Suitability of Adaptive Self-Regulated e-Learning to Vocational Training:
A Pilot Study in Heat Pump System Installation

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ABSTRACT

Many studies have been conducted, mainly in a university environment, and researchers have identified both advantages and disadvantages of e-learning. Very little is known about the applicability and suitability of e-learning to vocational and skills-based training. The research presented in this paper evaluates an adaptive e-learning model (INNOVRET) which combines skills-based learning by means of the Competence based Knowledge Space Theory (CbKST) with the principles of self-regulated learning (SRL) for a practically-oriented vocational training area, namely highly skilled heat pump system installation, in Ireland. The research methodology employed to carry out this study consists of a participative study to develop the INNOVRET approach for e-learning for heat pump systems installation and an empirical study carried out to evaluate the INNOVRET system. The results show that it is the IT skills of the installers that determine the way they perceive the system and the whole learning experience, as well as the level of knowledge acquired.

Keywords: *Adaptive e-Learning Model, Competence Based Knowledge Space Theory, e-Learning, Heat Pump System Installation, Vocational Education and Training*

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INTRODUCTION

The relatively recent development of information and communication technologies (ICT) has changed all the aspects of our lives, including education (Conole, 2006; Stephenson, Brown, & Griffin, 2008). The use of computers and digital media in education (known as 'e-learning') has become an important component of teaching and learning especially in third level education (Paechter, Maier, & Macher, 2010; Stephenson et al., 2008). It is common practice to complement face-to-face lectures with online material and activities (using learning environments such as Moodle or Blackboard), which is known as 'blended learning' or 'hybrid learning' (Delialioglu & Yildirim, 2008; Glogowska, Young, Lockyer, & Moule, 2011; Vernadakis, Antoniou, Giannousi, Zetou, & Kioumourtzoglou, 2011). Another approach is distance learning that may be implemented as pure online learning, where the face-to-face component is completely eliminated. In this case, the course material is usually either presented in a structured manner and includes multimedia (e.g. images and videos) and various forms of interaction (including self-assessments – quizzes) or as a recorded lecture presented synchronously or asynchronously (Stephenson et al., 2008). Self-Regulated Learning (SRL) (Zimmerman, 2002; Zimmerman & Schunk, 1989) is where learners are encouraged to control and regulate their own learning process towards their learning goals, it plays an important role in e-learning and even more in distance learning. In order to enhance self-regulatory skills, online courses should be built on SRL principles (Bernacki, Byrnes, & Cromley, 2012; Lee & Tsai, 2011).

As learning assisted by ICT is relatively new, research regarding the effects of e-learning versus traditional face-to-face classes is not conclusive. Many studies have been conducted, mainly in a university environment, and researchers have identified both advantages and disadvantages of e-learning (Klimova, 2012; López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011; Paechter & Maier, 2010). Very little is known about the suitability of e-learning, especially adaptive e-learning, where vocational training content is personalised to the learner's needs (Holmgren, 2012; Martin, Platis, Malilta, & Ardeleanu, 2011; Pfefferle, Van den Stock, & Nauerth, 2010).

The research presented in this paper aims to answer the question: is adaptive self-regulated e-learning a viable alternative for practically-oriented vocational training? Based on findings from existing research (Holmgren, 2012; Martin et al., 2011; Pfefferle et al., 2010), the assumption would be that yes, it is a viable option. To test this, an evaluation of the adaptive self-regulated learning approach in the context of vocational training has been carried out. An experiment was organised in order to:

- Assess the influence of different learning systems on the level of knowledge gained by the learners (effectiveness);
- Identify the users' opinion on their learning experience and their behaviour when interacting with the SRL system, the influence of the type of learning system on the users' time, effort and comfort (efficiency).

The test case was based on the training of the skills required to install heat pump systems.

The paper begins by presenting a review of the literature on e-learning and associated aspects. The focus is on several areas: first, on types of e-learning, self-regulated learning and the influence of e-learning on developing self-regulatory skills; secondly, on measures of effectiveness and efficiency of e-learning; thirdly, on the use of e-learning in vocational training; current limitations are identified. Next, the research methodology and data collection methods are presented and the findings are discussed and analysed. Finally, the paper discusses the contributions and limitations of the study and makes suggestions for further research.

RESEARCH IN THE AREA OF E-LEARNING AND ASSOCIATED ASPECTS

A comprehensive review of research on e-learning, which compares "electronic lecture" versus traditional learning and highlights the advantages offered by the use of ICT in teaching and learning is presented by (Stephenson et al., 2008). The novelty of their study is the comparison of two e-learning models. On the one hand "Virtual Lectures", where courseware is text based and presented in a structured manner, while also including multimedia and self-assessment questions. On the other hand "e-Lectures", where courseware is presented as recorded lectures. Evaluation results give insights on their effectiveness at different levels of learning as classified by Bloom's taxonomy (Anderson & Krathwohl, 2001; Bloom, 1956). The outcome of the study indicated no overall greater effectiveness of either of the two course delivery modes (including traditional face-to-face), which confirms the findings of many other studies (Delialioglu & Yildirim, 2008; Holmgren, 2012; López-Pérez et al., 2011; Paechter & Maier, 2010; Vernadakis et al., 2011). However, when the levels of Bloom's taxonomy were assessed, the students that used the "Virtual Lectures" scored higher for knowledge, comprehension and application questions and lower for the higher levels in Bloom's hierarchy. These results are interesting for this research as competences addressed by the heat pump system installation course are situated mainly at the bottom of Bloom's pyramid (e.g. understand what a heat pump is; estimate the length of a vertical heat exchanger etc.).

Learning achievements/outcomes or the effectiveness of e-learning is the most common measure of e-learning courses. However, student satisfaction is equally important, as mentioned in various studies (Kuo, Walker, Schroder, & Belland, 2014; Paechter & Maier, 2010; Paechter et al., 2010). Paechter et al. studied the students' experiences in five areas (course structure and design, interaction with instruction, interaction with peer students, individual learning process and course outcomes (Paechter & Maier, 2010). The analysis of the outcomes permitted the researchers to identify the main aspects that contribute to learning achievements and course satisfaction. One of them, consistent with findings from (Kuo et al., 2014), is the design of the e-learning course: content structure, presentation, choice of delivery platform, opportunities for self-regulated learning and self-test to measure progress. One aspect of the individual learning process that has not been considered and which would be of importance for the current study is the efficiency of the learning process in terms of time, which is very important for the target audience (installers).

Lee & Tsai (2011) and Kuo et al. (2014) mention many studies which suggest that Self-Regulated Learning (SRL) is essential for success in e-learning. SRL emphasises the learner's ability to control and regulate their own learning process. Zimmerman defines SRL as the way individuals control their own feelings, thoughts and behaviours which are oriented towards goal achievement (Zimmerman, 2002). The SRL process is accomplished in a proactive way, in which a learner's self-regulation of cognitive, metacognitive and motivational processes within an educational context is emphasised. This means that the learners 'direct' their own way of learning based on their own decisions. Meta-cognition, the 'awareness of, and knowledge about one's own thinking' plays a crucial role in this model. Zimmerman suggests that, considering the high correlation of SRL with academic achievements, students should be taught to become self-regulated learners (Zimmerman, 2002). A cyclical three-phase structure of the self-regulatory process is suggested: (1) Forethought, (2) Performance, and (3) Self-Reflection. *The Forethought Phase* is the phase which occurs before learning and involves goal setting, strategic planning and self-efficacy beliefs. The *Performance Phase* occurs during learning and includes self-control and self-observation, whilst the *Self-Reflection Phase* occurs after learning and refers mainly to self-evaluation. Implementing the SRL process in the e-learning course will enhance the

learners' self-regulatory skills and, therefore, improve their performance.

Another interesting approach in e-learning is skills-based or personalised learning (Heller, Steiner, Hockemeyer, & Albert, 2006; Steiner, Nussbaumer, & Albert, 2009), where the learning content is adapted to the learner's needs. Competencies and skills that already exist do not have to be taught and new learning content can be built on content that already exists. Skills-based learning systems should be adaptive, with regard to the assessment on the one hand and the recommendation of learning content on the other hand. The main advantage of adaptive and competence-based/personalised learning is a considerably greater efficiency in learning leading to an increased amount of time saved when learning the content, which would be a considerable advantage for the target group of this study. Heller et al. (2006) present a psycho-pedagogical theory, the Competence-based Knowledge Space Theory (CbKST), which is suggested as a formal framework for implementing adaptivity in e-learning. The CbKST is a framework for representing the conceptual organisation of a given body of competences and for linking learning objects and assessment problems to the required competences. The result of the application of the CbKST is a structured competence model enriched with corresponding learning objects and associated assessments. This serves as a basis for selecting personalised learning paths but also, allows for an adaptive assessment of the learner's skill state.

e-Learning in Vocational Education

A review of the research regarding e-learning in vocational education showed only a few studies, most of them in nursing education (Abdelaziz, Kamel, Karam, Abdelrak, & Abdelrahman, 2011; Glogowska et al., 2011; Pfefferle et al., 2010) and a huge deficit in the area of heat pump system installation. Holmgren presents a study on e-learning in firefighter education (Holmgren, 2012), which resembles the heat pump system installation course in terms of structure and practical aspect. The results show very similar findings to other research studies on e-learning: no significant difference in learning outcomes when the two delivery modes (e-learning and face-to-face training) were used, encouragement of students' reflection in the case of e-learning, but at the same time less interpersonal interaction, which can create a feeling of isolation for the student.

The current study tries to complement these findings with answers to the questions 'How is the learning process affected by the introduction of personalized learning recommendations, in line with the learners' needs'? 'How do installers perceive their learning experience'?

To this end, we have designed, implemented and integrated an adaptive learning approach in Moodle, as similarly described by (Nussbaumer, Gütl, & Hockemeyer, 2007) and further elaborated on within the following section.

The INNOVRET Approach

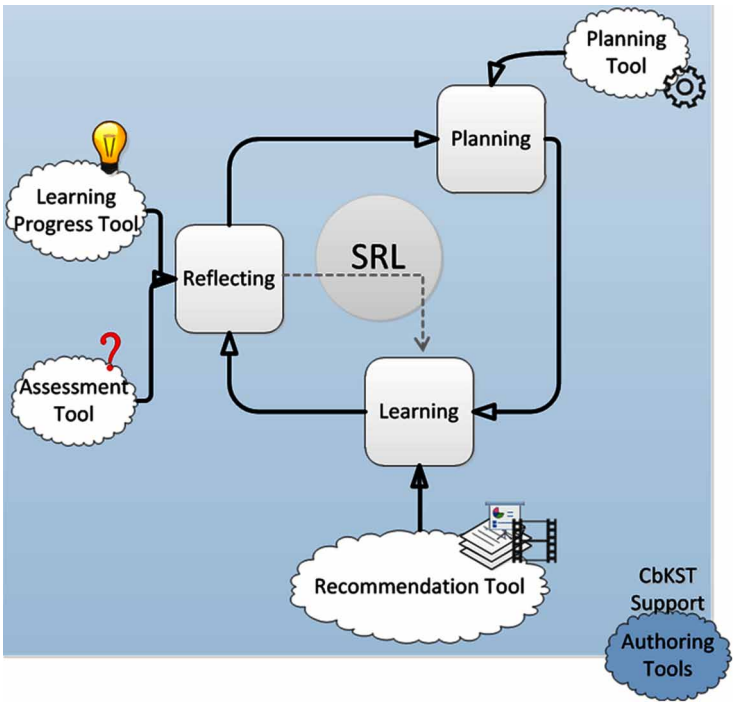
The INNOVRET (Innovative Online Vocational Training of Renewable Energy Technologies) approach (Winter, Kopeinik, Albert, Dimache, Brennan, & Roche, 2013) describes the implementation of a Moodle based on-line learning environment that combines the benefits of two pedagogical approaches, self-regulated learning (Zimmerman, 2002) and skills-based learning. By applying Competence-based Knowledge Space Theory (CbKST) (Heller et al., 2006) we personalize two aspects of the course: (1) the structure of the learning content by recommending learning resources tailored to a learner's current knowledge state; (2) the assessment of a learner's knowledge state, asking not all questions, but only enough to draw conclusions on a learner's competence state. The CbKST is a psychologically sound framework to represent the organisation of a given body of competences by introducing pre-requisite relations (Heller et al., 2006). Pre-requisite relations define which competences need to be shown before learning others and in reverse it allows to conclude over a learner's competence state by inferring on competences that are hidden but

relate to observed competences. The resulting competence structure forms a domain model that is used to instantiate learner models. Domain and learner models are essential in providing adaptive assessment and recommendation strategies (Brusilovsky & Millán, 2007). However, instead of dictating to the learner on how to learn, a SRL approach is pursued where the learner can choose learning targets and learning objects. The combination of SRL and CbKST enhances the benefits for the learner by enriching the learning experience with a combination of self-management, reflection and guidance.

The CbKST principles are used to adaptively support the learners in every phase of their self-regulated learning process (see Figure 1). For that purpose the CbKST principles are linked to the three SRL-phases: planning, learning and reflection. When entering the learning process learners determine their current knowledge state, and set a learning goal (planning phase). Then, based on the domain model, learning content presented to a learner is selected according to the learner's current competence state (i.e. the set of competencies that a learner demonstrates). The learning content is presented to the learner in form of recommendations that can be followed or not (learning phase). After engaging with the learning content, the learner may leave the learning phase by completing an assessment. Assessment results update the learner model and feed into the visualisation tools. The visualisations of the learner's competence state and learning history support reflection and awareness (reflection phase).

The adaptive INNOVRET approach was used to provide the online training solution for heat pump installers. Given the fact that all learning recommendations are based on competence state and learning goal of a learner, the learning process shall be efficient (time and effort) whilst at the same time self-regulated. A more detailed

Figure 1. SRL in the INNOVRET approach



description of tools and background algorithms can be found in Kopeinik, Winter, Dimache, Albert, & Roche's (2014) study.

RESEARCH METHODOLOGY

The primary research methodology consisted of two phases:

1. A *participatory research study* was carried out to develop the INNOVRET approach to e-learning for heat pump systems installation – to adapt the CbKST system and the content to suit the target audience;
2. An *empirical study* organised in two parts – an experimental study and a survey – was used to evaluate the INNOVRET online solution. For triangulation purposes, the think aloud protocol (or protocol analysis technique) was used to identify the installers' feelings about the system used and their behaviour when interacting with the system.

The research presented in this paper is not of sensitive nature. However, as primary research involved an experiment, interviews and questionnaires, the following issues need to be clarified:

- **Voluntary participation:** No coercion was used to force people to take part in the experiment. Information about the nature of the experiment and survey, the location of the experiment, length of time, and requirements from the participants, was communicated in advance to all potential participants;
- **Anonymity and confidentiality:** In order to offer anonymity and confidentiality to the participants, the following measures were taken:
  - Usernames for the system are in the format 'GuestNo', where No is 01, 02;
  - Personal data (e.g. name, phone number and email) are optional;
  - For the protocol analysis, the recordings were done using a video screen and sound capturing software (e.g. Camtasia); no image of the participants was taken.

The Participatory Research Study

The participatory research study was a cyclical process; the researchers continuously refined the INNOVRET training system based on feedback collected from end users and an advisory group consisting of academics and trainers.

In order to capture the *academic perspective*, the following events/activities have been organised:

1. Two focus groups with industry experts and trainers in the area of heat pump system installation;
2. Evaluation of the pedagogy (the CbKST model) by an external evaluator with an academic background;
3. Three training sessions/workshops for GMIT staff involved in third level skills-based education;
4. Workshop during CESI (Computers in Education Society of Ireland) conference.

The industry experts and trainers expressed their interest in the INNOVRET approach and welcomed it. The heat pump industry lacks training methods and tools appropriate for distance learning. They also provided important insights into heat pump installation and installers' profile and encouraged the use of images and videos.

Valuable feedback was received from the academic evaluator, who appreciated the highly sophisticated CbKST model used for the development of the e-learning system. She considered it appropriate for the target group of the project especially because of its structured nature. Also, it makes learning more efficient as it avoids teaching students content where they already have the competences. The evaluator found the use of pictures and animations an important asset of the e-learning system as

many aspects of the topics of installation of heat pumps cannot be described verbally.

A high number of lecturers (fifty-one) in GMIT participated in the INNOVRET sessions and engaged in discussions with the researchers. GMIT being a technological college as distinct from a university, most of the lecturers are involved in skills-based education, therefore they could provide valuable feedback. They found CbKST a step forward in online learning and it was considered by a few lecturers for the future. GMIT does not have a long history in online learning, therefore appropriate tools and methodologies are very welcome at this developmental stage.

Good feedback was also received from educators during the CESI event. They liked the INNOVRET model especially for the learners that have limited access to education due to location and/or time constraints. The use of the GMIT online energy lab was considered key for the delivery of the course.

The feedback from academics and industry specialists is summarised in Table 1.

The INNOVRET model was also presented to installers in order to collect feedback from the *practitioners' perspective*, as they are the beneficiaries of the training. The following activities were organised:

1. Several learning objects were presented and discussed with five end users during a training session organised by the industrial partners;
2. Three lessons and the learning platform were evaluated by twelve installers. A few evaluation sessions with end users were organised. Data were collected through observation and semi-structured interviews.

The following aspects were of interest to the researchers:

- Training programme for installers:
  - Quality of content;
  - Quality of content presentation;
  - Correct application of the CbKST methodology;
  - Appropriateness of content to industry needs;
  - Suitability of content to online learning;

Table 1. Summary of feedback from academics and industry specialists

Aspect of INNOVRET	Feedback
Course on heat pump installation	• The course is believed to be welcomed by plumbers, especially the ones that have limited access to upskilling, mainly due to location. • The ICT skills of the end users were envisaged to be one of the main challenges of the course. • The challenge of the assessment of skills as opposed to knowledge was also identified.
Visual component	• Videos as well as animations are very strong tools to impart knowledge in the online vocational training sector. • The use of the GMIT online energy lab is very important for the delivery of the course. • Addressing all types of learners (visual, auditory, read-write and kinaesthetic) is very important; it will be difficult though to address the kinaesthetic type.
Online training	• Online vocational training has great potential mainly because of time and space barriers. • The way INNOVRET is planned to be delivered will meet the needs of the target audience. • Simplicity and easy navigation are key for the end users.

- Learning platform:
  - Platform delivers expected results i.e. easy to access it and use it;
  - Reliability (platform is stable).

The feedback received was very good (see the main aspects synthesised in Table 2). The content was found very useful and suitable for online delivery provided that the visual component is predominant. There were some issues (e.g. navigation difficulties etc.) that researchers took in consideration to improve the training course and the delivery platform.

The Empirical Study

The experiment was organised in two phases: a pre-test and a final experiment with the target audience, a mix of mature (over 23 years of age) and younger installers. The original plan was to organise a third stage of the experimental study in another country (Belgium) in order to have a larger spectrum of end users (installers), but it was not realistic in the time frame allocated.

The Pre-Study

A pre-study was organised with five students in Energy Engineering in Galway-Mayo Institute of Technology (GMIT). The students had a specific interest in the area and had limited prior knowledge; therefore they were very motivated and willing to have a new learning experience in their discipline of interest. The purpose of the pre-study was to simulate the real experiment (with the target audience – installers) in order to identify possible problems and to rectify them before the actual study. The students were provided with usernames and passwords, as well as user guides.

The pre-study was organised as follows:

- Testing the students' knowledge of heat pump system installation. A set of 15 multiple choice questions were presented to the students and they were requested to answer them before starting the learning session;
- Learning. The students that used the CbKST system started the learning process with an assessment of their knowledge and then went through a first learning iteration. The students that used Moodle started the learning process; they could either learn one/more topics of their choice or take up quizzes;
- Testing the students' knowledge of heat pump system installation after the learning process. The students were required to answer similar questions or maybe the same questions but having the answers in a different order;

Table 2. Summary of feedback from evaluation sessions with end users

Aspect of INNOVRET	Feedback
The online aspect of the course	• Online training is important for installers because of time and space barriers. • The ICT skills of the end users represent a real challenge. • Quizzes are important and were very appreciated by the end users as a way of assessing their knowledge. • The visual aspect is very important for the online delivery of the course. • Guidance offered at the beginning of the session was very much appreciated and considered key for the success of the project.
Presentation	• Videos and animations were very well received by the installers. The visual component of the course was essential. • The use of the GMIT online energy lab was found useful. • Sometimes there were navigation problems.
Content	• Some aspects of the course were considered difficult. • Some of the questions were found too difficult or difficult to understand. • Suitable for the end users' needs.

- Evaluating the system. All the students were requested to answer a set of questions. The results were compiled with the rest of the results (from the survey) to draw conclusions regarding the system.

The Experiment with the Target Group

The experimental study was organised in a computer laboratory in GMIT. Fourteen installers of various ages and experience level were invited to GMIT to test the system. The purpose of the experiment was to observe how the installers interact with the system, if their IT skills influence their attitude towards the new learning support system and what they think in general about this way of learning. The participants were organised into two groups: one group (the control group) had access to training material via Moodle; the other group (the experimental group) used learning support tools built on the CbKST principles in order to access the same training material. They were all provided with usernames and passwords, as well as user guides. Data were collected through non-participant overt observation, when the researcher observed and recorded what installers said and did without being involved, and short semi-structured interviews with the participants to the experiment. Due to time constraints, only four participants were interviewed for approximately five minutes. The researcher took notes and analysed them at a later stage. One important conclusion was that an introductory training session is necessary, where installers are explained in detail what the online delivery system is and how to use it to their maximum benefit.

The Survey

The survey was conducted through a set of questionnaires that participants to the experiment were required to fill out after the experiment. The questionnaire contained ten questions (eight for the Moodle group) to be answered on a Likert scale from "strongly disagree" to "strongly agree". The questions targeted three areas: the overall approach, the learning experience and the quality of content. Three questions targeted the overall approach, namely the iterative learning process (Q1), the awareness support (Q2), and the guidance support (Q4). One question regarded the quality of content (Q10), whilst the rest of the questions addressed the learning experience: questions 3 and 5 addressed learning problems, namely: if the approach was limiting (Q3) or stressful (Q5); questions 6 and 7 questioned the participants' enjoyment (Q6) and the perceived learning success (Q7); question 8 aimed at evaluating the user interface and question 9 referred to the willingness to use such a system in the future.

The study also used secondary data offered by the LMS in the form of results to self-assessment tests, which indicated the effectiveness of the system.

The Think Aloud Protocol

The Think Aloud (TA) protocol (Lewis, 1982), (Boren & Ramey, 2000) is based on the protocol analysis technique (Ericsson & Simon, 1993) and is a widely used method for testing the usability of software applications or websites. The participants are requested to think aloud as they are performing a set of specified tasks: to say what they are looking at, thinking, doing, and feeling as they perform the task. The researchers can thus observe the activities and facial expressions of the subject as well as listen to the decisions made whilst in the problem solving process. Test sessions are often recorded so that researchers can go back and refer to what participants did and how they reacted.

The TA method was used to test how well installers can use the learning support system. The object of the TA study was the CbKST learning support system embedded into Moodle. Three installers with different profiles (in terms of IT skills and knowledge about heat pump system installation) participated in the test in three different sessions in the same location (GMIT). The Think Aloud method was used for the evaluation.

Table 3. Results of the pre-test

Name	Result Before Learning	% Before	Result After Learning	% After	Improvement	System Used
Guest10	8	0.53	11	0.73	38%	CbKST
Guest11	10	0.67	13	0.87	30%	CbKST
Guest12	8	0.53	11	0.73	38%	CbKST
Guest13	7	0.47	10	0.67	43%	Moodle
Guest14	6	0.40	10	0.67	67%	Moodle

Note: No. of Qs=15

Before the evaluation, the participants were briefed on the TA procedure and the CbKST learning support system and were given written instruction on the task they were required to perform. They were explained that it was the system that was tested and not themselves. They were also asked for permission to capture the screen and their voice (Camtasia application was used) thinking aloud while performing the task. The facilitator observed and took notes for the duration of the experiments. Once the users had finished the task, they were required to fill out a questionnaire to evaluate their experience.

Analysis of Results

This section summarises the findings of the experimental study. Due to time constraints and the profile of the participants involved in the experiment, the research was confined to a relatively low number of participants, five Energy Engineering students and fourteen installers in the Galway area.

Results of the Pre-Study

Five GMIT students participated; three used the CbKST system and two used Moodle.

The results of the knowledge tests were inconclusive (see Table 1) because of the short learning time (the whole evaluation took little over one hour). Therefore, the researchers decided not to do these tests in the next stage of the experiment. The results of the students' evaluation were compiled with the rest of the results to draw conclusions regarding the system.

The Results of the Experiment with the Target Group

The main conclusion of the observation was that the IT skills of the installers play a very important role in the way they perceive the system and the whole learning experience. The installers whose IT skills are good or average did not have any problems navigating, using and interacting with the system, either Moodle or CbKST. The installers who are not used to using computers were quite nervous at the beginning of the experiment, could not use the system properly and became gradually very frustrated. Their main target did not seem to be the learning, but being able to use the system.

Due to time constraints, only four participants were interviewed. As it was noticed that the IT skills dictate their attitude towards the system, only installers that were used to using computers were interviewed. They thought the CbKST learning system is "a good start" and such a system would save time. However, sometimes it is confusing and needs to be simplified – "it is usable but needs to be simpler". Regarding content, the main issues were related to the assessment questions, which were found very difficult and tricky. Although all the installers found the animations, images and videos very helpful, they mentioned that "this theoretical course needs the practical

component" and "must be complemented by face-to-face practical sessions".

There were a few issues regarding the reflection tool and the presentation, but they were fixed after the experiment.

The Results of the Survey

The 19 evaluation results (including the students' evaluations) were compiled and analysed in Excel. The two systems – Moodle (10 users) and CbKST (9 users) – were compared. Frequencies were calculated as a measure of variability, and mode for central tendency (see Table 4).

In order to present the Likert scale data more efficiently, a numerical value was assigned to each answer, from 1 to 5 (1 for "strongly disagree" and 5 for "strongly agree"). This allowed us to report a single average response for each system. Converting the data to a single number makes it easier to draw comparisons between the two systems (see Figure 2). The first two questions were only for the CbKST system users, therefore the results are not charted.

Three of the questions targeted the *overall approach*, namely the iterative learning process (Q1), the awareness support (Q2), and the guidance support (Q4). The results show a positive response to the first two questions referring to the CbKST system, as most of the respondents answered "agree" (56%) or even "strongly agree" (11%). When the two systems were compared with respect to the users' satisfaction with the guidance support (Q4), the CbKST system scored slightly higher (3.9 compared to 3.6).

Further questions targeted the *learning experience*.

The only two negative questions concerned learning problems, namely: if the approach was limiting (Q3) or stressful (Q5). According to the answers, the CbKST approach is less limiting and less stressful than Moodle, proved by the lower agreement (therefore higher disagreement) of the CbKST users compared to the Moodle users (2.3 vs. 2.9 and, respectively 2.4 vs. 2.8).

Questions 6 and 7 referred to the participants' enjoyment and the perceived learning success. The CbKST users either enjoyed it or did not (only 11% were not sure), while most of the Moodle users (40%) were not sure. Overall, the CbKST users seemed to have enjoyed the learning experience more than the Moodle users. As expected, the users of CbKST felt greater learning success due to the visualisation tool (3.4 agreement rate compared to 3.2).

The user interface (Q8) scored well in the users' evaluation. Moodle users were even happier than the CbKST ones (3.5 vs. 3.1 agreement level). That matches the findings of the observation: installers with low IT skills found it difficult to understand how the CbKST works and needed a period to get experience with the new system.

The question evaluating if the users would like to use a system like this in the future (Q9) scored considerably better for the CbKST than for the control group (67% agreed and 11% strongly agreed). The result corresponds with the other findings regarding the users' learning experience.

The last question referred to *content quality*. Both groups were satisfied with the quality of the training material, which shows that the efforts put by the research team in the first phase of the research (the participatory study) paid off.

According to the logged data of the CbKST group, the participants have performed on average 3.2 learning iterations, visited 9.4 learning objects, followed 82% of the recommended learning objects, and answered 9.2 assessment questions. As mentioned, there was a discrepancy between participants with good and poor IT skills, which became also visible in the usage frequency. The fact that users followed 82% of the recommended learning objects shows that the recommendation strategy was appropriate for the participants.

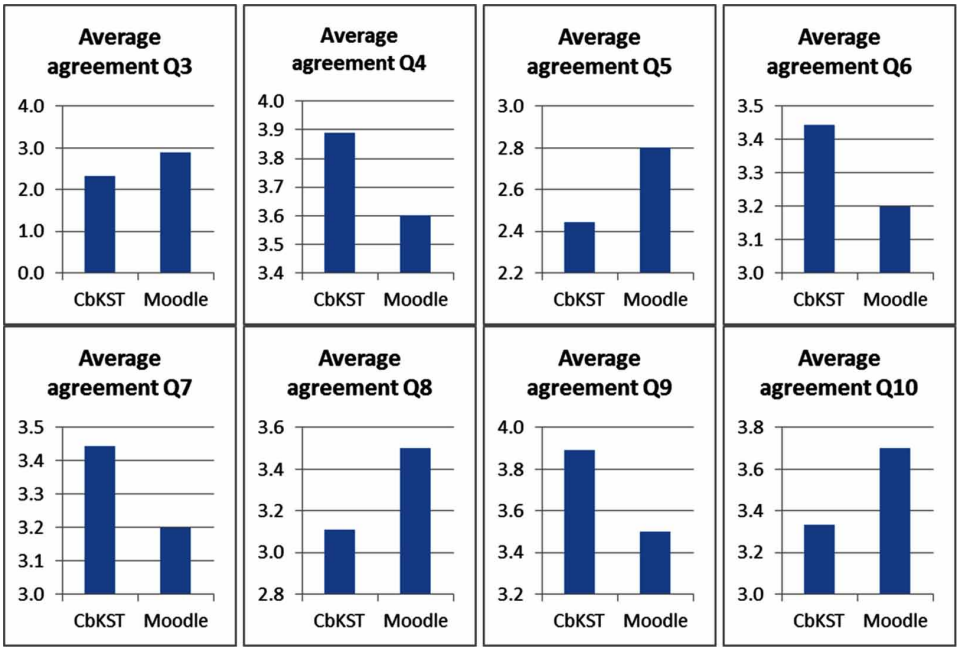
The Results of the Think Aloud Protocol

The recordings of the three experiments and the notes of the observations were analysed in order to identify various issues such as doubt, difficulty, incomprehensibility and

Table 4. Results of the survey

Question 1: The cycle of learning, assessment, and visualisation was good for my learning					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	0%	11%	22%	56%	11%
Question 2: The system supported me to become aware about my learning process					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	0%	22%	11%	56%	11%
Question 3: The system was limiting my learning					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	11%	56%	22%	11%	0%
Moodle %	0%	40%	40%	10%	10%
Question 4: The system provided helpful guidance for my learning					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	11%	0%	11%	44%	33%
Moodle %	0%	20%	0%	80%	0%
Question 5: This way of learning was stressful					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	22%	33%	22%	22%	0%
Moodle %	0%	50%	30%	10%	10%
Question 6: I enjoyed the way of learning with that system					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	0%	33%	11%	33%	22%
Moodle %	10%	10%	40%	30%	10%
Question 7: I was successful with the learning task					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	0%	22%	22%	44%	11%
Moodle %	10%	20%	10%	60%	0%
Question 8: The information in the user interface was easy to understand					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	22%	11%	11%	44%	11%
Moodle %	10%	10%	10%	60%	10%
Question 9: I would like to use a system like this in the future					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	0%	0%	22%	67%	11%
Moodle %	10%	10%	30%	20%	30%
Question 10: I am happy with the quality of the content presentation					
System	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
CbKST %	0%	33%	11%	44%	11%
Moodle %	0%	20%	20%	30%	30%

Figure 2. Comparison between the CbKST and the moodle system with respect to average agreement of the respondents



annoyance related to the use of the system. The following types of problems were identified:

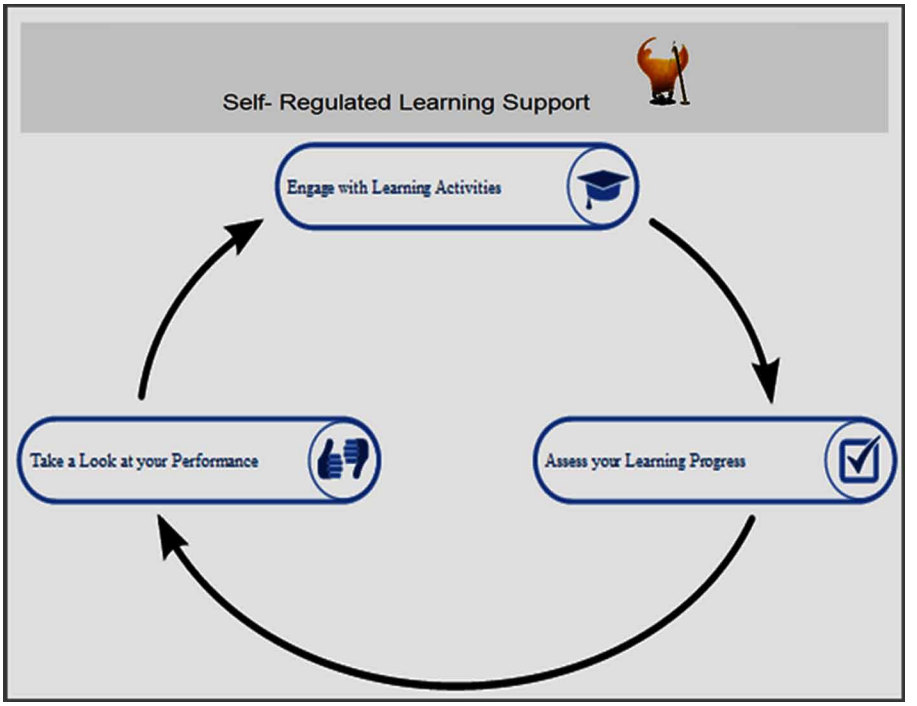
- Navigation problems:
  - The users did not know what to do once the SRL-tools main menu (see Figure 3) or the Learning Recommendations appeared;
  - The users found inconsistencies in the design of the learning objects (e.g. 'Close' button not in the same position, links not working);
  - The user with very limited IT skills was not able to go back to the Internet browser once a learning object was open;
- Comprehensiveness problems – some of the terms used are not familiar to the users (e.g. learning resources, learning iteration).

CONCLUSION

Existing research studies show no major difference between traditional training (in classroom) and e-learning, especially in terms of effectiveness. The differences lie in the learning experience and the course satisfaction, mainly less personal interaction but higher opportunity for self-reflection in the case of e-learning. As there was not enough evidence of the suitability of e-learning to vocational training or the factors that influence it, the authors introduced an adaptive e-learning system to heat pump installers in order to identify if and how the learning process is affected and how the installers perceive their learning experience.

The results of the study are very interesting. As time was the main constraint, little conclusions can be drawn in relation to the effectiveness of the study. However, regarding the learning experience and suitability of adap-

Figure 3. Screenshot of the SRL tools main menu



tive e-learning to vocational training, the main finding was that it is very much influenced by the IT skills of the learner. In contrast to other studies carried out at third level education, where IT skills are taken for granted, in vocational training and in particular in domains where the use of IT equipment is not part of the day-to-day job, the subjects' IT skills play an important role. It dictates how the learners perceive the learning experience, how they appreciate the support system and the content.

The research methodology adopted for the study is robust and can assure the validity of the study. In the literature review validity was achieved by using various sources (books, journal papers, websites) to gather relevant information and different points of view about various aspects of e-learning and its applicability to vocational education. For the primary research, the adoption of mixed methods in a triangulated approach assured that the research is valid and reliable.

The generalisability of the study is quite limited due to the relatively low number of participants to the experiment – all installers were from Ireland, mainly self-employed. However, the participatory study in the first phase of the research, the use of a variety of installers' profiles (the group comprised installers of all ages and prior knowledge in heat pump system installation) and carrying out the pre-test with GMIT students enhanced the generalisability of this pilot study. More experiments should be organised with bigger sample groups in order to improve generalisability.

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