E-Learning Content Creation for Interdisciplinary Master of Science Program in Product Lifecycle Management (PLM)

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Abstract

This contribution introduces an educational Product Lifecycle Management (PLM) curriculum suitable for undergraduate and young professionals, which enables a graduation as Master of Science. The main goal is to increase the accessibility of valuable PLM content for educational purposes and to introduce students to the productive "hands on" features of PLM by developing an international, interdisciplinary and online-based program. This program focusses on a fundamental PLM understanding, the usability of available software systems and an industrial PLM integration and application. A highly professional cooperation between five technical universities from Turkey, Spain, Germany and Austria, international experts designed interactive online classes, which are suitable for distance learning. Sharing technology for international educational platform enables students, professors and partners from industry to share their PLM expertise with students and improve the common and different understandings. This new PLM program shows the usability of the applications, which were implemented and tested in a pilot training course. The results are very promising and further suggestions and feedback for improvement will be taken into account. Student feedback and the exceptional motivation of the whole project team shows that interdisciplinary online education has a promising future in international academic PLM education integrating practical use cases.

Keywords: product lifecycle management, online platform, curriculum

1 Introduction

Young professionals need new requirements to develop smart products in an industrial environment. The development of smart products in various disciplines, but also across a value network, creates ever greater complexity. Graduates and employees who can deal with the complex structures in companies and products could reduce existing uncertainties in industrial companies. To educate these young professionals,

on the one hand, the requirements and problems for graduates in the field of engineering have to be broken down, and on the other hand, in addition to the professional skills, social skills have to be addressed by a degree program.

To educate young professionals with the right technical knowledge, it is necessary to establish a curriculum that teaches how to deal with complex information systems in the product life cycle and product development processes. Today's smart products are interdisciplinary and complex, requiring various IT solutions during the development and use phases [1]. Product lifecycle management (PLM) refers to central IT solutions supporting product development and creation. The integration of tools and data in a digital environment that spans the entire product lifecycle plays an important role [2]. In this context, PLM is considered a business paradigm that companies view as a key factor for success in the engineering and technology sector [3]. Several PLM solutions have evolved over time and exist in parallel in many companies today [4]. However, the competence to work in a collaborative environment with PLM is not very common among graduates in the job market [5]. Another point is that most companies operate globally. This means that in addition to having a complex IT environment in the company, being able to work together in a large international and distributed team is a key skill [6]. Therefore, it is essential to bring the two topics together and to sensitize and introduce graduates to the topic of PLM through an international course of study. This can be covered in the location-independent collaboration by integrating different international universities into one study program.

Until 2009, there were no study programs for students that also considered the technical processes in the context of PLM [7]. The current situation at the universities involved in the research project shows that PLM has so far only been offered as a component of other courses of degree programs. PLM usually only plays a major role in the master’s program and is attempted to be covered by a single course. There are no specific PLM courses in the bachelor’s degree programs, but only in individual lecture units, for example, in digital engineering. Singular educational institutions quickly reach their limits with specialized courses of study, whether for bachelor's or master's degrees. This makes it more important to bring together the existing know-how from different teaching and research institutions to create and manage smart products in an industrial environment. Through the synergies of new partnerships in the field of teaching, innovative and future-oriented courses of study for specializations can be introduced. Various measures can be taken to promote internationalization and the ability to work in a team in addition to the specialized topics. According to studies, international study programs with various educational cooperation partners in two or more countries and exchange semesters in other countries greatly impact students' professional, personal, and social skills. In addition to the professional maturity that is strengthened by the acquisition of a master of science degree, study-related stays abroad also result in the acquisition of important competencies and skills, e.g., in areas such as intercultural learning, personality development, promotion of social skills, and foreign language acquisition [8]. The experience gained here also plays a not inconsiderable role in later professional life. Another study found very positive effects especially in European experiences abroad of students through the exchange program ERASMUS, among others in the areas of a biographical change, which stands for a growing self-

confidence, but also the ability to deal with unforeseen events more easily, as well as that the stay abroad has a positive influence on the academic and professional career [9].

The coronavirus pandemic has forced educational institutions to move to alternative teaching formats more quickly. This change has brought digital formats into focus, allowing for different learning experiences. E-learning has several implications for the study. As a tool, it is indispensable in modern and forward-looking educational institutions, especially since the beginning of the corona crisis. To use e-learning profitably, several requirements must be met. On the one hand, the requirements for a study program and the professional acquisition of competencies in it, on the other hand, due to a new learning method, requirements for the platform, the design of it as well as the learning offers are equally important. To be able to deal with all topics such as e-learning via a platform, mapping of the individual courses in the learning platform, general learning objectives and competencies in the courses as well as the teach-the-teacher concept, the Connect4PLM project is divided into six different work packages, each with its own intellectual results.

2 PLM Master Curriculum approach

PLM represents a specialization in engineering. Both, to be able to understand PLM from a student perspective and to be able to apply PLM inevitably require fundamental knowledge from the field of engineering. Especially in the abstract university environment, problems from the field of PLM, which arise from the challenges of companies, are difficult to convey [10]. Therefore, it is essential that a potential PLM curriculum builds on a science or engineering undergraduate or bachelor's degree. This is, among other things, one of the reasons why the Connect4PLM research project is specifically pursuing the development of a master's curriculum. To achieve the necessary learning objectives, it is therefore also necessary to design a holistic and multidisciplinary curriculum approach [11]. There are already offers, e.g., how young professionals and other employees can be educated in PLM. One example is the PLM Professional Program from Fraunhofer IPK [12]. Nevertheless, the course of studies presented here already focuses on students who want to specialize in PLM before starting their careers.

Studies from the 2000s show a strong industrial need for students well-trained in PLM, so a solid foundation exists, and additional employee training is no longer necessary [13]. Current studies continue to show that there is a need for further action in the area of teaching in educational institutions [14]. The structure of a curriculum must cover various considerations in advance [15]. Resource planning and the relationship between knowledge and skills are part of it, in addition to pedagogical practice, curricula, and methods. As a more constructive definition, a curriculum is "the multi-layered social practices, including infrastructure, pedagogy and assessment, through which education is structured, enacted and evaluated" [15, p.136]. The core of a curriculum can be based, among others, on nine terms [16]. These target resources,

contents, goals, environment, and circumstances. Figure 1 shows the curriculum spider web, which describes the terms and the corresponding question.

The curriculum concept is an important part of the Connect4PLM project. However, in order to be able to deal with all topics sufficiently, the entire project is divided into six work packages, each of which is led by a different university. The exact structure of the preceding and following work packages can be found in Chapter 3. The initial structure of the curriculum was defined according to the topics and the guiding questions of the curriculum spider in work package four (Curriculum development). However, it was clear from the outset that not all topics could receive the same attention. Therefore, within the work package for building a general curriculum, assumptions were already made to be able to set a focus and postpone other topics to a later point in time. Figure 1 shows the consideration of the different topics for a general structure.

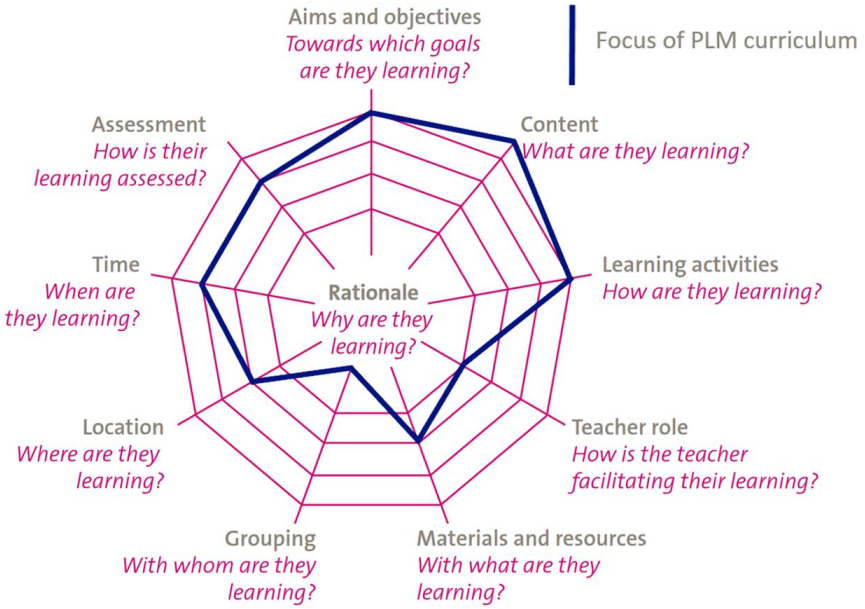

Fig. 1: Curriculum spider web [16] and focus of PLM curriculum

Work package four was initially worked on by a single university, but all partner institutions have influenced the curriculum structure in various feedback and iteration rounds.

3. Connect4PLM project educational framework

Connect4PLM project aims to combine background knowledge of the academic partners from Turkey, Spain, Germany and Austria in order to generate awareness about PLM. The basic idea of the project is to develop an e-learning platform for interdisciplinary master of science program to train graduates, researchers and young professionals in PLM. The approach to be implemented at the project partners' universities is based on practice-oriented courses designed to stimulate technical learning through the development of competencies essential to the ability of individuals to perform specific functions efficiently and solve complex scientific and practical problems. The project Connect4PLM enhance accessibility, fosters learning experiences, supports scalability, encourages collaboration, aligns with industry needs, and facilitates continuous professional development. It addresses the evolving demands of the PLM field and empowers individuals to gain the skills and knowledge necessary for successful careers in PLM. It is built on the following concepts, shown in Fig 2.

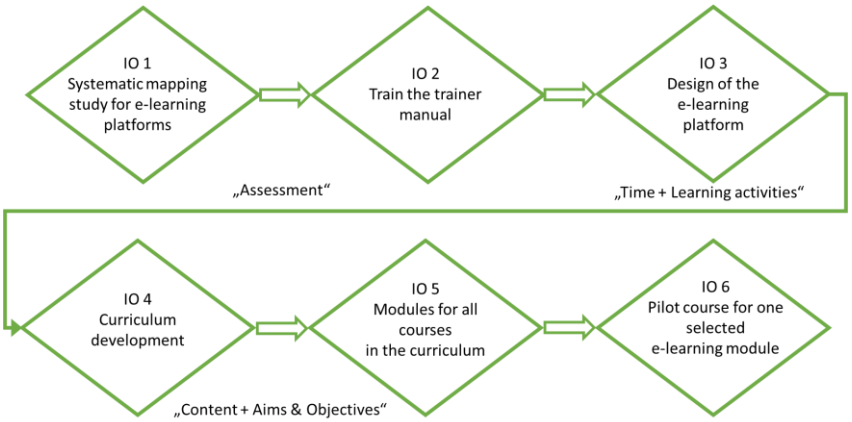

Fig. 2: Structure of the project with the associated intellectual outputs (IO)

3.1 Systematic mapping study for e-learning platforms

The objective of a systematic mapping study is to apply a systematic mapping process and create a systematic map for e-learning platforms. First, research questions are defined. The Master of Science program will be made available on the e-learning platform. Research questions are generated for each of the requirements. The keywords are selected from the abstracts of relevant studies and classified according to the requirements of the e-learning platform.

3.2 Train the trainer manual

The goal of the “Train the Trainer Manual” is to support PLM trainers in the methodology defined in the ADDIE model (model for the development of an instruction

system) for e-learning. The ADDIE model has five phases: analysis, design, development, implementation and evaluation. PLM trainers have various roles in e-learning, such as instructional designer, subject matter expert, online moderator and tutor. The ADDIE manual itself consists of the instructions for the needs analysis, target group analysis, task and topic analysis in the analysis phase. The e-learning course combines the teaching methods of presentation, application and collaboration. When the delivery strategy is defined, the appropriate e-learning formats such as video conferencing, live webcasting, audio conferencing, application sharing and animations, slides are selected. For self-paced e-learning, practice and tests consist mainly of questions associated with answer options and feedback.

3.3. Design of the e-learning platform

The e-learning platform should be open source. The most important characteristic of open source platforms is that they can be extended easily and cost-effectively. This function is provided by the extensibility of the database model. The database model of the e-learning platform is expanded to include the specific requirements for the MSc title. The main features of the platform include the preparation of interactive course content, support for multi-client user management and access to course content from mobile devices. The spread of the custom e-learning platform for PLM will be possible through the spread of the open-source e-learning platform.

Appropriate configurations are supported to enable local use of the e-learning platform in the participating countries of the project. The learning analytics module is developed in the platform and the e-learning process thus becomes an essential part of a personalized master’s degree.

3.4. Curriculum development

The aim of the MSc curriculum is to develop the qualification description, the curriculum itself and the curriculum content of the master's program. For this purpose, the content of existing international master's programs is evaluated and the necessary information and reports on the requirements and needs for curriculum development are obtained. A selection of 26 bachelor's and master's degree programs with strong tendencies towards PLM topics was made for closer examination. This selection was mainly but not only based on European institutions, both universities and universities of applied sciences. Based on these reports and instructions, all project partners will create the description of the Master of Science program. After the curriculum has been developed, the qualification description is developed, which contains all the requirements for the master’s degree. The tasks leading to the design and development of the master's curriculum are as follows:

- Evaluation of the content of existing international master programs
- Development of curriculum and qualification descriptions
- Development of curriculum and their content materials
- Improvement of academic staff in blended learning

3.5. Modules for all courses in the curriculum

This project focuses on the creation of a new curriculum and the implementation of e-learning modules for the Master of Science program on PLM. The proposed study plan will be evaluated and approved by the European partner institutions. The master's program also includes blended learning technology in PLM and e-learning in the Master of Science education system. It obviously requires academic staff to have enough knowledge, experience and skills to share blended learning technologies while also teaching the course content of PLM. Since the master's program will have a close relationship with existing PLM education and with the institutions where PLM has been used extensively, academic staff should also know how to use the e-learning tools directly in the teaching process. Members of each partner university and institution are sent to a German University to complete this training. The development of the curricula and the teaching materials is the responsibility of the five European Universities from Germany, Austria, Spain and Turkey to teach them at each partner university. The involvement of the PLM-experienced partner university with all partners will help to integrate the master's course with high quality and ensure the future viability of the master's course.

3.6. Pilot course for one selected e-learning module

The Connect4PLM project aims to create a new curriculum and e-learning platform for the PLM Master of Science program. The created curriculum is to be developed, created and implemented by the partner institutions. The concept of the pilot course will be exemplary for adapting several courses for PLM to e-learning. The prerequisite for the pilot course is a completed bachelor's degree in any engineering discipline. Interest and feedback from university teachers is very welcome! In our Pilot Course in PLM, we used Moodle. It suits our online platform perfectly, because the knowledge imparted by teachers needs to build the mind of the student, without so many books in between and, through collaborative learning. The individual approaches and strategies used by professors in different countries to impart knowledge to students and inspire them to learn are likely to build on academic training, instinct and intuition using the various teaching methods laid down in our curriculum. In May 2022, the Connect4PLM team conducted a pilot course as part of the 2nd Transnational Meeting. Each module was followed by an assessment of the learners' acquired knowledge, conducted after the hands-on activity. This finding is used to enhance learners' online experience and allow teachers to monitor their progress in real time.

4. PLM Curriculum structure

In the following we describe the concept, the didactic approach and the content of the courses, which were set up in cooperation and coordination with all project partners. The course concept builds on the one hand the needs of the students and the challenges and needs of the industry and on the other hand the pedagogical experiences of the activity partners (Fig.3)

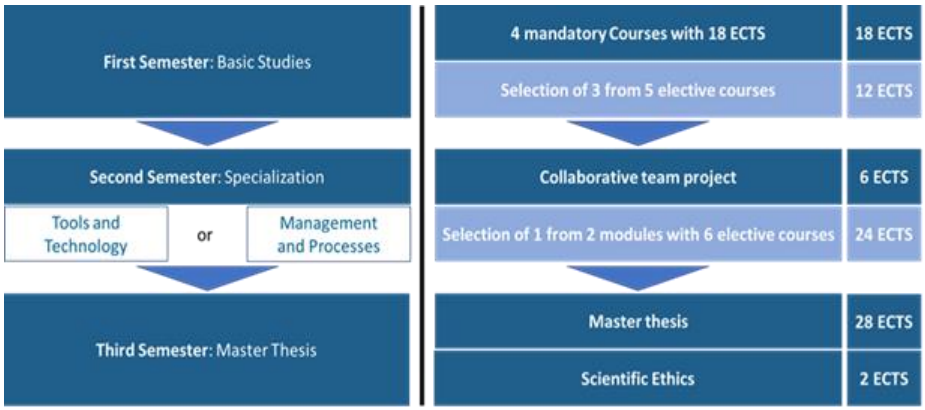

Fig. 3: Curriculum sequence and content

Several qualifications and prerequisites should be considered when implementing the master's program:

- Bachelor's Degree in a relevant field such as engineering, computer science, business, or a related discipline. The degree should be from an accredited institution.
- relevant work experience in areas related to PLM. It demonstrates practical knowledge, real-world application, and a clear understanding of the industry context.
- proficiency in the English language for international students. Applicants may need to submit English language test scores, such as TOEFL, to demonstrate their proficiency.
- technical skills to navigate online learning platforms, use communication tools, submit assignments, and engage in online discussions.
- prerequisite knowledge in relevant subjects: foundational knowledge in engineering principles, manufacturing processes, computer-aided design (CAD), supply chain management.

4.1. Basic Studies in PLM curriculum

The concept for the first semester, which provides the basic knowledge, is shown in detail in Fig.4. Here one can see the main focus which needs to be achieved. It consists of the four mandatory and five elective modules.

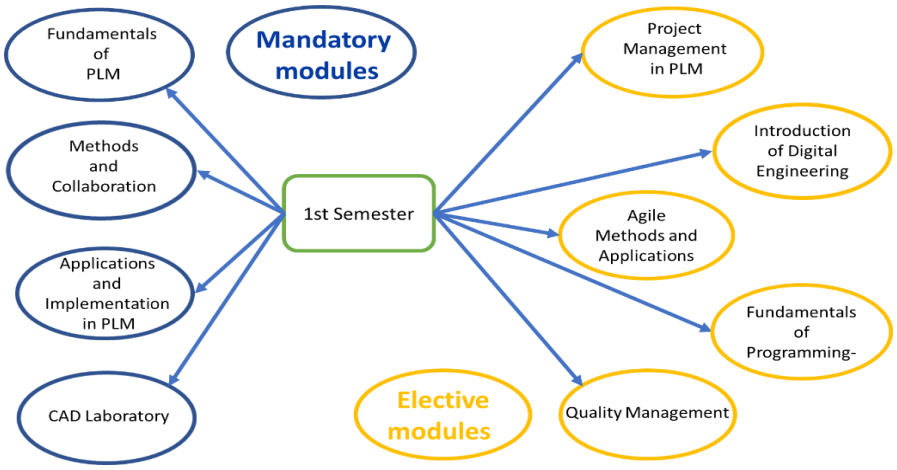

Fig. 4: Course structure overview 1st Semester

4.2 Specialization in PLM curriculum

The courses address not only bachelor students, but also all current and future employees of manufacturing companies - technicians, maintenance managers, industrial engineers, quality managers, production managers, etc. - in general for everyone who is interested in gaining more knowledge and practical experience in the area of PLM. Accordingly, the second term is divided in two main subject areas: "Tools and Technologies" and "Management and Processes" (Fig. 5). Each of them contain six selectable courses. The participants must choose out of these twelve courses at least six to achieve the requirements.

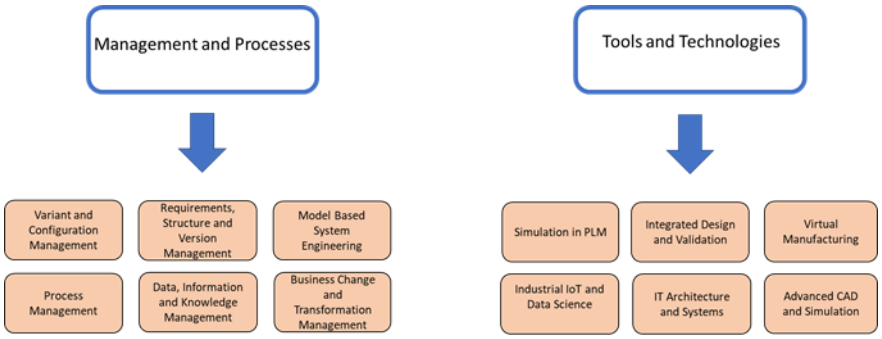

Fig. 5: Course structure 2nd Semester in specializations "Management and Processes" and "Tools and Technologies"

Furthermore a "Collaborative team project" will be mandatory for all students in the second term (Fig. 3). Many subjects are directly related to product life cycle

management. The project team will assure that all the lectures have a certain amount of overlapping throughout the chosen courses so that the intersections are suitable for many other topics in the field of product development and various fields in mechanical engineering.

4.3 Graduation semester in PLM curriculum

In the third semester, a master thesis with 30 Credit points (28cp+2cp) needs to be written. This completes the training and the academic degree Master of Science is awarded. The emerging trends of global multidisciplinary teams and the associated skills of cross disciplinary work in the field of PLM should be reflected in this master thesis. The graduates of the final semester are absolutely capable of dealing with the rapid development of current and emerging technologies which need to be understood and above all their potential has to be captured for the advancements of the industry.

5. Conclusion

The curriculum developed within the EU founded project Connect4PLM supports closing gap in the PLM education. This is suitable for bachelor graduates, who are aiming for a masters degree in PLM and young industrial professionals. Both meet the industry's needs, which is looking for well-trained and experienced engineers in the PLM area. On the one hand, the graduates are motivated to work in several production branches of the industry, on the other hand, young professionals are enabled to learn new technical topics that are valuable for their future leaders positions. Even if young engineers only have limited time in active professional life to take part in university courses, the present project will raise PLM training in multidisciplinary engineering areas to a new level. This makes a significant contribution to improve and expand the use of PLM solutions in industry applications. Furthermore, added value for companies that need excellently trained PLM graduates to solve complex projects is created.

The rapid developments in current technologies, both in industry and in university education, are taken in to account and the potential for further development in education is massively supported with the project. The specific PLM skills which graduates could need are addressed and represented in the proposed curriculum. The international design, considering also the emerging trends, is done by our global multidisciplinary Connect4PLM project team. The framework is currently being defined. The authors strive to create a comprehensive online platform that can be implemented in the next project.

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