, UNED has developed 7 courses covering materials for all seven main subjects of the project. These courses are tailored to educational levels ranging from EQF3 to 6, encompassing the spectrum from initial VET to University degrees. Detailed information regarding the EQF levels, covered fields, and estimated hours per course can be found in Table I.

The courses developed by UNED span a comprehensive total of 625 hours, divided into 43 modules across 7 distinct courses. Notably, these courses are exclusively offered in an online format, distinguishing them from offerings provided by other partners, which may include hybrid, or onsite modalities.

UNED provides its educational platform (based on Moodle, inside a secured server and network) to 12 courses of the ECoVEM repository (a total of 42 courses), 7 from UNED (plus 1 devoted to Train the Trainers in Spain, and mainly in Spanish), 3 from ANCCP, and 1 from J-ArtEck.

Regarding the activities implemented in the courses, the training is oriented to Continuous VET (Vocational Educational Training), the mode of delivery is oriented always to online learning, and we used the innovative educational methods summarize in next table.

The courses developed by UNED are designed following a unified educational approach, ensuring seamless online accessibility and fostering autonomous learning process. Accessible from any location, at any time, and on any device, these courses are intended to accommodate diverse learning preferences and schedules. The modular design of the courses is a intended in order to allow learners to progress through the material at their own pace and convenience. Each completed module is rewarded with a unique badge, serving as a tangible acknowledgment of the learner's accomplishment. This modular structure empowers students to curate their learning journey based on their specific interests and prior knowledge. Moreover, upon successful completion of all modules within a course, learners are not only awarded individual module badges but also receive a course badge, signifying their comprehensive mastery of the subject matter. This dual badging system not only incentivizes continuous learning but also provides learners with tangible recognition of their achievements. Furthermore, the attainment of a course badge grants learners access to a final assessment, culminating in the issuance of a certificate that attests to their successful completion of the course, validating their mastery of the course content and workload.

TABLE I. UNED Courses Overview

Course title	Language of course	EQF Level						Duration (hours)	Modules	Main Subject						
		EQF3	EQF4	EQF5	EQF6	EQF7	EQF8			Design and manufacture of PCB	Microelectronics packaging technologies	Fundamentals of microelectronics	Integrated circuits design	System design	Microelectronics for a greener economy	Key competences and transversal skills
Task-oriented simulation with OrCAD Pspice	English		x	x	x			75	8				x	x		
Bridge the Gap: Photovoltaic Systems	English		x	x				90	6			x		x	x	
Foundations on Microelectronics	English		x	x				60	7			x				
Smart Industry and Circular Economy	English		x	x	x			50	5						x	x
Foundations and Simulations on FPGAs	English		x	x	x			50	4				x	x	x	
Overview of Biotechnology and Microelectronics from the Point of View of Gender, Equality and People Integration	English	x	x	x				50	5						x	x
Basics of microelectronics manufacturing processes	English		x	x				250	8	x	x	x				

TABLE II. UNED COURSES: ORIENTATION AND ACTIVITIES

Course title	Trainin			Mode of delivery								Innovative Learning								
	Initial VET	Continuous VET	Work based training	On-line (stand-alone)	On-line (tutored)	Visio	Work-based training	On-site training	Hybrid on-site/on-line	Other	Performance-centered approach & EPSS	Innovation in instructional design	Project-Based Learning	Activity Based Learning	Simulation Based Learning	Remote and Virtual Laboratories	Blended Learning	Microlearning	Open educational resources (OER)
Task-oriented simulation with OrCAD Pspice		x		x							x	x		x	x		x		x
Bridge the Gap: Photovoltaic Systems		x		x							x	x				x			x
Foundations on Microelectronics		x		x							x	x				x			x
Smart Industry and Circular Economy		x		x	x						x	x		x			x		x
Foundations and Simulations on FPGAs		x		x							x	x		x			x		x
Overview of Biotechnology and Microelectronics from the Point of View of Gender, Equality and People Integration		x		x	x						x	x		x			x		x
Basics of microelectronics manufacturing processes		x		x							x		x	x			x	x	x

Each course presents unique student statistics, including gender distribution, country of residence, and EQF level. A noteworthy observation is that most non-Spanish students enrolled in the courses hold higher educational qualifications. However, none of them complete any course, primarily accessing the courses to explore their content, educational activities, and ideas, likely intending to integrate them into their curriculum or syllabus. This trend is particularly evident among former UNED students who have pursued higher VET or degree studies. A similar observation can be made regarding gender distribution, with most of female students belonging to EQF levels 5 or 6, indicating their attainment of higher VET or degree qualifications. This trend is consistent with our database and the distribution lists within UNED, where a significant portion of students are former degree or master's students. This pattern also applies to Spanish and male students, with the majority holding higher VET or degree qualifications (EQF 5 or 6).

B. Survey

In addition to collecting information about students' personal aspects such as age, native language, gender, and educational background, the survey comprised 12 questions dedicated to evaluating each course. These questions encompassed various aspects, ranging from the quality of course content to the clarity of its structure, interaction with the instructor, usefulness of available resources, and overall satisfaction with the learning experience. This broad range of questions allowed for gathering detailed insights into students' perception and satisfaction regarding each course individually, providing a comprehensive view of their educational experience.

TABLE III. UNED COURSES: PARTICIPATION

Course	# of complete/ participants	Gender complete / participants			Country complete / participants	
		Male	Female	Non answer	Spain	Out of Spain
Task-oriented simulation with OrCAD Pspice	4/33	3/25	0/8	0/0	3/28	0/5
Bridge the Gap: Photovoltaic Systems	8/20	6/17	2/2	0/1	8/19	0/1
Foundations on Microelectronics	2/29	2/22	0/5	0/2	2/19	0/10
Smart Industry and Circular Economy	0/17	0/17	0/0	0/0	0/16	0/1
Foundations and Simulations on FPGAs	3/29	2/23	1/5	0/1	3/25	0/4
Overview of Biotechnology and Microelectronics from the Point of View of Gender, Equality and People Integration	12/30	9/24	3/6	0/0	12/26	0/4
Basics of microelectronics manufacturing processes	0/22	0/17	0/5	0/0	0/15	0/7

The survey is based on a 5-level Likert scale to gauge the extent to which students agree with the evaluated statements. This scale allows students to express their level of agreement or disagreement, providing nuanced feedback on various aspects of the courses. For instance, students may indicate whether they strongly agree, agree, are neutral, disagree, or strongly disagree with statements assessing course content, instructor interaction, or resource usefulness.

Unfortunately, only 24 out of the 180 students enrolled in the 7 courses offered by UNED as part of the ECOVEM project have responded to the survey. 2 courses have received no evaluation. This low response rate presents a challenge in obtaining a representative sample of student opinions on the educational experience. Increasing participation in future surveys would be beneficial to gain a more comprehensive and accurate understanding of students' perceptions of the courses and their quality.

Aspects related to the platform, such as intuitive navigation, accessibility of course documents, the effectiveness of exams, and other tools, have been consistently positively evaluated by

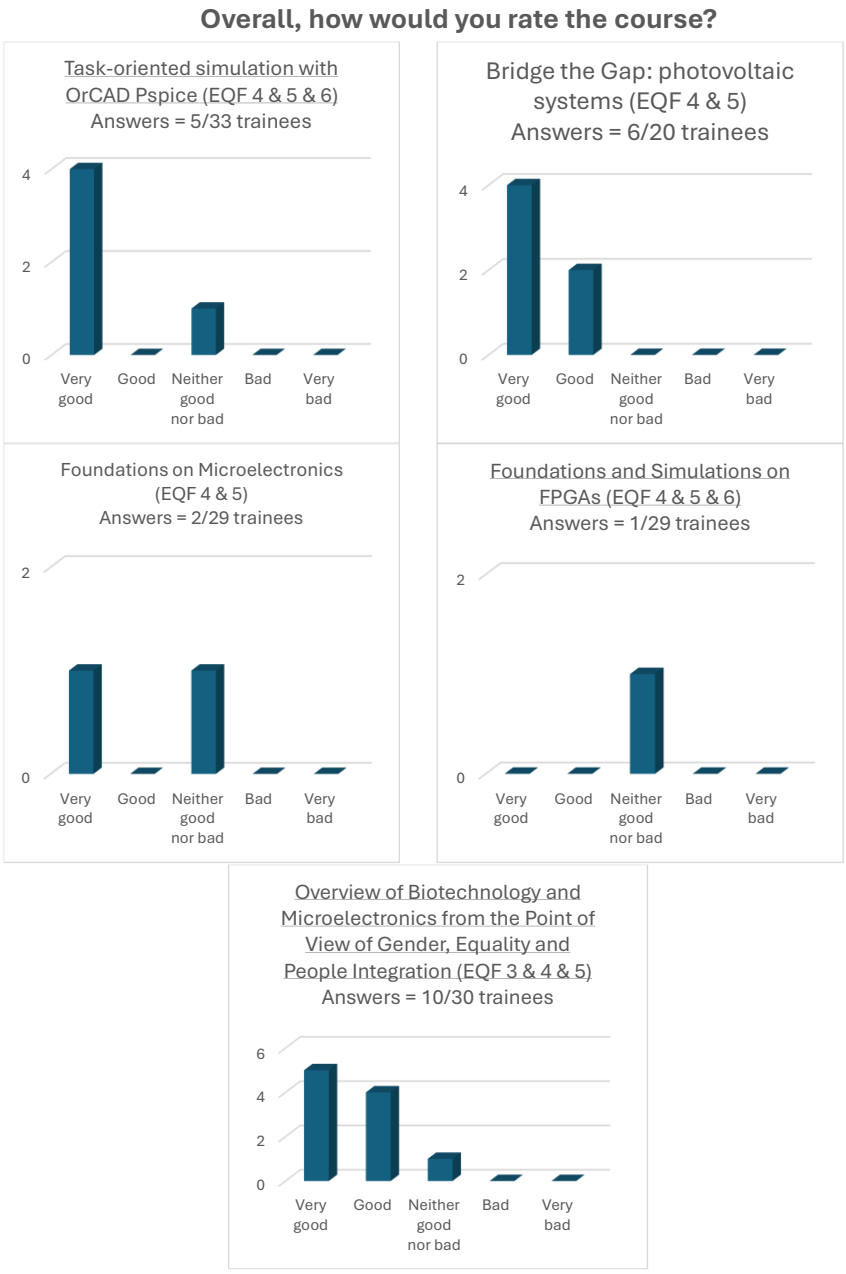

Fig. 1. Course Evaluation by students.

students. The 24/7 availability of the course has been particularly highlighted and appreciated. This uninterrupted access to learning materials has allowed students to progress at their own pace and review content at any time that is convenient for them. These aspects of the platform have received praise especially from those students who have actively participated in at least two courses. The uniformity in the design and structure of the courses, along with a clear and coherent evaluation system, has significantly contributed to improving the user experience. This consistency facilitates navigation and comprehension of content for students, enabling them to focus on learning without unnecessary distractions.

The unanimity among students in positively evaluating the relevance and suitability of the course content suggests that the educational materials have been effective in addressing the intended topics and objectives. This high rating may indicate that the courses are well-designed and adequately cover key aspects of the subject matter. Furthermore, it suggests an effective alignment between the course description and its actual delivery, contributing to a satisfying learning experience for students. These results indicate high satisfaction and positive perception among students regarding the quality and relevance of the course content, as well as an agreement that the course meets their expectations. However, it would be beneficial to supplement these findings with additional evaluations to better

understand students' perceptions and identify any potential areas for improvement in the design and delivery of the course.

Some positive comments about the courses include:

- The materials and methods are appropriate.
- I have noticed that sometimes I don't give enough importance to the preparation of the presentation and what I've seen in this course is that the teacher has prepared very well his presentation, and this makes him to explain easily and it's really easy to follow the lesson.
- I liked the practical cases, that help to understand the principles.
- The course is organized in a logical and progressive manner, which facilitates learning.
- The visual and written materials complement each other, which facilitates the assimilation of the concepts.
- The most i like were the infographics.
- I know the background behind the PV installations, but I have never studied it directly, so it was like an interesting practical approach.
- Very good interface and practical training.
- Good to learn about Gender, equality and people integration for improving my professional skills.
- I liked that it showed the reality of gender inequality that exists in the world of work and how to confront it.
- They are good to remember old knowledge and refresh/update it.
- It was well structured. The difficulty of the course progressed progressively with each module completed.

Main areas for improvement and related comments are:

- Maybe include Tutorial videos.
- To have some real experience online of the circuits.
- Some real specification components.
- To add open questions to make student think and later give answers.
- Regarding the contents, I missed some more information about IA, something that is at the moment becoming an important tool.
- Interaction with students could be improved, although I liked the course overall.
- Not disliking themselves, but personally I am not able to use the podcast to study.
- Interaction with students and practical evaluation of the course could be improved.
- The course was in English.
- It would be interesting to introduce interviews with professionals in the sector talking about how these issues are addressed in their companies.
- Some difficulty to understand some acronym.
- I would like more open books.

IV. Analysis and Conclusions

Despite a low response rate, student feedback on course evaluations has been positive, particularly regarding course content relevance and suitability. However, there is room for improvement in understanding students' perceptions and identifying areas for enhancement in course design and delivery.

Overall, while UNED courses have received positive feedback and demonstrate effective online delivery, there are opportunities for further refinement and expansion to meet the diverse needs of learners. Continued efforts in course development, platform optimization, and student engagement will contribute to the ongoing success and impact of UNED's role in ECOVEM project.

While there are courses where it has been observed that students have completed modules independently, there is a trend towards linear completion of courses. Analyzing student behavior in the course, this may be due to several factors: Although the course design aims to be modular and independent, the contents of different modules inevitably rely on those of previous modules, or at least on parts of them. Another factor is the background that students bring, which is clearly divided into two groups: those who cover the content easily, and those whose background is insufficient to scaffold knowledge within the courses.

In this regard, there is a need for effort on the part of the consortium regarding the integration of the different available contents so that students are guided between the various courses and modules, offering them solid opportunities and scaffolding between the different modules of the available courses (not only those provided by one institution).

The platform has proven to be an effective tool for delivering online courses, providing students with a smooth and rewarding learning experience. The combination of a user-friendly interface and well-organized educational resources has contributed to the overall success of the courses and has encouraged active participation of students in their learning process.

Course improvements (already implemented or planned for the next training year):

- In certain courses, such as "Task-oriented simulation with OrCAD Pspice," we have updated the tutorials for the software tools used in the curriculum to provide students with more comprehensive practical guidance. While these tutorials were initially included in other courses, like "Foundations and Simulations on FPGAs," we recognized the value of enhancing the learning

experience by incorporating them into additional modules.

- To enrich the practical learning experience, we have introduced real experiments in some courses. For instance, "Foundations on Microelectronics" now includes remote laboratory experiments, while "Foundations and Simulations on FPGAs" incorporates the use of external hardware [11], [12]. These additions aim to maximize students' real-world knowledge and competencies. We are also developing a course based solely on practical experiences in a remote lab, which will be available in June.
- We also intend to explore the incorporation of new technical areas, such as Artificial Intelligence, although these topics may be covered by other courses within the ECoVEM project.
- Additionally, while online tutored courses offer flexibility, we recognize the need for increased teaching and human resources to facilitate more meaningful online interactions with students in certain cases.

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