Tomorrow's On-Board Learning System (TOOLS)

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Abstract. Efficient maritime training is important to build a competent workforce of seafarers, able to operate safe, following rules and regulations. The most widely used methods of onboard training is the so called Computer Based Training (CBT), which simply is a set of electronic lectures and multiple choice tests afterwards. While widely used this method has been criticized for being individualistic, difficult to apply in a practical setting, boring and demotivating for learning. Alternative methods have not been developed, partly because of the dominance of the CBT method, but also because bandwidth and connectivity issues for ships have restricted both use of more interactive and internet based tools. The Tomorrow's onboard learning system (TOOLS) was a project to research and develop an innovative game-based learning platform for on-board training, along with a course on energy efficiency. The chosen topic was of keen interest to the ship owners that took part of the project, aiming to achieve fuel savings whilst reducing the impact on the environment. The paper describes the TOOLS platform, the course developed and the evaluation results from two vessels, one from each participating shipping company.

Keywords: Maritime training · Serious games · Onboard training

1 Introduction

A competent workforce implies more than knowing, but being capable of applying knowledge effectively and efficiently within the work context. Consequently, talent management, including training and education is a key element to success in any industry today, including the maritime industry. There is little disagreement on this, and there exists a plethora of training centres, of formal certificates as well as on-board training systems in the form of Computer Based Training (CBT). Further, ship-owners as well as vetting organizations, certificate providers, port authorities, and other agencies inspect and control actual work practice on-board. The seafarers are required to follow a long list of procedures and standards, in order to regulate work practice. It is acknowledged that the standard work practice is in general more than sufficient to ensure safe and agreed upon transportation of goods and people. However, in reality, what exists are erroneous and potentially dangerous work practice that can destroy the reputation of responsible ship owners, be costly to the shipping company due to fines

P. Zaphiris and A. Ioannou (Eds.): LCT 2016, LNCS 9753, pp. 528–538, 2016.
DOI: 10.1007/978-3-319-39483-1_48

and necessary improvement work, be environmentally un-friendly and dangerous. In short there is a need for improving the competence of the workforce even though the appropriate knowledge acquisition occurs.

Experience in the maritime industry and research pivoting around these topics, indicates that there is a gap between so-called intended and actual work practice among the officers on board (i.e. [3]). While officers seem to be familiar with the correct and preferred work routines given in steering documentation, training manuals, engine manuals and company policy, they sometimes use alternative work practices in their daily work on board. Unfortunately, since work operations at sea are quite risky, wrong or insufficient, work practice may lead to serious incidents. In addition, most department managers at sea such as the captains or other senior officers, do not have managerial training or education, with the result that on-board management style is left to each individual and varies substantially from vessel to vessel or from one sailing period to another [7].

This paper describes the Tomorrow's on-board learning system (TOOLS) platform, an attempt to improve the training methods by developing new game based methods intended as a substitution to one of the more popular on-board training methods. As part of the research work, a course for energy efficiency was developed that was composed of two episodes, with distinct intended learning outcomes. The rest of the paper is structured as follows: Sect. 2 describes current training practice, strengths and weaknesses, Sect. 3 and Sect. 4 describe the TOOLS platform and game respectively, both resulting from the co-design activities; Sect. 5 describes two formative evaluation studies carried out and finally conclusions are summarized in Sect. 6.

2 Current Onboard Training Practices

Several training methods are in wide spread use in the maritime sector today; training centers in-house or externally delivering training course, on-board computer based training (CBT), simulator training (usually delivered by external training centers specializing in this), video based training and of course drill and training on board. The methods fall into two big categories: On-board an on-shore. The off-shore methods are training centers and simulation centers, the on-board are drills and training, video based lectures and CBTs. The off-shore methods are more expensive and less flexible than the on-shore, because on-boards require travel and subsistence costs as well as a need for planning the training.

As a relatively cheap and flexible on-board training method CBTs have become quite popular. CBT can cover all topics, does not require the seafarer to go anywhere and the infrastructure required is simply a PC and the CBT course itself on a disk from the CBT provider. No connectivity to anything is required, which has been important because of low bandwidth and high prizes of satellite connectivity for ships. The seafarer is put in front of the computer and starts the CBT program, which is an old fashioned e-learning module. It is a lecture based teaching method, in the CBT the seafarer reads a text, or listens to a text spoken to him if it is a modern version and answers a multiple choice questionnaire based on this text. The course then assesses a total score and tells the seafarer if he/she has passed the text or not. The CBT provider

logs the use and if certificates are needed provides this.[1] However, the CBT training programs have not fully handled the transition from training sessions to actual work practice and they have the following limitations:

- The learning environment on board does not support experiential learning;
- Operational mistakes are costly, but there is no safe environment for experimentation;
- CBTS are individual and ignores social learning and community building
- There is no support for reflection, thus internalization of knowledge does not take place;
- A necessary characteristic of learning is motivation and the current delivery mechanisms for on board training are boring, which leads to low engagement and consequently poor learning.

2.1 Looking for New Training Methods

In 2012 two medium sized Norwegian ship owners wanted to try to do something different than CBTs working jointly with the contract research agency SINTEF. In an earlier collaborative R&D project (ended 2009) on bureaucracy and reporting the gap between theory and practice had been clearly exposed. In a survey to the seafarers (deck officers) it was discovered that more than a third of the officers reported breaking company procedures regulating use of auxiliary engine (several instances) and other safety and environmentally issues to a lesser degree [3]. This was the acknowledged breach of procedures which was admitted in a survey, and the possibility of underreporting such breaches was of course quite large.

Additional use of engines are both costly and environmentally unfriendly[2]. The same goes for using wrong kind of fuel, another type of error often seen. Avoiding excessive use of engines, and thus fuel, will lower costs as well as avoid pollution and emissions. The Transpacific Stabilization agreement, a research and discussion forum of major ocean container shipping lines that serve the transpacific trade in both directions between Asia and the USA states that: "*Fuel accounts for 60 % or more of total voyage operating costs for a typical scheduled container service. Even small changes in fuel costs have dramatic impacts on service levels and/or carrier balance sheets.*"[3] Thus, the breach of procedures had impact.

Not satisfied with its current training regime nor its operational effectiveness the shipping companies wanted to work with SINTEF on the possibility of creating improved training procedures that was better suited to bridge the gap between theory and practice, and the TOOLS project was created.

[1] Exact testing and certification procedures vary. They can be relatively complex.

[2] While not using enough when necessary creates a safety hazard.

[3] http://www.tsacarriers.org/fs_bunker.html.

2.2 The Seafarers Use and Assessment of Training Methods

As part of the project a survey was carried out among the officers of two shipping companies participating in the TOOLS project. The surveys were distributed to each ship be email, printed out onboard, answered and sent back by post. This method was chosen because it was relatively easy to reach all seafarers on board and no email lists of respondents were needed neither did the seafarers need to be on-line to answer the questionnaire. The respondents were all officers in all ships in the two companies. A total of 374 answers were received from 750 possible respondents, a response rate of 50.

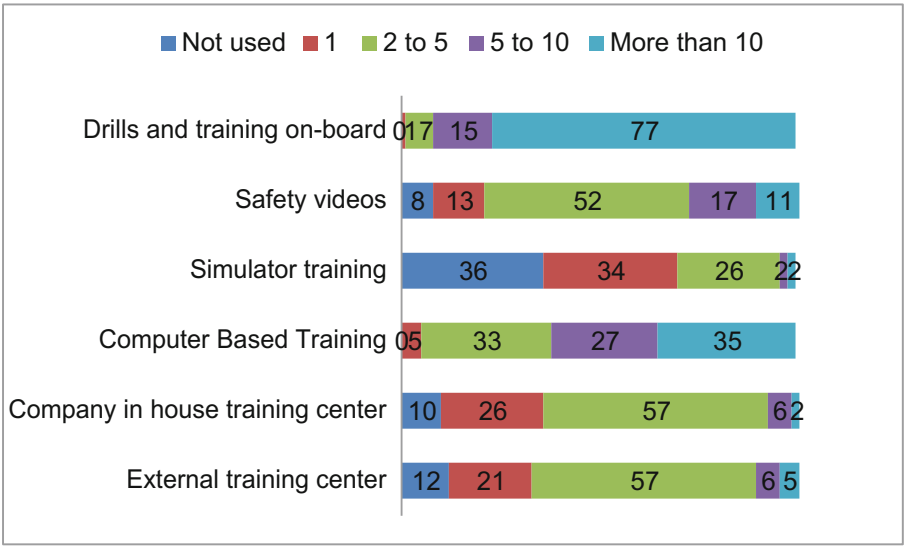

Fig. 1. Frequency of training methods in TOOLS participating companies, last 12 months, N = 374.

From Fig. 1 we can see that during a year the typical seafarer (officer) is subject to several training sessions. The method most frequently used is drills and trainings on-board, 77 % did that more than 10 times per year. CBT was the runner up in frequency, 34 % had more than 10 exposures to this, an additional 27 between 6 and 10 times. The least frequent method was simulator training, 36 % of the officers had not done this, and another 34 done it once.

Looking at the usefulness of the training as assessed by the seafarers we found that it was in general perceived as relevant and useful. Looking only at the on-board training we find that 68 % perceived on-board drills as very useful, 35 the same for safety videos and 30 % for CBTs. The most practical training was the most popular, but all training forms were viewed as useful. The problem is of course that questions like this does not measure learning outcome, only "happiness" with the training.

Since CBTs was of particular interest to the shipping companies some additional questions were asked on this. It was found that CBT training was done individually (79 % always did CBTs alone), and most of the seafarers (75 %) had to repeat the course before passing exam. Results from CBTs were sometimes discussed (61 %) but 32 % rarely or never discussed them. CBT is an individual training form.

One of the reasons for using CBTs has been concerns about connectivity and the need for additional devices for conducting training. We therefore surveyed the actual frequency of personal devices that could be employed for training and the use of internet for personal reasons. We found that 93 % had personal PCs (approximately half had either tabled and or smart phone) 86 % claimed to have local wireless connected to internet at all times, and Facebook was in daily usage by 76 % of the sailors. Overall we concluded that the infrastructure for doing a gamebased training platform with internet connectivity was in place.

3 TOOLS Platform

The survey conducted gave credence to the grievance of both the ship owner companies and seafarers that current on-board training solutions based on CBT failed miserably to support effective competence development. However, the survey also confirms that all stakeholders consider the relevance of on-board training, thus it is a need that is not being successfully addressed from current service providers. As documented in relevant literature e.g.: [6], namely in communities related to learning and technology enhanced learning, there are several limitations to both the process and delivery mechanisms used, such as:

1. **Motivation.** The key complaint for both the seafarers and the shipping companies is the failure of content to engage successfully, thus a pre-requisite for learning is not met [5];
2. **Delivery mode.** Learning content is based on the tell premise, using non-interactive content, which studies (e.g.: [6]) show such delivery modes yield the lowest form of retention;
3. **Shallow learning.** The didactical design is poor, with the focus on the meeting the minimal required to support the content certification. There is little consideration to the actual return on learning (ROL), thus what the seafarer acquires in terms of knowledge and their ability to apply the competence in the appropriate time and attitude.
4. **One size fits all.** Learning is not personalized to the particular needs of the seafarer, thus achieving flow [2] is difficult as one-size-fits-all does not accommodate the differences between each individual.

The above are an illustrative sample of the limitations of the existing on-board training solutions, which as put forth by Aldrich [1] resembles fast food where the nutritional value is low, in particular when compared to the well balanced diet of home-made food.

Building upon the recognized challenges of onboard training, the TOOLS project aimed to research and develop an innovative on-board training solution that is game-based learning, focused on the effective and efficient competence development of the seafarers. The overall process is depicted in Fig. 2, which starts with the login of the seafarer onto the TOOLS platform either with a dedicated account or with a social account, such as facebook or linkedin.

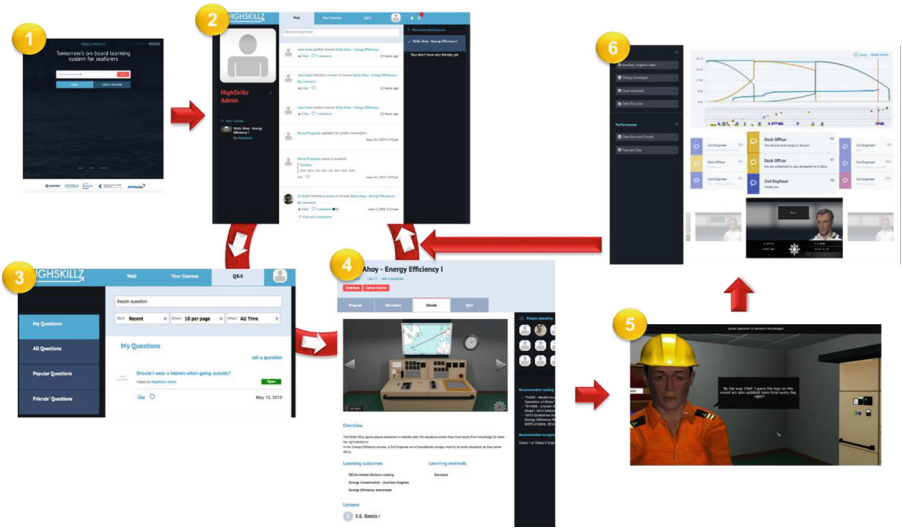

Fig. 2. TOOLS platform and learning process

Once successfully signed-in, the seafarer has three distinct options to consider:

- **Wall (step 2).** This section of the platform consists of a social activity line where the seafarer may publish their thoughts and share them with the students in the same classroom and their friends. The platform also publishes events concerning the activities of the seafarer.
- **Q&A (step 3).** This section of the platform consists of questions and answers shared within the community of seafarers across the fleet. The seafarers can pose questions, search and rate answers, with the one posing the question being responsible for overseeing the responses, deciding when the question was answered by deciding on best answer.
- **Courses (step 4).** This section of the platform contains all the courses that the seafarer has been engaged with and subscribed to. For each course, the seafarer has an atypical course description, including the break-down into lessons, the additional seafarers that have taken or are taking the course and recommended reading. In addition, the seafarer can access the detailed post-action review of their own past sessions and that of other seafarers, having the capability of searching best performances.

All the steps 2, 3 and 4, are interchangeable and not a linear process with precedence between the different steps. Step 5 corresponds to when a seafarer engages with a course, which provides them a believable immersive context where they need to make cognitive decisions (Sect. 4). After the session, the seafarer is presented with a detailed post-action review (step 6) where they are presented with 3 distinct layers:

- **Performance Curves.** The layer presents the performance curves depicting the competence (e.g.: trust building, decision making, etc.) of the seafarer at each sampling interval. These curves are determined by equations based on observable behavior indicators;
- **Events.** The layer indicates the events captured during the engagement with the session, which are correlated to the performance. Atypical events correspond to achieving particular objectives, learning outcomes, mistake committed, etc.
- **Context.** The layer presents snapshots taken at given intervals, which provide the seafarers with an important contextualization for both the performance measurements and events.

4 TOOLS Serious Game

The TOOLS platform is a game-based learning platform where the courses provide experiential learning through the engagement of believable contexts where the seafarers are required to make decisions.

Fig. 3. TOOLS learning content

The diagram of Fig. 3 reflect the interaction cycle with the course on energy efficiency, consisting of two main lessons:

- **Emission Control Area (ECA).** The learning of the outcome of the lesson is to have the seafarer to determine the crucial point in time when to switch from high sulfur fuel to low sulfur fuel to reduce the impact of emissions when entering a ECA, aligned with what regulations permit. The decision needs to take into account the fuel in the engine and the rate of consumption, thus calculating how long it takes to switch effectively the fuel.
- **Fuel Efficiency.** The intended learning outcome is to achieve the optimal fuel efficiency whilst in port. A seafarer needs to determine how many auxiliary engines to have in operation taking into account the necessary power consumption depending on the activities taking place.

Both lessons were co-created with multiple stakeholders, involving in addition of the development team, seafarers, management, subject matter experts and experienced instructors. The development process was iterative with frequent releases for testing the concepts and instructional design of the course. As important to the intended learning outcomes, the lessons of the course have-inbuilt pitfalls indicative of poor work practice, thus the seafarer needs to apply critical thinking and follow procedure.

As illustrated in steps 2–6 of Fig. 3, the seafarer engages in dialogue (step 2) with multiple characters, from higher and lower ranking officers. The higher ranking officers provide orders, which essentially corresponds to guiding the seafarer in what goals to achieve in a step-wise manner. However, the use of lower ranking officers facilitated the abstraction to the particulars of a shipping vessel since evidence demonstrated a signification absence of layout and design standardization. Consequently, the seafarer would decide what to action to take and instruct their team mate to carry it out. The dialogue was carefully crafted to encourage particular behaviours, such as to always ask instead of making assumptions, to demonstrate principles of leadership by communicating well and building rapport with the remainder crew members, and ensure that lower ranking officers understand and commit to the given orders. Due to the prominence of Filipinos in the seafarer population, the dialogue was carefully created to eliminate potential cultural stereotypes.

In addition to the dialogue interaction, the seafarers is required to consult with the engine room log book (step 4), specifications of the vessel (step 6) and the company procedures. Both are actions that are seldom followed by seafarers, who usually follow whatever is the existing practice onboard even if wrong. This was another key learning outcome designed into the course's lessons as a result of the co-design activities.

Finally, in step 5, the seafarer is given the chance of controlling how time is governed thus allowing real-time for decision making whilst permitting to advance time to verify the outcomes of particular decisions.

Steps 1 and 7 correspond respectively to in-game briefing and debriefing of the course. Although the seafarer is given a detailed post-action review, it is important to include in-game debriefing where the human resource manager can provide relevant feedback to the seafarer.

5 Evaluation Study

For the formative evaluation of the TOOLS platform, two studies were carried out with population of seafarers from two different shipping vessels, belonging to two different shipping companies (Grieg Star and KGJS). However, both consisted of predominately Filipino population. To support the evaluation, both quantitative and qualitative measures using questionnaires, which were complemented by observational studies involving two facilitators, one involving a member of the development team and another being an occupational psychologist.

A total of 37 seafarers, 13 from Grieg Star and 24 from KGJS, took part of the two studies. The setup used was to have a server installed onboard with two laptops for seafarers to engage with the course on energy efficiency. For this reason, only two seafarers at a time would take part of the study as shown in the photograph of Fig. 4.

Fig. 4. Evaluation session involving officers onboard

One questionnaire was used to capture user satisfaction and it was designed with two distinct parts, the first part consisted of three questions with 7-point likert scale (Fig. 5), ranging from "not at all" to "strongly agree"; the second part consisted of an additional three open-ended questions (Fig. 6).

Did you enjoy playing the training game?
Would you play it again if you had the time?
Do you think you know more about energy efficiency after playing the game?

Fig. 5. Questions based on 7 point likert scale

The second questionnaire was to measure usability, thus the standard System Usability Scale (SUS) was used without modification, entailing the 10 questions each with a 5-point response.

What did you like?
What would you change?
Anything else you want to share with the development team?

Fig. 6. Qualitative open-ended questions

The seafarers would engage with the platform and asked to do the course on energy efficiency. Once they completed the course, they were asked to complete both the questionnaires on user satisfaction and usability. There was no assistance or clarification provided to the seafarers, which impacted negatively the SUS score due to seafarers not being English native speakers [4].

As a result of the user satisfaction questionnaire, 78 % enjoyed the course, 80 % would play again if they had the time and finally 81 % reported knowing more about energy efficiency. Although the usability questionnaire yielded an average SUS score of 60, which is below the recommended 68, there was a clear distinction between two groups of the seafarer population. A third of the population averaged a score of 71, whilst two thirds consistently scored 50 with a standard deviation of 3.5.

6 Conclusions

The paper presented the TOOLS game-based learning platform as an innovative solution to support the competence development of seafarers. Although the use of serious games for training and development of competences is not novel, their use in the maritime sector has been limited with the incumbent service providers remaining limited to traditional CBTs.

The solution was co-created with multiple stakeholders within two shipping companies concerned with addressing the evidenced gap between the traditional training and the demonstrable on-board work practices. The results from summative evaluation have yielded very promising results, with seafarers having a very high acceptance. Although the SUS questionnaire was used with less promising results, there was clear improvements from one study to another as improvements were made to the TOOLS platform based on the feedback collated. An important factor that had a negative impact on the SUS scores is based on the fact that the seafarer population was not native English speakers. In addition, the poor digital literacy of the seafarers created significant barriers to usability.

Acknowledgments. The authors would like to thank the funding of the TOOLS project from the national Norwegian research council.

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