Maintenance Management e-Training: What we Learn from the Users

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Abstract: The Maintenance Management profession requires a truly multidisciplinary set of skills. Higher education courses do not offer the necessary body of knowledge in a single course. Maintenance engineering training is offered by some postgraduate & vocational training courses. These often target specialized aspects of Maintenance skills. An important hurdle is that target groups are in most cases professionals who have already entered their working life. Due to their professional engagements, such user groups are under significant time and location constraints, often preventing them from attending a professional training course. E-Training is a viable, flexible and cost-efficient alternative for delivering Maintenance Management training. We report on the development of such an e-learning system, namely iLearn2Main. The main design considerations are briefly discussed, as well as its structure and key features, including a tool for automated competence assessment. A key focus in this work is to present results from pilot testing the system with different user groups. Some of the key findings of the user survey are outlined. It has been particularly encouraging to find evidence of practically uniform acceptance of e-learning technologies as a means of delivering maintenance management training. Among the survey findings are useful directions for further system enhancement and enrichment.

Keywords: Maintenance Engineering, Maintenance Management, Educational Technology, Maintenance Training, e-Learning, Self- Assessment, Learning Management Systems, Engineering Education

1. INTRODUCTION

Industries are confronting 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. Maintenance management training is rarely included in formal education. It requires a multi-disciplinary set of skills that is often not readily available in higher education or postgraduate courses. Thus, it is often delivered through vocational Education and Training (VET). 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. Substantial work is currently under way in an effort to bring maintenance Vocational Education and Training (VET) in line with competence requirements for the maintenance function (Franlund 2008; Roe 2003). In Europe the EFNMS has specified competence requirements both for maintenance management, as well as for maintenance technician specialists (Franlund 2008). As engineering assets are of varying nature, form and function, the need for specialised training in specific aspects of the maintenance function is

also often highlighted (Starr and Bevis 2009). In particular, the need for the certification in more targeted maintenance-related topics, such as condition monitoring, has led to the drafting of dedicated requirement specifications (Roe 2003) leading to their standardisation (ISO 18436-1:2004).

Maintenance training can be made more efficient if delivered in the form of on-the-job training or experiential learning. 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. Head Mounted Displays (HMDs), cameras and special clothes usually co-exist in a AR-based training environment (Nakajima and Itho 2003). Industrial maintenance (Li et al. 2003), power systems maintenance (Nakajima and Itho 2003) and aerospace maintenance (Haritos and Macchiarella 2005) are just a few examples of maintenance training aided by augmented reality technology. Although AR-aided maintenance training can be much cheaper and flexible compared to actual on-the-job training, it is still relatively expensive to produce and is mostly applicable to specialized maintenance rather than generic training, which is still largely delivered by conventional vocational training. Yet, 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 technologies, enabling trainees to choose the training pace and courses that fit their needs. The e-tools can also facilitate the competence assessment procedure, by providing a uniform and standardized way to assess Maintenance Management knowledge. Such tools can be used to deliver training on both basic and advanced maintenance-related areas (Emmanouilidis 2009). 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). Based on the open source Learning Management System platform Moodle (www.moodle.org), the toolkit offers customized maintenance management training and automated competence assessment. The paper focus is on what we can actually learn from the users, by presenting results from an evaluation study. The study provides evidence of the wide acceptance that the e-learning technology may have in this field, while also highlighting the importance of producing and delivering high quality and visually appealing training content that matches learner and trainer needs. More details on the training content development and the e-learning system can be found in (Emmanouilidis et al. 2009).

2. EX-ANTE EVALUATION & CURRICULUM

The development of a Maintenance Management training curriculum needs to take into account maintenance theories & practice, academic knowledge and industrial needs. Close collaboration between academics, professional trainers and industrialists is crucial in the development of this curriculum (Bakouros and Panagiotidou 2008). At the same time, the transparent recognition of maintenance-related competences, which would facilitate personnel mobility, requires a common accreditation framework to be established. In the EU, the main such effort is through the EFNMS (European Federation of National Maintenance Societies) recommendations on maintenance competencies. As a result, a number of European initiatives lately are seeking to provide up to date and adequate maintenance training (Franlund 2008). The nature of maintenance training can vary considerably depending on the targeted learner group. In the ilearn2Main, the target groups were identified as maintenance management learners and trainers. Maintenance management training has very different requirements compared to the training of maintenance technical personnel. 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 machinery are almost always out of their scope of interest. The iLearn2Main training curriculum was based on both EFNMS requirements and survey studies of both teachers and learners within the five partner countries involved in the project. Stakeholders were engaged early on in the project. This included meetings with business clientele and research/academic liaisons, participation in info-days, workshops, conferences and ex-ante evaluation user surveys. The user survey involved discussions and interviews with

learners and trainers and completion of needs assessment questionnaires, comprising questions on:
(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) basic computer use and literacy questions, as well as questions aimed at identifying the likely adoption prospects of an e-learning system.

The survey took the form of an ex-ante evaluation, which was taken into account in defining training requirements. The main findings of the ex-ante evaluations were summarised in (Emmanouilidis et al. 2009). Based on the identified needs, the following training curriculum was suggested by the University of Portsmouth and was adopted in iLearn2Main:

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 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 Performance)
    3.2 Analysis of the economical results
    3.3 Documentation – See Standards on Documentation
    3.4 Laws and regulations
    3.5 Determination of human & material resources

This is also in line with EFNMS recommendations in terms of fulfilling both basic activities and some improvement techniques. In order to establish a 'uniform' course format, a standardised course template was adopted, which 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)
4. Case Studies. 5. Assessment Questions. 6. Glossary.
7. List of References

The courses template foresaw both comprehension & independent assessment questions. The comprehension questions are blended within the training content and their use is for testing comprehension while learning. The assessment questions belong to a different batch of questions and are used for the Assessment test.

3. E-LEARNING AND SELF-ASSESSMENT

The iLearn2Main curriculum has been developed using the Moodle LMS platform that was setup and customised at CETI/R.C.Athena. The Learning system resides inside the project portal, which is accessible at www.ilearn2main.eu. Users can have access to the courses summary and check for other online users. They also have access to an animation demo and user guide. An evaluation questionnaire is

available both on-line as well as a downloadable form to be completed. Inside a course, under the course title, there are the different parts that comprise an iLearn2Main course (Figure 1). These are :

(a) Course modules in the centre of the screen, including Lessons, Glossaries and References (training content).
(b) Links to other participants for communication, if needed.
(c) Links to activity types in the course for easier navigation.
(d) Direct access to the student history.
(e) List of all other courses the student has enrolled to.
(f) Latest news and events relevant to the course, i.e. uploading of a new module.

The courses content includes pointers to references so that trainees can seek additional information or resources. References can be accessed as a separate web page, which is convenient for direct linking from the courses but also as a collective reference for external material. Adequate training requires familiarisation with the typical terms relevant to the course content. This is supported by the use of an e-glossary. The e-glossary provides links to definitions for all the terms that have been used inside the course. This glossary is integrated with the training 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 reference guide of commonly employed maintenance terms. When navigating through a course, the user can get an indication on how much more content exists in a particular lesson through a progress bar (Figure 2). One of the key advantages of employing e-training, as opposed to conventional training is the ability to customise training according to the circumstances and the progress achieved by each learner. Thus, it is possible to personalise e-training, on the basis of user roles, performance and recognition of competence gaps. The added value offered by the ability to automatically process training history data and the interaction of the trainee with the LMS is that the e-training can make a systematic, automated and independent assessment of each individual training case and thus seek to customise the offered training accordingly. Through the use of comprehension and review tests, it is possible identify knowledge and skills gaps. Hence the learning sequence can be diverted to address the identified gaps, by encouraging the trainee to focus on areas that he seems to be in need for additional training. Different trainees can follow distinct training paths, making the whole training procedure more efficient. 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 customisation by e-training is particularly beneficial. While knowledge testing constitutes an essential function that is blended with the e-training, there still is a clear need for an independent assessment of Maintenance Management competences. This independent assessment is needed in order to support an objective assessment of Maintenance Management competences. In iLearn2Main, it is offered by a separate and stand-alone tool. The underlying design consideration is that a number of tests are created, to cover the breadth of the iLearn2Main courses. The e-Assessment tool randomly picks a subset of those each time to offer a different competence assessment test. Although the choice is random, care is taken so that the chosen tests cover the range of topics an courses that are deemed essential to successful perform the Maintenance Management function (Figure 3).
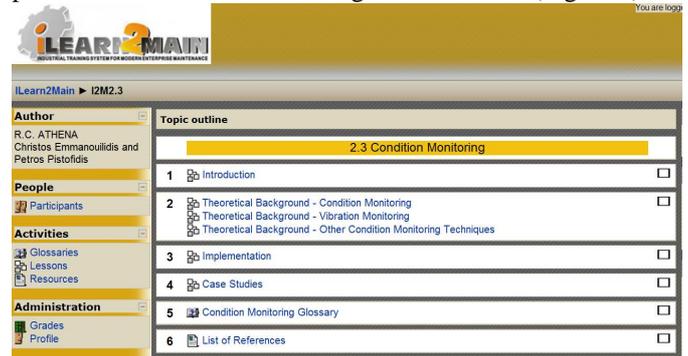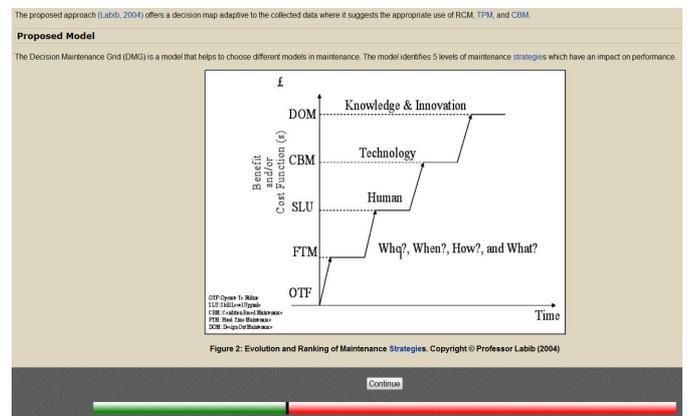

Fig. 1. Inside a course
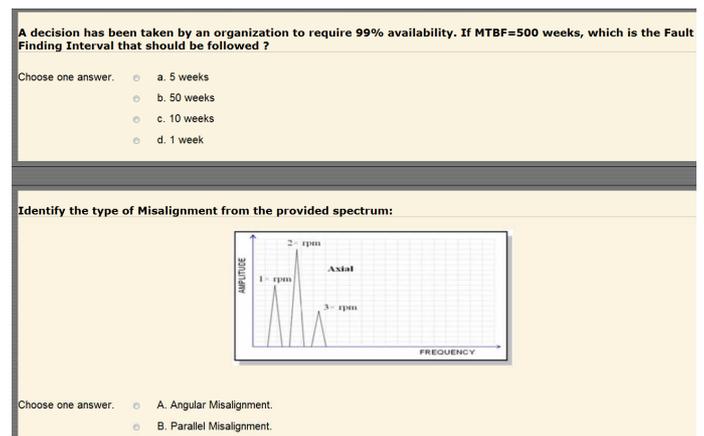

Fig. 2. Inside a lesson

Fig. 3. Self-competence assessment

4. PILOTING & EVALUATION

The iLearn2Main e-learning and competence e-assessment has been pilot tested by different end user groups. This included both learners and trainers. Overall, the system includes 14 courses, available in five languages, namely

English, Swedish, Romanian, Latvian and Greek. Furthermore, it includes in total 116 review and 269 assessment tests, also available in the above five languages. The tests are in the form of multiple choice questions. Piloting is ongoing and so far has included:

(a) a parallel workshop at the 4th World Congress on Engineering Asset Management (www.wceam.com – a mixup of both academic and industrialists

(b) the industrial machinery exhibition FETEC in Greece (www.fetec.gr) – primarily industrial user group

(c) Masters Post Graduate Students in Maintenance Engineering at Manchester University (the cohort consists of both industrialists and full time students).

(d) a workshop organised by CNIPPMR, the SME association of Romania (industry user group)

(e) a piloting action organised by the Latvia Technology Park (a mixup by industry and academia)

(f) individual expert evaluation in the UK, Sweden and Greece, both from industry and academia

(g) additional evaluations by remote end-users

In total there were so far 151 participants in the pilot testing, from all the above cases. Piloting sessions included a system introduction and demonstration by an instructor, as well as an interactive workshop session for system trial, lasting between 90 minutes to 3 hours. Most participants only had time to complete between one and three courses during the piloting. Some of them volunteered to try the system further, remotely and were able to complete more courses. All participants were provided with an evaluation questionnaire, designed by CETI/R.C.ATHENA in consultation with the project partners and included four types of questions. The first was tailored to assess the effectiveness and acceptance of the e-learning system; the second was about the taught modules content; the third was directed to the trainers; and the fourth was about competence assessment. Free-form evaluation comments were also provided. A summary of the questionnaire follows:

A. General Questions on e-Learning

These are aimed at identifying how the e-learning system is perceived in terms of ease of use and navigation, content delivery visual impression.

B. Questions on Taught Modules Content

The intention is 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 seek 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 here is to assess the clarity, the adequacy and soundness of the tests, as well as the topics coverage.

As the evaluation questionnaire was rather lengthy, 89 out of the 151 participants filled the evaluation questionnaire and most of them (86) did provide individual marking of results (courses). As some of the participants tried more than 1 course, a total of 152 course questionnaires were completed. In the remainder we focus on the main evaluation findings:

4.1 e-Learning evaluation

The way that training content is delivered is considered to be good (2,97 out of 4) and so is the general appearance of the

courses (2,98 out of 4 on average), the ease of use of the system (3,02 out of 4) and ease of navigation (2,92 out of 4).
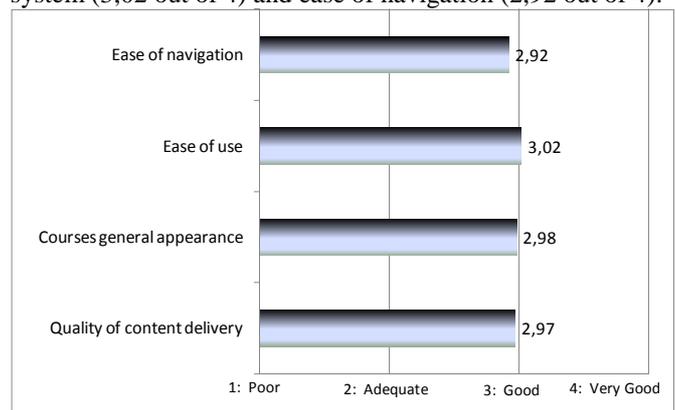

Fig. 4. E-Learning assessment

4.2 Training content evaluation

The overall impression of the training content quality is good (3,01 out of 4) and rather good is the way the content is supported by complimentary material, such as images, tables and illustrations (2,77 out of 4). Looking at the courses content evaluation in more detail, we asked users to separately evaluate the following parts of the courses:

1. Introduction
2. Theoretical background
3. Case studies
4. Assessment tests
5. Glossary
6. References.

From the obtained responses it appears that the users judge the training content sections to be good on average.
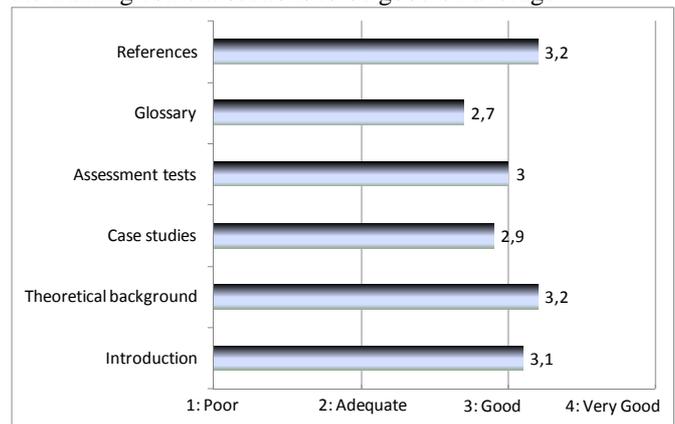

Fig. 5. Content assessment

Improvements should be directed mostly towards presenting better or additional case studies and a more carefully constructed glossary. Having said this, it should be clarified that at the time of the pilot testing there was no global maintenance glossary and instead each separate course has had its own glossary available. Later, once all courses were completed, a global glossary was produced, taking into account the EN 13306 maintenance terminology standard. Therefore it is likely that the perceived impact of the glossary

has improved. Nonetheless, the issue of producing a maintenance glossary for training purposes is highlighted as an important one. Furthermore, it is acknowledged that the educational impact of practical examples and case studies is invaluable and every effort should be made to enrich and expand existing case studies. Focusing separately on each one of the two targeted user groups, trainers and trainees, it can be said that in general trainees appear to be somewhat more satisfied with the training content, compared to trainers. However, the variation is not very large.

Table 1. Learners rating of training content

ID	Replies	Course Content Question					
		1	2	3	4	5	6
1.1	11	3,4	3,1	2,1	2,7	2,8	3,6
1.2	13	3,3	3,3	3,1	3,1	2,8	3,3
1.3	13	3,2	3,3	2,9	2,9	2,7	3,3
1.4	8	2,8	3,1	2,8	3	2,6	2,6
1.5	9	2,9	3,2	3,3	3,2	2,9	3
2.1	7	3,6	3,6	3,2	3,6	3	2,9
2.3	11	3,3	3,3	3,1	3	3	3,1
2.4	7	3,4	3	3,4	3,4	3	3,4
2.5	7	3,7	3,6	3,7	3,3	3	3,7
3.1	2	3	3,5	2,5	3	3,5	3,5
3.2	6	3,3	3,3	3	3,2	3	3
3.3	4	3,5	3,5	2,8	2,8	3,3	3,3
3.4	5	3,6	3,6	2,8	3,4	3,4	3,8
3.5							
		Average					
Total	103	3,1	3,1	2,8	2,9	2,8	3,0

Table 2. Trainers rating of training content

ID	Replies	Course Content Question					
		1	2	3	4	5	6
1.1	6	2,5	2,7	2	2,7	2,7	3
1.2	5	2,4	2,2	2	2,8	2,4	2,8
1.3	4	2,8	2,5	2,8	2,5	2	2,8
1.4	3	2,7	3	3,3	3	2,3	3,3
1.5	4	3	3	3,3	3	2,5	3,3
2.1	4	2,8	3,5	3	3,3	2,5	3,3
2.3	3	3	3,7	3	3,3	2,7	3,3
2.4	3	3	3,3	3	3	2	3
2.5	3	2,7	3	2,7	2,3	2,3	3
3.1	3	1,7	3	2,7	2,5	2,3	3,3
3.2	4	3,3	3,5	3	2,8	2,8	3,3
3.3	4	3	2,8	2,3	2,3	2,5	2,5
3.4	2	3,5	4	4	3,5	2	4
3.5	1	3	3	3	3	1	3
		Average					
Total	49	2,8	3,1	2,9	2,9	2,3	3,1

The difference could be because trainers are in most cases more knowledgeable about the training subjects and therefore more demanding. The courses that one can distinguish a much higher satisfaction rate among the trainees, compared to the trainers, are (in descending order):

2.5 Information systems
1.2 Preventive and inspection activities
3.3 Documentation
3.1 Maintenance concepts
Perhaps this could be due to the fact that the above topics are more generally understood among the learners. There are a few courses that trainers are more satisfied with, compared to learners, although this difference is much smaller, compared to the previous one. Among the courses that one can distinguish a higher satisfaction rate among the trainers, compared to the trainees, are (in descending order):
1.4 Goals, strategies, results.
2.3 Condition monitoring
3.4 Laws and regulations
Perhaps this could be due to the fact that these topics require more specialisation in areas less familiar to the learners.

4.3 Trainers-specific evaluation

We now focus on the questions addressed only to the trainers. In general, trainers consider that the content covers well the basic maintenance concepts (2,91 out of 4) and somewhat less so the more advanced ones (2,77 out of 4). This is in line with the expectation that the basic maintenance activities should first be in place and only then an organisation should focus on more advanced aspects. The trainers also consider that the e-learning tool is a useful tool in terms of helping them to deliver maintenance training (3,12 out of 4). The trainers appear more than happy to recommend using the iLearn2Main training content, irrespective of their view of the e-learning tool, but only after some but not many improvements (3,22 out of 4). They appeared to be even happier to recommend usage of the e-learning tool, irrespective of the training content (3,3 out of 4).
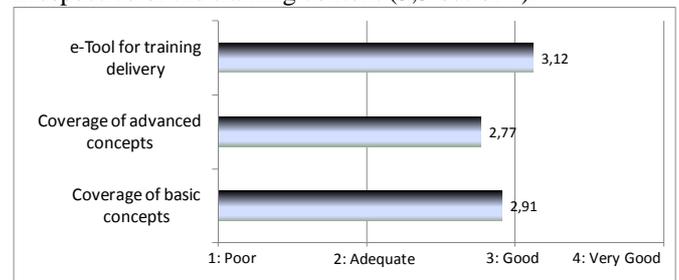

Fig. 9. Trainers evaluation

4.4 Competence assessment evaluation

The clarity of the tests was judged to be good (3 out of 4). Questions were rated to be rather easy but adequate (2,3 out of 4, with 3 being rather hard but adequate, while 1 and 4 represented the two extremes (very easy/very hard). The users consider that the assessment tests cover the training content well but with room for improvement (2,73 out of 4).

4.5 Additional evaluation comments

There have been many additional comments in 'free text format', ie comments addressing aspects of the training content for particular courses, or e-learning-specific issues.

These have been particularly useful for improving fine details of both the e-learning and the training content. Sometimes comments where received that may reflect the particular viewpoint taken but a specific user and not necessarily shared by other users. One common request from all end users is their wish to see more visual features, ie more figures, tables and even possible audio, video and animation. Of course the addition of multimedia-rich content would strengthen the appeal of the courses and will engage the learners more in the training process. However, this is a more costly development process that requires resources that were not available, during the development stage. The partnership is fully aware of the great benefits of adding such multimedia content and is looking at opportunities to enhance the training content in this way. Another common request was to see more practical examples and case studies. Users generally agreed that the system was easy to use and navigate. It should be mentioned that although an animation demo and a user manual were available, they were not provided to the users and yet they did not have any difficulty using the system. This is a strong evidence in practice that the system is user friendly, easy to use and navigate. On the other hand there was conflicting feedback too. Some users wish to see a more thorough coverage of the courses topics, while some other believe that for many of the courses too many details and advanced topics are covered, which are not necessarily mandatory in such a training course. One issue that appeared to cause difficulties to the users is the extensive use of abbreviations. Such an issue is best dealt with by a proper list of abbreviations and an adequate glossary. After the trial, the individual course glossaries have been replaced by a global glossary, which can be considered as addressing this specific issue. Not all courses had the same length. This also caused some confusion to the users, as they did not have an indication about how far they progressed with the course and how much was still to study. A lesson progress bar was needed. It was found the native moodle features were too buggy and unstable to serve this request. However, as moodle is an open source LMS, it was possible to add code, thus extending moodle's features to address this need.

6. CONCLUSION

This paper presented an e-Learning system for Maintenance Management training and e-competence assessment. It has been argued that the use of e-learning technology is very appropriate in this application domain. As maintenance management training is not usually part of formal education, it falls mostly under the realm of vocational education and training. End users who receive such training are in most cases professionals who have little flexibility to enter a conventional course, due to constraints posed by their job function. The use of e-learning enables them to enter a vocational 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 competences, thus leading to a more transparent procedure for skills recognition, which is of great usefulness for personnel mobility and human capital recruitment and management. The system has been pilot tested by different user groups. These included industrialists and academics,

trainers and trainees. User testing provided useful knowledge about adoption prospects and pointers for further improvements. A key finding was that the usage of e-learning technologies appeared to be uniformly accepted by all user groups. This justifies further investment into the direction of enriching the e-learning content, by adding more practical examples and case studies, preferably in multimedia format.

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