Preprint of the original appearing in Proceedings of the 5th International Conference on Condition Monitoring and Machinery Failure Prevention Technologies - CM and MFPT, 15-18 July 2008, Edinburgh, UK

Current trends in e-training and m-training and prospects for maintenance vocational training

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Abstract

Maintenance training and educational activities are increasingly exploiting technological innovations. Desktop and web-based e-learning applications offer academics and industrialists new tools to raise maintenance-related knowledge and competence. As the first generations of related e-learning toolsets and services have matured, latest efforts are paying increasing attention to the usability of the offered learning process, while attempting to structure the learning curricula and assessment tools in ways that make them appropriate for knowledge accreditation and competence assessment schemes. Usage of multimedia-rich content, virtual reality, as well as personalisation of the learning experience, by adjusting content to fit the needs of different learner groups are increasingly receiving more attention. On the other hand, the increasing penetration of mobile and handheld devices in industrial settings enables the development of mobile learning solutions, which implement the concept of offering educational services anytime, anywhere and to the right person. This paper surveys ongoing work and trends in these new directions and highlights current requirements and challenges for vocational training in maintenance.

1. Introduction

Desktop and web-based e-learning applications offer academics and industrialists new tools for maintenance-related training and competence assessment. In this paper we survey current practice and the state of-the-art in Learning Management Systems (LMS) technology. LMSs increasingly follow specific educational technology standards, so that the developed content can be ported to different learning platforms and can be customised for different applications. The offered solutions are increasingly paying attention on usability. To this end, they employ multimedia-rich content, augmented reality, as well as personalisation of the learning experience, by adjusting content to fit the needs of different learner/teacher groups and by observing the users learning paths. At the same time, the learning content can be structured in ways that facilitate implementing knowledge accreditation and competence assessment schemes. On the other hand, the advent of mobile technologies and handheld devices in industrial settings, makes it possible to deploy mobile learning solutions. These solutions implement the concept of offering educational services anytime, anywhere and to the persons authorised to access them. This paper surveys ongoing work and trends in these new directions and highlights current requirements and challenges for vocational training in maintenance from the educational technology perspective. There is substantial work in the direction of defining the requirements for maintenance-related training. This paper seeks to address issues of concern for Maintenance eLearning developers, focusing on requirements for developing the Training system development process. Naturally any such effort should also take into account specific maintenance-training and competence requirements specifications, which are described elsewhere. Section 2 reviews Learning Management Systems technology and standards. Section 3 provides a description of one of the most popular open source LMS platform, namely Moodle. Section 4 discusses the potential offered by the use of advanced learning technologies, such as education grids, mobile learning, and augmented reality-based training. The following section outlines educational technology requirements for designing an eTraining Maintenance System, stemming from vocational education guidelines. Section 6 is the conclusion.

2. Learning Management Systems

2.1 Introduction and Terminology

eLearning has redefined the way education is provided in schools, academia and industry. It is defined as a technological, organizational and management system that enables and facilitates web-based learning. eLearning users, both teachers/trainers and students/learners are offered integrated solutions which facilitate authoring, structuring and delivering educational content, as well as assessing the educational outcome. Such solutions are termed *Learning Management Systems* (*LMS*s). Most current LMSs include functionality to handle lesson content, often in the form of Learning Objects (*LO*). Any entity that can be used, reused or referenced in eLearning is called Learning Object. These systems are more accurately called Learning Content Management Systems (LCMS) but both terms are used interchangeably, thus the term LMS will be employed for both LMS and LCMS in this context. There are many obvious advantages in web-based learning, compared with the conventional training. Typically, elearning enables anytime, anywhere and to anyone with authorised access, to participate in the learning process. Apart from this flexibility, elearning is usually associated with lower costs, compared to engaging a qualified teacher [1]. On the other hand, elearning involves extra costs in producing the actual educational content, as well as in customising it for the e-learning environment.

Nevertheless, just presenting information over the web does not provide education and is not considered eLearning in the real sense. A robust and usable way of communication between the teacher and the students and between students themselves is necessary to exist. Conferencing, mailing, bulleting boards, chat, forums are among the additional features which are typically integrated with the learning environment and content. Furthermore, eLearning systems are greatly benefiting by adopting theories artificial intelligence and cognitive science practices, in order to approach and mimic the human tutor. The learning outcome must also be assessed and adequate competence assessment tools and content linked with the learning content and the targeted learner groups are needed for that. Moving beyond simple presentation of information relevant to the learning subject, the e-learning experience needs to be enhanced to engage the learner groups in a stimulating and practical learning process. Irrespective of the specific conditions of use of any developed learning material, its added value is increased if the learning content can be employed in different systems or varying contexts. Therefore, the re-usability of the learning content should not be ignored. With

Internet's ubiquity and the plethora of learning solutions offered, being proprietary or open-source, reusability remains an issue.

A key challenge is to develop flexible eLearning systems, which can be adapted and deployed to serve diverse communities of teacher/learner groups and usage environments. *Intelligent Tutoring Systems* (ITSs) have been around for several years, claiming to possess the ability to present the teaching material adapted specifically for each user. The main focus is in the development of Web-based Intelligent Learning Environments (*WILE*s). Such an environment can keep track of the student current knowledge on the subject matter by storing it in a student model database. In doing so, the Learning Environment can adapt the presented content according to the student learning needs, by keeping track of the individual learner's *learning path*. Typically, the learning content is stored in a standardised format and can be dynamic in nature [2]. The benefit of doing so is that the the developed content can be ported to another learning environment, which follows the same standard in handling learning objects. An ITS is typically built around three main concepts: how to handle expert's knowledge, learner's knowledge and educational principles. The model tracks the learner progression and responses, compares his knowledge with the expert knowledge, and employes some form of intelligent reasoning to dynamically generate the best sequence of instructions, learning content and tests for the learner [3, 4]. The following section briefly discusses the role of standardised learning objects in an eLearning system.

2.2 Learning Objects and Standards

Learning objects can be developed for any type of learning curricula or learning objectives but the way this is done need not follow different specifications. Educational technology standards have been developed to determine the way educational content is being defined, packaged, sequenced and delivered, alongside with information about the learning activities and the learners. Indeed, sharing and reusing existing learning objects can reduce costs and speed up the process of course content construction. This reuse is ensured if the learning objects themselves follow specified educational technology standards. If such interoperability is ensured, the bulk of the effort will then need to be devoted to the quality of the implementation and content presentation. Educational content consumers would be able to choose a product that would suit their needs without the fear of sudden obsolensce that is so common in proprietary software solutions. It is through the definition and adoption of such standards that eLearning practitioners can exploit existing information and communication technologies to deliver eLearning modules which can enhance the learning progress, ease the delivery of learning services and streamline the development, delivery and assessment of training. The most widely employed such standard is the Sharable Content Object Reference Model (*SCORM*) developed by the Advanced Distributed Learning initiative (*ADL*), a joint White House/ U.S. Department of Defense initiative .eLearning interoperability standards deal with the following issues[5]:

Metadata definition. Metadata is a convenient way to label each learning object. In this way, it is possible to index, store, discover and retrieve learning objects from multiple educational repositories by employing different tools. Information stored about learning objects is called learning object metadata. Different metadata standards can be employed. The IEEE Learning Standards committee has produced the *LOM* (Learning

Object Metadata) metadata standard. LOM has been adopted by IMS Global Learning Consortium, the Advanced Distributed Learning initiative (ADL), the Alliance of Remote Instructional and Distribution Networks for Europe and many other organizations and has become the leading standard for describing learning objects. Other metadata standards following the Dublin Core Metadata Initiative, or more specialised educational activities to connect high-level pedagogical methodologies with low-level machine interpretable descriptions can also be employed. The LMS learning design team should be concerned with the metadata definition choices.

Content Packaging. Content Packaging standards deal with how learning objects are stored and delivered to the users. They ensure that learning objects and packages of them (*learning units*) will be reusable and editable in any conformant software tool or environment. Content Packaging standards are included in:

- The IMS Content Packaging Specification.
- The IMS Simple Sequencing Specification.
- The IMS Question and Test Interoperability specification (QTI), which is a set of specifications governing assessments and their questions.
- The Aviation Industry CBT Committee.
- The SCORM Reference Model
- The IEEE Learning Technology Standards committee.

Learner Profiles. These standards allow sharing of information about learners A learner profile can include personal data, learning plans, learning history, degrees and current e-learning status. Relevant to Learner Profiles standards are:

- The IMS Learner Information Package (LIP) specification.
- The Personal and Private Information (PAPI) specification.

Learner Registration. Learner Registration contains information about the selection of which learning content and administration components should be delivered to the users: Relevant initiatives include:

- Specification for exchanging offering and registration data among learning systems by the IMS Enterprise working group.
- Specification for exchanging the above data in K-12 environment by the Schools Interoperability Framework.

Content Communication. Content Communication refers to standards about how learners data are linked with the content and the learning activities. Single assessment question answers, course grades and completion status are all included in here. Existing standards include:

- Communication component in Computer Managed Instruction (CMI) by the Aviation Industry CBT committee.
- Communication JavaScript API in SCORM

2.2.1 SCORM

A discussion on the main characteristics of the SCORM model, which is the most widely employed educational technology standard is included here. SCORM was established in 1997 as an ADL initiative. It was developed with the view to incorporate the best parts of the existing e-learning standard groups, like IMS, AICC, ARIADNE and IEEE-LTSC and provide a new, more complete model [2]. These standards regulate aspects like meta-data, content tracking and content sequencing. SCORM defines sharable content objects (*SCO*s) as the smallest logical units of instruction and considers them as the smallest building blocks for content. SCOs contain assets packaged for a learning context and they are delivered through a SCORM-conformant runtime environment. Any type of educational digital media, such as text, video, sounds or any form deliverable through Web can be characterised as educational asset [2]. The most recent SCORM version is the 2004 3rd Edition, available since 2006. It is described in three separate volumes; their content is briefly described as follows:

SCORM Content Aggregation Model (*CAM*): The SCORM Content Aggregation Model (CAM) contains information on metadata and content packages. The main use of metadata is for searching and discovering learning objects. Content package is a collection of content objects, about a course, a module, a lesson or even a generic collection of related learning objects. In every content package, an *imsmanifest.xml* file describes the contents of the package and sometimes the package structure too. Information about how an LMS should handle a content package may also exist [6].

SCORM Sequencing and Navigation (*SN*). It describes all the requirements of an LMS, which enable it to sequence content objects at run-time. Moreover, it contains information on how the content object should accept and handle user navigation requests. Sequencing and navigation is in turn defined by user choices and achievements at run-time. It comprises sequencing terminology, navigation requirements and models for navigation model, sequencing definition and sequencing behaviour [7]. It deals with the way to respond to the learner choices and activities, so as to define which content object will be delivered next.

SCORM Run-Time Environment (*RTE*). The actual delivery of the content object is the subject of the SCORM run-time environment The SCORM Run-Time Environment (RTE) defines what an LMS must do in order to be able to deliver SCORM content. SCORM content is divided into two distinct categories *SCO*s, which are objects with the ability to communicate during run-time; and Assets, which are content objects that are not capable to communicate. Based on these, the way of launching content objects is defined, as well as the way to establish communication between SCOs and LMSs. The RTE also presents a model to track user's interaction with the content objects [8] [9]. Based on the above, SCORM combines Metadata, Content Packaging and Sequencing and Navigation to aggregate SCOs. Several LMSs currently exist, many of them providing SCORM compliance support. A brief survey of LMSs key features follows.

2.3 Comparing LMSs

There are several LMSs surveys in the literature. When comparing LMSs, there is no single set of criteria to focus on and therefore it is easy to end up with subjective results. Each comparison puts weight on specific factors, directly relative to the context and time that the LMS were tested. The timing of performing the tests can also make a difference as typically LMS releases are becoming available at different frequencies, so a survey can offer a snapshot of LMS features at a specific time. Comparisons have been made against a single criterion, such as adaptivity [10], functional assessment [11] or SCORM conformance [12] or against multiple criteria [13, 14]. Evaluations consider both the viewpoint of those concerned with producing an LMS solution for a specific application, as well as for specific targeted teacher and learner user groups. The LMS developers are concerned with the LMS offered features for customising, extending, deploying, upgrading or migrating the content from one platform to another. Users on the other hand are more concerned with the offered features to support the learning process, as well as with the system usability. Here we summarise the main factors considered when reviewing LMSs and we focus on the features offered by the best known among them.

- *Adaptability*. This refers to the ability of LMSs to be modified according to the needs of each installation case.
- *Affordability*. This is broadly related to the Return of Investment for each LMS solution. Specifically, it examines for each LMS case, cost and time required and the benefits of its use, like improved productivity and efficiency.
- *Interoperability*. The ability of an LMS to be independent of specific software tools and platforms.
- *Reusability*. Ability of LMSs to accept and use learning objects from different LMS platforms. This will have also a direct impact on the cost of application of each LMS.
- *Durability*. For how long an LMS will be useful without the need for redesign or a complete change.
- *Accessibility*. It examines the ease to find and use learning objects from anywhere.

The above factors are all among SCORM objectives and are all important from the LMS developer point of view. It is therefore making sense to examine exiting LMSs for SCORM-conformance [12]. Nonetheless, employing eLearning is ultimately about serving the user needs and it is therefore important to focus on whether the LMS offers enhanced teaching and learning experience to the teacher and learner user groups. What is important from the user perspective is to have a number of learning-related features present in the LMS and offered in a user-friendly manner.

- *Usability*. It deals with difficulties involved in the installation and consequent use of an LMS. Intuitive environment, integrated authoring tools, visual enhancements are all constituent parts of a user-friendly platform.
- *Features*. Every LMS presents a series of features that can be used in the development and delivery of courses. The extent to which an LMS offers such features can by itself be an important factor for the adoption of an LMS platform.

With regard to SCORM conformance and ease of use, it seems that there is still a conflict between these two. SCORM conformance demands a set of extra variables and descriptions to be used for each learning object. Despite that the extra work is justified and it will certainly contribute to accomplishing many of the aforementioned goals, many learning object authors are not willing to get involved in the overload and prefer to use older, usually proprietary and less demanding software packages.

A major consideration when considering adopting a specific LMS platform is whether this is a *proprietary* software tool or an *open source* solution. Many organisations and practitioners would opt for a commercially supported solution justifying their choice by the availability of commercially-driven support in developing and deploying the eLearning solution. Others would prefer to avoid the costs associated with a proprietary ('licensed') solution and work with open source platforms. The latter are distributed together with their source code, making it possible to study the code, run the program for any purpose, customize it according to specified needs and have a much more flexible distribution policy. Open source software is often associated with non-professional, research-only efforts, not applicable for professional deployment. Although open-source developen is often driven by non-commercial research efforts, arguing that it is inappropriate for professional ignores reality. This is especially true for eLearning, where open source solutions are known to offer [15]:

- Fast software development due to the parallel work of many programming groups versus a single team in proprietary software. The collective work may lead to satisfying the user community needs in shorter time.
- Wide base for testing as new versions, as test are performed by a multitude of users on much more environments and platforms than any proprietary software.
- Frequent release of new versions and immediate testing of them by the "community" of the involved users.
- Peer reviewing, testing and improving the code can lead to enhanced transparency, security and better quality in code, as all the weak points or bugs will be most definitely pointed out by the user community.

Among the various LMS solutions, Blackboard/WebCT and Moodle are among the most popular, with SAKAI enjoying also a large user community. Blackboard is perhaps the most widespread commercial e-learning solution. WebCT was developed at the University of British Columbia in 1995 and it is considered as the first virtual learning environment with commercial success. WebCT has recently been bought by Blackboard. The SAKAI open source collaboration and learning environment, encapsulates many useful features: SCORM support, shared displays and whiteboard, blogs etc. Moodle is another open source content management system (*CMS*) solution, with a very large active supporting community and several features making it a collaborative environment for teacher and learner communities.

Between WebCT/Blackboard and Moodle there are many common features. Moodle provides more support for different course formats and grading systems, discussion fora and wiki, while WebCT offers a whiteboard tool enabling learners to share drawings in real time. Both include several aspects of SCORM functionality. Moodle supports SCORM packages in courses and collaborative creation of course content. As Moodle is both open source and popular, the next section takes a closer look at it.

3. The Moodle LMS

Moodle is an Open Source "Course Management System" that follows specific "pedagogical principles". These principles are *constructivism*, *constructionism*, *social contructionism* and support for "connected" or "separate" behaviours. We will elaborate on these terms in the next paragraphs. The word Moodle is an acronym for "Modular Object-Oriented Dynamic Learning Environment".

3.1 The Educational Perspective

Constructivism referes to the concept that learners should build their own understanding. In principle, this should be based on a complex mix of interactions and experiences and should be realized through the social negotiation of meaning. Constructionism implies the construction of learning content for others, in order to enhance the learning effectiveness. One usually pays more attention on a subject when he has to explain it to someone else, thus constructionism guarantees better understanding. Social constructionism is the expansion of the idea of constructionism to collaborating groups of learners. This has the potential to create a local “culture”, a set of shared meanings between the group members, a type of common shared collective knowledge that will enhance further understanding of topics. Connected behaviour refers to students that face topics in a subjective manner, taking into consideration the opinion of others. Separate behaviour refers to students that have a tendency to support their own ideas against others, based on “facts”. Moodle supports “constructed” behavior which is a combination of both, with the ability to select which one is more appropriate for each case.

3.2 The Technical Background

Moodle supports several major databases, such as the open source MySQL and PostgreSQL and also the commercial Oracle and Access and many others. It is built in PHP and has minimal requirements for the content server and for the client computers. It fully supports IIS and Apache and the simplicity of its interface make it suitable for course delivery even in mobile communication machines, such as PDAs .Moodle offers a rich set of features to support educational principles during development and delivery of courses. Open source allows also for programming extensions to be written.

3.3 Key Features

Roles specify rights and involvement of users in the courses and they are assigned dynamically. A user can be a student, a teacher with or without editing rights, a course creator or an administrator. For example, a student in one course can be teacher in another, or a group of students may have rights to collaboratively construct learning material for other students. The idea of “social constructionism” is most pervasive here.

In Moodle, all course content is separated into two categories:
- *Resources*, which are the static learning elements.
- *Activities*, which are the dynamic and collaborating learning elements.

Resources include text pages, web pages, links to web material, directory views and IMS content packages. Activities include assignments, choices, journals, lessons, quizzes, forums, chat, glossaries, wikis, SCORM conformant learning objects and surveys. For the creation of text and web pages, Moodle provides a simple *wysiwyg* (what you see is what you get) editor, but one can use any web page creation tool and paste the results inside the Moodle pages. There is also an organized directory structure where all the necessary files for the lessons can be uploaded and become accessible.

4. Advanced Learning Technologies

A direction for eLearning R&D has been the creation of larger scale educational environment infrastructures and content repositories. *GRID* technology and services are enabling this shift, but there are two major hindering factors in the procedure: first the creation of educational hierarchies and organized directory services, so it would be possible to effectively search for information, based on metadata; and second the content standardisation itself [16]. Grid educational infrastructure and technology can essentially support collaborative construction of learning objects with the involvement of many disparate experts, teachers and learners [17] [18].

The penetration of mobile and wireless technologies have opened up new opportunities for educational technology in the form of mobile learning (*mLearning*). While eLearning enabled the delivery of web-based training to remote desktop users, *mLearning* extends this by offering ubiquitous services to mobile users. In this way it becomes possible to deliver educational content anytime, anywhere and to anyone authorised to access it. Although mLearning learning can be useful in school and academic education [19, 20], it is lifelong learning which is likely to benefit most from it [21]. Indeed a key driving factor for lifelong learning is the fact that school and academic education cannot possibly equip learners with the needed skills for a professional carrier. On the other hand, lifelong learning participants need to follow a self-paced learning process, much depended on their available time. Through the use of mobile devices in industrial settings, users can gain access to training material from multiple locations, being at home, office or even at the shop floor, next to the machinery and production processes. In this way, the gap between text and theoretical knowledge and practice is narrowed and the users may engage in a problem-based learning process, actually taking place next the operating environment. The immediacy and ubiquity of the learning process may enhance the learning experience and positively influence the learning outcome through a learn by-example educational program.

Maintenance training can be made more efficient if accompanied by case studies in a form of on-the-job training. In several domains, such as in aircraft maintenance to name one, this is prohibitively expensive. Augmented reality (AR) technology offers the means to provide problem-based maintenance training, without the costs associated with going through the real case study. AR combines real-world objects with computer-generated data, as opposed to Virtual Reality (VR) that deals only with computer generated environment. Based on sensors and motion detectors AR can provide object recognition and learner's motion tracking. Head Mounted Displays (HMDs), cameras and special clothes usually co-exist in a AR-based training environment [22]. Industrial maintenance [23], power systems maintenance [22], aerospace maintenance [24, 25] and medical training are [26] just a few of the involved sectors that are greatly benefited by augmented reality in their teaching procedures.

5. Implications for Vocational Maintenance Training

Developing Maintenance Vocational Education and Training (VET) is of critical importance for industry in its pursue to establish adequate maintenance practice, excercised by qualified Maintenance personnel. Although focusing on VET and creating a high skilled personnel is a matter of great importance, its implementation relies on public and private funding. Focusing on the private sector, larger companies have established internally funded vocational training policies for most of their employees. The situation is different on SMEs, who are struggling to offer such opportunities and when they do, this is often through participation in public-financed training programs. Therefore, attracting smaller enterprises to VET is a difficult task. Moreover, employees should be persuaded to get involved in VET courses. This group of stakeholders may be unwilling to consume time on VET programmes and as a result it should be informed and persuaded about Maintenance training benefits.

Current advances in eLearning and Advanced Learning technologies can benefit greatly the delivery of Maintenance Training. In designing an efficient LMS for that purpose, several questions need to be addressed:

- How will training in the LMS be in line with the general EU recommnendations on VET and the specific EFNMS (European Federation of National Maintenance Societies) recommendations on maintenance competences ?
- What short of maintenance qualifications are envisaged?
- How will the LMS provide and accommodate the transfer of learning outcomes?
- What type of learning paths will be crafted and who will assure that the competence assessment tool keeps step with the recommendations?
- How will maintenance qualifications be divided in units of learning outcomes?
- What is the best way of connecting each maintenance lesson with its expected learning outcomes?
- Would it be recommended to define units, attach credit points to units and connect them to an European Maintenance Quality Framework level ?
- Which knowledge, skills and competences will constitute the learning outcomes of each unit?

Any Maintenance VET training must be quality-assured or validated. According to the recommendations of the Technical Working Group (TWG) on quality, this should be defined as a context-dependent term. A validated Maintenance Training System should ideally be accompanied by a carefully designed credit transfer mechanism. Such a mechanism would providee a way of measuring and comparing learning achievements and transferring them from one institution to another, using credits validated in training programmes [27]. With this in place, it would become possible to transfer maintenance learning achievements between different countries, organizations and educational systems. A Maintenance credit transfer system should support the transparency of proceedings and the comparability of learning outcomes. It should ultimately facilitate the mobility of learners and of their qualifications. The availability of eTraining systems for Maintenance can facilitate formalising qualifications mobility and in particular:

- the transfer of learning outcomes between national systems
- the transfer of learning outcomes between formal, non-formal and informal pathways
- the accumulation of learning outcomes
- transparency of processes
- mobility of people between countries, professional levels and learning pathways
- mutual trust and cooperation in the area of Maintenance Education and Training.

The above discussion highlights important considerations that need to be taken into account when designing an LMS-based training system for maintenance training and competence assessment. The Leonardo da Vinci funded project iLearn2Main deals with such issues with the aim to develop an LMS Maintenance training system observing educational technology standards, vocational training guidelines and recommendations for maintenance-related training.

6. Conclusion

This paper has provided an outline of currently available eLearning technogy in the form of Learning Management System platforms and a discussion on their potential impact on Maintenance Training. The latter can benefit by the recent advent of web-based and mobile technologies and handheld devices in industrial settings, resulting in the a range of mobile learning solutions. Such solutions essentially are compatible with the concept of offering educational services anytime, anywhere and to the persons authorised to access them. Other advanced training technologies involving Augmented and Virtual reality can provide 'virtual' on-the-job training. The paper also provided a description of one popular open source LMS platform, namely Moodle, which is selected within the context of the iLearn2Main project to develop an LMS Maintenance training system observing educational technology standards, vocational training guidelines and recommendations for maintenance-related training. iLearn2Main is a Leonardo da Vinci Transfer of Innovation project, aiming at delivering training content and IT tools for Maintenance Management. VET-related guidelines are considered together with their implications for Maintenance Training. This survey consists part of the requirements analysis phase. The project considers complementarity with other Maintenance Training initiatives and aims to contribute towards the development of efficient eTraining based solutions in Maintenance Management.

Acknowledgements
The authors wish to acknowledge the financial support received through the UK/07/LLP-LdV/TOI-004 project iLearn2Main, which is a collaboration between the Univ. of Portsmouth, the Athena Research & Innovation Centre, ATLANTIS Engineering, the Swedish Maintenance Society UTEK, the Latvia Technology Park and the CNIPMMR National Council of Small and Medium Sized Private Enterprises.

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