Reflection Continuum Model for Supporting Reflection and Game-Based Learning at the Workplace

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Abstract. Game-based learning provides experiences where the learner has the opportunity of learning by doing. Existing theoretical models of learning describe the role of reflection and its importance in the consolidation and internalization of knowledge. However, reflection is often neglected in the game development process, where the emphasis is on balancing the didactical design of what is required to be taught with the game design to facilitate high engagement that leads to high motivation and flow. The Reflection Continuum Model brings together different theories of reflection into three levels: micro, macro and meta. The paper presents the analysis of three game-based learning experiences in corporate training according to the model.

Keywords: Reflection Continuum Model · Workplace learning · Game-based learning · Thoughtful action · Tacit knowledge

1 Introduction

Learning in the workplace is often situated learning [7] and involves learning by doing along with observing peers and experts at work. Adults learn best when they are actively engaged in the process and they participate and have engaging experiences. This type of learning is best described by Kolb's experiential learning cycle containing four related parts: concrete experience, reflective observation, abstract conceptualization, and active experimentation [5]. Experiential learning is also described as four phases: planning for action, carrying out action, reflection on action, and relating what happens back to theory [1] and as thinking about the experience, identifying learning needs that would improve future practice in the area, planning what learning to undertake, and applying the new learning in practice [2]. The EU project MIRROR, focused on reflection and learning at the workplace, builds upon experiential learning and considers the return to an experience to reflect and make changes in the work [6]. One of the key concepts in experiential learning appears to be reflection on an activity or an event.

Game-based learning provides an engaging learning experience, an ideal environment for learning cognitive skills and an interactive decision making context [3]. Simulation games are a virtual arena for people to experience and practice a variety of situations at the workplace. Reflection triggers are often designed as a part of the game;

M. Alcañiz et al. (Eds.): JCSG 2017, LNCS 10622, pp. 224–234, 2017.
https://doi.org/10.1007/978-3-319-70111-0_21

e.g. prompts about the knowledge to be learned [9], or through more subtle ways such as an icon or a visualization or the scores of other players [4]. Designing good support for reflection is not trivial for several reasons; firstly, Csikszentmihalyi's flow theory describes a state when the player is so engaged in the play that there may be little or no room for reflection [11]. This requires careful balance between flow and reflection for optimal benefit from the game. Secondly, not all players may be able to perceive the meaning of subtle or indirect reflection tools within a game [4]. Therefore, there is a need to build effective reflection tools in the game that help players achieve the desired learning. This paper presents the Reflection Continuum Model (Sect. 2) as a means of designing effective reflection support in serious games along with the analysis of three serious games to illustrate the model: Sect. 3 describes accelerating learning in the process industry (ALTT); Sect. 4 describes on-board learning solutions in the maritime industry (TOOLS); Sect. 5 describes LifeCycle Assessment in sustainable manufacturing (LCA) and Sect. 6 provides conclusions.

2 Reflection Continuum Model

The cognitive processes, such as diagnosis, analysis, judgment and choices of actions, in a workplace, need to be taken into account when designing learning solutions such as simulation games for competence development in the industry. Support for reflection is a major contributing factor for successful learning. The Reflection Continuum Model [12], shown in Fig. 1, illustrates the different levels of reflection support that can be designed into games and learning solutions.

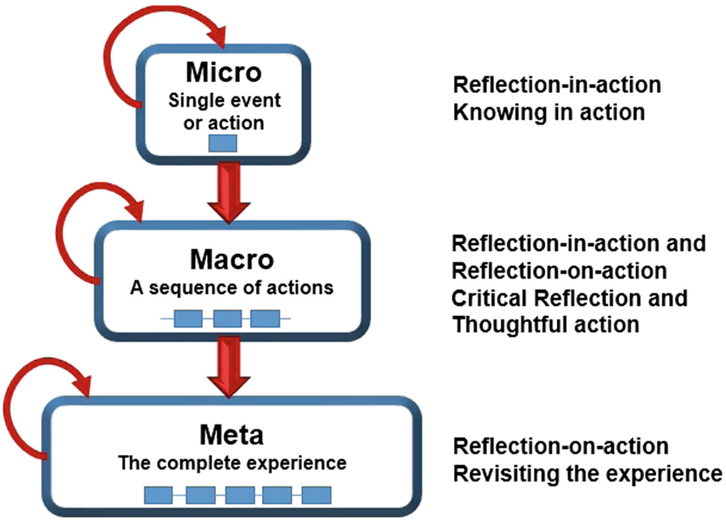

Fig. 1. Reflection Continuum Model

As with any experience, the learning experience comprises of a number of activities, where each activity can be considered as a micro activity. These micro activities are not isolated and have a degree of salience that makes a sequence of these activities, a relevant part of the learning experience. This is the macro level of the learning experience. The macro level emphasizes the evolution of the experience rather than a subset of activities that belong together. As most often explored in games, the entire experience seen as a whole provides a meta learning experience. The micro, macro and meta levels of learning experiences can be related to the relevant theories on reflection and learning; the micro level is reflection-in-action and knowing-in action and the meta level is reflection-on-action and revisiting an experience for improving one's understanding and future actions [12]. The macro level brings the other two levels together to provide support for critical reflection and thoughtful action [10], stimulating the reflective practice and encouraging the operators to reflect continuously about their actions and act intentionally. The three levels of reflection are necessary to support understanding, to encourage reflective action and to raise awareness of the consequences of their actions.

3 Accelerating Learning Through Technology in the Process Industry

The Norwegian company, Hydro, is keen to enhance the knowledge of their operators in the aluminium plants so that they will be able to make better and efficient decisions in the workplace. Today, the operators learn about heat balance, one of the critical processes in aluminium production, by observing and following instructions from their more experienced peers. They learn to follow procedures and recognize patterns without a deep understanding of the chemical process of aluminium extraction. Hydro is keen to accelerate the learning process and support operators acquire a level of understanding and experience that is closer to that of experts in a shorter time. Thus, the Norwegian project ALTT (Accelerate Learning Through Technology) project is funded by the Norwegian Research Council, bringing together the domain expertise and users from Hydro, a game developer (Attensi), the knowledge in the dynamic process models and process simulation experts (Cybernetica) and researchers and designers of Technology Enhanced Learning (TEL) solutions (SINTEF).

3.1 ALTT Game Concept

The ALTT Heat Balance game was designed to support operators learn about heat balance in the aluminium production cells. One of the main challenges in understanding this process is posed by the slow reaction times, which makes it harder for operators to see the consequences of their actions on the cell. The selection of which action to take is a complex cognitive decision making process, which involves establishing the current status of the cell and how it got there. The main game screen for the ALTT Heat Balance game is shown in Fig. 2.

The gameplay is based on rounds, each corresponding to a 24-h time period. The 9-cell matrix (top right) is the board game to indicate the current status w.r.t. to the

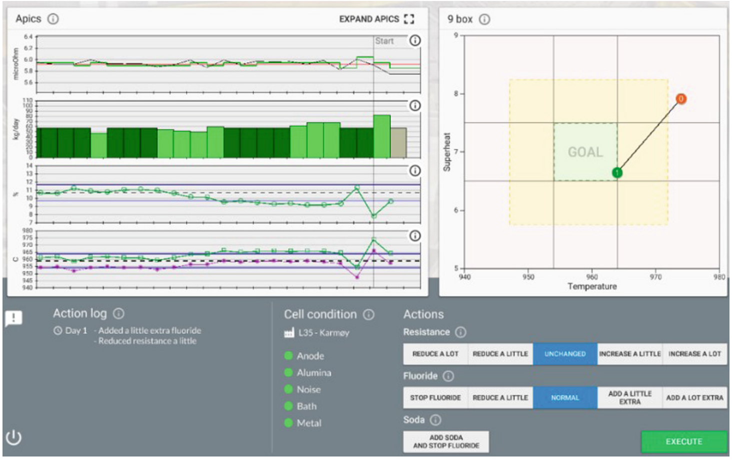

Fig. 2. ALTT heat balance game

temperature in the cell and the graphs to the left of the screen shows the recent history with values for several parameters including the temperature and acidity. The buttons to the bottom right of the screen show the actions in the game, which can be translated as parameter values for the dynamic process model. The available actions are adjusting the resistance and the amount of fluoride (acidity) in the cell, wait without taking any action or add soda to the cell. Once an action is taken, the graphs and the 9-box matrix are updated with the new state of the cell, calculated using the dynamic process model.

3.2 Reflection and Learning in ALTT

The learning needs in the ALTT project highlight the complex cognitive demands posed by the domain and the need to go beyond a single reflection model or theory [12]. Reflection in the ALTT Heat Balance game is designed to encourage operators to think carefully of each action they take, by studying the current state of the cell, detecting how it got there by looking at historical information and anticipating consequences of their action. The reflection tools incorporated in the game are shown in Fig. 3.

The micro level of reflection aims at drawing the operator's attention to each action they take to encourage knowledgeable and thoughtful action, based on the information available to them in the game. This is supported in each round of the game using knowledge questions, by asking the operator to anticipate how the behaviour of three important parameters of the cell (temperature, acidity and superheat) will change, which are also the focus of the learning goal. This is done by asking the operator to select one of the three possible behaviours of the parameters (increase, decrease or stable); Fig. 3(a). The feedback for this is provided as the actual consequences of the actions.

The macro level of reflection aims to draw attention to the dynamic nature of the process and to emphasize that each action (or round in the game) is not an isolated

Fig. 3. Reflection support in ALTT

action and a consequence. It is designed to encourage operators to take thoughtful actions by dwelling upon past actions and anticipating the consequences of actions and to promote critical reflection. The reflection tool at the macro level is a slider, which allows the operator to revisit each point in the game when the operator took an action (or each round), see the status of the cell, and to reflect on how her actions at that point in time affected the cell and contributed to the current state of the cell. This functionality is shown in Fig. 3(b), where the operator has played three rounds and has moved the slider to show the cell status at round two. In addition to displaying the cell status at any round on graphs, the cell status at the round is also highlighted on the game board, the 9-box model; see Fig. 2.

The meta level of reflection is aimed at revisiting the whole experience after each game scenario and to encourage the operator to reflect upon their actions and how they had affected the whole performance. The intention is also to encourage the operator to think why they had either won or lost and to detect when or which actions may have been critical to the outcome of the game. This will serve as a stimulus to think strategically about how to adjust their choice of actions next time they play. This level is also supported by the slider functionality, enabling the operator to revisit.

Several novices and expert operators and engineers have played the game. The responses have been very enthusiastic and the operators appeared motivated and engaged. The novices found the knowledge questions at the micro level of reflection very helpful and said that they helped them understand the concepts and the cell dynamics. The experts, however, found it annoying that they had to anticipate the consequences of their actions at every round. They said that to think ahead is what they do already, and therefore, they did not see any benefits of the functionality. Nevertheless, they appreciated the value of the functionality; they would just like to be able to switch off the functionality when they desired. The slider functionality was not used by any of the operators during the evaluations. When the functionality was demonstrated to them afterwards, they liked it and said that it will be a great help, specially for the less experienced operators. Valuable feedback was received to improve the GUI for the slider. This is perhaps an example of a reflection trigger that was not perceived by users as it is meant to, thus reducing the envisioned effects on the learning process.

4 Tomorrow's Onboard Learning Systems in the Maritime Industry

Experience in the maritime industry, which upheld by research, indicates that there is a gap between so-called intended and actual work practice among the officers on board [8]. While officers seem to be familiar with the correct or 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. 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 environmental issues to a lesser degree [8]. 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. The TOOLS game-based learning solution was developed to research a novel approach that addressed specifically the registered gap.

4.1 TOOLS Game Concept

The TOOLS serious game provides a rich experiential learning experience where a seafarer assumes the role of 2nd engineer on a vessel that departs from Rotterdam on the way to Houston. The game consists of two distinct episodes:

- **Emission Control Area (ECA)**. The learning of the outcome of the episode 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 of the episode 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.

The diagram in Fig. 4 reflects the different contexts that support the TOOLS learning experience. The start of the game (step 1) corresponds to a briefing of the HR resource manager providing the seafarer with their assignment. Thereafter, 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 significant absence of layout and design standardization. Consequently, the seafarer would decide what 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

Fig. 4. TOOLS learning content

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.

The seafarer is confined to the engine room (step 3), which gives them access to the instrumentation providing information on fuel, engine load, distance, etc. The seafarer also has access to the engine room log book (step 4), specifications of the vessel (step 6) and the company procedures. The acquisition of information to make informed decisions is a key behaviour that shaped the design of the TOOLS game since traditionally seafarers seldom practice consultation. 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.

Once the seafarer finishes the game session, they are given an in-game debriefing of the course (step 7). 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.

4.2 Reflection and Learning in TOOLS

In TOOLS, there is only a meta level of reflection, which consists of the in-game debrief and a rich-detailed feedback (Fig. 5) of their experience. The former provides overall recommendations for the seafarer to improve their performance in their next session whilst the latter provides feedback using a time-based continuum so the seafarer may reflect on the impact of the decisions made. The reflection support consists of three main areas, all governed by the timeline:

- **Competence Performance Measurement**. This provides feedback on the performance of particular skills, some are continuous over time (e.g.: building of trust with your team) and others are discrete in time (e.g.: decision made to change the fuel).

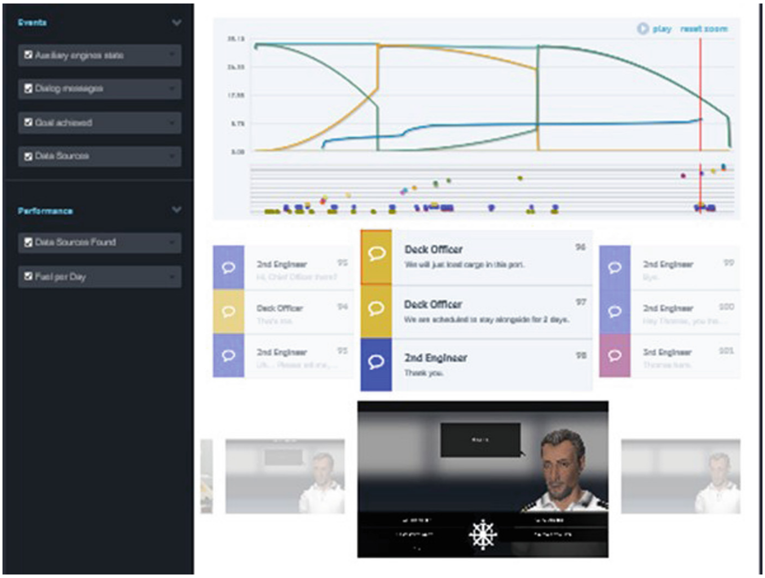

Fig. 5. Reflection support in TOOLS

- **Events and Dialogue**. This captures all the relevant events of the game, including dialogue, thus enabling the seafarer to know the precise context at each particular instance along with the build up until that moment.
- **Context**. Although the events provide insight into what happened, it is not sufficient for a seafarer to recall precisely the context. Consequently, this area consists of a timeline of images derived from snapshots taken at regular intervals.

5 Life Cycle Assessment in Manufacturing

Life Cycle Assessment (LCA) is a complete, structured and standardized method for environmental impacts evaluation. The innovative approach of LCA allows to avoid the shifting of a potential environmental burden between life cycle stages or individual processes, through the evaluation of resources consumption, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal. The increasing of awareness of environmental implication has allowed the development of LCA training in many courses (e.g. university, master, professional training). However, these courses focus mostly on the theory, supported with practical work, thus failing to convey the complexities for implementing a LCA in a real context. In particular, the discovering of information needed for the Life Cycle Inventory, into the complexity of Business Company. The development of a full LCA, can require an important amount in terms of costs, people and time, and one of the most important reason of time consuming is the gathering of information between the company, databases and statistical data.

5.1 LCA Game Concept

The student is given the role of a sustainability manager working for a manufacturing company of coffee machines. The CEO of the company wants to optimize the production process with the following specific goals:

- Reduction of energy by 15%
- Zero emission of ozone-layer destroying substances
- Reduction of solid waste by 10%.

For the LCA inventory, the student needs to interact with several stakeholders within the manufacturing company, being aware of their biases when answering requests for information. In addition to the social interactions, the student needs to access different sources of information from databases, production cells on the shopfloor and documentation. However, the student must apply critical analysis to resolve the perceived contradictions and avoid pitfalls of erroneous (and outdated) data (Fig. 6).

Fig. 6. The screenshot on the left is the default view of the user with the icon on the lower portion of the screen to activate the screenshot of the right where the user has all the functions of the LCA reporting process

The session is completed when the user submits the LCA report to the CEO via the LCA tool.

5.2 Reflection and Learning in LCA

With regards to the reflection continuum, the LCA serious game supports both the macro and meta levels of reflection. The meta level is facilitated by a rich in-depth feedback based on a time continuum similar to the TOOLS serious game, with three level of information: competence performance, events/dialogue, and context based on visual snapshots.

The initial studies demonstrated that whilst useful, the meta level of reflection was not sufficient for students to develop their understanding on the decisions made concerning LCA since the game focus on the creating the LCA report. Consequently, the game design was refined to embed in the game a macro level of reflection where the student is required to make recommendations to the CEO to accompany the LCA report. This level of reflection requires the student to understand the output of the LCA simulation and interpret the results within the business context and strategy outlined by the CEO.

6 Conclusions

An analysis of the three serious games according the reflection levels of the Reflection Continuum Model the analysis is summarily captured in Table 1. This analysis based on concrete examples provides a clearer understanding of the Reflection Continuum Model. Most serious games support the meta level of reflection, with a final debrief of the learning experience with different levels of richness and details. The TOOLS serious game only support the meta level of reflection and the reason is rooted on the procedural nature of TOOLS, since seafarers are required to follow Standard Operating Procedures as determined by the shipping companies. Although TOOLS could be enhanced to support additional reflection levels, it would not be necessary considering the didactical aims driving the game design.

Table 1. Comparison of the levels of reflection of the three serious games based on the Reflection Continuum Model

Serious game	Micro	Macro	Meta
ALTT	Yes	Yes	Yes
TOOLS	No	No	Yes
LCA	No	Yes	Yes

The LCA serious game supports both Macro and Meta levels of reflection due to the requirement of students reflecting in-game, between the phases of data collation and providing recommendations to the CEO.

The most comprehensive serious game is ALTT, which is to be expected considering that the strong focus on the development of the cognitive ability of operators to make the correct decisions concerning the heat balancing with regards to aluminium production.

Acknowledgements. The ALTT and TOOLS projects were funded by Norwegian Research Council and the ManuSkills project was funded by the EU TEL program. The authors would like to thank the participants of the projects for their contributions to the development of the games presented in the paper.

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