Abstract—A significant challenge for Maintenance Management professionals is related to the need for them to possess a truly multi-disciplinary set of competencies. This paper presents an analysis of Maintenance Management training and competence assessment requirements, including results of a user survey conducted in EU countries. On the basis of this, a maintenance management curriculum has been defined. The design principles for an e-learning and self-assessment tool for maintenance management training and competencies assessment are outlined. The iLearn2Main tool has been developed based on an open source Learning Management System and is currently delivered in five European languages. It has been pilot-tested by user groups from industry and academia. The evaluation results analysis show high acceptance rates for the educational tools, while highlighting that real-life case studies, practical examples, visually-appealing and well-structured content are crucial for the user acceptance of maintenance management e-training.

Keywords-component – Maintenance Management, Competencies Assessment, Curriculum Design, User Evaluation

I. INTRODUCTION

The increasing importance given by modern industry to quality and safety, while meeting sustainability targets, has upgraded the attention paid to effective maintenance and asset management. Confronting global competition and a rapidly changing business environment, industries seek to elevate their advantages by improving the management of their assets, including both tangible and intangible ones. The latter requires that staff members have the necessary competencies to perform their intended function. Maintenance and asset management competencies are critical in this setting. However, maintenance management training is rarely included in formal education. It requires multi-disciplinary skills, which in most cases are not readily targeted by higher education or postgraduate courses.

Efficient maintenance management training enhances the capacity of human capital to contribute towards the enterprise strategic goal of rationalizing asset usage [1]. In Europe, maintenance competence requirements are usually based on standardisation bodies recommendations [2]), or requirements defined by National bodies, such as the Institute of Asset Management (IAM) in the UK, or the European Federation of National Maintenance Societies (EFNMS) [3-6]. The accreditation of competence qualifications would enhance employees’ mobility and skills recognition, while aiding enterprises recruitment decisions. Demand for certification in specialised Maintenance has also lead to standardisation [7].

Different training methodologies are applicable to support competencies development in a practice-oriented discipline, such as Maintenance Management. Training is often delivered through vocational Education and Training (VET), which may target employees entering their working life (initial VET) or employees progressing in their working life (continuing VET). Although VET is the common channel for field expertise conveyance in professional skills development, it can become impractical, as staff needs to operate under time and space constraints that lack flexibility. More efficient training can be achieved through on-the-job training (OJT). However, real-life OJT can incur significant costs. Imitation of OJT can be achieved by augmented reality (AR) for problem-based maintenance training, avoiding the cost of setting up a real case [8-10]. Yet, AR is still rather expensive and mostly applicable to special training. E-learning can support asynchronous training in a cost-efficient way. With personalized virtual environments, trainees can choose the training pace, the course subjects and self-assessment that fit their needs [11].

This paper presents the design, development and evaluation of a Maintenance Management e-learning and competencies assessment toolkit, iLearn2Main (www.ilearn2main.eu). The training content and toolkit were developed taking into account standards and maintenance competence guidelines, as well as results from a user survey [12]. The design and development were based on the Learning Management System platform Moodle. The courses are blended with review questions, to aid comprehension tracking and diversification of the learning path. Independent assessment questions are included in the competence assessment tool. User evaluation was performed in piloting events with participation from industry and academia. The key evaluation findings indicate positive user-acceptance, while emphasizing the need for blending the content with more case studies and visual content, also providing evidence for what constitutes good practice in structuring training material.

The paper is structured as follows. Section II briefly presents the target goals and details of the ex-ante evaluation survey. Section III outlines the training curriculum and content, while offering an overview of the iLearn2Main tools. Section IV deals with the piloting results and is followed by an analysis of the user evaluations. Section V is the conclusion.
II. EX ANTE EVALUATION SURVEY

The iLearn2Main training curriculum was based on both EFNMS requirements and a survey of trainers and learners. The user groups are personnel involved (or having the intention to be involved) in Maintenance Management training (both trainers and trainees). Survey questionnaires were produced in five languages (English, Greek, Romanian, Latvian, and Swedish) to identify training needs. The stakeholders were addressed with questions about:

a) their background, working situation and experience
b) their knowledge in the field of maintenance
c) maintenance subjects they wish to learn more about
d) their computer use and literacy
e) likely adoption prospects of an e-learning system.

The survey conducted interviews from 70 professionals from five EU countries. The results of this ex-ante evaluation were summarized in [12]. Some interesting findings are:

(a) trainers appear to have little to moderate knowledge in procurement, selling of service, laws and regulations.
(b) learners appear to have very little knowledge in economical control, Life Cycle Profiting (LCP), laws and regulations.
(c) 67% of learners work less than three years in maintenance and thus are not very experienced yet, while 33% are more experienced, having more than three years in the field.
(d) both managers and engineers (including technicians) ranked their training in maintenance to be at the same level.
(e) a significant proportion (25%) believe that their training is inadequate (low); as this reflects their “own view” the actual percentage may be even higher.

The ex-ante evaluation analysis was taken into account in forming the training requirements. A review was conducted to elaborate on the maintenance management VET needs and collect material for producing the training content. The open source Moodle Learning Management System was chosen as the development platform, due to its openness, flexibility, ubiquity, and modest hardware and software requirements. The learning curriculum and training tools are discussed next.

III. THE iLEARN2MAIN TOOLS

A. The Curriculum

Maintenance management training focuses on decision making and planning in order to devise the enterprise maintenance policy, rather than on how to perform specific maintenance tasks. On the basis of the requirements analysis, the following curriculum was designed:

1. Performed activities on the assets (Asset Care)
   1.1 Maintenance involvement in design, procurement
   1.2 and operation of assets
   1.3 Preventive and inspection activities
   1.4 Repair techniques and methods
   1.5 Goals, strategies, results.
2. Asset Performance Evaluation
   2.1 Analysis of the technical performance of the assets
   2.2 Remote control
   2.3 Condition monitoring
   2.4 Measurements
   2.5 Information systems

3. Management/Economy of Assets:
   3.1 Maintenance concepts (Dependability / Availability
   3.2 Performance)
   3.3 Analysis of the economical results
   3.4 Documentation – See Standards on Documentation
   3.5 Laws and regulations
   3.6 Determination of human & material resources

A standardized course template was adopted and included:
1. Introduction, (1.1 Objectives, 1.2 Learning Outcome, 1.3 Summary, 1.4 Prerequisites/Related Topics, 1.5 Keywords).
2. Theoretical Background, (2.1 Prerequisites, 2.2 Main part, 2.3 Review Questions).
3. Implementation, (3.1 Action plan, 3.2 Success factors, 3.3 Review Questions)
5. Assessment Questions.
7. List of References

![Figure 1: The iLearn2Main curriculum.](image)

B. The e-Learning Tool

The iLearn2Main training and competencies self-assessment was based on a customised version of Moodle and is available at www.ilearn2main.eu. Users are presented with list of available courses (Figure 1). When attending a course, a sidepanel offering links to resources and user-profile features is available underneath the dynamically updated course path. At the center of this view users can browse through the content at several levels (curriculum, courses and lessons). The sidepanel features include (Figure 2):

- Links to other training participants..
- Links to activity types in the course for easier navigation.
- Direct access to the student history.
- List of all other courses the student has enrolled to.
- Uploads of new modules and other events.
The courses content includes pointers to references, enabling trainees to access relevant resources at anytime. References are presented as separate web pages, providing direct viewing of external resources, while maintaining the current training session. The courses are supported by a two-tier e-glossary:

i. A global glossary, providing access and listing options to definitions for all important maintenance terms.

ii. The course-section e-glossary, which provides links to definitions for all terms used inside the specific course.

Both glossaries are integrated with the training platform so as to provide direct and easy access to the listed terms. Course progress is indicated by a progress bar (Figure 3). Through the use of blended comprehension tests, iLearn2Main identifies knowledge gaps. Hence, the learning sequence can be diverted to address them. Maintenance management involves knowledge and skills which are multi-disciplinary by the very nature of the job function. Therefore, the ability to offer this level of training customization is beneficial. iLearn2Main contains 14 courses, available in English, Swedish, Romanian, Latvian and Greek. To facilitate self-assessment, the syllabus is supported by 116 review and 269 assessment tests, also available in the above languages. The tests include multiple choice questions with carefully scaled difficulty.

C. e-Assessment

The EN ISO/IEC 17024:2003 standard indicates that certification must be separate from training, to ensure impartiality. While knowledge testing constitutes an essential function that is blended with e-training, the final assessment of Maintenance Management competencies is performed independently via a separate self-assessment tool (Figure 4).

The underlying design consideration is that a number of tests are created to cover the courses. The e-Assessment tool randomly picks a subset of those each time to offer a different competencies assessment test (Figure 5). Although the choice is random, care is taken to choose tests that cover the whole range of subjects that are deemed essential to successfully perform the Maintenance Management function.

IV. PIOTING AND EVALUATION

The iLearn2Main tools were evaluated by trainers and trainees from industry and academia (Figure 6). The piloting included:

a) workshop at the 4th World Congress on Engineering Asset Management / A mixup of both academic and industrialists.
b) industrial machinery exhibition FETEC (www.fetec.gr) – Greece / Primarily industrial user group.
c) evaluation from MSc Post Graduate Students in Management – Manchester University.
d) workshop organised by CNIPPRM (the SME association of Romania) / Industry oriented user group.
e) piloting action organised by the Latvia Technology Park / A mixup of both academic and industrialists.
f) individual expert evaluation in the UK, Sweden and Greece, both from industry and academia.
g) additional evaluations by remote end-users

A total of 151 users participated in the piloting. At each pilot session a system introduction and a demonstration were provided by an instructor. The introduction was followed by an interactive workshop session, lasting between 90 minutes to 3 hours. In some cases, professionals volunteered to continue their evaluation remotely. Evaluation was provided by filling in evaluation questionnaires, comprising questions about:
A. General Questions on e-Learning

These assess how the e-learning system is perceived in terms of usability, content delivery and visual impression.

B. Questions on Taught Modules Content

The intention was to evaluate the quality and soundness of the training content and how fit it is for educational purposes.

C. Additional Questions addressed to Maintenance Trainers

These questions sought to identify whether the system and the content are judged as appropriate by trainers and whether they are inclined to use the content the tool or both.

D. Questions about Assessment

The aim was to assess the clarity, adequacy and soundness of the tests, as well as the topics coverage.

89 out of the 151 participants filled the questionnaire, while most of them (86) provided additional comments and individual marking of courses. A total of 152 course questionnaires were collected.

V. ANALYSIS OF iLEARN2MAIN EVALUATION

Both learners and trainers provided scaled (1 to 4) evaluations for specific system aspects, while also assessing the training content quality. Mean value, variability and pattern asymmetries of evaluation data revealed both strengths and weaknesses for the presented platform. Additional insight was gained through the classification of evaluations between learners / trainers, as well as between managers / engineers.

A. Analyzing and Comparing Grouped Evaluations

Learners have a positive perception of the e-learning tools (Figure 7). System features such as usability and visually-appealing presentation contribute in building a positive user experience. Populating content pages with course/ lesson path links, a progress bar, glossary and references links, creates a rich and attractive virtual training environment, which features (i) tuned-for-learning course appearance, (ii) speedy content delivery, (iii) support flexible navigation/browsing.

The evaluation parameters displayed at Figure 8, exhibit a positive overall impression on the course content quality, positioning it above “Good”. Managers seem to acknowledge more the importance of illustrations and tables. Functioning at higher decision levels, they probably value comprehension and problem-solving via visual aids, global views, detailed figures and structured tables, rather than text.

Turning our attention towards the trainers’ evaluations, it is worth mentioning that the number of manager-trainers compared to the number of engineer-trainers was approximately 5 to 1, with only a few engineer-trainers. Therefore, as the number of engineer-trainers was low, we focus our analysis on the evaluation of manager-trainers. According to Figure 9, manager-trainers appear more than happy to recommend usage of the e-learning tool, irrespective of the training content (3.00) and they were also content with the training material (3.10). Viewing iLearn2Main as a complete system, they consider it “Good” (2.92) but with room for improvement, thus it can be employed by enterprises to deliver professional maintenance training to their staff.
B. Analyzing Course Evaluation

Users have provided ratings for tested courses. The ratings scale was 1:Poor; 2:Adequate; 3:Good; 4:Very Good. Ratings were provided for all course sections: (1) Introduction (2) Theoretical background (3) Case studies (4) Review tests (5) Glossary (6) References. The mean values of the ratings for each one of the courses are shown in Figure 10 and Figure 11.

The variability of course sections evaluation is seen in Figure 12. While all medians are very close to “Good” (3.00), quartiles and sample min/max values show that it is hard to closely match all users’ expectations, although in most cases ratings are clustered together (exception was a course without references). A global glossary was created after piloting, reflecting on the need to improve the user glossary perception.

C. The impact of measurable parameters on user acceptance

The analysis assessed the impact of measurable training content parameters, which can be linked with the impact and quality of the e-training content. These parameters are:

1) Theoretic Background

The theoretical background content emphasizes the connection between fundamental concepts with practical applications and results. Courses VI, VII and XIII have received the highest rating for their Background section (Figure 13). They also have the highest P1 values. This indicates the importance of a well-structured theoretical part. Users taking an on-line course exhibit a behavior similar to the internet browsing. They dislike long text and prefer compact knowledge structured in concise lists of information.

Courses I and II have received the lowest rating for their Background sections (Figure 13). The content profiles of these courses appear to have the lowest values for P2 parameters. The observed similarities indicate how much learners value the presence of linked resources and references.

2) Case Studies

Case studies provide learners with the opportunity to familiarize with practical implementations on real problems that cannot be easily reproduced in a training environment.
Lesson by explanatory figures, pictures and tables corresponding to longer and tiresome on the key issues.

Studies - training requirements, piloting The use of e-learning has been pilot tested by different user groups (piloting) is gratefully acknowledged.

The Mean Number of Glossary Terms per Lesson signifies the need for structured content, appropriate for case specifications, action steps, and items that can be easily studied and understood when listed.

VI. CONCLUSION

This paper presented an e-Learning system for Maintenance Management training and self-assessment of related competencies. The use of e-learning enables professionals to enter a maintenance management training e-course at the time, the location and pace of their choice. Furthermore, employing e-tools for knowledge assessment can streamline the assessment of competencies, leading to a more transparent procedure for skills recognition. The system has been pilot tested by different user groups, including industrialists and academics, trainers and trainees. User testing provided useful knowledge about adoption prospects and insight into good practice in structuring e-training content.

ACKNOWLEDGMENTS

The contribution of ATLANTIS Engineering (training content and piloting), UTEK (training requirements, piloting and content), Latvia Technology Park and CNIPMMMR (piloting) is gratefully acknowledged.

REFERENCES