

# MECHMATE

Strategic Partnership in the field of Mechatronics for innovative and smart growth of European manufacturing SMEs

## METHODOLOGY, CURRICULA AND GUIDELINES

2016-1-PL01-KA202-026350

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**Strategic Partnership in the field of Mechatronics for innovative and smart growth of European manufacturing SMEs (MechMate)**

## **MECHMATE METHODOLOGY**

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## PREFACE

This document as all of the MechMate project products is elaborated based on the results from a conducted desk research and focus groups with representatives of MechMate project target groups in Poland, Bulgaria, Estonia and Greece. The methodology as well as all other intellectual outputs included in the MechMate training is meant to reflect and address the training needs of the project target groups in the field of mechatronics and advanced technologies and to equip them with the necessary skills and competencies to effectively implement and use innovative mechatronic-based technologies into the everyday working processes.

The main aim of the MechMate Methodology is to provide a detailed didactic methodology by active participation of all partners. This document presents the MechMate methodology, which has been elaborated for the training course in Mechatronics applicable for managers and employees in SMEs and university students and teachers. This product is a core product for the project and is providing input for the platform development and integration. The Methodology combines new learning approaches including classical and e-learning.

The document is divided in the following sections:

- ☑ *Introduction to e-learning method* – provides general information on what e-learning is and which are the main features and advantages of the method compared to the traditional classroom training methods
- ☑ *Methods of e-learning* – presents the main domains or categories of learning which could be developed by applying e-learning methods as well as what are main types of e-learning.
- ☑ *E-learning content design* – provides information on how to perform task analysis with regard to developing e-learning serving specific occupational needs; presentation of Bloom's taxonomy applied for development of the MechMate learning methodology and the connection between the learning taxonomy and the MechMate learning platform.
- ☑ *The form of learning resources* – this short section describes the types of learning resources and the kind of knowledge they promote
- ☑ *Learning approach* – describes the self-paced e-learning approach
- ☑ *Just in time learning* – defines the fast knowledge and the sources of such
- ☑ *Online collaborative learning* - provides general information on the means for online collaborative learning
- ☑ *Assessing the quality of e-learning course* – this section defines some requirements which must be fulfilled in order to ensure high quality of the learning course
- ☑ *The e-learning platform of MechMate (Coursevo)* – this section presents the technical e-learning solution on which the MechMate training course is implemented. The section describes Coursevo services and course management as well as the main features of Coursevo ensuring efficient use of multimedia

- ☒ *Organisation of MechMate courses in Coursevo* - this section presents the organization and structuring of MechMate modules, implemented as courses in Coursevo.

## Table of Contents

PREFACE .....	3
List of Figures.....	6
List of Tables.....	6
Introduction.....	7
1 Introduction to e-learning method .....	9
2 Methods of e-learning.....	11
3 E-learning content design .....	13
4 The form of learning resources.....	20
5 Learning approach.....	20
6 Just in time learning .....	20
7 Online collaborative learning.....	20
8 Assessing the quality of e-learning course.....	21
9 The e-learning platform of MechMate (Coursevo).....	22
9.1 Coursevo services and course management .....	23
9.2 Coursevo features for efficient use of multimedia.....	24
10 Organization of MechMate Courses in Coursevo .....	26
11 References.....	28

## LIST OF FIGURES

Figure 3.1 Operational learning architecture (different qualities in learning context (Bloom's Taxonomy)).....	15
Figure 3.2 IT infrastructure for people working and learning in SMEs .....	16
Figure 3.3 The learning taxonomy and Mechmate e-learning platform .....	17
Figure 3.4 The architecture of a realization quality axis .....	18
Figure 3.5 Visualisation (Geometrization) of the realization architecture dimensions.....	18
Figure 3.6 Mechatronic system organization architecture dimensions (3D-Cartesian space, X, Y, Z dimensions) .....	19
Figure 3.7 Geometrization and visualization of higher-dimensional content of a concept ....	19
Figure 9.1. MechMate e-learning platform (main page) .....	23
Figure 10.1 Main page of a MechMate course in Coursevo .....	26
Figure 10.2 Organization of MechMate courses in Coursevo.....	27

## LIST OF TABLES

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## INTRODUCTION

The purpose of this guide is to provide detailed guidance on designing and developing an e-learning course for trainers and instructional designers who are preparing e-learning modules (courses) for MechMate project.

It also provides basic concepts and information on the processes and resources involved in e-learning development, which might be of interest to personal development and capacity-development managers (managers in SMEs).

The information in this guide is based on consolidated instructional design models and learning theories.

This guide focuses on formal learning, specifically on structured modules designed to meet adult learner's job-related training goals. The MechMate curricula includes 10 e-learning modules in the field of Mechatronics.

Each e-learning module within the curricula forms a self-contained training unit. The e-learning modules are available as training materials. Each module, implemented as a course on MechMate e-learning platform (Coursevo) is divided into lessons. Each lesson is accompanied by a presentation, a number of resources for further study (including advanced materials such as videos and animations), a self-assessment consisting of multiple choice questions to assess student's knowledge on the subject, and assignments to apply the theoretical knowledge gained in practice.

While there are several definitions of e-learning which reflect different perspectives, e-learning in this document is defined as follows: E-learning is defined as the use of computer and Internet technologies to deliver a broad array of information to people in form of solutions (applications, mechatronic processes, components) to enable learning and improve performance in real life.

In particular, adult learners:

- ☒ need to know the benefits of learning (why they have to learn something);
- ☒ like to learn experientially (understanding of the actual process does not command too much attention and the focus can instead be on the actual training contents);
- ☒ approach learning as problem-solving (Structured contents (instructions) help beginning learners to obtain an overview of what they are doing and enables advanced learners to skip certain individual steps when they are already familiar with the action);
- ☒ learn better where they can see the immediate value and application of content in real life (earn more money or exponentially increase cashflow);

- ☒ prefer to study at a time, place and pace convenient for them;
- ☒ prefer final checklist as a tool that is providing some feedback.

## 1 INTRODUCTION TO E-LEARNING METHOD

Because of the increasing number of requests for training and retraining from different EU countries, some vocational education centres are considering the option of including e-learning in the organization's training plan. At first they would like to know if e-learning is a convenient option for the SMEs and manufacturing organizations where most of adult people work, and if it can ensure the same effectiveness as traditional training.

Many SMEs are using e-learning because it can be as effective as traditional training at a lower cost [2].

Developing e-learning is commonly more expensive than preparing classroom materials and training the trainers, especially if modern multimedia (e.g. You Tube videos) or highly interactive (cloud based) methods are used. However, delivery costs for e-learning (including costs of web servers and technical support) are considerably lower than those for common classroom facilities because of instructor time, participants' travel and job time lost to attend classroom sessions.

E-learning easily reaches a much wider target audience by engaging learners who have difficulty attending conventional classroom training because they are:

- ☒ geographically dispersed with limited time and/or resources to travel;
- ☒ busy with work or family commitments which do not allow them to attend courses on specific dates with a fixed schedule;
- ☒ facing some difficulties with real-time communication (e.g. foreign language learners from different EU countries).

Some of the features of e-learning are:

- ☒ Learning is self-paced and gives learners a chance to speed up or slow down as necessary.
- ☒ Learning is self-directed, allowing learners to choose content and tools appropriate to their differing interests, needs, and skill levels.
- ☒ Accommodates multiple learning styles using a variety of delivery methods geared to different learners; more effective for certain learners.
- ☒ Designed around the learner.
- ☒ Geographical barriers are eliminated, opening up broader education options.
- ☒ 24/7 accessibility makes scheduling easy and allows a greater number of people to attend classes. On-demand access means learning can happen precisely when needed.
- ☒ Travel time and associated costs are reduced or eliminated.
- ☒ Fosters greater learner interaction and collaboration.
- ☒ Enhances computer and Internet skills.

- ☒ Draws upon hundreds of years of established pedagogical principles.

E-learning courses have certainly made a huge mark. Businesses, schools, and organizations find this a highly cost-effective tool in making the learning process more interactive, interesting, and fun. Countless reports, surveys, and studies have shown that e-learning industry is more fast-growing than ever. In fact, an increasing number of individuals, corporations, and institutions are turning to e-learning as they recognize its advantages.

## 2 METHODS OF E-LEARNING

E-learning can offer effective instructional methods, such as practising with associated feedback, combining collaboration activities with self-paced study, personalizing learning paths based on learners' needs and using simulation and games which also can implement the example technical process. Further, potential learners receive the same quality of instruction because there is no dependence on a specific instructor.

An e-training course may aim at developing different types of skills. These called also as domains or categories of learning. Commonly the three type of skills are considered:

- ☑ Cognitive skills, mental skills which can involve knowledge and comprehension (e.g. understanding of new information, new scientific concepts), following instructions (procedural skills), as well as applying known methods in new situations to solve problems (thinking or mental skills). Most e-learning courses are developed to build cognitive skills. The cognitive domain is the most suitable for e-learning. Within the cognitive domain, thinking skills may require more interactive e-learning activities because those skills obtained better “by doing”.
- ☑ Interpersonal skills, growth in feelings and emotional areas (e.g. skills involved in active listening, presenting, negotiating, empathy, attitude of mind, be interested etc.).
- ☑ Psychomotorical skills involving the acquisition of physical perceptions and movements (e.g. making specific real physical product). Development of these skills requires practice and is measured in terms of speed, precision, distance, procedures, or techniques in execution. Thus, psychomotor skills range from manual tasks, such as washing a machine, to more complex tasks, such as operating a complex piece of mechatronic machinery.

This taxonomy of learning behaviours may be thought of as “the goals of learning process”. The terms used here above tend to be little bigger than we normally use in everyday life.

The most cost-effective application of e-learning may be to complement conventional training in order to reach as many learners as possible (allows effective marketing of training courses). Conventional university or vocational school training course can include references to an existing e-learning course materials located in cloud-based Web servers. Deployment of well-known ontologies and ontology-based reconfiguration agents for intelligent mechatronic systems can help understanding of new concepts. E-learning is a good option for people from SMEs when:

- ☑ there is available a suitable amount of structured information (ontology-based content, stable operational architectures) to be delivered to a large number of learners;
- ☑ learners come from geographically dispersed locations, (e.g. from different regions or countries);

- ☒ learners have limited daily time to devote to learning;
- ☒ learners are required to develop homogeneous background knowledge on the topic;
- ☒ learners are highly motivated to learn and appreciate proceeding at their own pace;
- ☒ offered e-course or topic addresses long-term rather than short-term training needs.

There are two general approaches to modern e-learning:

- ☒ self-paced and
- ☒ facilitated/instructor-led.

Self-paced learners are alone and completely independent. Self-paced learners are offered e-learning courseware (called Web-based training (WBT)), which can be complemented by supplemental resources from Internet and self-assessments. The courseware commonly housed on a Web server, and learners can access it from an online learning platform. Learners are free to learn at their own pace and to define personal learning paths based on their individual needs and interests. E-learning providers do not have to schedule, manage or track learners through a linear learning process.

In instructor-led and facilitated e-learning model, a linear curriculum is developed. That integrates several content elements (knowledge, information) and activities into a chronological course or curricula. Course commonly scheduled through an online learning platform and led by an instructor. E-learning content for individual study can be connected with instructor's offered lectures, individual assignments, tasks and collaborative activities among participating learners. Learners, facilitators and instructors can use communication tools such as e-mails, discussion forums, chats, polls, whiteboards, and application sharing and audio and video conferencing to communicate and work together.

E-learning approaches combine different types of e-learning components (functions), including e-tutoring, e-coaching, e-mentoring; collaborative learning; and virtual classroom.

At the end, a final step typically includes an exercise or assessment to measure learning.

A virtual classroom is the instructional method most similar to traditional classroom training, as it is led completely by an instructor. This approach needs appropriate technology. It must be in place for both the learners and providers (e.g. software for the virtual classroom and very good data connectivity). Augment reality tools can support virtual classroom. Sometimes real laboratory equipment is also used. In some cases, e-learning students rent (book) this laboratory equipment for a short period.

### 3 E-LEARNING CONTENT DESIGN

Learning content is designed according to a set of learning objectives (goals) of the people working in SMEs. Daily work context (tasks) analysis is a prerequisite for developing specific learning objectives and the mechatronics curriculum outline. Task content analysis is probably the most critical step in the instructional design process. If the designer does not include accurate and relevant content, then there is little value in finding the best instructional methods and media to transfer the information to learners.

Task analysis is used mainly for courses designed to build specific work (job) related or interpersonal skills. The task analysis consists of four main steps:

- ☑ **Step 1.** Identify and describe tasks and for each task the corresponding lessons that learner should learn or improve specific skills to achieve the learning goals;
- ☑ **Step 2.** Classifying tasks as either:
  - a. procedural (i.e. tasks that are performed by executing an ordered sequence (a process) or functional steps; or
  - b. principle-based (i.e. tasks requiring judgments and decisions to be creatively applied in different situations and under conditions that change every time, such as “Organizing a product component manufacturing”).
- ☑ **Step 3.** Break each task logically into one or several works. Future if needed break each work to smaller steps or activities (for procedural works) or guidelines that should be applied to perform the work (for principle-based works).
- ☑ **Step 4.** Identify the knowledge and skills needed to best perform those steps or apply those guidelines.

Topic analysis is carried out to identify and classify the training module content. Topic analysis is appropriate for MechMate modules that are primarily designed to provide information or achieve broader educational objectives (also called “inform modules”).

Blended learning combines different training media (e.g. technologies, activities and events) to create an optimum training programme for a specific audience. The term “blended” means that traditional instructor-led training is being supplemented with electronic formats. Two main models of blended learning:

**1. Programme flow model:** Learning activities are organized in a linear, sequential order and learners have deadlines to accomplish the various assignments; this is similar to traditional training, but some of the activities are conducted online. The programme flow model is more suited for observable outcomes and assessment purposes (including later certification), since it enables formal tracking of learners’ progress. Programmes can be designed using one of several approaches:

An online pre-class event can be used to bring learners with different levels of knowledge and skill to the same level before the face to face (F2F) class begins. The online event can be an assignment. The instructor can review the results of the pre-class assignment for each learner and adjust the programme (curricula) for the F2F class by focusing on knowledge and skills gaps. This approach has several advantages over a traditional F2F approach, because it forces learners to come prepared to the classroom. It allows the design of more efficient classroom activities, which then tailored to the specific needs or interests of the participants and reduces the total time in classroom, which reduces costs. Online events can also be used to conclude a blended learning programme.

Another approach consists of starting with a core classroom event, followed by online independent experiences which can include, for example, interaction with online resources or e-mentoring services for continuous reinforcement. This approach could be used to develop communities of learners or to engage in further discussions on advanced topics of individual interest.

**2. Core-and-spoke model:** A major course (e-learning or F2F) is provided and a set of supplemental materials are available to reinforce the main course. These materials are optional and not scheduled.

An e-course provider predefines course organization (course structure, curricula) and an operational learning architecture framework (e.g. using Bloom's taxonomy) which then integrated into blended learning methodology [3]. Bloom's taxonomy is described in Figure 3.1.

This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. Bloom's learning taxonomy clearly presents different qualities (merits) of the learning processes. The Bloom taxonomy promote higher forms of thinking in education, such as analysing and evaluating principles, remembering and understanding basic concepts of technical processes, (mechatronic) tasks and work procedures. Cognitive learning domain should include **metacognitive** [4]. Metacognitive dimension - knowledge of cognition in general, as well as awareness and knowledge of one's own generalized cognition (wisdom). New learner can apply cognitive dimensions, predefined for specific domains.



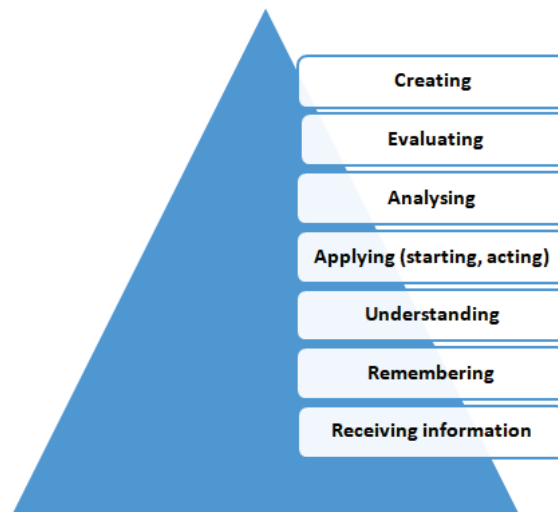


Figure 3.1 Operational learning architecture (different qualities in learning context (Bloom's Taxonomy))

At the beginning of learning, a learning subject must be able to **receiving** information. The information is available from different sources including books and internet sites. Information is received data with a defined meaning. For that, a metadata set or in other words, data about the data is used. Commonly glossaries and basic concepts definitions are used. Subject must understand words and the syntax of an applied language. Selection of the context for specific information is useful.

In cognitive domain **remembering** defined as recall or retrieve previous learned information.

**Understanding** described as comprehending the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem is one's own words.

**Applying** (first starting and then acting) is use of a concept in a new (learning) situation or unprompted use of an abstraction. Acting is mandatory to get some real results. Student applies what he learns in the classroom or e-learning environment into novel situations in the work place.

**Analysing** separates learning material or concepts of a mechatronic system into modules, components, and elements parts so that its organizational structure may be understood. Distinguishes between facts and inferences. A mechatronic system also can be separated into different operational levels (using a pre-established functional architecture or taxonomy) so that its complex functions may be understood .

**Evaluating** make judgements about the value of ideas or materials. The evaluating level (learning taxonomy level) is used to select the most effective solution for client or explain and justify a new budget.

**Creating** builds a system structure or pattern from diverse elements, components and modules. Put parts together to form a whole, with emphasis on creating a new meaning or structure. Examples: make documentation of a mechatronic machine (as organized product); describe operations or processes in manual for a worker; design an application to perform

specific technological tasks. Developer integrates training information from several sources to solve a problem. Revises technological process to improve the useful outcome. Keywords: categorizes, combines, compiles, devises, designs, explains, summarizes, writes manual.

The learning content is delivered using different devices (computer, laptop, smart phones), media elements, such as e-book text, graphics, audio and video [5]. It must provide as much learning support as possible (through explanations, examples, interactivity, feedback, glossaries, etc.), in order to make learners self-sufficient. Modern hybrid IT infrastructure integrates private (in-house) and open (public) cloud based resources (Figure 3.2).

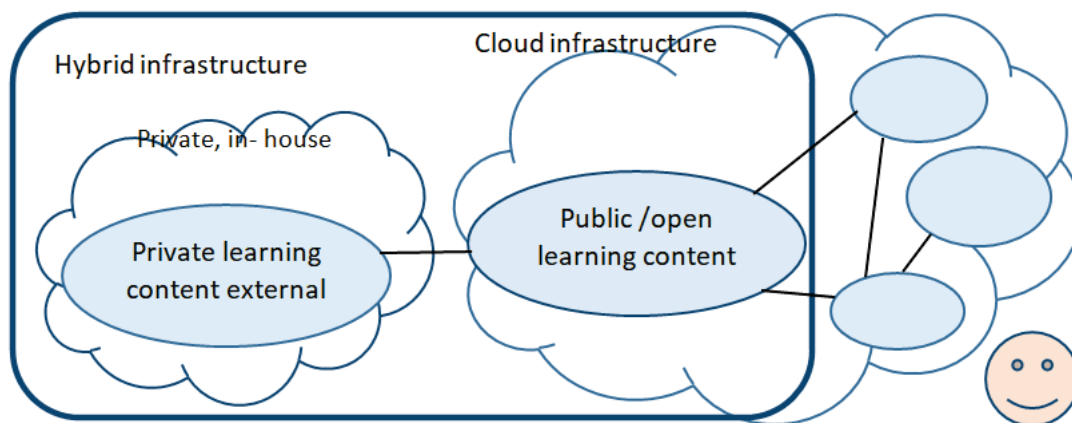


Figure 3.2 IT infrastructure for people working and learning in SMEs

MechMate project uses Bloom's taxonomy for development of the E-learning methodology.

The learning taxonomy and MechMate learning platform is shown visually in Figure 3.3.

The current mass customization era in production factories requires increased flexibility and agility in the mechatronic manufacturing systems to adapt changes in manufacturing requirements and in corresponding learning environments.

E-learning content in the field of mechatronics normally designed using a structured methodological tool or a software agent. The agent infers facts about the manufacturing environment and from the ontological knowledge model called mechatronic system organization and operational architecture framework [6]. The organization and operational architecture framework clarify relationship between different (existing) concepts and minimises overheads of the current reconfiguration processes implemented by e-learning content designers.

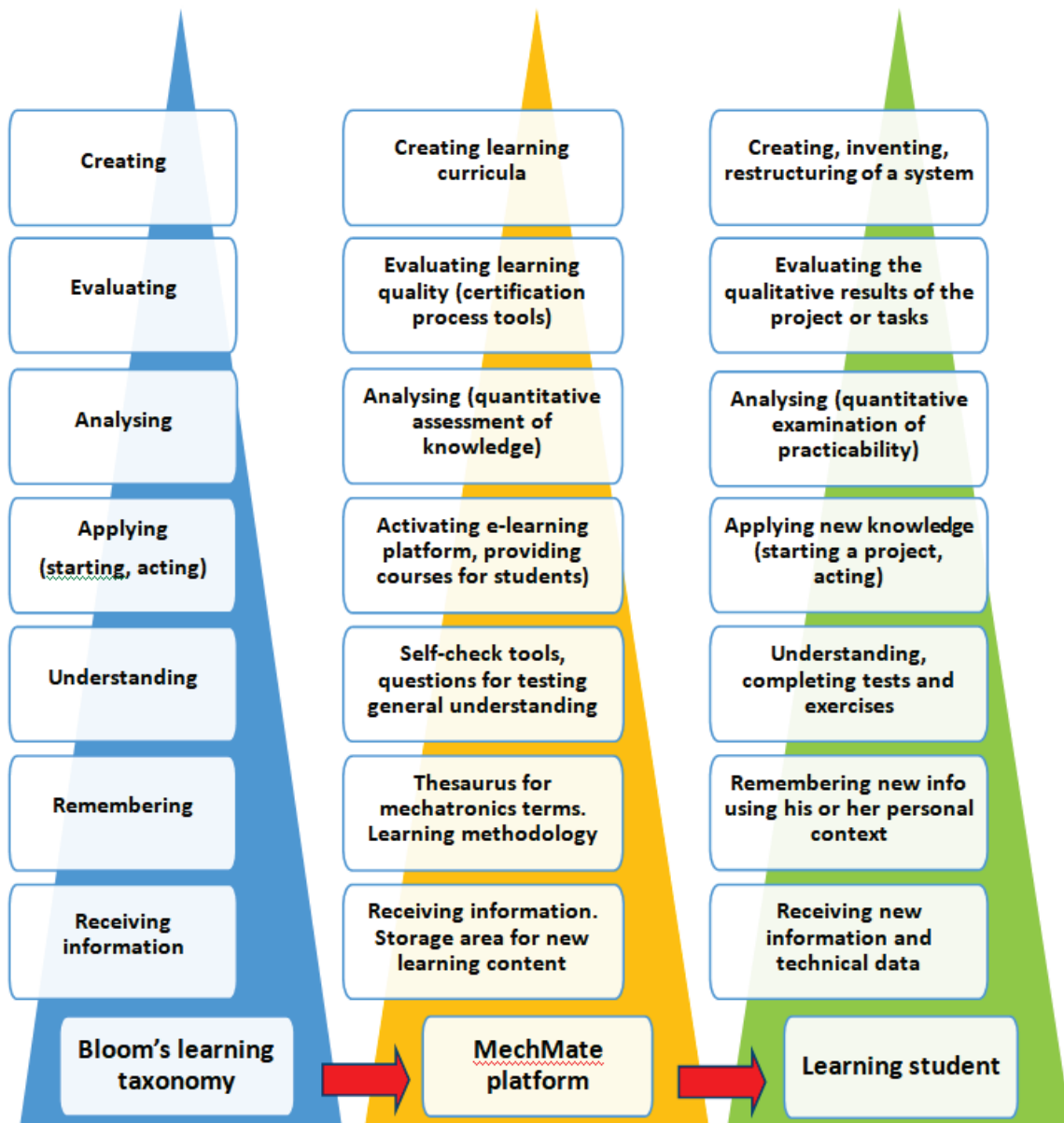


Figure 3.3 The learning taxonomy and Mechmate e-learning platform

Conceptual hierarchies (that is to say - taxonomies) are much deeper than a single mind ever needed to face before development of modern concepts named „Internet of Things” and “Industry 4.0”. Industry 4.0 is a global movement that has great impact on the modern industrial automation and particularly mechatronics.

An industrial mechatronic system realization (operation) quite sufficiently described with a set of dimensions. Dimensions are very useful tools (inventions) for a system description. Well-defined realization quality dimension (named Merit dimension,  $L$ ) presented in Figure 3.4. The merits architecture is described with corresponding taxonomy having 12 layers. Operational space dimensions  $L$ ,  $T$  and  $V$  (see Figure 3.5) and well-known organization architecture dimensions (exactly alike 3D-space dimensions, Figure 3.6) conjointly form new six-dimensional space framework (6D-space).

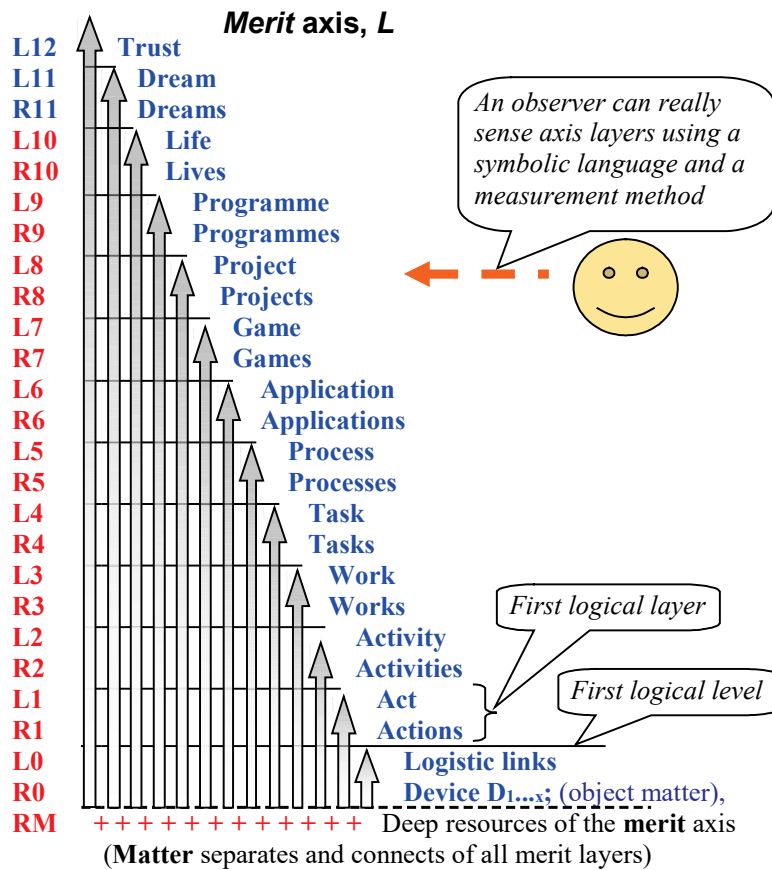


Figure 3.4 The architecture of a realization quality axis

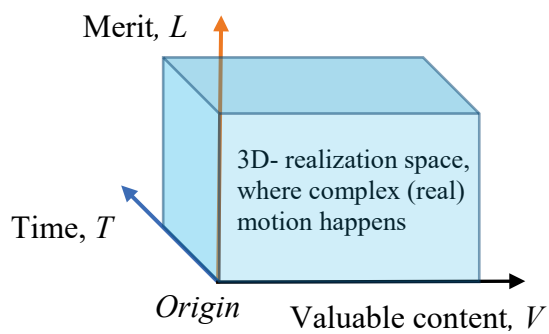


Figure 3.5 Visualisation (Geometrization) of the realization architecture dimensions

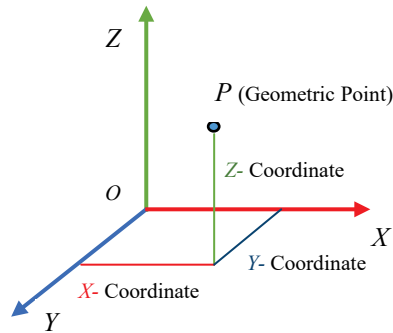


Figure 3.6 Mechatronic system organization architecture dimensions (3D-Cartesian space, X, Y, Z dimensions)

Material content, defined by a concept (logical) name and temporal (logistic) links to the action of the concept is realized outside the 3D points. The geometrized 6D action is illustrated (visualized) in Figure 3.7. A set of steadily bounded different actions of matter (described with a conceptual name) is generally called (named) a ***motion***.

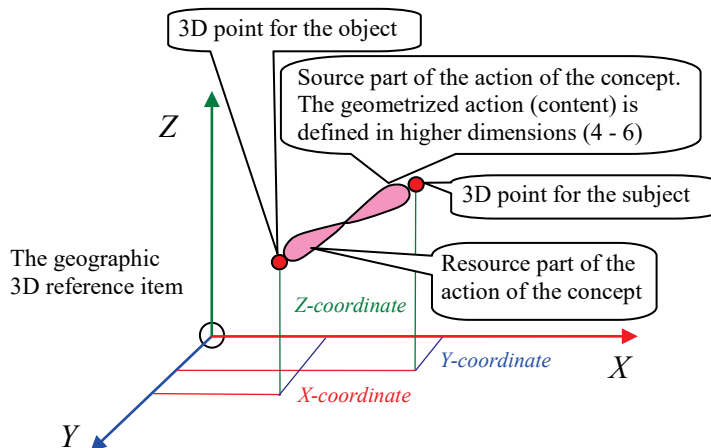


Figure 3.7 Geometrization and visualization of higher-dimensional content of a concept

6D-space is new tool that used in MechMate project for development of E-learning courses. For example, such framework is also reflected indirectly in a user interface design of PLC programming tools like Siemens TIA Portal. Because the PLC hardware configuration can be performed and learned independent of a specific manufacturing tasks this topic has been placed first. The topic of hardware configuration (generally **organization**) is subdivided again into the hardware configuration of the various controllers that are available. The subsequent chapters describe functions and function blocks used during programming of mechatronic processes (or generally **realization** of a distributed application), also counters and timers, analog values and “global data blocks” round out this topic area. Some e-learning tools implement the example process as a simulation.

#### 4 THE FORM OF LEARNING RESOURCES

E-learning content can include simple learning resources, interactive e-lessons, electronic simulations, and real job aids.

Simple learning resources are non-interactive resources such as documents, PowerPoint presentations, videos or audio files. These learning materials are non-interactive in the sense that learners can only read or watch content without performing any other specific action. When they clearly match defined learning objectives and designed in a structured way using an agreed taxonomy, they can be a valuable learning resource even though they sometimes do not provide or need any interactivity. Simple learning resources are more suitable for getting **long-time knowledge**. Such deeply structured learning resources give to student a general overview of a topic.

#### 5 LEARNING APPROACH

The most common approach for self-paced e-learning is Web-portal based training consisting of a set of interactive e-lessons. An e-lesson is a linear sequence of screens, which can include text, graphics, animations, audio, video and interactivity in the form of predefined questions and feedback. E-lessons can also include recommended reading and links to recommended online resources, as well as additional information on specific topics. Computer based simulations are highly interactive forms of e-learning.

#### 6 JUST IN TIME LEARNING

Advanced job aids provide just-in-time knowledge. Such sources provide practical information for acquiring so called fast knowledge. They are very useful for people working in SMEs. They usually provide immediate answers to specific questions about user interface of the technology and usable manufacturing methods, thus helping users accomplish job task. Technical glossaries provide particular context info. Mobile phones with downloaded apps and special checklists are a few examples of simple job aids. Sophisticated expert systems (e.g. decentralized apps or dapps) can be developed to assist SME workers in complex decision-making situations.

#### 7 ONLINE COLLABORATIVE LEARNING

Collaborative activities range from discussions and knowledge-sharing to working together on a common study project (common prescribed application). Social software, such as chats, discussion forums and blogs, are used for online collaboration among learners in different field of activity including mechatronics.

## 8 ASSESSING THE QUALITY OF E-LEARNING COURSE

The quality of an e-learning course is normally enhanced by learner-centred content structure. Some requirements must be fulfilled:

- ☑ Relevant e-learning curricula should be predesigned and it should be specific to learners' needs, roles and responsibilities in professional life;
- ☑ Professional information, knowledge and skills (obtained also through practical exercises) should be provided to this end;
- ☑ E-learning content should be segmented to facilitate assimilation of new knowledge and to allow flexible scheduling of time for learning;
- ☑ Instructional methods and techniques should be used creatively to develop an engaging and motivating learning experience;
- ☑ Self-paced courses should be customizable to reflect learners' interests and real needs.
- ☑ During learning process a professional electronic development, tools or platforms (for example a multi-platform software development kit (SDK) should be used that allow wider implementation of obtained skills in everyday working life.
- ☑ A suite of reference apps (use cases) can be considered, interactive overlays in learning documentation (e.g. augment reality), interactive in-video interactivity to speed up provision of information and just-in-time services (e.g. supporting In-video shopping);

## 9 THE E-LEARNING PLATFORM OF MECHMATE (COURSEVO)

The global competitiveness in economy the last years confirmed the need for an investment in knowledge development, to ensure not only basic literacies but also to secure research development and growth for a sustainable future [1]. To address this need the traditional model of education is not enough. We should underline, though, that traditional education, mainly relying on the so called “industrial model” of organization and management was an important innovation in itself as it brought education to the masses of people in the western countries, initially, and then to the whole world. For many years this model has prevailed, producing a sustainable education model and ensuring a steady flow of individuals to the tertiary sector. With the advent of the computer and the possibility of technology for the masses a belief was affirmed amongst governments and educationalists that technology would take education forward and there would be even greater benefits. This belief led to huge investments in the purchase of various types of hardware and software systems that would render the organization a solution that would not only meet their needs but surpass their expectations.

The prevailing mentality coupled with the “industrial model” of teaching is that the introduction of digital technology is the critical factor to modernize teaching and reap the benefits of ICT [1]. This mentality is promoted by technology vendors that seek a way to increase their sales as well as governments that want an easy way to advertise their willingness to put forward “educational reforms”. However, this prevailing mentality and resulting policies, fail to follow the practice of people when it comes to the use of technology for learning, especially outside the walls of classrooms. With the proliferation of ubiquitous computing technologies (especially mobile technologies) and the wide use of social networks to promote new personal learning opportunities, many people worldwide pursue a personalized approach to technology use and learning [6]. This personalized mode of learning, which flourishes outside official educational systems and their “industrial mode” of teaching presents many challenges and opportunities for effective integration into mainstream education and professional training. This new way of learning is ideal for addressing life-long learning settings, especially when it comes to the need to continuously update and extend the technical knowledge of engineers, technologists and teachers in related disciplines.

To adequately address this need of recognizing and promoting the personalized use of technology to meet individual learning and training needs, there is a clear need to design and develop appropriate learning platforms and use them within appropriate learning and training frameworks for diverse learning modes ranging from face-to-face teaching and training to distant-learning [1]. Pedagogical approaches that are focusing explicitly in the integration of technology to enable the set-up of learning environments that promote personalization are directly or indirectly related to the theory of constructivism [7], a paradigm for teaching and learning that promotes personalization and rich interactions to offer opportunities for knowledge construction in a personally meaningful manner.



Such a platform is Coursevo, used as the e-learning platform of MechMate. Coursevo [1] is a multilingual multimedia information system for managing courses, supporting learning processes and learning communities through the Web, developed by the Laboratory of Distributed Multimedia Information Systems and Applications of the Technical University of Crete (TUC/MUSIC). It implements modern pedagogical approaches and supports blended learning.

The MechMate project e-learning platform can be accessed from:

<http://mechmate.coursevo.com>

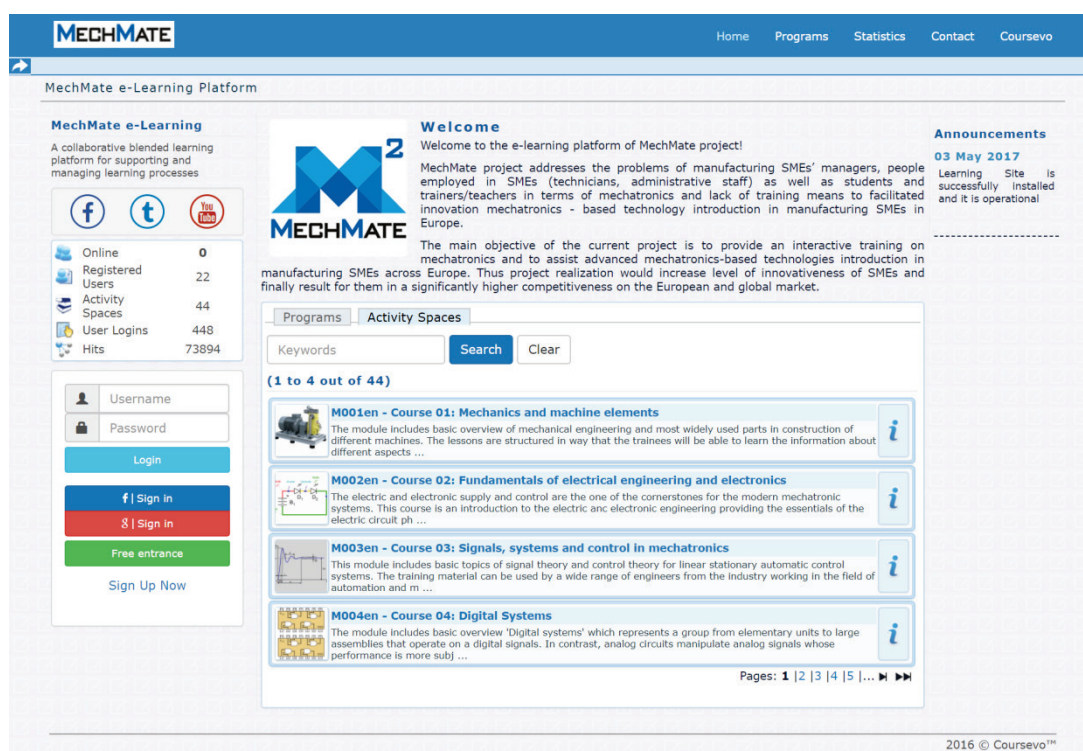


Figure 9.1. MechMate e-learning platform (main page)

## 9.1 Coursevo services and course management

Coursevo offers a set of services for:

- ☑ **Organization and management of digital educational content:** Lectures' presentations and recordings, notes, exercises, technical lab material, literature, FAQs etc.
- ☑ **Course attendance:** Announcements, email messages, course calendar, personal rating, automatic track of exercises and deadlines, content update messages, course syllabus, learning path, assessment tests, and generation of course certificates.

- ☑ **Learning communities' communication and collaboration:** Course and group mailing lists, live chat rooms, forums, polls, personal messaging, instant messaging, annotation tools, file sharing, video conferencing and collaboration.
- ☑ **Educational activities:** Courses registration, lab teams' formation, exercise uploads and deadline management, assessment tests, multimedia presentations, resource scheduling and reservations.
- ☑ **Course monitoring:** Course usage statistics and class performance indicators.
- ☑ **Interoperability** with other educational platforms via SCORM packages.

Each course can be configured to follow specific registration and content access policies. The educators are able to activate the proper subset of course services depending on the course needs. They can use services and tools that allow for easy content creation and web publishing. They have the ability to use common office applications for document creation. These documents can be processed by Coursevo for indexing purposes and then published in a web friendly presentation format.

Besides office documents, educators are able to upload images, videos and SCORM Sharable Content Objects (SCOs) or quickly and simply re-use existing content in the web that is accessible in popular web platforms like YouTube, Slideshare and Wikipedia. All the above course content can be combined with other Coursevo services like video-lectures, forums, assessments etc. and organized in different learning paths in order to meet diverse educational needs.

### ***9.2 Coursevo features for efficient use of multimedia***

Coursevo provides an integrated educational environment for synchronous and asynchronous learning that offers significant advantages in comparison with other eLearning systems: It gives emphasis in the use of multimedia as a powerful learning means.

Indeed, learning activities using multiple media can be more effective than doing it through a single medium (such as text), but what is important is combining media effectively. Effective multimedia for learning requires carefully combining media in well reasoned ways that take advantage of each medium's unique characteristics. The most effective multimedia provides learning experiences that mirror real-world experiences and let learners apply the content in various contexts.

In particular, the features offered by Coursevo regarding the efficient educational use of multimedia are the following:

- ☑ Effective support of multimedia and video/audio data streams management.
- ☑ Mechanisms for the synchronization of multimedia presentations.
- ☑ Support of synchronous and asynchronous learning activities.
- ☑ Support of live synchronized multimedia transmission through the system, and access to the recorded multimedia content.

- ☒ Support of learners' intervention in live sessions.
- ☒ Multimedia educational content creation in two ways:
  - Through the Web-based interface without the need for specialized software installations.
  - Through an autonomous desktop application (Coursevo Studio) for the offline creation of high-quality video presentations with automatic slide synchronization that can be easily exported and published at a later time. The Coursevo Studio supports also the generation of demonstrations and presentations of software by capturing the screen, recording the speaker and the presentation of slides.
- ☒ Communication tools to support educational communities:
  - Live video chat between online users.
  - Video Conferencing Services with collaboration tools employing BigBlueButton (<http://bigbluebutton.org/>).
  - Asynchronous multimedia communication messages.
- ☒ Advanced multimedia collaborative annotation tools on educational materials using multimedia.

## 10 ORGANIZATION OF MECHMATE COURSES IN COURSEVO

Each module forms a self-contained training unit implemented as a course in MechMate e-learning platform (Coursevo), also supported by a number of services for communication and collaboration (Figure 10.1).



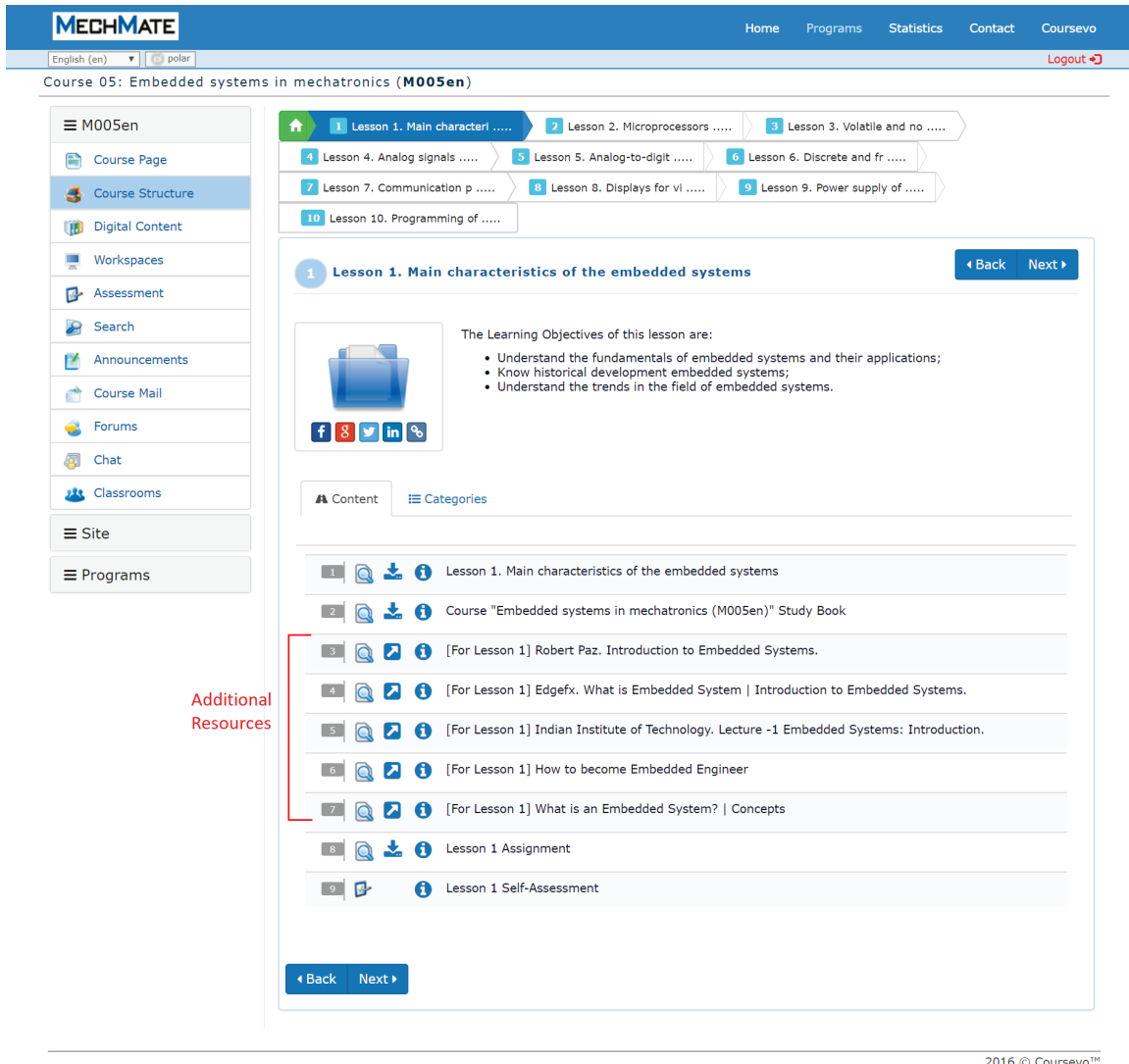
The screenshot shows the Coursevo interface for 'Course 05: Embedded systems in mechatronics'. The interface includes a top navigation bar with links to Home, Programs, Statistics, Contact, and Coursevo. A sidebar on the left contains a menu with options like Course Page, Course Structure, Digital Content, Workspaces, Assessment, Search, Announcements, Course Mail, Forums, Chat, Classrooms, Site, and Programs. The main content area displays the course title, a brief description, and a list of objectives. It also features a 'Free registration' section with a 'Register in Course' button and a 'Registration Deadline' section with an 'Open' button. A 'Keywords' section lists 'embedded systems' and 'mechatronics'. Below this, there are sections for 'Course Structure' and 'Program - Category'. The 'Course Structure' section lists three lessons: 'Lesson 1. Main characteristics of the embedded systems', 'Lesson 2. Microprocessors and microcontrollers in embedded systems', and 'Lesson 3. Volatile and nonvolatile memories used'. The 'Program - Category' section lists 'MechMate training program on Mechatronics (English)' and 'MechMate courses'. A 'Course Syllabus' section includes a 'Download file' button and a 'References - Links' button. At the bottom, there is a 'Hits' section with a bar chart showing the number of hits for each month from September to August. The chart shows a significant increase in hits in November, reaching over 1000.

Month	Hits
Sep	~100
Oct	~200
Nov	~1100
May	~100
Aug	~100

Figure 10.1 Main page of a MechMate course in Coursevo

A module is divided into lessons. Each lesson is accompanied by a presentation, a number of resources for further study (including advanced materials such as videos and animations), a self-assessment consisting of multiple choice questions to assess student's knowledge on the subject, and assignments to apply the theoretical knowledge gained in practice (Figure 10.2). Each module has a study book and is also accompanied by a syllabus, which is available for downloading, containing a short description of the module, its learning objectives and

contributors, and its structure, e.g. its lessons, their learning objectives and content (Figure 10.1).



MECHMATE

Home Programs Statistics Contact Coursevo

English (en) polar Logout

Course 05: Embedded systems in mechatronics (M005en)

M005en

- Course Page
- Course Structure
- Digital Content
- Workspaces
- Assessment
- Search
- Announcements
- Course Mail
- Forums
- Chat
- Classrooms
- Site
- Programs

Lesson 1. Main characteristics of the embedded systems

Lesson 2. Microprocessors

Lesson 3. Volatile and no

Lesson 4. Analog signals

Lesson 5. Analog-to-digit

Lesson 6. Discrete and fr

Lesson 7. Communication p

Lesson 8. Displays for vi

Lesson 9. Power supply of

Lesson 10. Programming of

1 Lesson 1. Main characteristics of the embedded systems

Back Next

The Learning Objectives of this lesson are:

- Understand the fundamentals of embedded systems and their applications;
- Know historical development embedded systems;
- Understand the trends in the field of embedded systems.

Content Categories

1 Lesson 1. Main characteristics of the embedded systems

2 Course "Embedded systems in mechatronics (M005en)" Study Book

3 [For Lesson 1] Robert Paz. Introduction to Embedded Systems.

4 [For Lesson 1] Edgefx. What is Embedded System | Introduction to Embedded Systems.

5 [For Lesson 1] Indian Institute of Technology. Lecture -1 Embedded Systems: Introduction.

6 [For Lesson 1] How to become Embedded Engineer

7 [For Lesson 1] What is an Embedded System? | Concepts

8 Lesson 1 Assignment

9 Lesson 1 Self-Assessment

Back Next

Additional Resources

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Figure 10.2 Organization of MechMate courses in Coursevo

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**Strategic Partnership in the field of Mechatronics for innovative and smart growth of European manufacturing SMEs (MechMate)**

## **MECHMATE CURRICULA**

### **PARTNERS**

**INDUSTRIAL INSTITUTE OF AUTOMATION AND MEASUREMENTS (PIAP)**

**TECHNICAL UNIVERSITY OF GABROVO (TUGAB)**

**TALLINN UNIVERSITY OF TECHNOLOGY (TALTECH)**

**TECHNICAL UNIVERSITY OF CRETE (TUC)**

**EUROPEAN CENTER OF QUALITY (ECQ)**





## PREFACE

This book contains the curricula of the 10 modules developed in the context of MechMate project “Strategic Partnership in the field of Mechatronics for innovative and smart growth of European manufacturing SMEs” (project No. 2016-1-PL01-KA202-026350), executed within the framework of Erasmus+ Programme, KA2-Cooperation and Innovation for Good Practices, funded by European Union - Project website: <http://www.mechmate.eu>

These modules have been implemented as e-learning courses on MechMate e-learning platform (Coursevo). To attend the full online courses of MechMate, implemented on MechMate e-learning platform based on MechMate methodology, please visit:

<https://mechmate.coursevo.com/>

## Curricula

**Mechanics and machine elements (M001)**

**Fundamentals of electrical engineering and electronics (M002)**

**Signals, systems and control in mechatronics (M003)**

**Digital Systems (M004)**

**Embedded systems in mechatronics (M005)**

**Communication interfaces and protocols (M006)**

**PLC systems (M007)**

**Measurement and data acquisition (M008)**

**Sensors in mechatronics (M009)**

**Actuators in mechatronics (M010)**



## Table of Contents

PREFACE .....	3
Curricula .....	3
<b>M001 - MECHANICS AND MACHINE ELEMENTS .....</b>	<b>11</b>
<i>Syllabus</i> .....	11
<b>Learning objectives</b> .....	<b>11</b>
<b>Course Structure</b> .....	<b>11</b>
<i>Learning Objectives</i> .....	12
<i>Content of the Lesson</i> .....	12
<b>Lesson 2: Basic strength of materials</b> .....	<b>12</b>
<i>Learning Objectives</i> .....	12
<i>Content of the Lesson</i> .....	13
<b>Lesson 3: Drive components</b> .....	<b>13</b>
<i>Learning Objectives</i> .....	13
<i>Content of the Lesson</i> .....	13
<b>Lesson 4: Shafts</b> .....	<b>13</b>
<i>Learning Objectives</i> .....	13
<i>Content of the Lesson</i> .....	14
<b>Lesson 5: Bearings</b> .....	<b>14</b>
<i>Learning Objectives</i> .....	14
<i>Content of the Lesson</i> .....	14
<b>M002 - FUNDAMENTALS OF ELECTRICAL ENGINEERING AND ELECTRONICS .....</b>	<b>15</b>
<i>Syllabus</i> .....	15
<b>Learning objectives</b> .....	<b>15</b>
<b>Course Structure</b> .....	<b>16</b>
<b>Lesson 1: Electric and Electronic Circuits, Basic Terms and Structure</b> .....	<b>16</b>
<i>Learning Objectives</i> .....	16
<i>Content of the Lesson</i> .....	16
<b>Lesson 2: Circuit elements, components and concepts</b> .....	<b>17</b>
<i>Learning Objectives</i> .....	17
<i>Content of the Lesson</i> .....	17
<b>Lesson 3: Kirchhoff's current law</b> .....	<b>18</b>
<i>Learning Objectives</i> .....	18
<i>Content of the Lesson</i> .....	18
<b>Lesson 4: Kirchhoff's voltage law</b> .....	<b>18</b>
<i>Learning Objectives</i> .....	18
<i>Content of the Lesson</i> .....	19
<b>M003 - SIGNALS, SYSTEMS AND CONTROL IN MECHATRONICS .....</b>	<b>20</b>
<i>Syllabus</i> .....	20
<b>Learning objectives</b> .....	<b>20</b>
<b>Course Structure</b> .....	<b>21</b>
<b>Lesson 1: Signals. Classification of signals</b> .....	<b>21</b>
<i>Learning Objectives</i> .....	21
<i>Content of the Lesson</i> .....	21
<b>Lesson 2: Systems. Basic definitions</b> .....	<b>22</b>

<i>Learning Objectives</i> .....	22
<i>Content of the Lesson</i> .....	22
<b>Lesson 3: A brief classification of control systems</b> .....	22
<i>Learning Objectives</i> .....	22
<i>Content of the Lesson</i> .....	23
<b>Lesson 4: Basic types of linear systems models</b> .....	23
<i>Learning Objectives</i> .....	23
<i>Content of the Lesson</i> .....	23
<b>Lesson 5: Elementary dynamic systems. Rules for connection of dynamic systems</b> .....	23
<i>Learning Objectives</i> .....	24
<i>Content of the Lesson</i> .....	24
<b>Lesson 6: Stability of linear systems</b> .....	24
<i>Learning Objectives</i> .....	24
<i>Content of the Lesson</i> .....	24
<b>Lesson 7: Quality indicators of control systems. Basic types of linear controllers</b> .....	25
<i>Learning Objectives</i> .....	25
<i>Content of the Lesson</i> .....	25
<b>M004 - DIGITAL SYSTEMS</b> .....	26
<b>Syllabus</b> .....	26
<b>Learning objectives</b> .....	26
<b>Course Structure</b> .....	27
<b>Lesson 1: Analog vs. Digital</b> .....	27
<i>Learning Objectives</i> .....	27
<i>Content of the Lesson</i> .....	27
<b>Lesson 2: Number systems</b> .....	27
<i>Learning Objectives</i> .....	27
<i>Content of the Lesson</i> .....	28
<b>Lesson 3: Digital circuits/Logic circuits</b> .....	28
<i>Learning Objectives</i> .....	28
<i>Content of the Lesson</i> .....	28
<b>Lesson 4: Programmable Logic Devices</b> .....	29
<i>Learning Objectives</i> .....	29
<i>Content of the Lesson</i> .....	29
<b>Lesson 5: Microcontroller, Microprocessor</b> .....	29
<i>Learning Objectives</i> .....	29
<i>Content of the Lesson</i> .....	30
<b>M005 - EMBEDDED SYSTEMS</b> .....	31
<b>Syllabus</b> .....	31
<b>Learning objectives</b> .....	31
<b>Course Structure</b> .....	31
<b>Lesson 1: Main characteristics of the embedded systems</b> .....	32
<i>Learning Objectives</i> .....	32
<i>Content of the Lesson</i> .....	32
<b>Lesson 2: Microprocessors and microcontrollers in embedded systems</b> .....	32
<i>Learning Objectives</i> .....	32

<i>Content of the Lesson</i> .....	32
<b>Lesson 3: Volatile and non-volatile memories used in embedded systems</b> .....	33
<i>Learning Objectives</i> .....	33
<i>Content of the Lesson</i> .....	33
<b>Lesson 4: Analog signals and electronic circuits for their processing</b> .....	33
<i>Learning Objectives</i> .....	33
<i>Content of the Lesson</i> .....	33
<b>Lesson 5: Analog-to-digital and digital-to-analog converters in embedded systems</b> .....	33
<i>Learning Objectives</i> .....	33
<i>Content of the Lesson</i> .....	34
<b>Lesson 6: Discrete and frequency signals in embedded systems</b> .....	34
<i>Learning Objectives</i> .....	34
<i>Content of the Lesson</i> .....	34
<b>Lesson 7: Communication protocols in embedded systems</b> .....	34
<i>Learning Objectives</i> .....	34
<i>Content of the Lesson</i> .....	35
<b>Lesson 8: Displays for visualization of information</b> .....	35
<i>Learning Objectives</i> .....	35
<i>Content of the Lesson</i> .....	35
<b>Lesson 9: Power supply of the embedded systems</b> .....	35
<i>Learning Objectives</i> .....	35
<i>Content of the Lesson</i> .....	35
<b>Lesson 10: Programming of the embedded systems</b> .....	36
<i>Learning Objectives</i> .....	36
<i>Content of the Lesson</i> .....	36
<b>M006 - Communication interfaces and protocols</b> .....	37
<b>Syllabus</b> .....	37
<b>Learning objectives</b> .....	37
<b>Course Structure</b> .....	38
<b>Lesson 1: Introduction to industrial communication networks</b> .....	38
<i>Learning Objectives</i> .....	38
<i>Content of the Lesson</i> .....	38
<b>Lesson 2: Communication network</b> .....	39
<i>Learning Objectives</i> .....	39
<i>Content of the Lesson</i> .....	39
<b>Lesson 3: Network topologies and models</b> .....	39
<i>Learning Objectives</i> .....	39
<i>Content of the Lesson</i> .....	39
<b>Lesson 4: Industrial Field Networks. General Characteristics</b> .....	40
<i>Learning Objectives</i> .....	40
<i>Content of the Lesson</i> .....	40
<b>Lesson 5: Specification for Profibus field networks</b> .....	40
<i>Learning Objectives</i> .....	40
<i>Content of the Lesson</i> .....	40
<b>Lesson 6: CANBUS and MODBUS communication protocol</b> .....	41

<i>Learning Objectives</i> .....	41
<i>Content of the Lesson</i> .....	41
<b>Lesson 7: Industrial networks of control level. Network specification ControlNet</b> .....	41
<i>Learning Objectives</i> .....	41
<i>Content of the Lesson</i> .....	42
<b>Lesson 8: Industrial networks of information level</b> .....	42
<i>Learning Objectives</i> .....	42
<i>Content of the Lesson</i> .....	42
<b>Lesson 9: Ethernet network specification</b> .....	42
<i>Learning Objectives</i> .....	42
<i>Content of the Lesson</i> .....	42
<b>Lesson 10: Wireless communications in industrial environment</b> .....	43
<i>Learning Objectives</i> .....	43
<i>Content of the Lesson</i> .....	43
<b>M007 - PLC Systems</b> .....	44
<b>Syllabus</b> .....	44
<b>Learning objectives</b> .....	44
<b>Course Structure</b> .....	45
<b>Lesson 1: Programmable logic controller</b> .....	45
<i>Learning Objectives</i> .....	45
<i>Content of the Lesson</i> .....	45
<b>Lesson 2: PLC programming</b> .....	46
<i>Learning Objectives</i> .....	46
<i>Content of the Lesson</i> .....	46
<b>Lesson 3: First project using Siemens S7-1200 PLC</b> .....	47
<i>Learning Objectives</i> .....	47
<i>Content of the Lesson</i> .....	47
<b>Lesson 4: Basic Boolean logic functions</b> .....	47
<i>Learning Objectives</i> .....	47
<i>Content of the Lesson</i> .....	47
<b>Lesson 5: Advanced Boolean logic functions</b> .....	47
<i>Learning Objectives</i> .....	47
<i>Content of the Lesson</i> .....	48
<b>Lesson 6: Transfer and program control functions</b> .....	48
<i>Learning Objectives</i> .....	48
<i>Content of the Lesson</i> .....	48
<b>Lesson 7: Math and conversion functions</b> .....	49
<i>Learning Objectives</i> .....	49
<i>Content of the Lesson</i> .....	49
<b>Lesson 8: PID control</b> .....	49
<i>Learning Objectives</i> .....	49
<i>Content of the Lesson</i> .....	50
<b>Lesson 9: Control of an application with one pneumatic cylinder</b> .....	50
<i>Learning Objectives</i> .....	50
<i>Content of the Lesson</i> .....	50

<b>Lesson 10: Control of an application with two pneumatic cylinders .....</b>	<b>51</b>
<i>Learning Objectives .....</i>	<i>51</i>
<i>Content of the Lesson .....</i>	<i>51</i>
<b>Lesson 11: Control of an application with a frequency converter.....</b>	<b>51</b>
<i>Learning Objectives .....</i>	<i>51</i>
<i>Content of the Lesson .....</i>	<i>52</i>
<b>Lesson 12: PLC selection, safety and commissioning .....</b>	<b>52</b>
<i>Learning Objectives .....</i>	<i>52</i>
<i>Content of the Lesson .....</i>	<i>52</i>
<b>M008 - MEASUREMENTS AND DATA ACQUISITION .....</b>	<b>53</b>
<b>Syllabus .....</b>	<b>53</b>
<b>Learning objectives.....</b>	<b>53</b>
<b>Course Structure .....</b>	<b>53</b>
<i>Learning Objectives .....</i>	<i>54</i>
<i>Content of the Lesson .....</i>	<i>54</i>
<b>Lesson 2: Signals theory .....</b>	<b>54</b>
<i>Learning Objectives .....</i>	<i>54</i>
<i>Content of the Lesson .....</i>	<i>55</i>
<i>Learning Objectives .....</i>	<i>55</i>
<i>Content of the Lesson .....</i>	<i>55</i>
<b>Lesson 4: Measuring transducer, errors .....</b>	<b>55</b>
<i>Learning Objectives .....</i>	<i>55</i>
<i>Content of the Lesson .....</i>	<i>56</i>
<b>Lesson 5: Measuring systems .....</b>	<b>56</b>
<i>Learning Objectives .....</i>	<i>56</i>
<i>Content of the Lesson .....</i>	<i>56</i>
<b>M009 - Sensors in Mechatronics .....</b>	<b>57</b>
<b>Syllabus .....</b>	<b>57</b>
<b>Learning objectives.....</b>	<b>57</b>
<b>Course Structure .....</b>	<b>57</b>
<b>Lesson 1: Sensor Classification .....</b>	<b>58</b>
<i>Learning Objectives .....</i>	<i>58</i>
<i>Content of the Lesson .....</i>	<i>58</i>
<b>Lesson 2: Sensor Characteristics .....</b>	<b>58</b>
<i>Learning Objectives .....</i>	<i>58</i>
<i>Content of the Lesson .....</i>	<i>58</i>
<b>Lesson 3: Position and Displacement Sensors.....</b>	<b>59</b>
<i>Learning Objectives .....</i>	<i>59</i>
<i>Content of the Lesson .....</i>	<i>59</i>
<b>Lesson 4: Force, Strain, and Tactile Sensors .....</b>	<b>60</b>
<i>Learning Objectives .....</i>	<i>60</i>
<i>Content of the Lesson .....</i>	<i>60</i>
<b>Lesson 5: Inertial Sensors .....</b>	<b>60</b>
<i>Learning Objectives .....</i>	<i>60</i>
<i>Content of the Lesson .....</i>	<i>60</i>

<b>Lesson 6: Pressure Sensors</b> .....	61
<i>Learning Objectives</i> .....	61
<i>Content of the Lesson</i> .....	61
<b>Lesson 7: Flow Sensors</b> .....	61
<i>Learning Objectives</i> .....	61
<i>Content of the Lesson</i> .....	61
<b>Lesson 8: Proximity, Object Detection and Level Sensors</b> .....	62
<i>Learning Objectives</i> .....	62
<i>Content of the Lesson</i> .....	62
<b>Lesson 9: Temperature Sensors</b> .....	63
<i>Learning Objectives</i> .....	63
<i>Content of the Lesson</i> .....	63
<b>M010 - Actuators in Mechatronics</b> .....	64
<b>Syllabus</b> .....	64
<b>Learning objectives</b> .....	64
<b>Course Structure</b> .....	64
<b>Lesson 1: Introduction</b> .....	65
<i>Learning Objectives</i> .....	65
<i>Content of the Lesson</i> .....	65
<b>Lesson 2: Electro-mechanical conversion</b> .....	66
<i>Learning Objectives</i> .....	66
<i>Content of the Lesson</i> .....	66
<b>Lesson 3: Power electronic converters</b> .....	66
<i>Learning Objectives</i> .....	66
<i>Content of the Lesson</i> .....	67
<b>Lesson 4: Electric drives</b> .....	67
<i>Learning Objectives</i> .....	67
<i>Content of the Lesson</i> .....	67
<b>Lesson 5: Pneumatic and hydraulic actuators</b> .....	67
<i>Learning Objectives</i> .....	67
<i>Content of the Lesson</i> .....	68



## M001 - MECHANICS AND MACHINE ELEMENTS

### *Syllabus*

The module includes basic overview of mechanical engineering and most widely used parts in construction of different machines. The lessons are structured in way that the trainees will be able to learn the information about different aspects of mechanical engineering and to understand the basic principles that stay behind them.

#### Learning objectives

Upon completion of this course the students will be able to:

- Apply the fundamental principles of mechanics and strength of materials
- Distinguish the different elements used in the machine construction
- Design the complex driving system with a chosen method of transferring the power
- Use the basic formulas, simple software and the catalogues to select the required elements

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#### Course Structure

The course is divided into 5 lessons. Each lesson is accompanied by a presentation, a number of resources for further study, a self-assessment consisting of multiple choice questions to assess your knowledge on the subject, and exercises/assignments to apply the knowledge you gained in practice.

The course consists of the following lessons:

## Lesson 1: Basic mechanics

The lesson contains revision of the basic principles of mechanics and examples of their real-life application. It is necessary for the strength of materials and design calculations.

### *Learning Objectives*

- Understanding what Mechanics is
- Being able to distinguish the static and dynamic analyses cases
- Recallment of the basic laws and relationships applied in Mechanics
- Becoming familiar with the basic principles of work presented for the simple machines, to facilitate further learning about the specific machines' parts

### *Content of the Lesson*

- Introduction
- Forces
- Torques
- Momenta
- Energy
- Simple machines

## Lesson 2: Basic strength of materials

The lesson explains internal forces and stresses occurring in the object. Their repercussions are presented as well and illustrated with the relevant examples.

### *Learning Objectives*

- Understanding the theory of the strength of materials
- Being able to create a geometrical model and calculate the internal forces
- Awareness of the different deformation types based on the types of the loads
- Being able to solve the basic cases
- Understanding the complex cases
- Awareness of the different material parameters

### *Content of the Lesson*

- Theoretical introduction
- A beam and its constraints – the geometrical model of an object
- Internal forces in the beam
- Expansion, compression, bending and torsion
- Materials

### **Lesson 3: Drive components**

The lesson presents the variety of drive components and their applications. It covers engines and motors as well as power transmission systems.

### *Learning Objectives*

- Being able to distinguish between different types of motors
- Understanding the practical approach towards selection of the motor
- Awareness of the aim of the gears and being able to distinguish their different type, as well as to choose the most appropriate one
- Understanding an idea of the belting systems applications and being able to calculate the correlated parameters
- Being able to distinguish between different types of couplings and to select the one for the given purpose

### *Content of the Lesson*

- Motors
- Gears
- Belts
- Couplings

### **Lesson 4: Shafts**

The lesson presents the shafts' design. It covers the keys and methods of assembling as well.

### *Learning Objectives*

- Understanding the purpose of shafts' usage
- Awareness of the different shafts' elements, useful for the assembling and decreasing the inner stresses
- Being able to distinguish the different types of keys and to choose the best for the particular case
- Being able to calculate the parameters of the shaft and the key for the given design intent
- Understanding the purpose of the different fits and tolerances, especially useful for the designing of the shafts

#### *Content of the Lesson*

- Shafts basics
- Designing the shafts
- Keys
- Keys' selection
- Fits and tolerances

### **Lesson 5: Bearings**

The lesson presents the basic Types of bearings, their application and their geometries.

#### *Learning Objectives*

- Understanding the purpose of the usage of the bearings
- Awareness of the different types of bearings and the ability to choose the most appropriate one for the particular case
- Being able to choose the adequate locking system for the particular case and to know which modifications are necessary to use it for the assembly
- Being able to select the bearing for the particular case with the use of a presented method and the catalogue data

#### *Content of the Lesson*

- Theory
- Types of bearings
- Locking methods
- Selection of a bearing

## M002 - FUNDAMENTALS OF ELECTRICAL ENGINEERING AND ELECTRONICS

### *Syllabus*

The electric and electronic supply and control are the one of the cornerstones for the modern mechatronic systems. This course is an introduction to the electric and electronic engineering providing the essentials of the electric circuit physical phenomena description, working circuit creation and description, and the essential rules and methods for the electric and electronic circuit analysis and calculation. Using the essentials for electrical and electronic engineering, students can further develop their skills with application-specific circuit design and analysis for the other fields of digital and information engineering, control engineering etc. where the electric signals are used for passing the sensed, measured and processed information. Electric energy delivery in specific portion in the mechatronic system is mandatory for guaranteeing reaching the control targets via the electric motors and actuators of different kinds.

### Learning objectives

Upon completion of this course basic module the students will be able to:

- Understand the role of electric and electronic systems for the delivery of energy in different forms;
- Describe the main electric quantities, such as voltage and current in electric circuits, and their role of delivery of power and energy;
- Understand the physical nature of electric current and voltage, and can measure the values of this in an electric circuit;
- Describe the components in the electric circuit, present the components of an electric circuit with schematic symbols and present a simpler circuit with a schematic;
- Can describe the rules for the currents calculations through a junction using the Kirchhoff's current law;
- Can describe the parallel and series circuits using equivalent resistance components; can calculate the equivalent resistance values;
- Can describe and analyse the circuit operation using the Kirchhoff's voltage law;
- Understands the concepts of current and voltage dividers, can use the calculation rules of such circuits for analysis.

## Contributors

Prof. Lauri Kütt, Tallinn University of Technology (TalTech).

## Course Structure

The basic course is divided into basic and extended parts. The basic course includes 4 lessons. Each lesson is accompanied by a presentation, a number of resources for further study, a self-assessment consisting of multiple choice questions to assess your knowledge on the subject, and exercises/assignments to apply the knowledge you gained in practice.

The course consists of the following lessons:

### Lesson 1: Electric and Electronic Circuits, Basic Terms and Structure

#### *Learning Objectives*

Upon completion of this lesson the students will be able to:

- Understand the meaning and role of energy in a electric and mechatronic system
- Identify the main parts electric system, and explain the roles of these systems: source, transmission and control, load.
- Describe the main electric terms of charge, interactions of charged particles and electric current.
- Explain the terms of voltage and potential, ground potential.
- Describe the units and quantities related to electric energy, electric power and efficiency of the electric system.
- Calculate the power and energy of the electric sources and loads.
- Describe the terms of resistance, explain the Ohm's law physical background, characteristic resistance and conductor resistance.
- Describe the differences between conductor and insulator materials.

#### *Content of the Lesson*

##### Introduction

- Energy and its conversion
  - Different forms of energy
  - Energy conversion, transmission and control in an electric system

- Transmission and control system
- Electric charges, current and voltage in energy transfer
  - Charged particles
  - Forces between charges
  - Electric current
- Voltage and potential
  - View of power and energy in the circuit through voltage and current
- Resistance
  - Ohm's law
  - Conductors
  - Insulators and semiconductors

## Lesson 2: Circuit elements, components and concepts

### *Learning Objectives*

Upon completion of this lesson the students will be able to

- Describe the components and connections of the components in an electric circuit;
- Draw a schematic of some simpler circuits, featuring power sources, switches and loads;
- Describe the connections between the components using ideal wires, branches, junctions points;
- Explain the difference between series and parallel connected components;
- Describe the operation of a circuit, including terms of open circuit, closed circuit and short circuit;
- Understands the role and function of switches in the electrical circuits;
- Can identify nodes and branches in a simpler electric circuit.

### *Content of the Lesson*

- Circuit elements, components and concepts
  - Conductor and connections markings
  - Logical symbols and reference designators
  - Current passage control and switches
- Circuit topology and operation
  - Closed circuit and simple node
  - Branches and complex nodes

- Measurement of electric quantities
  - Current measurement
  - Measurement of voltage
  - Measurement of resistance

### Lesson 3: Kirchhoff's current law

#### *Learning Objectives*

- Upon completion of this lesson the students will be able to
- Understand the physical phenomena of current preservation in a junction point;
- Describe the current preservation rules for junctions with numerous connections;
- Establish the mathematical relations of currents for a specific junction in a practical schematic;
- Understand the operation of parallel circuit and calculate the currents and voltages of each component in the parallel circuit;
- Substitute the circuit with several parallel components with a single equivalent resistance component; calculate the equivalent resistance values;
- Describe the concept of current dividing circuit, and calculate the current values in different branches using the current divider calculation rules.

#### *Content of the Lesson*

- Current preservation in a junction
  - Junction with 2 connections
  - Junction with numerous connections
- Kirchhoff's current law
- Parallel circuit
  - Parallel circuit equivalent resistance
  - Current divider

### Lesson 4: Kirchhoff's voltage law

#### *Learning Objectives*

Upon completion of this lesson the students will be able to

- Describe the physical operation, including voltage drops and voltage levels in a series connected circuit;



- Describe the rules of proportionality for the voltages, power ratings and resistance in a series connected branches;
- Use the general KVL presentation to describe the loops of the simpler series and parallel circuits, to mark the current and voltage values for the circuits.
- Establish the circuits mathematical descriptions using the KVL principles, for the series and parallel circuits;
- Can describe the series circuit with its equivalent resistance component and calculate the equivalent resistance value;
- Can use the concepts of voltage divider to design the circuits where a specific voltage is required (with very light load).

#### *Content of the Lesson*

- Current and voltage in series connected circuit
- Rules of proportionality for resistance, power and voltage
- Kirchhoff's voltage law
  - KVL example for the series connected circuit
  - KVL example for the case of parallel circuit
- Series circuit equivalent resistance
- Voltage divider

## M003 - SIGNALS, SYSTEMS AND CONTROL IN MECHATRONICS

### *Syllabus*

This module includes basic topics of signal theory and control theory for linear stationary automatic control systems. The training material can be used by a wide range of engineers from the industry working in the field of automation and mechatronic systems, as well as by students from technical universities.

For the adequate acquisition of the learning material, basic knowledge from the higher mathematics is required - solving of linear differential equations, Laplace transformation, actions with complex numbers and matrices, etc., and for understanding some of the exemplary tasks - elementary knowledge in some technical sciences such as electrical engineering and mechanics is required.

The learning material is structured in seven lessons.

### Learning objectives

Upon completion of this course the students will be able to:

- Understand the basic principles of control systems, which are used to build automation systems of industrial applications.
- Define the basic types of control (input) signals, used in the large variety of systems in mechatronics.
- Describe the main types of control systems in terms of different classification signs.
- Work with the main types of mathematical models to describe the behavior of the system – differential equation and transfer function.
- Understand the concept of presenting the automatic control system as a combination of simple subsystems called elementary dynamic systems.
- Define the basic types of elementary dynamic systems used in control theory.
- Define the three main types of connections of dynamic systems.
- Understand the concept of stability of control systems and the general condition for system stability is shown.
- Assess the stability of a system according to the Hurwitz stability criterion.

- Define the main qualitative indicators in control systems.
- Define the basic types of linear regulators - P, I, PI, PD and PID.

### Contributors

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### Course Structure

The course includes seven lessons. Each lesson is accompanied by a corresponding presentation, a number of resources for further study and self-assessment consisting of multiple choice questions to assess your knowledge on the subject and some exercises/assignments to apply the knowledge you gained in practice.

The course consists of the following lessons:

#### Lesson 1: Signals. Classification of signals

This lesson defines the main types of signals used in mechatronics. Classification of signals is given according to different signs.

#### *Learning Objectives*

- To acquaint the trainees with the main types of signals used in mechatronics;
- Understand what is a signal;
- To make different classifications of signals;
- To define the most common control signals – the unit step function and the unit impulse function.

#### *Content of the Lesson*

- Signals. Classification of signals
  - Classification of signals
    - Classification by “continuity”
    - Classification by “determinism”
    - Even /odd signals
    - Classification by “periodicity”

- Main types of signals in the control systems
  - Unit step function
  - Unit impulse function (Dirac delta function)
  - Unit sinusoidal function (Unit sine function)
  - Polynomial-type signals

## Lesson 2: Systems. Basic definitions

This lesson defines the concept of an automatic control system. The four basic principles for building automatic control systems are presented.

### *Learning Objectives*

- To define the main principles of automatic control systems;
- To acquaint the trainees with the principle of negative feedback control;
- To define one-dimensional and multi-dimensional systems.

### *Content of the Lesson*

- Systems. Basic definitions
  - Basic definitions and concepts
  - Principles of automatic control systems
    - Open loop control systems
    - Control systems operating on the principle of disturbance
    - Control systems operating on the principle of deviation. The feedback principle
    - Control systems operating simultaneously on the principles of disturbance and deviation
    - An example illustrating the basic control principles

## Lesson 3: A brief classification of control systems

In this lesson, a classification of control systems is given according to different signs - linearity, dynamism, etc.

### *Learning Objectives*

- A brief classification of the control systems according to various signs is given to provide a general overview of the main classes of systems.

### *Content of the Lesson*

- A brief classification of control systems
  - Classification of automatic control systems by “linearity”
  - Classification of automatic control systems by the principle of control
  - Classification of automatic control systems by “stationarity”
  - Classification of automatic control systems according to their purpose
  - Classification of automatic control systems by “dynamism”

### **Lesson 4: Basic types of linear systems models**

In this lesson the basic types of mathematical models that are used in the classical control theory are presented - differential equation and transfer function.

### *Learning Objectives*

- To understand the difference between physical and mathematical model;
- To understand the difference between the analysis and the synthesis tasks;
- To define the two approaches for creating a mathematical model of a system: the identification approach and the mathematical modelling approach;
- To define the five types of mathematical models used in the control theory;
- To examine in detail the models of type „differential equation“;
- To examine in detail the models of type „transfer function“.

### *Content of the Lesson*

- Basic types of linear systems models
  - Mathematical models. Basic definitions
  - Mathematical models of control systems of type “differential equation”
  - Mathematical models of control systems of type “transfer function”

### **Lesson 5: Elementary dynamic systems. Rules for connection of dynamic systems**

This lesson presents the concept of presenting the automatic control system as a combination of simple subsystems called elementary dynamic systems. The basic types of elementary dynamic systems used in control theory are discussed in detail. In the second part of the lesson the three main types of connection of dynamic systems are presented.

### *Learning Objectives*

- To acquaint the trainees with the concept of decomposing a system into smaller elementary subsystems;
- To acquaint the trainees with the basic types of elementary dynamical systems;
- To understand the rules for connection of dynamic systems;
- To solve tasks for equivalent structural transformations.

### *Content of the Lesson*

- Elementary dynamic systems. Rules for connection of dynamic systems
  - Basic types of elementary dynamic systems
    - Proportional system
    - Integrating system
    - Aperiodic system of first order
    - Oscillatory system
    - Differentiating system
    - Ideal delay system
  - Rules for connection of dynamic systems
    - Sequential connection
    - Parallel connection
    - Feedback coupling
    - Equivalent structural transformations

## **Lesson 6: Stability of linear systems**

This lesson addresses issues related to the stability of control systems. The general condition for system stability is shown. The Hurwitz stability criterion is presented.

### *Learning Objectives*

- To understand the concept of stability;
- To define the basic requirements for system stability for linear systems;
- To define the main stability condition;
- To define the Hurwitz stability criterion.

### *Content of the Lesson*

- Stability of linear systems

- Definition of stability. A basic condition for system stability
- Hurwitz stability criterion

### **Lesson 7: Quality indicators of control systems. Basic types of linear controllers**

This lesson defines the main qualitative indicators in control systems. The basic types of linear regulators are considered - P, I, PI, PD and PID.

#### *Learning Objectives*

- To define the main qualitative indicators of automatic control systems such as response time, error in settled mode, etc.;
- To define basic types of controllers in automatic control systems;
- To define the advantages and disadvantages of the different controllers.

#### *Content of the Lesson*

- Quality indicators of control systems. Basic types of linear controllers
  - Quality indicators of automatic control systems
  - Basic types of controllers in automatic control systems
    - Proportional controller (P-controller)
    - Integral controller (I-controller)
    - Proportional-Integral controller (PI-controller)
    - Proportional-Derivative controller (PD-controller)
    - Proportional-Integral-Derivative controller (PID-controller)

## M004 - DIGITAL SYSTEMS

### *Syllabus*

The module includes basic overview 'Digital systems' which represents a group from elementary units to large assemblies that operate on digital signals. In contrast, analog circuits manipulate analog signals whose performance is more subject to manufacturing tolerance, signal attenuation and noise. Digital techniques are helpful because it is a lot easier to get an electronic device to switch into one of a number of known states than to accurately reproduce a continuous range of values.

In today's world, the term digital has become part of our everyday vocabulary because of the dramatic way that digital circuits and digital techniques have become so widely used in almost all areas of life: computers, automation, robots, medical science and technology, transportation, telecommunications, entertainment, space exploration, and on and on. You are about to begin an exciting educational journey in which you will discover the fundamental principles, concepts, and operations that are common to digital systems, from the simplest on/off switch to the most complex computer. You should gain a initial understanding of how all digital systems work, and you should be able to apply this understanding to the analysis and troubleshooting of any digital system.

### Learning objectives

Upon completion of this course the students will be able to:

- Understand the fundamentals of digital signals and digital systems
- Be aware how digital systems cope with analog world
- Distinguish the different elements used to build complex digital circuits
- Design the complex facilities using basic building blocks (logic gates)
- Use and count in different numeric systems and convert numbers between them
- Distinguish the difference between microcontrollers and microprocessors and apply a proper solution to project

### Contributors

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## Course Structure

The course is divided into 5 lessons. Each lesson is accompanied by a presentation, a number of resources for further study, a self-assessment consisting of multiple choice questions to assess your knowledge on the subject, and exercises/assignments to apply the knowledge you gained in practice.

The course consists of the following lessons:

### Lesson 1: Analog vs. Digital

#### *Learning Objectives*

- Understanding what is an analog signal;
- Understanding what is a digital signal;
- Distinguish between analog and digital representations;
- Cite the advantages and drawbacks of digital techniques compared with analog;
- Understand the need for analog-to-digital converters (ADCs) and digital-to-analog converters (DACs).

#### *Content of the Lesson*

- Introduction
- Analog signal
- Digital signal
- Analog vs. Digital

### Lesson 2: Number systems

#### *Learning Objectives*

- Recognize the basic characteristics of the binary number system;
- Convert a binary number to its decimal equivalent;
- Count in the binary number system;

- Understand octal and hexadecimal number system;
- Identify the advantages of octal and hexadecimal number systems in use with digital systems;
- Convert a number to its equivalent in different number systems.

#### *Content of the Lesson*

- Introduction
- Decimal Number System
- Binary Number System
- Octal Number System
- Hexadecimal Number System
- Number Systems – Some Common Terms
- Conversion between number systems
- Representing Binary Quantities

### **Lesson 3: Digital circuits/Logic circuits**

#### *Learning Objectives*

- Understand the principles of digital circuits;
- Perform the three basic logic operations;
- Describe the operation of and construct the truth tables for the AND, NAND, OR and NOR gates, and the NOT (INVERTER) circuit;
- Write the Boolean expression for the logic gates and combinations of logic gates;
- Implement logic circuits using basic AND, OR, and NOT gates;
- Use either of the universal gates (NAND or NOR) to implement a circuit represented by a Boolean expression.

#### *Content of the Lesson*

- Introduction
- Logic Gates
- Basic integrated circuits

## Lesson 4: Programmable Logic Devices

### *Learning Objectives*

- Describe the fundamental idea of programmable logic devices;
- Awareness of the different PLD implementations;
- Being able to distinguish the different PLD types;
- Define PLD terminology;
- Compare the different programming technologies used in PLDs;
- Compare the architectures of different types of PLDs.

### *Content of the Lesson*

- Introduction
- Programmable ROM
- Programmable Logic Array
- Programmable Array Logic
- Generic Array Logic
- Complex Programmable Logic Device
- Field-Programmable Gate Array
- Programming Languages

## Lesson 5: Microcontroller, Microprocessor

### *Learning Objectives*

- Understanding the fundamental differences between a microprocessor and a microcontroller;
- Awareness about some of the major application areas of microcontrollers;
- Being able to describe the hardware components are likely to be found inside a typical microcontroller and microprocessor;
- Compare eight-bit, 16-bit and 32-bit microcontrollers with reference to internal hardware structure;
- Describe the parameters that you would consider while choosing the right microprocessor for your application.

*Content of the Lesson*

- Introduction to the Microcontroller
- Applications
- Inside the Microcontroller
- Introduction to Microprocessors
- Evolution of Microprocessors
- Inside a Microprocessor

## M005 - EMBEDDED SYSTEMS

### *Syllabus*

This course is an introductory to embedded system used in mechatronics, focusing on the underlying principles of how embedded systems work. In the module are presented the main parts of one embedded system and is given brief information about its main parts as microprocessor, memory, interfaces, etc.

The information included in the course is prepared for personnel working in small and medium enterprises and concerns basic topics related to the fields of mechatronics and industry automation.

### Learning objectives

Upon completion of this course the students will be able to:

- Understand the main principles of embedded systems;
- Know the main components included in the structure of one embedded system;
- Know the main classifications of microprocessor architectures;
- Know the main types of memories used in embedded systems;
- Understand the principles of operation of analog-to-digital and digital-to-analog converters;
- Know the most often used communication standards for inter chip communication;
- Know the main topologies of power supply systems used in embedded systems.

### Contributors

Associate Professor Stefan Ivanov, Technical University of Gabrovo (TUGAB)

Assistant Professor Todor Todorov, Technical University of Gabrovo (TUGAB)

### Course Structure

The course book is divided into 10 lessons. The lessons are accompanied by a presentation, a number of resources for further study, a self-assessment consisting of multiple-choice

questions to assess your knowledge on the subject, and assignments for gathering of new theoretical knowledge.

The course book consists of the following lessons:

### **Lesson 1: Main characteristics of the embedded systems**

#### *Learning Objectives*

- Understand the fundamentals of embedded systems and their applications;
- Know historical development embedded systems;
- Understand the trends in the field of embedded systems.

#### *Content of the Lesson*

- Introduction
- Structure and main components of the embedded systems
- Historical development of embedded systems
- Trends in the development of the embedded systems

### **Lesson 2: Microprocessors and microcontrollers in embedded systems**

#### *Learning Objectives*

- Understand the basics in the architecture of microprocessors;
- Understand the difference between microprocessors and microcontrollers;
- Know the main architectures of microprocessors;
- Know the historical trends in the field of microprocessors and microcontrollers.

#### *Content of the Lesson*

- Introduction
- Historical development of microprocessors
- Architecture of modern microprocessors and microcontrollers
- Microprocessors and microcontrollers. Main characteristics
- Current trends in microcontrollers

### **Lesson 3: Volatile and non-volatile memories used in embedded systems**

#### *Learning Objectives*

- Understand the difference between volatile and non-volatile memories;
- Know the main types of memories used in embedded systems;
- Know the principle of operation of RAM memories;
- Understand the difference between ROM, PROM, EPROM, EEPROM and Flash memories.

#### *Content of the Lesson*

- Introduction
- Memories

### **Lesson 4: Analog signals and electronic circuits for their processing**

#### *Learning Objectives*

- Understand the main characteristics of analogue signals;
- Identify the circuits used for analog processing of signals;
- Understand the principle of work of operational amplifiers;
- Know the most often used circuits based on operation amplifiers.

#### *Content of the Lesson*

- Introduction
- Analog signals and analog signal processing
- Operational Amplifiers
- Basic circuits with operational amplifiers
- Analog Comparators. Principle of operation.

### **Lesson 5: Analog-to-digital and digital-to-analog converters in embedded systems**

#### *Learning Objectives*

- Understand the principle of analog-to-digital conversion;

- Understand the principle of digital-to-analog conversion;
- Know different types of ADCs;
- Know different types of DACs.

#### *Content of the Lesson*

- Introduction
- Converting of signals
- Analog-to-digital converters
- Digital-to-analog converters

### **Lesson 6: Discrete and frequency signals in embedded systems**

#### *Learning Objectives*

- Understand different logic levels used in embedded system;
- Understand the principle of operation of pulse width modulation (PWM);
- Know how the inputs and outputs of one embedded system are protected from high voltages.

#### *Content of the Lesson*

- Introduction
- Discrete and frequency signals
- Levels of logical signals
- Digital inputs and outputs of embedded systems

### **Lesson 7: Communication protocols in embedded systems**

#### *Learning Objectives*

- Describe the communication interfaces and their principles;
- Understand of SPI interface;
- Understand of I2C interface;
- Understand of UART interface.



### *Content of the Lesson*

- Introduction
- Serial peripheral interface (SPI)
- Serial I<sup>2</sup>C interface
- Universal Asynchronous Receiver Transmitter - UART

## **Lesson 8: Displays for visualization of information**

### *Learning Objectives*

- Describe the working principle of different types of displays;
- Know about LED indicators;
- Understand the principle of operation of LCD displays;
- Understand the principle of operation of OLED displays.

### *Content of the Lesson*

- Introduction
- LED - Light Emitting Diode Indicators
- LCD - Liquid Crystal Display
- TFT - Thin Film Transistor displays
- OLED - Organic Light Emitting Diodes

## **Lesson 9: Power supply of the embedded systems**

### *Learning Objectives*

- Describe the different types of power supplies;
- Understand the principle of operation of linear voltage regulators;
- Understand the principle of operation of switched voltage regulators;
- Know about function of power management unit.

### *Content of the Lesson*

- Introduction
- Linear voltage regulators

- Switched voltage regulators
- Using multiple voltage sources for embedded systems

## Lesson 10: Programming of the embedded systems

### *Learning Objectives*

- Know about program languages used for software development for embedded systems;
- Understand the compilation process of embedded software;
- Understand the operation of programs with and without RTOS;
- Know how to program embedded system.

### *Content of the Lesson*

- Introduction
- Programming languages
- Creation of embedded systems software
- Basic principles of software operation
- Debugging the software
- Programming of the embedded systems

## M006 - Communication interfaces and protocols

### *Syllabus*

Industrial automation underlies productivity boost in economy. Its development involves the design and make up of automated systems for control of various manufacturing processes and machines. Contemporary industrial automation integrates the achievements in the areas of information, management and communication technologies.

The course "Communication interfaces and protocols" is intended to provide basic knowledge for operators, who work in small and medium size companies, about utilization of standard interfaces and set up of industrial networks in automation systems. In preparing the course the authors have followed the contemporary level of achievements in that particular field and have tried to reduce the number of theoretical formulations and mathematical descriptions to a reasonable minimum. The course is divided into ten lessons.

### Learning objectives

Upon completion of this course the students will be able to:

- Understand about the Communication interfaces and protocols;
- Understand the types of communication networks;
- Understand the general background of network models and topologies, special consideration being given to devices for physical and logic setup of networks plus network models OSI and DoD;
- Understand the special properties and characteristics of industrial field networks as representatives of the lowest level in the hierarchy of industrial systems for control;
- Understand the properties of the field nets specifications Profibus and CAN,
- General knowledge about industrial networks at "control" level and the specific features of ControlNet specification;
- Understand the industrial networks at information level, the Ethernet network specification and the application of wireless communications in industrial automation systems.

## Contributors

Assoc. Prof. Aldeniz Rashidoc, Technical University of Gabrovo (TUG),  
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## Course Structure

The content of the course is distributed in ten lessons. Each lesson is accompanied by a presentation, a self-assessment consisting of multiple choice questions to assess your knowledge on the subject, and exercises/assignments to apply the knowledge you gained in practice.

The course consists of the following lessons:

### Lesson 1: Introduction to industrial communication networks

#### *Learning Objectives*

- Understand the specific features of contemporary production systems;
- Explain main characteristic features of contemporary communication systems;
- Understand the communication systems architecture;
- Understand about the automatic control systems with network communication.

#### *Content of the Lesson*

##### Introduction

- Specific features of contemporary production systems
- Communication systems architecture
- Characteristic features of contemporary communication systems
- Distributed control systems – DCS
  - Decentralized vertically integrated architectures of DCS – type one
  - Decentralized vertically integrated architectures of DCS – type two
  - Horizontally integrated architectures of DCS
- Automatic control systems with network communication – ACSNC
- Functional distribution of distribution systems with network communication
  - Field level systems
  - Control level systems

- Information level systems

## Lesson 2: Communication network

### *Learning Objectives*

- To understand for communication networks;
- To understand for types of networks.

### *Content of the Lesson*

- Communication network. Types of networks
- Types of networks
  - Peer access network
  - Client – server type of network
  - Composite type of networks

## Lesson 3: Network topologies and models

### *Learning Objectives*

- To understand what are network topologies and physical topologies;
- To understand what are network models and devices for physical and logical network structuring.

### *Content of the Lesson*

- Network topologies
- Types of physical topologies
  - Bus topology
  - Ring typology
  - Star typology
  - Extended star
  - Hierarchical topology
  - Mesh topology
- Network models
  - OSI network model
  - DoD Model

- Devices for physical and logical network structuring
  - Passive devices
  - Active devices
  - Devices for configuring the network into segments and subnetworks

#### **Lesson 4: Industrial Field Networks. General Characteristics**

##### *Learning Objectives*

- To understand for features and functionality of industrial field networks;
- To understand what are the methods for information transmission employed in field networks;
- Understand what are the communication mechanisms in field networks.

##### *Content of the Lesson*

- Features of industrial field networks
- Functionality of field networks
- Methods for information transmission employed in field networks
- Types of devices used in field networks
- Communication mechanisms in field networks
- Contemporary specifications of field network

#### **Lesson 5: Specification for Profibus field networks**

##### *Learning Objectives*

- To understand what are the specific futures of Profibus field networks;
- To understand for PROFIBUS-DP functioning and BUS Timing at Profibus.

##### *Content of the Lesson*

- Introduction
- Description of protocol
- PROFIBUS-DP functioning
- BUS Timing

## Lesson 6: CANBUS and MODBUS communication protocol

### *Learning Objectives*

- To understand what are the specific features of CANBUS communication protocol;
- To understand what are the specific features of Modbus communication protocol.

### *Content of the Lesson*

- CANBUS communication protocol
  - Description of protocol
  - The principle of the action
  - Description of information package
  - Types of frames
  - Arbitrage during data transmission
  - Error control
  - Transfer rate and network length
  - High level/layer protocols
  - Advantages of CAN
  - Disadvantages of CAN
- Modbus communication protocol
  - A description of protocol
  - A format of frame
  - Categories of function codes
  - Standardized commands
  - User commands
  - Reserved commands
  - Model of data
  - Error control in Modbus RTU protocol

## Lesson 7: Industrial networks of control level. Network specification ControlNet

### *Learning Objectives*

- To understand what are the main characteristics of the industrial networks of control level;
- To understand what are the specific features of ControlNet communication protocol.

### *Content of the Lesson*

- Industrial networks of control level
- Network specification ControlNet
- Topology of networks ControlNet
- Message types in ControlNet
- ControlNet frame structure
- Classes of devices in ControlNet networks

## **Lesson 8: Industrial networks of information level**

### *Learning Objectives*

- To understand the specific features of the Industrial networks of information level;
- To understand what is Real time operation of information level networks;
- To understand which are Devices used with networks of information level.

### *Content of the Lesson*

- Networks general characteristics and requirements
- Real time operation of information level networks
- Devices used with networks of information level
- Content of the software
- Topology of information level networks
- Types of exchange at information level

## **Lesson 9: Ethernet network specification**

### *Learning Objectives*

- To understand for Ethernet network specification;
- To understand about Fast and Gigabit Ethernet;
- To understand what are the used protocols with Ethernet specifications.

### *Content of the Lesson*

- Fast Ethernet (100 Mb/s)
- Ultra high speed Ethernet (Gigabit Ethernet)



- Transmission medium
- Communication protocols
- ARP and RARP 87
- Protocols TCP/IP
- User Datagram Protocol (UDP)
- Internet Protocol IP

## **Lesson 10: Wireless communications in industrial environment**

### *Learning Objectives*

- To understand for substance and background of wireless nets;
- To understand basic groups of wireless networks;
- To understand about Logical topologies of wireless networks and data protection at wireless networks.

### *Content of the Lesson*

- Substance and background of wireless nets
- Groups of wireless networks
  - High Throughput Technology
  - Medium Throughput Technology
  - Bluetooth technology
  - Low Data Rate Technologies
  - Z-Wave
- Logical topologies of wireless networks
  - AD-HOC
  - Access Point – Client
  - WDS – Wireless Distributed System
  - Repeater
  - Bridge
- Data protection

## M007 - PLC Systems

### *Syllabus*

This course is an introductory to Programmable Logic Controls (PLC), focusing on the underlying principles of how PLCs work and providing practical information and skills about installing, programming, and troubleshooting a PLC system. The primary aim of the book “PLC systems” is to provide basic knowledge to employees in small and medium enterprises in the field of programmable logic controller, which are used to control automated (production) systems. The PLC systems find their place in the automation of machines and production processes. They are closely related to mechatronic systems, because they can implement the control algorithms of these mechatronic systems. The training module consist information about structure of PLCs and program languages which are used for their programming.

### Learning objectives

Upon completion of this course the students will be able to:

- Understand the goal of automation of industrial applications and the meaning of a programmable logic controller,
- Understand the fundamentals Programmable Logic Controllers systems,
- Identify the PLC hardware parts, compare the main existing PLC types and explain how a PLC based on Siemens PLCs works,
- Understand structure of a software project, creation of a control program, testing of the program in computer, and downloading into Siemens S7-1200 PLC,
- Apply basic and advanced Boolean logic (also called bit logic) operations construct, design, edit, test, and document PLC Ladder Logic Programs.
- Diagnose and troubleshoot Siemens PLCs using TIA Portal Series software.
- Specify safety consideration for personnel, field devices and automated production equipment.

### Contributors

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## Course Structure

The basic course is divided into basic and extended parts. The basic course includes five lessons. The extended course includes 12 lessons. Each lesson is accompanied by a presentation, a number of resources for further study, a self-assessment consisting of multiple choice questions to assess your knowledge on the subject, and exercises/assignments to apply the knowledge you gained in practice.

The course consists of the following lessons:

### Lesson 1: Programmable logic controller

#### *Learning Objectives*

- Understand the goal of automation of industrial applications and the meaning of a programmable logic controller;
- Explain main terms used in the field of PLC;
- Understand what is PLC;
- Understand the fundamentals Programmable Logic Controllers systems;
- Identify the PLC hardware parts, compare the main existing PLC types and explain how a PLC based on Siemens PLCs works.

#### *Content of the Lesson*

##### Introduction

- Programmable logic controller
  - Automated manufacturing system
  - Programmable Logic Controller
  - Hardware of Programmable Logic Controller
    - PLC Power Module
    - Central Processing Unit
    - Signal Modules
    - Other modules of
    - Hardware of Siemens S7-1200 series PLC
  - Types of PLC
    - Compact PLC
    - Modular PLC
    - PLC with an integrated operator panel

- Industrial computer
- Slot PLC
- Soft PLC
- Signals of PLC
  - Binary signals
  - Digital signals
  - Analogue signals
- How does the PLC work?
- Multitasking

## Lesson 2: PLC programming

### *Learning Objectives*

- To understand what are the main programming languages used for PLC;
- To realize the significance of variables (data) types and addressing;
- To understand the PLC program creation phases.

### *Content of the Lesson*

- PLC programming
  - IEC 61131 standard
  - The Program Organization Unit (POU)
  - PLC programming languages
    - IL (Instruction List)
    - ST (Structured Text)
    - FBD (Function Block Diagram)
    - LD (Ladder Diagram)
    - SFC (Sequential Function Chart)
    - Programming languages for SIMATIC S7-1200 PLC
  - Variables and addressing in STEP 7
  - Data types used in PLC
    - Elementary data types
  - Programming by configuring with IEC 61499
  - Creating a PLC program – the phase model

### Lesson 3: First project using Siemens S7-1200 PLC

#### *Learning Objectives*

- To understand how to initiate a new Project in TIA Portal environment, create of a control program, test of the program in computer, and download into Siemens S7-1200 PLC.

#### *Content of the Lesson*

- First project using Siemens S7-1200 PLC
  - Creating new project
  - Hardware configuration
  - Variables declaration
  - Program composition
  - Program testing
- Downloading a configuration and program

### Lesson 4: Basic Boolean logic functions

#### *Learning Objectives*

- To understand what are the main (basic) logic (function) blocks;
- To understand how functional blocks operate in a PLC.

#### *Content of the Lesson*

- Basic Boolean logic functions
  - AND and OR connections
  - Negation
  - Exclusive-OR connection
  - SR and RS flip-flops
  - Edge detection

### Lesson 5: Advanced Boolean logic functions

#### *Learning Objectives*

- To understand what are the number systems in PLC programming;
- To understand what are advanced Boolean functions like timers, counters, comparators, shift and rotate functions.

### *Content of the Lesson*

- Advanced Boolean logic functions
  - Number systems in PLC programming
    - Decimal number system
    - Binary number system
    - BCD number system
    - Hexadecimal number system
    - Signed binary numbers
    - Real numbers
    - Number presentation in the PLC memory
  - Timers
  - Counters
  - Comparators
  - Shift and rotate functions

## **Lesson 6: Transfer and program control functions**

### *Learning Objectives*

- To understand what are transfer and control functions;
- To understand how the functions and data is processed in central processor;
- To familiarize with program control functions used in PLC programming.

### *Content of the Lesson*

- Transfer and program control functions
  - Transfer functions
  - Program control functions
    - Unconditional and conditional jump functions
    - Block call functions
    - Block end functions
    - Additional control functions

## Lesson 7: Math and conversion functions

### *Learning Objectives*

- To understand what are the main mathematical functions used in PLC;
- To understand what are the main data types used for calculations in PLC;
- To realize the significance of numeric data types used in math functions;
- To understand what are the numeric functions defined in IEC61131.

### *Content of the Lesson*

- Arithmetic functions
- Numeric functions
  - NEG instruction
  - INC and DEC instructions
  - ABS instruction
  - MIN and MAX instructions
  - LIMIT instruction
  - SQR and SQRT instructions
  - LN and EXP instructions
  - Trigonometric functions
  - FRAC instruction
- Date, time-of-day, and clock functions
- Conversion function CONV
- More conversion functions
  - Conversion of real values
  - Conversion of BYTE, WORD and DWORD
  - SCALE\_X and NORM\_X instructions

## Lesson 8: PID control

### *Learning Objectives*

- To understand what is Proportional–Integral–Derivative (PID) controller;
- To understand what is the closed-loop controller role in a control system;
- To understand the time response of a typical continuous-action (called PID) controller and its three components: proportional, integral and derivative;

- To realize how PID controller as a functional component can be used for sophisticated control schemes.

#### *Content of the Lesson*

- Controlled system
- Closed-loop control technology
- Description of the dynamic response of a controlled system
- Controllers
  - Time response of a PID controller
  - The proportional controller
  - The integral controller
  - The derivative controller
  - Combination of several controllers
- Tuning criteria or “How do we know when it’s tuned?”
  - The extremes: instability or no response
  - Informal methods
- PID control in S7-1200 PLC

### **Lesson 9: Control of an application with one pneumatic cylinder**

#### *Learning Objectives*

- To document physical mechatronic process description;
- To compose and document pneumatic and electric diagrams;
- To define, compose and document variables list used in a process control;
- To construct (write) simple PLC program using different (standard based) PLC programming languages.

#### *Content of the Lesson*

- Pneumatic diagram
- Electric diagram
- PLC program



## Lesson 10: Control of an application with two pneumatic cylinders

### *Learning Objectives*

- To describe (document) operation of a mechatronic process, draw an sample application layout schema;
- To select different pneumatic actuators for mechatronic process automation;
- To draw and document electric schema of an mechatronic system;
- To understand basic rules about GRAFSET programming language;
- To define process variables and symbols for a mechatronic process description;
- To compose GRAFSET diagram for automatic control of a sample application (consisting two pneumatic actuators (cylinders));
- To compose and document the control programs using SCL, LAD and FBD programming languages.

### *Content of the Lesson*

- Pneumatic diagram
- Electric diagram
- PLC program

## Lesson 11: Control of an application with a frequency converter

### *Learning Objectives*

- Understand possibilities of pre-set speed control using frequency converter of an electric motor;
- To describe control and operation of different mechatronic processes;
- To write and draw project documentation for mechatronic application;
- To compose and document electric schema of complex mechatronic system including different sensors, actuators and a frequency converter;
- To compose an control algorithm and define variables list for the process control system;
- To compose algorithm for air valve control;
- To write PLC program in LAD language for automatic control of predefined mechatronic application.

### *Content of the Lesson*

- Application example
- Electric diagram
- PLC program

## **Lesson 12: PLC selection, safety and commissioning**

### *Learning Objectives*

- To understand main criteria for a PLC selection in the field of mechatronic process control;
- To understand importance of safety in automation system development, manufacturing and commissioning stages;
- To understand that in complex safety situations a big number of rules must be considered during automated system design and manufacturing;
- To understand meaning of the Machinery Directive, the Electromagnetic Compatibility (EMC) Directive and Low Voltage Directives;
- To understand importance of the automation project documentation and commissioning.

### *Content of the Lesson*

- PLC selection
- Safety of a PLC
- Commissioning

## M008 - MEASUREMENTS AND DATA ACQUISITION

### *Syllabus*

The module includes basic overview of measurements and data acquisition issue. The lessons are structured to enable the student to get easily acquainted with the most important aspects of this field.

### Learning objectives

Upon completion of this course the students will be able to:

- Recognize differences between seemingly similar issues in the field of measurements and data acquisition
- Recognize differences between measurement methods
- Recognize differences between measurement errors
- Predict types of measurement errors that can be expected during measurements
- Recognize differences between types of signals commonly used for measurements
- Understand characteristics of transducers and it's errors
- Use the basic definitions characteristic to the field of measurements and data acquisition

### Contributors

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### Course Structure

The course is divided into 5 lessons. Each lesson is accompanied by a presentation, a number of resources for further study and a self-assessment consisting of multiple choice questions to assess your knowledge on the subject.

The course consists of the following lessons:

### **Lesson 1: Basic definitions**

The lesson contains revision of the basic definitions useful in the field of measurements and data acquisition. It also indicates the difference between the most popular used measuring systems.

#### *Learning Objectives*

- Get knowledge about basic definitions used in the field of measurements and data acquisition;
- Understand what the measurement system is;
- Get to know International system of units;
- Get familiar with British Imperial and United States customary units.

#### *Content of the Lesson*

- Basic definitions
- Static and dynamic measurement definition
- Imperial System of Units
- British Imperial System
- United States Customary System

### **Lesson 2: Signals theory**

The lesson explains what the signals are and shows the differences between different kinds of signals.

#### *Learning Objectives*

- Understanding what the signals are;
- Being able to recognize different kind of signal;
- Be able to use mathematical equation to represent signal waveform if it's possible;
- Understand the difference between analog and digital signal.

### *Content of the Lesson*

- Introduction
- Periodic signals (sine/cosine/harmonic signal)
- Fourier series
- Non-periodic signals / almost periodic signals / disappearing message signal
- Analogue and digital signal

### **Lesson 3: Measurement methods and measurement errors**

The lesson presents the variety of measurement methods and errors.

### *Learning Objectives*

- Recognize differences between measurement methods;
- Recognize differences between measurement errors;
- Get familiar with the definition and different types of uncertainty of measurement.

### *Content of the Lesson*

- Introduction
- Measurement methods (direct/indirect/basic/differential/zero method)
- Measurement errors (absolute/relative/systematic/random/excessive)
- Uncertainty of measurement (Evaluation type A and B)

### **Lesson 4: Measuring transducer, errors**

The lesson presents issues related to the transducers, their characteristics and errors.

### *Learning Objectives*

- Understanding what the measuring transducers are and what function they perform in measuring system;
- Understanding issue of measuring transducers characteristic;
- Get familiar with the issue of measuring transducers errors.

### *Content of the Lesson*

- Introduction
- Measuring transducer definition
- Measuring transducer characteristics (accuracy / precision / sensitivity / linearity / repeatability error / reproducibility / resolution / range / stability / dynamic error)
- Measuring transducer linearity errors (BFSL / TBL)
- Measuring transducer dynamic error

### **Lesson 5: Measuring systems**

The lesson presents the basic definitions connected with measuring systems.

### *Learning Objectives*

- Indicating issues that need to be considered during choosing the right measuring system;
- Showing possible sources of measurement uncertainty;
- Showing different structures of measuring systems.

### *Content of the Lesson*

- Introduction
- Measuring system selecting
- Uncertainty of the measurement
- Analog to digital converter (ADC)
- Digital measuring systems
- Structures of measuring systems

## M009 - Sensors in Mechatronics

### *Syllabus*

This course is to provide basic knowledge in the field of sensors used to build automation systems. The module can be used as a source in training programmes for enhancing the qualification and re-qualification of employees in small and medium enterprises. In order to acquire this knowledge, the trainees should have basic knowledge of mathematics and physics.

### Learning objectives

Upon completion of this course the students will be able to:

- know the different types of sensors used in mechatronic systems;
- know the parameters and characteristics of the sensors;
- to know the basic principles of operation of the sensors used in mechatronics;
- to choose sensors for specific applications.

### Contributors

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### Course Structure

The course is divided into a number of lessons. Each lesson is accompanied by a presentation, a number of resources for further study, a self-assessment consisting of multiple choice questions to assess your knowledge on the subject, and exercises/assignments to apply the knowledge you gained in practice.

The course consists of the following lessons:

## Lesson 1: Sensor Classification

### *Learning Objectives*

The main aim of this lesson is to acquaint the trainees with the concept of sensors, their place in the structure of the automation systems and the classification of sensors by different classification principles.

### *Content of the Lesson*

- Sensors
- Classification principles

## Lesson 2: Sensor Characteristics

### *Learning Objectives*

The main aim of the lesson is to acquaint the trainees with the static and dynamic characteristics and parameters of the sensors.

### *Content of the Lesson*

- Static characteristics and parameters
  - Transfer function
  - Sensitivity
  - Measurement range
  - Minimum detectable signal
  - Accuracy and errors
  - Dead zone and saturation zone
  - Stability
  - Operating temperature range
- Dynamic characteristics and parameters
  - Step response
  - Impulse response
  - Frequency response
  - Bode magnitude response and Bode phase response
  - Response and recovery time of the sensor



- Cutoff frequency
- Phase offset
- Resonant frequency

### Lesson 3: Position and Displacement Sensors

#### *Learning Objectives*

The main aim of the lesson is to acquaint the trainees with the different types of position and displacement sensors, their operating principles, the sensors subtypes, structures, and the quantities, for the measurement of which they can be used.

#### *Content of the Lesson*

- Contact sensors
- Potentiometric sensors
  - - Potentiometric sensors with mechanical contacts
  - - Potentiometric sensors without mechanical contacts
- Inductive and mutually inductive sensors
  - Sensors with a magnetic core with a variable air gap length
  - Sensors with a magnetic core with variable air gap area
  - Sensors with a moving core
- Capacitive sensors
  - Capacitive sensors with variation in the distance between the electrodes for measuring linear displacements
  - Capacitive sensors with variation in the area of the electrodes for measuring linear and angular displacements
  - Capacitive sensors with variation in dielectric permeability for measuring small displacements and levels
- Absolute encoders
- Optical sensors
  - Optical position sensors
  - Incremental (relative) optical encoders
- Permanent magnet sensors
  - Moving coil permanent magnet sensors
  - Permanent magnet sensors with a moving magnet
  - Permanent magnet sensors based on position variation of a third element

## Lesson 4: Force, Strain, and Tactile Sensors

### *Learning Objectives*

The main aim of the lesson is to acquaint the trainees with the basic types of force, strain and tactile sensors, their principle of operation, subtypes, specifics and structures.

### *Content of the Lesson*

- Strain gauge sensors
  - Conductor strain gauges
  - Foil strain gauges
  - Semiconductor strain gauges
- Piezoelectric sensors
- Magnetoelastic sensors
  - Magnetoelastic sensors of inductive type
  - Magnetoelastic sensors of mutually inductive type
  - Magnetoanisotropic sensors
- Tactile sensors

## Lesson 5: Inertial Sensors

### *Learning Objectives*

The main purpose of the lesson is to acquaint the trainees with the types of inertial sensors by examining the different types of accelerometers, gyroscopes and inclinometers.

### *Content of the Lesson*

- Accelerometers
  - Capacitive Accelerometers
  - Piezoresistive Accelerometers
  - Piezoelectric Accelerometers
  - Thermal Accelerometers
- Gyroscopes
  - Rotary gyroscope
  - Vibrating gyroscope

- Optical (laser) gyroscopes
- Inclinometers

## Lesson 6: Pressure Sensors

### *Learning Objectives*

The main aim of the lesson is to acquaint the trainees with the basic types of pressure sensors according to the measurement method and operating principle by considering the realization and structures of those of them that can be used for automation of the processes of pressure measurement.

### *Content of the Lesson*

- Types of pressure sensors according to the measurement method
  - By absolute measurement
  - Gauge sensors
  - By differential measurement
- Types of sensors according to their operating principle
  - Mutually inductive sensors
  - Capacitive sensors
  - Piezoelectric sensors
  - Strain gauge sensors
  - Optical sensors

## Lesson 7: Flow Sensors

### *Learning Objectives*

The main aim of the lesson is to acquaint the trainees with the different types of flow sensors, their subtypes and structures according to the operating principle and the specifics and possibilities for their application.

### *Content of the Lesson*

- Rotary flow sensors
  - Flow sensors with a propeller

- Sensors with a turbine and inductive transducer
- Flow sensors based on pressure measurement
  - Sensor with a calibrated orifice
  - Sensor with Venturi tube
  - Sensor with a nozzle
- Ultrasonic flow sensors
  - Sensor by a continuous ultrasonic signal
  - Sensor by generating ultrasonic frequency pulses
  - Sensor by implementing Doppler effect
- Magneto-inductive flow sensors
- Calorimetric flow sensors
- Vortex flow sensors
- Flow sensors for open channels
- Coriolis Mass Flow Sensors

## **Lesson 8: Proximity, Object Detection and Level Sensors**

### *Learning Objectives*

The main aim of the lesson is to acquaint the trainees with the different types of proximity, object detection and level sensors, and their principle of operation, subtypes, work regimes and specifics of use.

### *Content of the Lesson*

- Contact sensors for object detection
- Proximity sensors
  - Inductive sensors with a variation in magnetic resistance
  - Eddy-current sensors
  - Capacitive proximity sensors
  - Proximity sensors based on the Hall effect
- Optical sensors
- Ultrasonic sensors
- Radar sensors
- Level sensors
  - Detection of boundary values of level
  - Continuous level measurement

## Lesson 9: Temperature Sensors

### *Learning Objectives*

The main aim of the lesson is to acquaint the trainees with the basic types of temperature sensors, their characteristics, specifics, parameters and temperature ranges of application.

### *Content of the Lesson*

- Thermoelectric Sensors
- Thermoresistive Sensors
  - Metallic thermoresistors (RTDs)
  - Thermistors
- Thermodiodes, thermotransistors and integral temperature sensors
- Non-contact temperature sensors

## M010 - Actuators in Mechatronics

### *Syllabus*

This course is an introductory to actuators in field of mechatronics, focusing on the underlying principles of how actuators work and providing additional information sources to the SME personnel working in the field of industry automation. The module presents information about different types of actuators used in mechatronic systems. The main attention is paid to electrical motors and their applications. In the lessons are also presented other types of actuators which are often used in mechatronics for execution of rotational and linear movements.

### Learning objectives

Upon completion of this course the students will be able to:

- Understand the nature and origins of the phenomenon in actuators;
- Understand what are the main features of actuators and compare main actuator types;
- Understand what are the main features of electric motors and what is the difference between different types of motors used in electrical drives (stepper motors, brushed DC motors, brushless DC motors, PM synchronous motors, AC induction motors);
- Explain what applications are AC induction motors used for;
- Understand the difference between different types of rotary and linear actuators;
- understand what are the main features of pneumatic and hydraulic actuators;
- Set the positions and regulate the speed of a typical motor actuator system;

### Contributors

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### Course Structure

The course book (study book) is divided into 5 lessons. The lessons are accompanied by a number of presentations, assignments to apply the theoretical knowledge you gained in

practice, self-assessments consisting of multiple choice questions to assess your knowledge on the subject and resources for further study.

Association of the course book lessons to the presentation numbers, assignment numbers and self-assessment numbers is shown in following Table.

<b>Lesson number</b>	<b>Presentation (topic) number</b>	<b>Assignment number</b>	<b>Self-assessment number</b>
Lesson 1	1,	1	1
Lesson 2	2, 3, 4, 5, 6, 7	2, 3, 4, 5, 6, 7	2, 3, 4, 5, 6, 7
Lesson 3	8	8	8
Lesson 4	8, 9	8,9	8,9
Lesson 5	10	10	10

The course book consists of the following lessons:

### **Lesson 1: Introduction**

#### *Learning Objectives*

- Understand the fundamentals of energy conversion processes in electric drive systems;
- Understand different functional features and operation modes of power switches,
- Know historical development of power electronics and development trends of electrical drives.
- Identify the types of drives;

#### *Content of the Lesson*

- Introduction
- Overview of electro-mechanical energy conversion
- Power switch as the Energy Converter
- Historical development of power electronics
- Development trends of electrical drives

## Lesson 2: Electro-mechanical conversion

### *Learning Objectives*

- Understand the principle of electro-mechanical energy conversion;
- Describe the working principle of direct current electric machine ;
- Describe the working principle of alternating current induction machine;
- Describe the working principle of synchronous and step-motors;
- Understand how the three-phase rotating magnetic field is realized;
- List of speed and torque regulation methods of electrical machines.
- Identify the different braking methods that used to stop the electrical motor.

### *Content of the Lesson*

- General principles
- Direct current electric machine
- Alternating current induction machine
- Synchronous and step-motors
- Three-phase rotating magnetic field
- Speed and torque regulation of electrical machines
- Dynamical models of electric machines
- Brake and generator modes of operation

## Lesson 3: Power electronic converters

### *Learning Objectives*

- Understand principles of the usage of pulsed control method (the pulse width modulation) of electricity consuming devices with semiconductor switches;
- Construct different power circuits of semiconductor switches used for control of energy flows (power);
- Describe the working principle of alternating voltage controller;
- Describe the application of three-phase voltage controllers in electrical drives;
- Describe the working principle of step-down converter (buck converter);
- Describe the working principle of step-up pulse width converter (boost converter);
- Describe the working principle of four-quadrant pulse width converter;
- Categorize circuit diagrams and main properties of inverters.



### *Content of the Lesson*

- Power semiconductor switch
- Network synchronized controllable rectifiers and inverters
- Alternating voltage controller
- Direct current converters and controllers
- Direct current converters used in electrical drives
- Inverters
- Frequency converters

## **Lesson 4: Electric drives**

### *Learning Objectives*

- Identify the main structural parts of electric drives;
- Understand functional qualities of electric drive controller;
- Understand and describe the working principle of electric drives with four-quadrant pulse width converter and DC machines;
- Describe the usage of soft starters for controlling the induction motors;
- Understand and describe the usage of frequency controllers for controlling induction machines;
- Understand the main principles of vector control;
- List the conductivity and radiation disturbances of power converters.

### *Content of the Lesson*

- General description
- Electric drive with DC machines
- Soft start of induction motor
- Frequency controlled electric drives
- Conductivity and radiation disturbances of converters

## **Lesson 5: Pneumatic and hydraulic actuators**

### *Learning Objectives*

- Describe the working principle of single- and double-acting cylinders;
- Analyze the cylinder performance characteristics;
- To select different pneumatic actuators for mechatronic process automation;
- Compose the classification of hydraulic cylinders and motors;

#### *Content of the Lesson*

- Pneumatic cylinders and motors
  - Single-acting cylinders
  - Double-acting cylinders
  - Cushioned Cylinder
  - Rodless cylinders
  - Cylinder with magnetic coupling
  - Band cylinder
  - Rotary cylinders
  - Cylinder performance characteristics
- Hydraulic actuators
  - Hydraulic cylinders
  - Hydraulic motors
- Conclusions

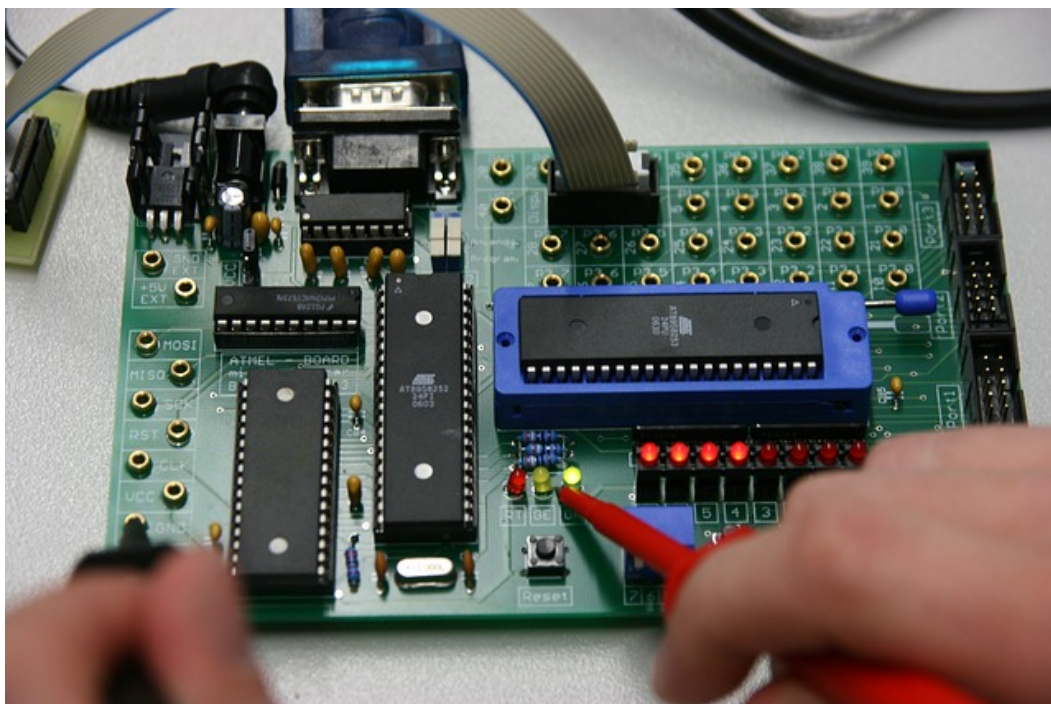


Erasmus+



Strategic Partnership in the field of Mechatronics for innovative and smart growth of European manufacturing SMEs (MechMate)

## MECHMATE GUIDELINES FOR SMEs AND VET PROVIDERS





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## About this document

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The MechMate project has been funded with support from the European Commission under the Erasmus + programme.

This document reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

This document as all of the MechMate project products is elaborated based on the results from a conducted desk research and focus groups with representatives of MechMate project target groups in Poland, Bulgaria, Estonia and Greece. The Guidelines as well as all other intellectual outputs included in the MechMate training is meant to reflect and address the training needs of the project target groups in the field of mechatronics and advanced technologies and to equip them with the necessary skills and competencies to effectively implement and use innovative mechatronic-based technologies into the everyday working processes.





## Table of Contents

About this document.....	5
List of Figures.....	8
List of Tables.....	8
Introduction.....	9
1 Overview of MechMate Project.....	10
2 Overview of MechMate Curricula, Methodology and Training Course.....	11
3 Guidelines for SMEs and VET providers for using the MechMate E-learning Platform Coursevo.....	12
3.1 What is Coursevo? .....	12
3.2 Course registration and content access policies.....	13
3.3 Organization of MechMate Training Programme in Coursevo.....	15
3.4 Recognition of competences: Certificate of Completion/Achievement.....	17
4 References.....	19

## LIST OF FIGURES

Figure 3.1 MechMate e-learning platform (main page) .....	13
Figure 3.2 Registration in MechMate e-learning platform .....	14
Figure 3.3 Creating a new account.....	14
Figure 3.4 MechMate training programme, available in 5 languages: English, Bulgarian, Greek, Estonian and Polish.....	15
Figure 3.5 Main page of a MechMate course in Coursevo .....	16
Figure 3.6 Organization of MechMate courses in Coursevo.....	17
Figure 3.7 Accessing and downloading the certificates awarded after successful completion of courses .....	18
Figure 3.8 Certificate of completion automatically created and delivered to the trainee by MechMate e-learning platform (Coursevo), upon successful completion of a course .....	18

## LIST OF TABLES

No table of figures entries found.

## INTRODUCTION

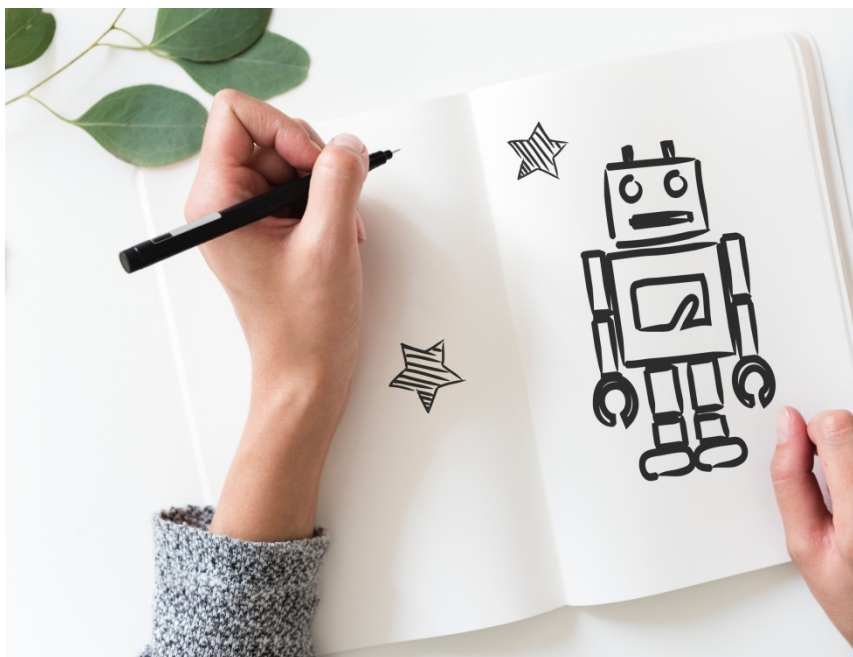
**MechMate Guidelines for SMEs and VET providers (IO5)** are developed by the partner team of the Erasmus+ project “Strategic Partnership in the field of Mechatronics for innovative and smart growth of European manufacturing SMEs” (MechMate, ref. number: 2016-1-PL01-KA202-026350).

The project’s main objective is to provide an interactive training on mechatronics and to assist advanced mechatronics-based technologies introduction in manufacturing SMEs across Europe. This aim is achieved through the development and launch of the MechMate learning materials & interactive platform.

The Guidebook contains 5 sections, providing:

- An overview of the MechMate project
- Reasons for using the MechMate learning materials and tools
- An overview of the contents of the MechMate training materials and the interactive web- platform
- Guidelines for using the MechMate e-learning platform.

We hope that these Guidelines will help manufacturing SMEs’ managers, people employed in SMEs (technicians, administrative staff), as well as VET providers, students and trainers/teachers in terms of mechatronics effectively use the MechMate learning materials and interactive platform.

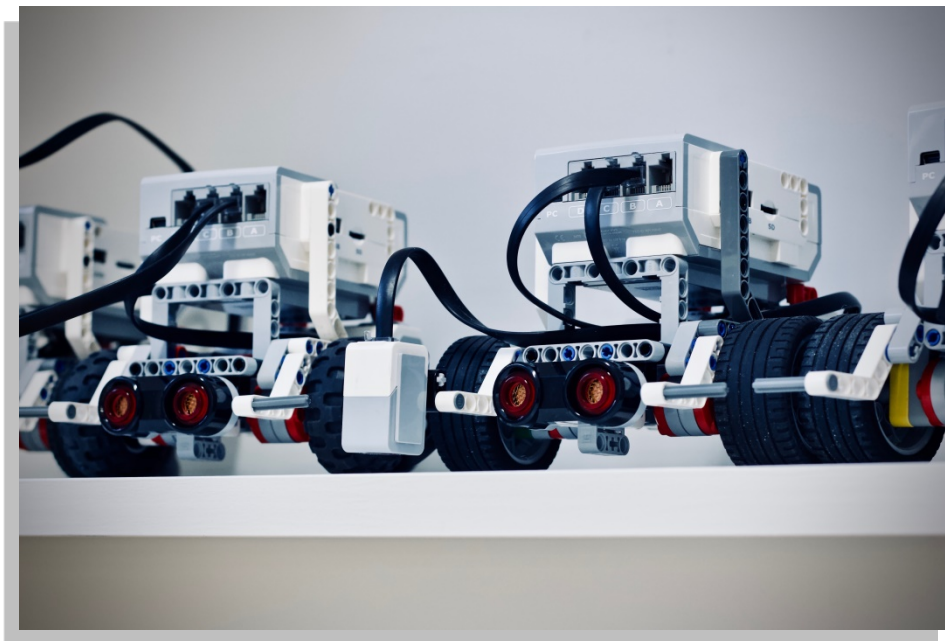


## 1 OVERVIEW OF MECHMATE PROJECT

### Why MechMate?

Manufacturing is a central pillar of the European economy – the EU manufacturing sector accounts for 2 million companies and 33 million jobs. The introduction of new, smart technologies, based on innovative, robotics and mechatronics drives have deeply changed the industrial production and energy conservation principles. In order to make use of the improved technologies, SMEs need highly qualified staff, competent in operating with the new mechatronics based technologies & solutions and competent in managing advanced manufacturing processes. Thus, our challenge is to ensure that all industrial sectors make the best use of new mechatronics technologies and manage their transition towards higher value digitized products and processes.

The MechMate project seeks to solve the outlined problems through interactive training materials of industrial mechatronics systems. All developed materials are hosted on an interactive web-based platform. The proposed e-learning educational approach is easily transferable to wide variety of manufacturing SMEs as well as vocational and higher educational institutions.



This project is a concerted effort on a transnational level to bring added value up to the European economy. The consortium partnership consists of 5 partners from 4 EU countries:

Poland, Bulgaria, Greece and Estonia. All partners have the necessary experience not only in the respective professional area they occupy but also in transnational cooperation in different EU projects and programmes.

MechMate project addresses the problems of manufacturing SMEs' managers, people employed in SMEs (technicians, administrative staff) as well as students and trainers/teachers in terms of mechatronics and lack of training means to facilitated innovation mechatronics - based technology introduction in manufacturing SMEs in Europe. The main objective of the project is to provide an interactive training on mechatronics and to assist advanced mechatronics-based technologies introduction in manufacturing SMEs across Europe. Thus project realization would increase level of innovativeness of SMEs and finally result for them in a significantly higher competitiveness on the European and global market.

By achieving its objectives, the MechMate project contributes to strengthening the performance of EU SMEs, thus supporting economic growth and employment creation in Europe.

Project website: [www.mechmate.eu](http://www.mechmate.eu)

## 2 OVERVIEW OF MECHMATE CURRICULA, METHODOLOGY AND TRAINING COURSE

The elaborated MechMate intellectual outputs/training materials include:

**1. MechMate Curricula** – a modular curriculum for the MechMate training course in mechatronics applicable for managers and employees in SMEs, VET providers, as well as university students and teachers. This product is a core product for the whole project and is based on the results from the conducted desk research and focus groups with representatives of project target groups in Poland, Bulgaria, Estonia and Greece. The curriculum outlines the main topics that are included in the MechMate training course.

**2. MechMate Methodology** - a detailed didactic methodology specially designed for the MechMate training course in mechatronics. The Methodology combines new learning approaches including classical and e-learning. The document provides general information to the used e-learning method, e-learning content design, online collaborative learning, as well as detailed overview of the e-learning platform of MechMate (Coursevo), information about Coursevo services, organisation and course management.

**3. MechMate Training Course** – the course itself as well as all other training materials included in the MechMate training is meant to reflect and address the training needs of the project target groups in the field of mechatronics and advanced technologies and to equip them with the necessary skills and competencies to effectively implement and use innovative mechatronic-based technologies into the everyday working processes.

The training modules in MechMate training programme cover the main aspects of Mechatronics:

- Module 1** "Mechanics and machine elements"
- Module 2** "Fundamentals of electrical engineering and electronics"
- Module 3** "Signals, systems and control in mechatronics"
- Module 4** "Digital Systems"
- Module 5** "Embedded systems in mechatronics"
- Module 6** "Communication interfaces and protocols"
- Module 7** "PLC systems"
- Module 8** "Measurement and data acquisition"
- Module 9** "Sensors in mechatronics"
- Module 10** "Actuators in mechatronics"

### **3 GUIDELINES FOR SMEs AND VET PROVIDERS FOR USING THE MECHMATE E-LEARNING PLATFORM COURSEVO**

#### **3.1 What is Coursevo?**

The e-learning platform used in MechMate is called Coursevo. Coursevo is a multilingual multimedia information system for managing courses, supporting learning processes and learning communities through the Web, developed by the Laboratory of Distributed Multimedia Information Systems and Applications of the Technical University of Crete (TUC/MUSIC) [1]. It implements modern pedagogical approaches and supports blended learning.

Coursevo offers a set of services for:

- ☒ **Organization and management of digital educational content:** Lectures' presentations and recordings, notes, exercises, technical lab material, literature, FAQs etc.
- ☒ **Course attendance:** Announcements, email messages, course calendar, personal rating, automatic track of exercises and deadlines, content update messages, course syllabus, learning path, assessment tests, and generation of course certificates.
- ☒ **Learning communities' communication and collaboration:** Course and group mailing lists, live chat rooms, forums, polls, personal messaging, instant messaging, annotation tools, file sharing, video conferencing and collaboration.
- ☒ **Educational activities:** Courses registration, lab teams' formation, exercise uploads and deadline management, assessment tests, multimedia presentations, resource scheduling and reservations.
- ☒ **Course monitoring:** Course usage statistics and class performance indicators.
- ☒ **Interoperability** with other educational platforms via SCORM packages.

The MechMate e-learning platform / courses can be accessed here:

<http://mechmate.coursevo.com>

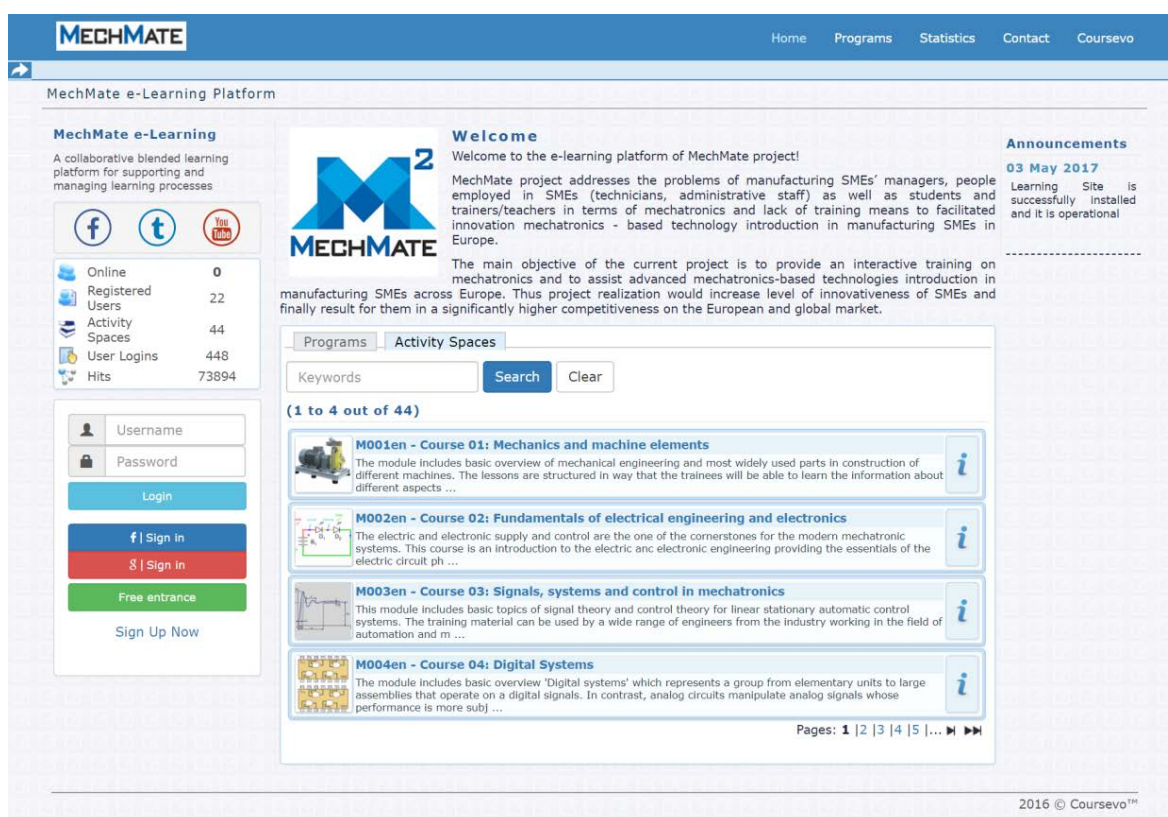


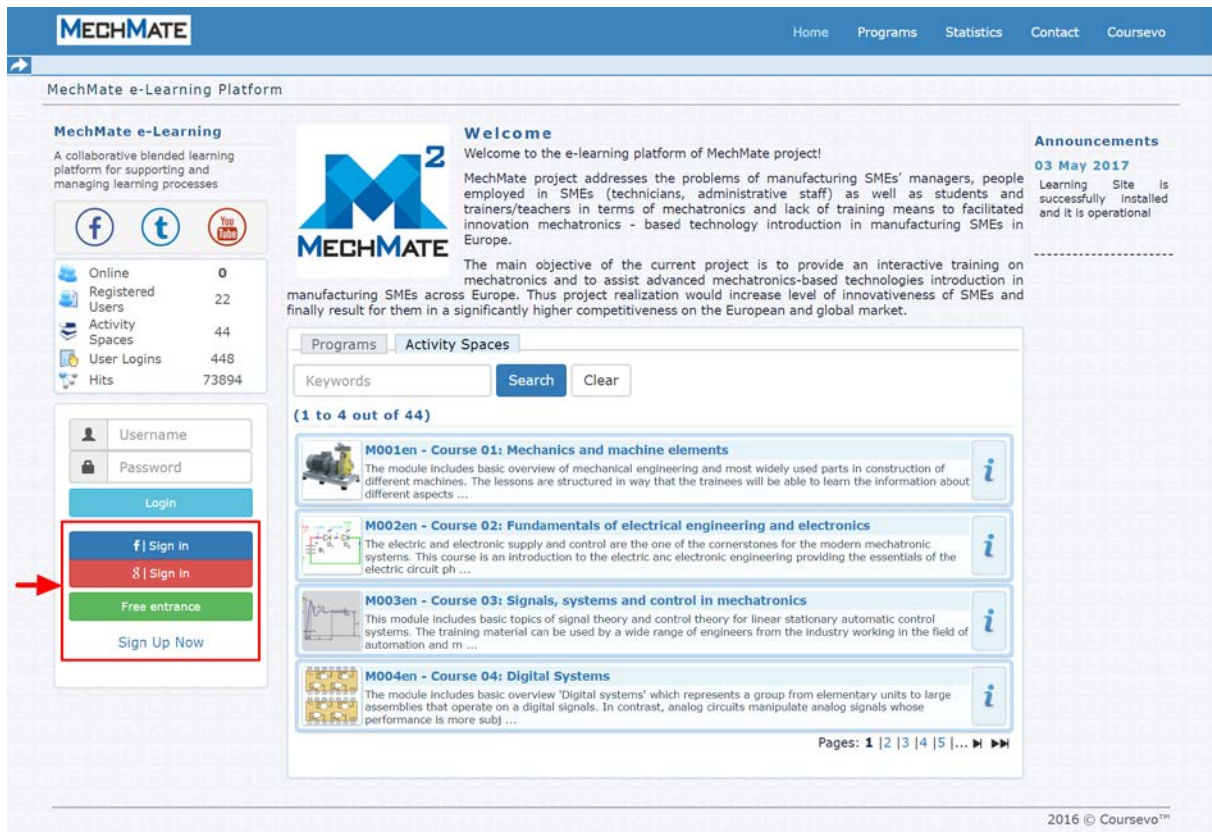
Figure 3.1 MechMate e-learning platform (main page)

### 3.2 Course registration and content access policies

You can freely access the MechMate e-learning platform and the courses developed on it. To do so:

- 1) You can register in the platform by opening a new account by selecting “Sign Up New” on the main page of the platform (Figure 3.2). You will need to complete the “Sign Up” form with your data (Figure 3.3). A temporary password will be sent to the provided e-mail account, as well as a link to activate your account (if you have not received that e-mail in your Inbox, please check your Spam folder). Then, you can login to the platform and change the password from your profile page if you want.
- 2) Alternatively, you can access the platform by using your Google or Facebook account.





**MechMate e-Learning Platform**

**MechMate e-Learning**  
A collaborative blended learning platform for supporting and managing learning processes

Online: 0  
Registered Users: 22  
Activity Spaces: 44  
User Logins: 448  
Hits: 73894

Username: \_\_\_\_\_  
Password: \_\_\_\_\_  
Login

f | Sign in  
g | Sign in  
Free entrance  
Sign Up Now

**Welcome**  
Welcome to the e-learning platform of MechMate project!  
MechMate project addresses the problems of manufacturing SMEs' managers, people employed in SMEs (technicians, administrative staff) as well as students and trainers/teachers in terms of mechatronics and lack of training means to facilitated innovation mechatronics - based technology introduction in manufacturing SMEs in Europe.  
The main objective of the current project is to provide an interactive training on mechatronics and to assist advanced mechatronics-based technologies introduction in manufacturing SMEs across Europe. Thus project realization would increase level of innovativeness of SMEs and finally result for them in a significantly higher competitiveness on the European and global market.

**Announcements**  
03 May 2017  
Learning Site is successfully installed and it is operational

**Programs** **Activity Spaces**

Keywords: \_\_\_\_\_ Search Clear

(1 to 4 out of 44)

**M001en - Course 01: Mechanics and machine elements**  
The module includes basic overview of mechanical engineering and most widely used parts in construction of different machines. The lessons are structured in way that the trainees will be able to learn the information about different aspects ...

**M002en - Course 02: Fundamentals of electrical engineering and electronics**  
The electric and electronic supply and control are the one of the cornerstones for the modern mechatronic systems. This course is an introduction to the electric and electronic engineering providing the essentials of the electric circuit ph ...

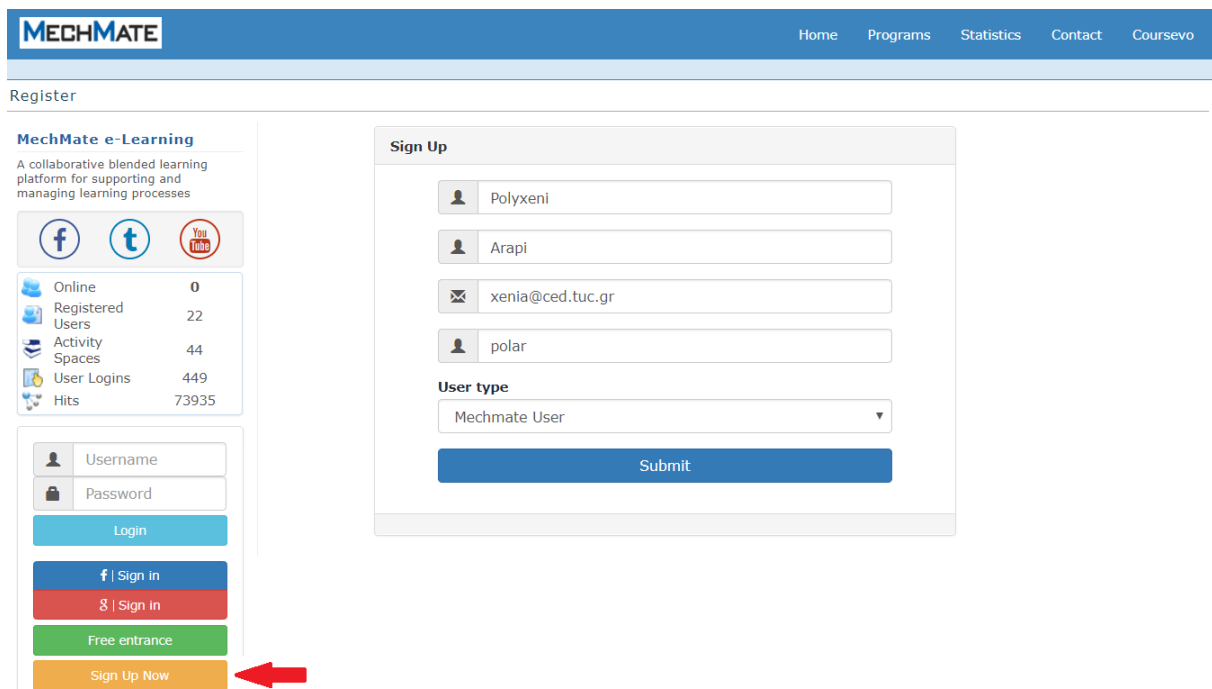
**M003en - Course 03: Signals, systems and control in mechatronics**  
This module includes basic topics of signal theory and control theory for linear stationary automatic control systems. The training material can be used by a wide range of engineers from the industry working in the field of automation and m ...

**M004en - Course 04: Digital Systems**  
The module includes basic overview 'Digital systems' which represents a group from elementary units to large assemblies that operate on a digital signals. In contrast, analog circuits manipulate analog signals whose performance is more subj ...

Pages: 1 | 2 | 3 | 4 | 5 | ... | »

2016 © Coursevo™

Figure 3.2 Registration in MechMate e-learning platform



**MechMate e-Learning Platform**

**MechMate e-Learning**  
A collaborative blended learning platform for supporting and managing learning processes

Online: 0  
Registered Users: 22  
Activity Spaces: 44  
User Logins: 449  
Hits: 73935

Username: \_\_\_\_\_  
Password: \_\_\_\_\_  
Login

f | Sign in  
g | Sign in  
Free entrance  
Sign Up Now

**Sign Up**

Username: Polyxeni  
Password: Arapi  
Email: xenia@ced.tuc.gr  
User type: polar  
Mechmate User  
Submit

Figure 3.3 Creating a new account

After logging in to the platform you can access the training programme (or program) of MechMate, which consists of 10 modules, developed in 5 languages: English, Bulgarian,



Greek, Estonian, and Polish. You can select which language version you want by selecting the corresponding program from the dropdown menu under “Programs” (Figure 3.4).

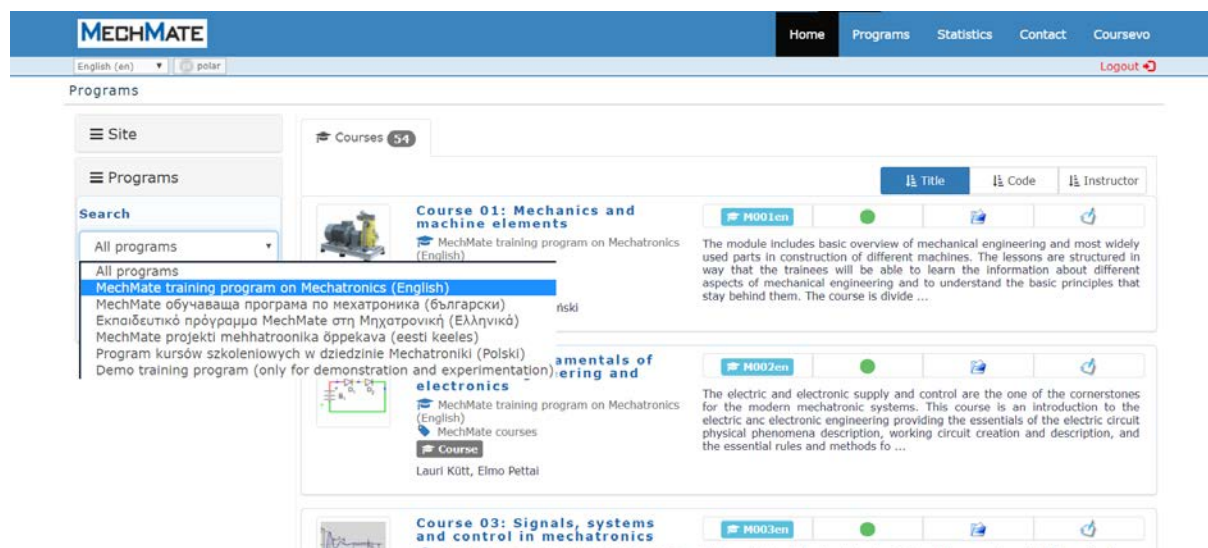


Figure 3.4 MechMate training programme, available in 5 languages: English, Bulgarian, Greek, Estonian and Polish

The next step is to select a course developed under the selected program. To attend the course and access the course material and services, you have to register in the course first (registration is free), by pressing the green button “Register in Course” (Figure 3.5).

### 3.3 Organization of MechMate Training Programme in Coursevo

As already mentioned, MechMate training programme contains a total of 10 modules. Each module forms a self-contained training unit implemented as a course in MechMate e-learning platform (Coursevo), also supported by a number of services for communication and collaboration (Figure 3.5).

A module is divided into lessons. Each lesson is accompanied by a presentation, a number of resources for further study (including advanced materials such as videos and animations), a self-assessment consisting of multiple choice questions to assess student’s knowledge on the subject, and assignments to apply the theoretical knowledge gained in practice. Each module has a study book and is also accompanied by a syllabus, which is available for downloading, containing a short description of the module, its learning objectives and contributors, and its structure, e.g. its lessons, their learning objectives and content.

By selecting “Course Structure” on the course menu, you can follow the course in a structured way, according to the structure described above (Figure 3.6).

MECHMATE

[Home](#)
[Programs](#)
[Statistics](#)
[Contact](#)
[Coursevo](#)

English (en)

polar

Logout

Course 05: Embedded systems in mechatronics

M005en

Course Page

Course Structure

Digital Content

Workspaces

Assessment

Search

Announcements

Course Mail

Forums

Chat

Classrooms

Site

Programs



[f](#)
[g](#)
[t](#)
[in](#)

Free registration

Register in Course

Registration Deadline

Open

Registered Users

0

Hits

1225

Course 05: Embedded systems in mechatronics

M005en

This course is an introductory to embedded system used in mechatronics, focusing on the underlying principles of how embedded systems work. In the module are presented the main parts of one embedded system and is given brief information about its main parts as microprocessor, memory, interfaces, etc. The information included in the course is prepared for personnel working in small and medium enterprises and concerns basic topics related to the fields of mechatronics and industry automation. The course book is divided into 10 lessons. The lessons are accompanied by a presentation, a number of resources for further study, a self-assessment consisting of multiple-choice questions to assess your knowledge on the subject, and assignments for gathering of new theoretical knowledge.

**Objectives**  
Upon completion of this course the students will be able to:

- understand the main principles of embedded systems;
- know the main components included in the structure of one embedded system;
- know the main classifications of microprocessor architectures;
- know the main types of memories used in embedded systems;
- understand the principles of operation of analog-to-digital and digital-to-analog converters;
- know the most often used communication standards for inter chip communication;
- know the main topologies of power supply systems used in embedded systems.

**Keywords**  
embedded systems mechatronics



Stefan Ivanov



Todor Todorov

Course Structure

Lesson 1. Main characteristics of the embedded systems

Lesson 2. Microprocessors and microcontrollers in embedded systems

Lesson 3. Volatile and nonvolatile memories used

Program - Category

MechMate training program on Mechatronics (English)

MechMate courses

Course Syllabus

Download file

References - Links

Hits

Sep

Oct

Nov

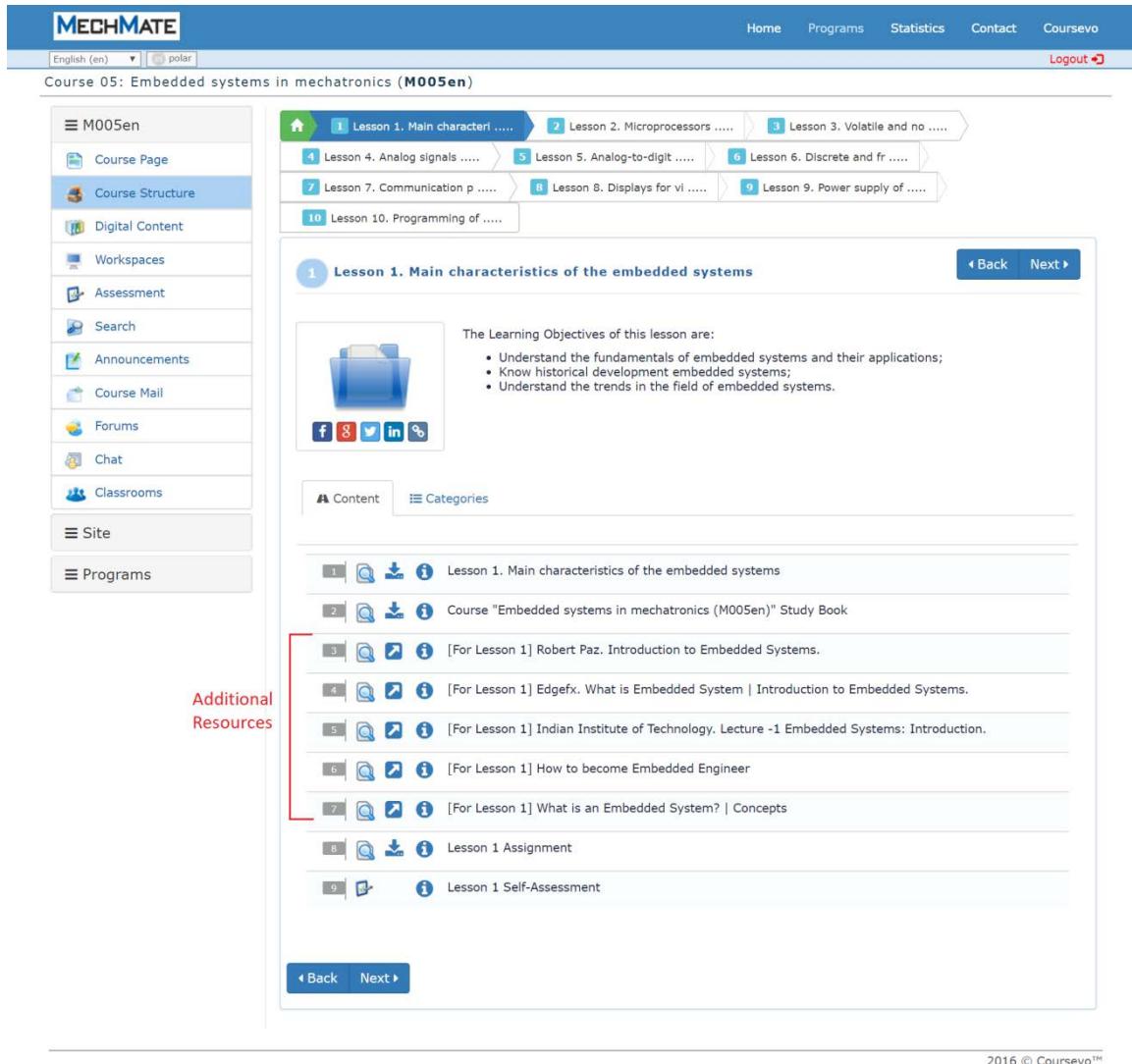
May

Aug

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Figure 3.5 Main page of a MechMate course in Coursevo

- 16 -



MECHMATE

Home Programs Statistics Contact Coursevo

English (en) polar Logout

Course 05: Embedded systems in mechatronics (M005en)

M005en

Course Page

Course Structure

Digital Content

Workspaces

Assessment

Search

Announcements

Course Mail

Forums

Chat

Classrooms

Site

Programs

1 Lesson 1. Main characteri ..... 2 Lesson 2. Microprocessors ..... 3 Lesson 3. Volatile and no ..... 4 Lesson 4. Analog signals ..... 5 Lesson 5. Analog-to-digit ..... 6 Lesson 6. Discrete and fr ..... 7 Lesson 7. Communication p ..... 8 Lesson 8. Displays for vi ..... 9 Lesson 9. Power supply of ..... 10 Lesson 10. Programming of .....

1 Lesson 1. Main characteristics of the embedded systems

The Learning Objectives of this lesson are:

- Understand the fundamentals of embedded systems and their applications;
- Know historical development embedded systems;
- Understand the trends in the field of embedded systems.

Content Categories

1 Lesson 1. Main characteristics of the embedded systems

2 Course "Embedded systems in mechatronics (M005en)" Study Book

3 [For Lesson 1] Robert Paz. Introduction to Embedded Systems.

4 [For Lesson 1] Edgefx. What is Embedded System | Introduction to Embedded Systems.

5 [For Lesson 1] Indian Institute of Technology. Lecture -1 Embedded Systems: Introduction.

6 [For Lesson 1] How to become Embedded Engineer

7 [For Lesson 1] What is an Embedded System? | Concepts

8 Lesson 1 Assignment

9 Lesson 1 Self-Assessment

Additional Resources

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Figure 3.6 Organization of MechMate courses in Coursevo

### 3.4 Recognition of competences: Certificate of Completion/Achievement

Upon successful completion of a course, a certificate of completion is automatically created and delivered to the trainees by MechMate e-learning platform (Figure 3.4). The decision of "successful completion" (or not) is based on the performance of the trainees in the self-assessments of all learning units (lessons) of a course, consisting of multiple-choice questions. It is considered that a trainee has mastered a course, if (s)he manages to successfully complete more than 70% of the questions of every self-assessment of this course. A unique code is generated and placed on each certificate, so that the validity of the certificate can be confirmed at any time, using a special validation service developed in Coursevo for this purpose that can be accessed at: <https://cloud.coursevo.com/validcert>.

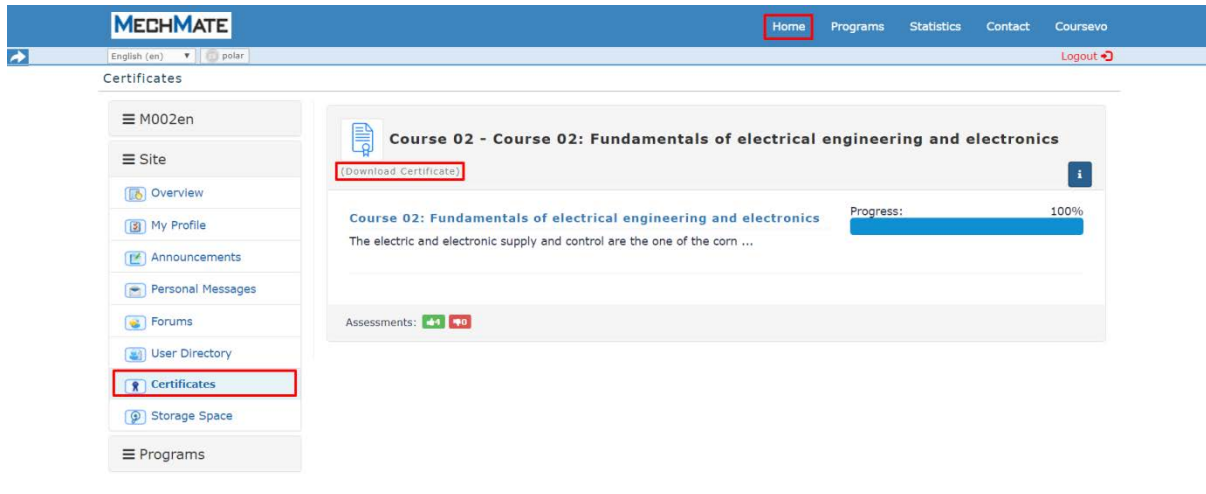


Figure 3.7 Accessing and downloading the certificates awarded after successful completion of courses

The trainee can access and download the certificates awarded after the successful completion of the courses (s)he has attended, by selecting “Home” from the top menu and then “Certificates” from the left menu (Figure 3.7). After that, (s)he can download the certificate of a course (Figure 3.8) by selecting “Download Certificate”.

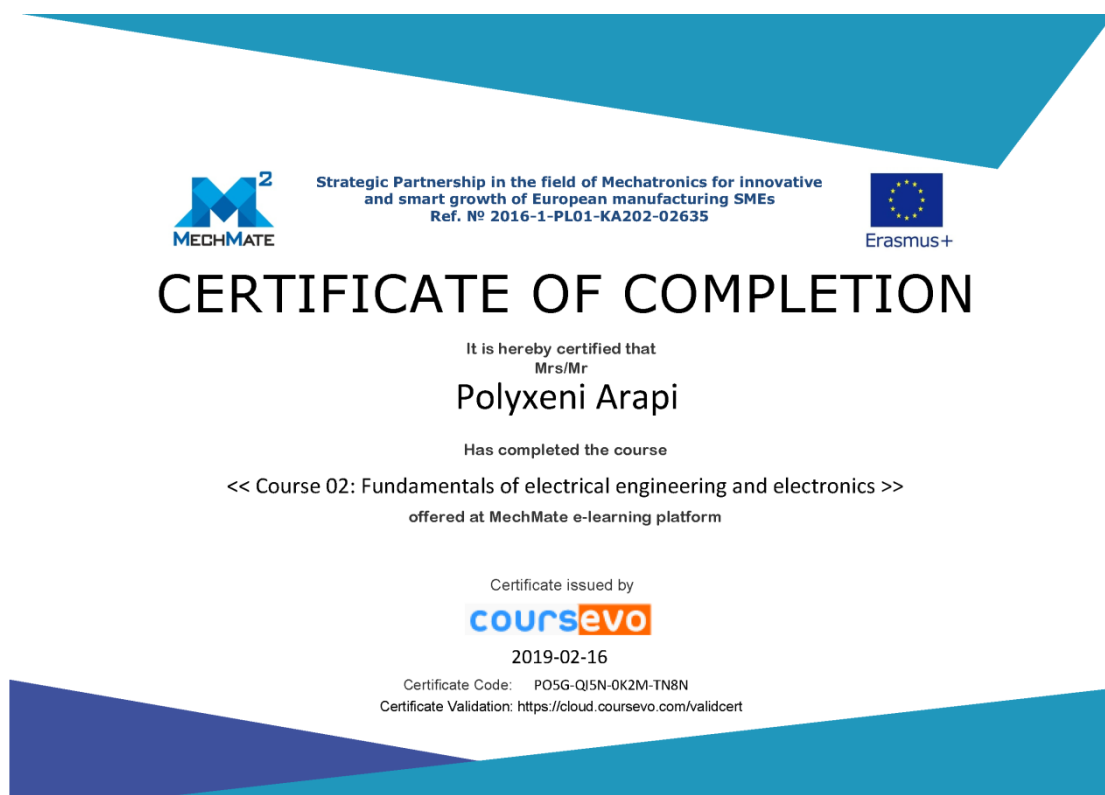


Figure 3.8 Certificate of completion automatically created and delivered to the trainee by MechMate e-learning platform (Coursevo), upon successful completion of a course

#### 4 REFERENCES

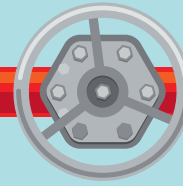
- [1] Pappas N., Arapi P., Moumoutzis N., and Christodoulakis S. (2017): “Supporting Learning Communities and Communities of Practice with Coursevo”, In Proc. of the Global Engineering Education Conference (EDUCON), IEEE, April 2017, Athens, Greece, ISSN: 2165-9567, doi: 10.1109/EDUCON.2017.7942862.







Co-funded by the  
Erasmus+ Programme  
of the European Union



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