

## **E-LEARNING FOR MAINTENANCE MANAGEMENT TRAINING AND COMPETENCE ASSESSMENT: DEVELOPMENT AND DEMONSTRATION**

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Recent advances in industrial production and manufacturing processes as well as the rapidly increasing global competition are key drivers in a growing demand for improving personnel competences in maintenance management. Most employees in the manufacturing sector are beyond the typical age of standard education, thus traditional teaching methods are not sufficient. Vocational Education and Training should be targeted to serve the specific needs for enhancing employable skills and competences. Time and place constraints, which are often a significant concern for professional training, can be mitigated by e-training. This paper presents an overview of the e-learning toolkit employed in the iLearn2Main project, a focused EU collaborative project targeting Maintenance Management Training. The learning toolkit offers customized maintenance management training, while facilitating the standardisation of competence assessment and learning evaluation. It is based on the Moodle Learning Management System platform and comprises a series of courses on maintenance management, structured in a complete Maintenance Management curriculum, specified by taking into account stakeholder needs. Each course is delivered in short and easily completed sessions, which are followed by comprehension questions, aimed at maximizing learner engagement and understanding. A full set of assessment questions certifies that learners acquire the required knowledge and provides an immediate, reliable and automated way of trainee performance evaluation. The learning toolkit is adequately customised to offer not only interactive training but to seek to steer the learners through individual learning paths, thus offering a more engaging and efficient learning process.

### **KEYWORDS**

Maintenance management training, e-learning, learning management systems

### **1. INTRODUCTION**

Industries are confronting challenging global competition that drives them to seek to rationalise the use of their assets. The maintenance management function is strengthened by the introduction of advanced tools and enabling technologies aimed at streamlining the planning and execution of maintenance and asset management tasks. This new environment increases pressure put on personnel involved in Maintenance Management to excel in performing their intended duties. As a consequence, there is a constantly increasing demand for improvement in maintenance management, delivered through personnel training. Vocational Education and Training (VET) should be targeted to specific needs and to the improvement of certain employable skills and competences. Whether VET is targeting people entering their working life (initial VET, IVET) or people during their working life (continuing VET – CVET), there is a clear need for a common framework for maintenance management competence assessment, ultimately leading to a competence certification process. An EU initiative in this direction is taken through the EFNMS, in the form of Competence Requirement Specification [1].

Traditional delivery of training in Maintenance Management is often considered impractical, as personnel need to operate under time and space constraints that lack flexibility. Therefore it is the training itself that needs to turn flexible. This can be achieved by employing e-learning techniques and tools, enabling trainees to choose the training pace and courses that fit their needs. Beyond that, e-tools can also facilitate streamlining the competence assessment procedure, by providing a uniform and standardized way to assess Maintenance Management knowledge and skills.

This paper presents steps taken towards developing a Maintenance Management e-learning and e-competence assessment IT toolkit, as part of the iLearn2Main EU project ([www.ilearn2main.eu](http://www.ilearn2main.eu)). Based on the popular open source Learning Management System platform Moodle, the toolkit offers customized maintenance management training and automated competence assessment. This paper describes the motivation for undertaking this work, as well as the key offered system functionalities.

## 2. MAINTENANCE TRAINING

Maintenance training has been acknowledged as of critical importance for industry to be able to effectively implement adequate practices in maintenance and support the effort of a modern enterprise to confront global competition through optimal use of their assets. Providing adequate maintenance training is a twofold issue:

- ✓ Appropriate maintenance training curricula should be constructed by taking into consideration maintenance theories & practice, academic knowledge and industrial needs. Close collaboration between academics, professional trainers and industrialists is crucial in the development of this curriculum [2].
- ✓ An acknowledged competence assessment and knowledge accreditation system that should lead to recognised qualification for maintenance personnel needs to be in place. An internationally recognised accreditation system would facilitate the recognition of maintenance competences. This in turn would facilitate personnel mobility as personnel on one hand would carry acknowledged qualifications, while industry will be aided in its pursuit to fill in maintenance posts with adequately trained personnel. In the EU, the main effort in the way of establishing a common accreditation scheme is through the EFNMS (European Federation of National Maintenance Societies) recommendations on maintenance competencies [3].

As a result, a number of European initiatives lately are seeking to provide up to date and adequate maintenance training [1]. Some of them are been funded by the European Commission Vocational Education and training (VET) funding scheme, Leonardo da Vinci. The nature of maintenance training can vary considerably depending on the targeted learner group. Maintenance management training has very different requirements compared to the training of maintenance technical personnel. In all cases training can more efficiently be delivered by employing additional tools, rather than relying on conventional training.

There have been several examples of employing advanced technology tools to deliver maintenance training. When the target group is maintenance technical personnel, a key learning outcome is the ability to perform maintenance tasks. Naturally, on-the-job training is well suited for this. Nonetheless, it is often impractical and in most cases too expensive. One of the most effective technologies is to employ Augmented Reality (AR), to provide “real-time” assistance to engineers. AR provides a way for problem-based maintenance training without the cost of on-the-job training, which in many cases such as aircraft maintenance [4] [5], large scale factory maintenance [6] or maintenance of power facilities maintenance [7], can become very expensive.

When aiming at delivering Maintenance Management training there are a number of factors that differentiate this type of training from the training that is appropriate for the industrial workers:

- ✓ The primary occupation of Maintenance Managers is the planning of the Maintenance procedures and observation of their correct application throughout the industrial system. Details about specific machine particularities are almost always out of their scope of interest.
- ✓ Trainees in Maintenance Management have to be constantly aware of the latest advancements and trends in the area of industrial maintenance and to be ready to apply them in practice. Excellent grasp of Maintenance Management concepts and strategies is a necessary ability.
- ✓ Their Maintenance training must harmonize with international standards and guidelines for maintenance management practice, such as the EFNMS Competence Requirement Specification.
- ✓ To be able to successfully perform in their role, personnel involved in maintenance management must be prepared to operate in a global competition environment; thus they be able at any time to take quick and informed decisions on their duties.

In maintenance management training, e-learning can be a practical and efficient means to deliver the required training. Although the cost of developing the e-training solution is higher than that of conventional training, the costs associated with running the training, the flexibility offered to the trainers & trainees and the fact that e-learning can offer interactive and engaging training experience makes it appropriate for maintenance management training. Before describing the iLearn2Main e-training solution, we first look into some aspects of e-Learning technology that makes it appropriate for Maintenance Management training.

### 3. e-LEARNING FLEXIBILITY AND ADAPTATION

One of the key advantages of employing e-Learning for maintenance management training is related to the flexibility it offers and the ease of adaptation of how the training is delivered to individual learners. Much of the adaptation capacity of Learning Management Solutions, draw inspiration from an understanding of the way humans learn. Two are the key principles involved in such a process:

- ✓ Learners should be actively involved in learning, thus be motivated to learn.
- ✓ People learn in different ways and rates. Customised and individual material leads to more efficient learning.

Reflecting on the way humans learn, three main learning theories have been influencing e-learning [8]:

- ✓ *Behaviourism* that treats learning as a set of changes to the learner as he reacts to environmental events. Memorising and imitation are critical in this learning process. Focus is on the teacher, or the computer providing the carefully arranged material and not the learner.
- ✓ *Cognitive science* that bases learning on attention, motivation, perception and other internal processes. It focuses on screen design and on human – computer interaction, where the teacher usually has the role of the facilitator or partner.
- ✓ *Constructivism* that claims that learners construct their knowledge as they react with and interpret their environment. The most important differentiation from other theories is that focus is located on the learner and his actions and not the teacher or the teaching methods. Thus the aim is to provide stimuli and support for the users to construct their knowledge.

A number of recent studies indicate that e-Learning has an exponential impact in learning practice, in every level or aspect of education [9, 10]. The number of universities and tutors including e-learning in their curricula demonstrates the maturity e-learning has reached. It offers unique benefits over traditional methods of studying, such as lower costs, ubiquitous learning and independence of time and space limitations. Especially in ages over compulsory education and VET teaching, mitigation of time and space limitations is an indisputable benefit.

Personalization is the latest trend in e-learning, and generally relates to the ability of a Learning Management System to deliver the best suited content for each user separately [8]. For example, personalisation can be seen as a way of tailoring learning content to each separate user. A learning system that supports personalisation should be able to identify learner educational needs and select to deliver the most appropriate learning material from a multitude of redundant resources to the learner. More general, adaptation is the ability of an e-Learning system to change the delivered training material, both in navigational and content level, to best fit each user needs. [11]. Adaptation can be distinguished between four levels [12]:

- ✓ Navigation adaptation that customises links by generating, hiding, annotating and ranking them.
- ✓ Content adaptation that customises content by hiding or providing extra or different versions of content.
- ✓ Presentation adaptation that changes the way content is delivered, by highlighting, adding, removing or sorting parts of it.
- ✓ Collaboration adaptation that bases customisation on collaboration preferences between the learners, and supports cooperative problem solving.

Personalization and adaptation base their efficiency on correct identification of learner's learning needs. This identification is closely intertwined with the notion of Learner Profiles. Learner profiles are described as a standardized method to store all the important information about a learner in one convenient and searchable place. This information usually includes his preferences, goals, previous knowledge about a subject, general knowledge, achievements, performance, and everything else that could be useful for an automated system or a tutor to decide the appropriate learning material for a learner [13]. Another research area on improving e-learning experience deals with Learning Styles. The identification of Learning Styles is based on cognitive theoretical approaches that attempt to classify users to different categories depending on the most efficient way for them to learn. In this way, a Learning Style can be defined as a set of characteristic cognitive, affective and physiological factors that indicate how a person learns and interacts in a learning environment [12]. Categorisation of users according to their Learning styles is presented also as an efficient way to implement customisation without an unmanageable number of differentiated parameters for each user.

The iLearn2Main toolkit seeks to exploit LMS adaptation concepts in order to deliver the right training and competence assessment content and tools to the targeted groups, ie those involved in maintenance management training, both trainers and trainees. It is of interest to assess the potential impact and acceptance likelihood of an e-learning solution to deliver maintenance management training. A survey of 70 professionals involved in the maintenance function in the UK, Sweden, Greece, Latvia and Romania, conducted as part of the iLearn2Main project. It is worth looking at the computer literacy of the interviewees. An especially high proportion (94,5 %) of them uses computer in a daily basis and believes to be “very much” familiar with computers (81,8%). Furthermore, 100% of the interviewees responded that they expect to benefit “much” (40%) or “too much” (60%) from a computer based automated learning platform. There were no negative or indifferent replies on this question. These responses indicate positive acceptance prospects for the iLearn2Main toolkit.

The next section provides an overview of the LMS system that the iLearn2Main toolkit is based upon.

#### 4. MOODLE LEARNING MANAGEMENT SYSTEM

Moodle is an acronym for “Modular Object-Oriented Dynamic Learning Environment”. By its core definition, Moodle is an open-source Learning Management System which aims at stimulating users to explore its pages, interact with the learning material and communicate with the teachers and other learners. Moodle has been the selected deployment platform of iLearn2Main training system for a series of reasons:

- ✓ Moodle has been built on top of a relatively new educational theory, called social constructivism. While most other LMSs have been designed around technological rather than educational concepts, Moodle has pedagogy in its core [14] Constructivism claims that we learn more efficiently when we construct knowledge artefacts for others. Social denotes that this construction of knowledge is even more efficient when it is performed in a collaborative way. Widespread acceptance and reactions from academic community everywhere prove that this is at least a successful theory.
- ✓ Learners are free to navigate through the material and choose the courses that they need. The learning environment can guide them by providing feedback and making recommendations on the courses that may be necessary for them to take. This, in conjunction with a learner enrolment system gives the course administrator or the tutor adequate control on which learners are attending specific courses.
- ✓ Open-source. This results in exceptional adaptability and transferability [3]. This is a significant advantage considering and enables easy expansion, amendment and porting of courses to different environments. A system built on proprietary software is always bound to the decisions of the software vendor.
- ✓ Huge user base. Registered Moodle based sites and users have grown exponentially, thus indicating a platform with positive outlook. It also designates the existence of an active support community. Furthermore it ensures multilingual support, which is necessary for the wider reach of the training. Moodle already includes language packs for more than 70 languages.
- ✓ Minimal requirements. Moodle has very limited resources requirements, thus supporting transferability, as lessons can be delivered to platform – independent computers with little hardware restrictions.

Moodle classifies all learning content into two large and distinct categories [15]:

- ✓ Resources. These are the static material that learners can read or attend but cannot interact with. They include Labels, Web pages, Text pages, File Directories and Links to files.
- ✓ Activities. This is the interactive course material, where learners can answer questions, upload files and communicate. They include Assignments, Choices, Journal, Lessons, Quizzes, Surveys, Wikis, Workshops, Chats, Forums and Glossaries. Some of the above further encourage collaboration between users, such as Forums, Wikis and Chats.

Course construction is relatively simple, enabling easy construction of taught curricula. Overall, Moodle provides a highly customizable environment. This customization is based on self contained, customizable entities called blocks. Blocks can be enabled, disabled and moved around the user screen by an administrator. Most commonly used standard provided blocks are Activities, Administration, Calendar, Course/ site description, Courses, Latest news, Main menu, Online users, People, Recent Activity, Site Administration and Search Fora [15]. It is worth mentioning here that in spite of the fact that Moodle basic installation contains a full set of blocks, there is a vast amount of blocks provided by other members of the open-source Moodle community.

Learners’ track record and performance data can also be stored and handled by authorised users. This can be done by handling detailed activity logs. Moodle keeps analytic logs for every type of action that occurs inside the LMS. The track data related to a particular user can shape up an individual learning profile. While it is possible to define a learning path to a user, social constructivism indicates that it is preferable to provide feedback and guidance, thus influence, rather than force the learning pathways.

Moodle manages users by defining user roles. Every user is member of one or more roles. Roles can be defined dynamically and determine exactly the rights of the user inside every piece of the environment. There are a number of predefined roles to facilitate quick setup of courses, like administrator, teacher, course creator, learner, but administrators can define new roles with more refined rights. It is worth noting that these roles are completely dynamic, meaning that a learner in one course, can be teacher to another, or have the right to create courses for a topic he is well aware of.

Regarding the interoperability support, course content in Moodle is pure HTML which means that core material is kept in a form completely independent of hardware and software limitations. However, other pieces of information, such as user personal data and qualifications can be stored inside the environment's database. From the e-learning perspective, an important consideration is conformance to Learning Object standards, such as SCORM [16] SCORM stands for Sharable Content Object Reference Model and was developed in 1997 by the Advanced Distributed Learning initiative (ADL), a joint White House / U.S. Department of Defence initiative. SCORM incorporated the best parts of pre-existing e-learning standard groups, like IMS, AICC, ARIADNE and IEEE-LTSC into a new model.[17] In SCORM, Sharable Content Objects (SCOs) are defined as the smallest logical, instruction units and considered as the building blocks for learning content. The most recent SCORM version is the 2004 4<sup>th</sup> edition, available since April 2009. SCORM compliance will lead to fully independent, interoperable Learning Objects which will contain all the information necessary to be deployed in different setups. Full compliance with SCORM is a primary goal for Moodle version 2.

## 5. ILEARN2MAIN LEARNING ENVIRONMENT

The targeted user group in iLearn2Main is personnel involved or aiming at becoming involved in Maintenance Management. An assessment of VET objectives was completed, that has taken into account a user survey of 70 stakeholders. On the basis of this a Maintenance Management Training Curriculum was defined (Figure 1). The iLearn2Main training toolkit offers an integrated environment that supports trainees and trainers to enrol and participate in e-training and e-assessment for Maintenance Management competences. The training modules have been developed and deployed in a Moodle platform that was setup and customised to fit the needs of Maintenance Management training, as specified in the VET objectives.

The screenshot shows the 'Maintenance Management Training Curriculum' page. On the left is a navigation menu with the following items: The Project, Objectives, Workplan, Partners, People, Training (highlighted), Target Groups, eTraining, News and Events, Links, Dissemination, and Contact. Below the menu is the 'Lifelong Learning Programme' logo. The main content area is titled 'Maintenance Management Training Curriculum' and contains three numbered sections:

- 1. Performed activities on the assets (Asset Care)**
  - 1.1 Maintenance involvement in design, procurement and operation of assets
  - 1.2 Preventive and inspection activities
  - 1.3 Repair techniques and methods
  - 1.4 Goal, strategies, results
  - 1.5 Work execution
- 2. Asset Performance Evaluation**
  - 2.1 Analysis of the technical performance of the assets
  - 2.3 Condition monitoring
  - 2.4 Measurements
  - 2.5 Information systems
- 3. Management/Economy of Assets**
  - 3.1 Maintenance concepts (Dependability / Availability Performance)
  - 3.2 Analysis of the economical results
  - 3.3 Documentation
  - 3.4 Laws and regulations
  - 3.5 Determination of human & material resources

At the bottom of the main content area, there is a link: [Click to connect to iLearn2Main training platform.](#)

Figure 1. iLearn2Main Maintenance Management Learning Curriculum

The Learning system resides inside the project site, which is accessible at [www.ilearn2main.eu](http://www.ilearn2main.eu). When a user first arrives at the project site, he is presented with a list of the offered learning courses. If the user selects a course, or clicks on the login hyperlink, he is presented with a login form where he has to enter his credentials. Inside a course, under the course title, there are the different parts that comprise a Moodle course (Figure 2):

- ✓ Course modules at the center of the screen: these include Lessons, Glossaries and References. This is the learning content.
- ✓ Links to other participants in the course to facilitate communication.
- ✓ Links to activity types in the course for easier navigation.
- ✓ Direct access to the learner grades for every type of quiz or exercise is included in the course.
- ✓ List of all other courses the learner has enrolled to.
- ✓ Latest news and events relevant to the course, i.e. uploading of a new module.

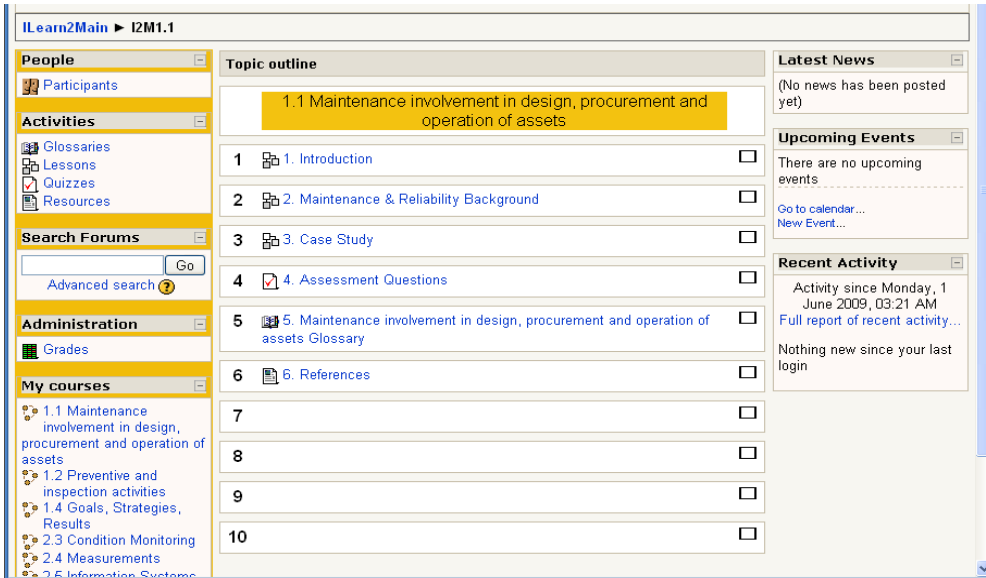


Figure 2. An iLearn2Main course page

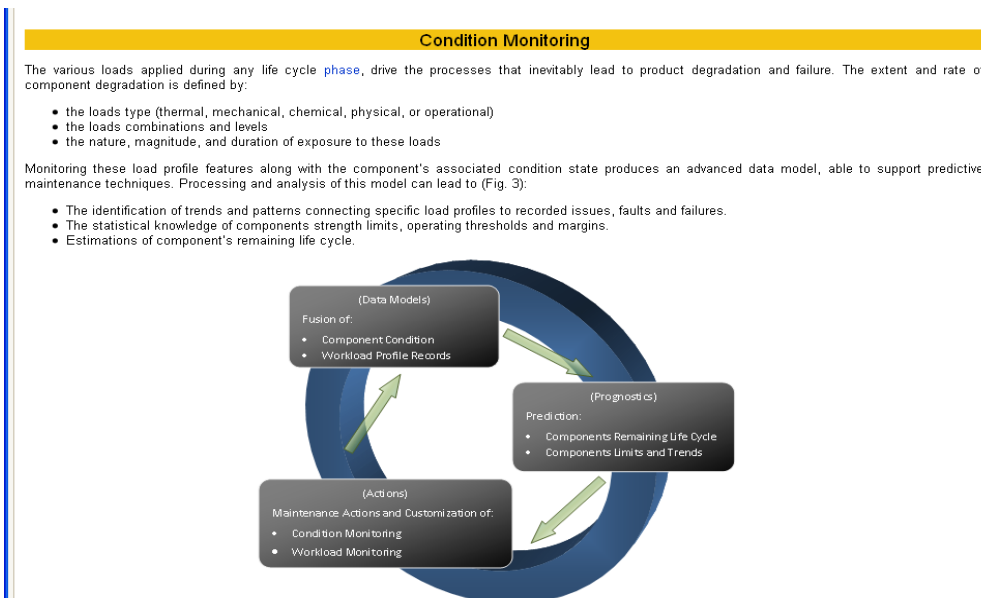


Figure 3. Part of an iLearn2Main course

As the learner progresses through the course screens (Figure 3), comprehension questions are offered (Figure 4). The learner has to answer to continue to the rest of the lesson. Multiple choice questions appear with shuffled answer order and help learners to assert their knowledge before continuing. According to [8], immediate feedback is three times more efficient than delayed in terms of learning time, thus the system provides immediate feedback on the given answers. When the learner

reaches the final page of a lesson, he is presented with a relevant message indicating his performance on comprehension questions and offering options for the next steps (Figure 5). Performance data can also be used to offer specific learning path suggestions, for example indicating to the learner that he is advised to take a specific course, repeat the same course content or progress to the next item.

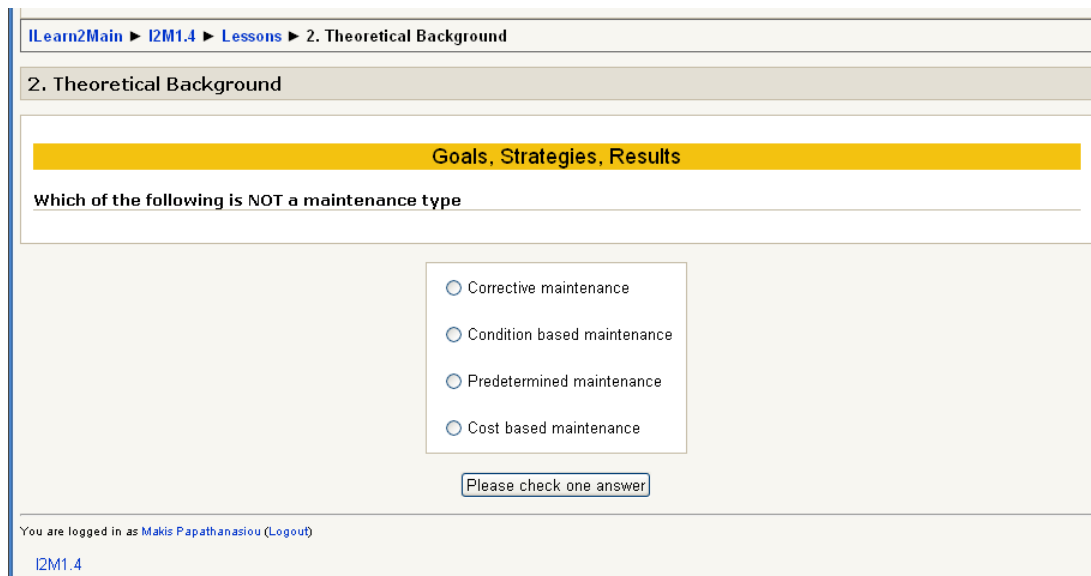


Figure 4. Comprehension question during a lesson

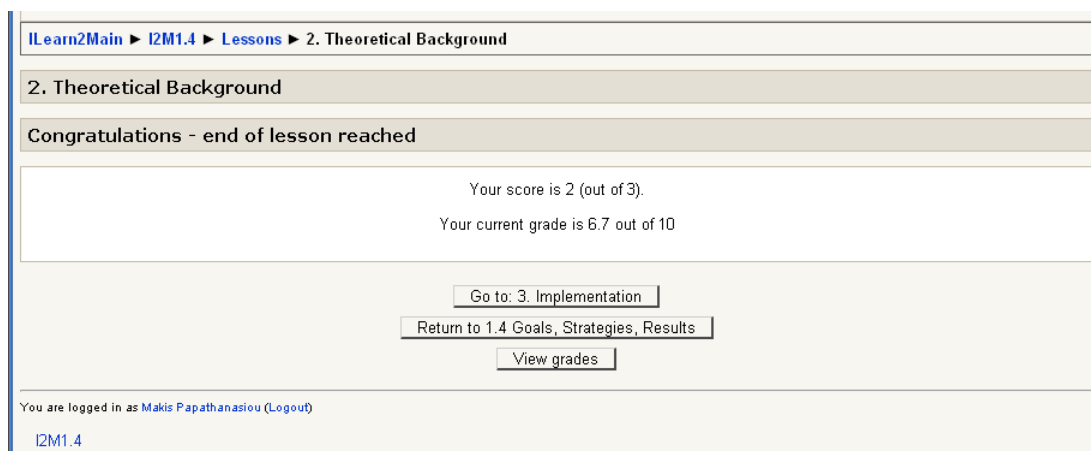


Figure 5. Learner results at the end of a lesson

Inside a course a user can find not only complete lessons but also References, in the form of a separate web page, which is convenient for direct linking from the courses but also as a collective reference for external material. Finally learners can see the course's glossary, with definitions for all the maintenance terms that have been used inside the course. This Glossary is integrated with the learning content, so as to provide direct and easy access to any of its terms. These terms are automatically linked everywhere they exist in the lessons, and comprise a full and analytic reference guide of all maintenance terms, conveniently located to help trainees accessing them when studying the training content.

Quite often in maintenance practice there is an evident lack of a common vocabulary between professionals involved in Maintenance Management. In recognition of the need to support the spread of such a common vocabulary, a Maintenance Management e-Glossary has been developed. The development is based on the established European Standard in Maintenance

Terminology (CEN EN 13306), while additional terms have been included, as needed for each different training course. The end result was a comprehensive glossary with terms interlinked with every course. A page with glossary definitions is shown in Figure 6.

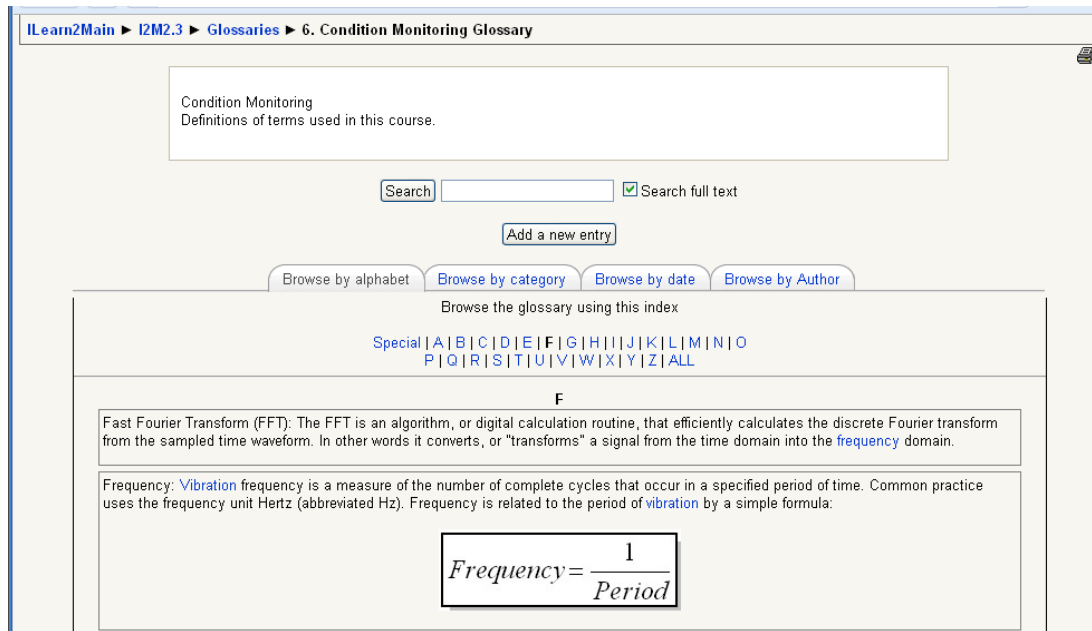


Figure 6. An iLearn2Main glossary page.

## 6. COMPETENCE ASSESSMENT

While delivered training helps learners expand their knowledge and acquire the required levels of technical and theoretical background, an assessment tool is necessary to evaluate performance of learners and the impact of the teaching solution. What is more, there are some desirable characteristics from an assessment tool that is based on an e-learning platform, especially targeted to Maintenance Managers:

- ✓ First, it should be fully automated. It has been already mentioned as a major benefit of our solution the freedom of any kind of class commitment or time restrictions, thus providing a flexible training alternative for Maintenance Managers, and this is true for the assessment tests too. Our implementation offers completely automated competence assessment, while it keeps detailed data about users attempts and grades to help a human tutor to check learners' performance.
- ✓ Second, it should provide useful feedback on learner's performance, so they can learn from their mistakes and perfect their knowledge. An automated learning tool should point the user to the right direction and clarify his mistakes or misunderstandings. Our system provides immediate feedback to user answers. It also locates wrong answers and lack of achievement of desirable competence level and directs user to relevant theory chapters.
- ✓ Third, it should be completely separate and independent from the e-Learning. The need for clear separation between training and certification procedures is stated in the ISO standard EN ISO/IEC 17024:2003 in order to certify confidentiality of the results. [1]. Accreditation and evaluation of learners' knowledge is appropriately undertaken by separate bodies from those offering training. Therefore it is important that the competence assessment tool is separate from the e-learning as it is intended to be used by different users. The assessment content can be updated and improved in the future to better cover the competence assessment requirements. However, assessment tests should cover sufficiently well all the required knowledge areas right from the beginning.
- ✓ Last, conformance to a widespread maintenance standard is necessary, since we primarily aim to the exploitation of our learning platform in an international level of assessment and accreditation in industrial maintenance. Adherence to the European Standard in Maintenance Terminology, namely CEN EN 13306, and EFNMS Guidelines on Maintenance Competence Assessment was the first important step towards this direction.

An example of a multiple choice quiz related to the condition monitoring course can be seen in Figure 7, while Figure 8 is a typical results page from an assessment test, where we can see the calculated grades.



17  
Marks: --  
/1

Study the following spectrum of a rolling element bearing and determine the stage of its deterioration:

Choose one answer.

a. Stage 1 - Start of deterioration  
 b. Stage 2 - Small scale defects  
 c. Stage 3 - Significant defects  
 d. Stage 4 - Faulty function, worn out gear

Submit

Figure 7. Questions within assessment test.

5. Assessment Questions

Review of Attempt 2

Started on:	Wednesday, 3 June 2009, 07:59 PM
Completed on:	Wednesday, 3 June 2009, 08:06 PM
Time taken:	7 mins 16 secs
Raw score:	[Redacted]
Grade:	out of a maximum of 10
Feedback:	[Redacted]

Continue

1 Which of the following statements is **not** true?

Marks: 1/1

Choose one answer.

a. Mean time to failure (MTTF) decreases as failure rate increases. x  
 b. Availability increases as mean time to repair (MTTR) increases. ✓  
 c. Reliability does not depend on maintainability. x  
 d. Overall equipment effectiveness (OEE) increases as downtime decreases. x

Correct Answer!

Figure 8. Results of an assessment test.

## 7. CONCLUSION

This paper presented the development of an e-learning toolkit for Maintenance Management training. Learners involved in such training are usually either people before entering their working life or – more often – people during their working life. The latter usually have to operate under time and space constraints, making conventional training impractical. E-Training offers a flexible and adaptable solution for Maintenance Management training. The iLearn2Main project, an EU initiative to establish IT tools for Maintenance Management training and competence assessment, is a concerted effort in this direction. The project results include a Learning Toolkit for delivering training content in a flexible and interactive way and an e-Assessment tool for automated competence assessment. Based on an open source LMS platform, the iLearn2Main toolkit is a flexible and expandable training platform that can be employed for web-based e-Training and e-Assessment in Maintenance Management. Evaluation of the platform in 5 EU countries is currently under way.

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