METHODS FOR TRANSFERRING KNOWLEDGE AND BUILDING CONTENT IN SERIOUS GAMES

Albena Antonova, Krassen Stefanov

Abstract. *Sophisticated Technology Enhanced Learning (TEL) instruments as training simulations and Serious Games (SG) do not provide knowledge content in an explicit form, but propose interactive solutions for learners to build their own skills and competences in close to real situations. The present research makes an overview of the processes of knowledge transfer and content development in SG. In the first place, there will be analyzed and proposed methods how to elicit and embed expert knowledge into design of SG and training simulations. Therefore in the first place we will discuss the problem of expert knowledge elicitation for building SG. In the second place we will review how learning content can be integrated in SG design, and will identify various SG elements and components that can transfer knowledge to the players. Finally, some practical implications will be discussed, derived from the experience in TARGET FP7 EU funded project.*

Keywords: *Serious games building, knowledge transfer, knowledge elicitation, expert knowledge codification*

МЕТОДИ ЗА ТРАНСФЕР НА ЗНАНИЕ И СЪЗДАВАНЕ НА СЪДЪРЖАНИЕ В СЕРИОЗНИТЕ ИГРИ

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Анотация: *Сложните инструменти на технологично поддържаното учене (Technology Enhanced Learning, TEL) като симулации и сериозни игри (SG) не предоставят съдържание на знания в експлицитна форма, но предлагат интерактивни решения на учащите се, за да могат те да изградят свои собствени умения и компетенции в ситуации близки до реалните. В настоящото изследване се прави преглед на процесите на трансфер на знания и развиване на съдържание в сериозните игри. На първо място ще бъдат анализирани и предложени методи за въвеждане на експертно знание в дизайна сериозните игри и симулациите. Ще обсъдим проблема за извличане на експертни познания за изграждане сериозните игри. На второ място ще разгледаме начина, по който учебното съдържание може да бъде интегрирано в дизайна на сериозните игри и ще идентифицираме различните елементи и компоненти в сериозните игри, които могат на предоставят знания на играчите. Обсъдени са и някои практически ефекти, свързани с опита от проект TARGET, финансиран по 7РП на ЕС .*
Ключови думи: *Сериозни игри, трансфер на знания, извличане на знания, експертни познания, кодификация*

1 Introduction

While increasingly popular in recent years, serious games and training simulations still represent a challenging learning environment. This is the reason developers of serious games often to experience various difficulties to transfer knowledge and to build successful learning paths. In traditional TEL systems expert knowledge is usually presented in explicit form and subject matter experts (SME) prepare and provide their own learning materials as text, audio or video content. Thus designers of TEL environments do not need to codify specific expert knowledge, as TEL role is to facilitate delivery and building of rich knowledge ecosystems around that learning content. This approach cannot be applied in serious games and training simulations.

The logic of serious games and training simulations is to develop complex scenarios, where learners can build skills coping with number of challenging situations. In serious games the Kolb's cycle for knowledge acquisition (Antonova & Todorova 2010) is adopted, where learning is developed through number of trial-and-error situations. Building successful SG include synchronization of multiple elements (game mechanics, appealing graphic environment, engaging scenarios), and therefore achieving good mix of learning elements is very difficult. Moreover, expert knowledge should be incorporated in good quality and form within game scenario and game elements in order to form learning path. So expert knowledge is crucial to make learning simulations useful and meaningful for learners, and to put them in situation where they can substantially build new skills. Another problem with serious game's design is to incorporate the knowledge content in serious games elements. As serious games should fulfill several objectives and namely to build skills and competences, to transfer knowledge and achieve learning and to remain enjoyable and fun, developing SG can be a challenging experience.

The present paper will discuss knowledge transfer in serious games from two points. The first problem is to analyze how expert knowledge can be elicited and codified in the process of game development. And the second question is to identify and analyze how specific game elements can be used to transfer knowledge to the player, in order to fulfill learning objectives. Finally the paper will discuss some of the results for scenario development, obtained in TARGET FP7 project.

2 Theoretical background

2.1 Serious games for learning

Serious games often overlap and extend the terms e-learning, edutainment (education and entertainment) and game-based learning (Antonova & Martinov 2010). Although slight variances among different authors, serious games are commonly described as (digital) games used for purposes other than mere entertainment or fun (De Freitas 2008). Serious games usually refer to games used for training, simulation, or education that are designed to run on personal computers or video game consoles. Thus, serious games transfer positive experiences of building skills and competences while entertaining and playing on computer games to apply it in more complex context and purpose-oriented learning.

The common elements of SG include: back story (plot/ story line), game mechanics (physical functions/actions), rules (constraints), immersive environment (including 2D/3D, animations), interactivity (impact of player's actions), and challenge/competition (against the game or against other players). In SG players have to perform a set of actions and take different decisions, following preliminary defined rules and constraints. Usually players receive instructions and feedback on their performance and are virtually assisted with additional learning materials.

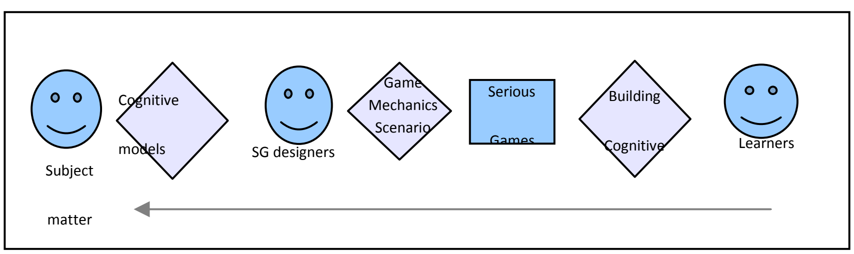
2.2 Cognitive Skills

The overview of skills provided in (Winterton et al. 2005), classify several approaches for conceptualizing skills, from manual or motor skills to cognitive skills, perceptual skills, response selection skills, and problem-solving skills (Proctor & Dutta 1995). Most schemes for categorizing skills are hierarchical, starting with the simpler form of skill and ending with the most complex. Welford (Welford 1968) defines skills as "combination of factors resulting in

competent, expert, rapid and accurate performance, equally applicable to manual operations and mental activities”. Proctor and Dutta (Proctor & Dutta 1995) define skill as “goal-directed, well-organized behavior that is acquired through practice and performed with economy of effort”. Seamster et al. (Seamster et al. 1997) propose a framework for hierarchy of skills, ranking on first place strategic skills, then decision-making skills, representational skills, procedural skills, and automated skills. Automated skills are sub-consious and are characterized with rapid execution and economy of effort.
A “cognitive skill” is a skill that is predominantly cognitive in nature. All skills have a perceptual, motor, and cognitive component (Proctor & Dutta 1995), but cognitive skills form the basis for training because they can be trained in relatively short period of time. The recognition that some skills have a predominant cognitive component, and the use of cognitive methods to analyze these skills, allows the application of meaningful Cognitive Task Analysis (CTA) methods (Seamster et al. 1997).

3. Transferring knowledge in serious games
3.1 Eliciting expert knowledge for building serious games

Using expert knowledge in the design and development of TEL in general, as well as in the case of design of SG and training simulations, is very important. As noticed in (Clark et al. 2007; Hinds et al. 2001), learners who receive explanations from experts perform better on knowledge transfer tasks than learners who received explanations from non-experts. Different research evidences prove that accurate identification of experts’ cognitive processes can be adapted into training materials that are substantially more effective than those developed through other means (Clark et al. 2007; Hinds et al. 2001).
Two main problems with expert knowledge elicitation for TEL and serious games development can be observed. The first problem consists of proper identification of expertise and complex cognitive processes of experts, because subject matter experts cannot easily externalize automated tacit knowledge. This is due to complex cognitive models for decision making developed with experience and practice.
The second problem refers to identification of suitable models for capturing and codification of expert knowledge in a way, appropriate for further use in SG design. The expert knowledge has to be transmitted via different game elements, as critical situations, game scenario, game tasks, communication with non-playing characters (NPCs) and others.



3.2 Cognitive task analysis and ACTA methodology
Task analysis represents a methodology for describing the physical tasks and cognitive plans required of a user to accomplish a particular goal. Traditional task analysis segments a job into distinct behavior tasks and their component activities. All forms of task analysis rely on the idea

that human action can be decomposed, and that the decomposition can be used to reason about what people should do and know to complete a task.

The CTA is a set of methods designed to elicit information about the knowledge thought processes, and goal structures that underlie observable performance. (CTA is used to elicit and represent knowledge and information about thought processes in a systematic way (Chipman et al. 2000). CTA describes and represents cognitive elements underlying goal generation, decision making, judgments and others. In CTA skills are analyzed in substantially more details based on their cognitive components. CTA uses a variety of interview and observation strategies to capture a description of the knowledge that experts use to perform complex tasks. Complex tasks are defined as those for which their performance requires the integrated use of both controlled (conscious, conceptual) and automated (unconscious, procedural, or strategic) knowledge to perform tasks. It is a valuable approach when advanced experts are available who reliably achieve a desired performance standard on target tasks (Clark et al. 2007).

Researchers have identified over 100 types of CTA methods currently in use (Cooke 1994). The number and variety of CTA methods are due primarily to the diverse paths that the development of CTA has taken, including behavioral task analysis, computer system interfaces, and military applications. Applications of CTA include system design, training design, human-computer interface design, accident investigation and the development of tests to assess competence (Chipman et al. 2000), (Baber et al. 2005). CTA methods have been applied within a wide range of domains including aviation, nuclear power plant operation, consumer behavior, air traffic control and military operations, and consumer research (Baber et al. 2005). One of the more extensive reviews of CTA (Cooke 1994) identified three broad families of techniques: (1) observation and interviews, (2) process tracing, and (3) conceptual techniques. Observations and interviews involve watching experts and talking with them. Process tracing techniques typically capture an expert's performance of a specific task via either a think-aloud protocol or subsequent recall. In contrast, conceptual techniques produce structured, interrelated representations of relevant concepts within a domain.

The CTA method called Applied Cognitive Task Analysis (ACTA) can be selected as appropriate technique for knowledge elicitation and codification in SG (Militello et al. 1998). Compared to traditional CTA techniques, ACTA methodology requires considerably less training for application, less time and resources (Militello et al. 1998). ACTA is easy to use, flexible method that don´t require interviewers to be experts in the knowledge domain. Moreover, ACTA methodology is suitable for job domains where observational data are difficult to obtain, and can be used for identification and codification of complex skills on the workplace.

ACTA provide three interview protocols: the task diagram interview, the knowledge audit, and the simulation interview. The task diagram interview elicits information about the task structure within a particular task domain (e.g. the main tasks and sub-tasks), and helps to identify which of these task components are typically experienced as challenging or difficult. The knowledge audit and simulation interviews generally focus on the more difficult/challenging components and elicit more detailed information about the underlying knowledge, thought processes and goal structures. The main output of the ACTA method is the Cognitive Demands Table. This framework includes information about why each element is often found to be difficult, identifies common pitfalls/errors incurred by novices, and identifies cues and strategies that experts use to overcome the difficulties (Militello et al. 1998).

3.3 Transferring knowledge in serious games

The second problem for knowledge transfer consists of identification of game elements that can be used to transfer expert knowledge. As mentioned earlier, in learning games and simulations, knowledge cannot be presented in explicit form, and that is up to the game development team to decide how to integrate it. Moreover, game development is considered as creative activity that could not be easily formalized. Usually development of serious games involves different experts around the table, including software developers, game scenarist, learning experts and art designers. That is why, the process of game development is often a challenging task, and knowledge transfer is not often a prioritized process.

The game put the player in specific context, where he needs to accomplish the goal or the game objective, while taking different decisions, making choices and performing activities in specific set.

Scenario building:

Game scenarios can be process-based or sandbox-based. In the first case, the game scenario follows the sequence of steps, taking part in a fixed process, and the player has to fulfill specific consecutive tasks, in order to achieve the goal. The sandbox approach gives more freedom to the player to choose his own path, not suggesting initially a fixed order to execute game steps or levels. Game scenario represents the main vehicle to transfer knowledge. Game scenario is composed of several scenes and identifies the context and put the player in specific situation, where he needs to take decisions and make good choices. Therefore, game scenario embed knowledge about process (it should be believable), about scenes, incorporates information about environment, about other characters and objects. The game scenario should be believable, but it has to be interesting for the player and should provide a specific challenge for him. Game scenario can be developed based on fixed processes (if learning objective is to identify specific processes) or can be based on a story, taken from fiction, business case study, or narrative, based on SME expertise. Usually the game scenario is closely related to game objectives.

Non-playing characters - NPCs

The non-playing characters usually are designed to interact with the player, in order to provide information or to provoke specific activities and decision making. NPC can have specific roles and objectives, and can support or impede the player. NPC can communicate the information and knowledge directly in the dialogue, or indirectly – via attitude, appearance, interactions in the environment, interaction with objects and others. As NPC are dynamic objects, their role in the game is substantial for knowledge communication and retention. Dialogues form direct knowledge transfer mechanism, providing specific information in specific place in the game and trigger answers (decision making) or further activities. Moreover, NPC can intervene in the game via methods as phone calls, messages, recommendations, mails, dreams and thoughts, specific places and others. It should be noticed that in order to keep the interest of the player, dialogues should not be very long, and humor is substantial element to NPC.

Knowledge objects

Objects are specific elements in the game that can serve the player to fulfill game objectives. Objects can provide knowledge directly as for example books, newspapers, reports, brochures, posters, video records or mails, and the player can read it on the screen. However, it should be highlighted that texts in the game should be limited. Knowledge objects can be indirect as communication tools as laptop or telephone. User can decide if he want to use it, and how exactly to use it. Another way to transfer knowledge with objects is to design specific processes where mastering, using or creating object can be crucial for game scenario.

Quizzes, puzzles, games-in-the-game

Knowledge can be transferred in the game via different interactive elements as quizzes, puzzles, tests, arcade games and others. These activities should be part of the learning experience, and have to be interesting and meaningful for the player. Testing in the game should be form of amusement and not exactly evaluation methodology. Finally it is important the player to receive a feedback for his performance.

Critical incidents

Critical incidents form unusual events that put the player in not-expected situation. Critical incidents make the game dynamics more appealing and put additional learning context how to deal with unpredictable events. They can be very important in knowledge building process as they put the player in situation to act under pressure, to take decision and to analyze critical situation.

4 Knowledge transfer methods in TARGET

4.1 Approaches for SG design in TARGET

The main aim of the TARGET Project is to research, analyze, and develop a new genre of Technology Enhanced Learning (TEL) environment that supports rapid competence development of individuals, namely knowledge workers within the complex domains of project management, innovations and sustainable global manufacturing. In TARGET, the learner is presented with complex situations in the form of game scenarios, and via interacting with the game results into enriched experiences that are gradually leading to knowledge and complex skills acquisition.

Developing serious games and training simulations require general understanding of the knowledge domain. Moreover, knowledge domain need to be further specified concerning skills that will be trained, general objectives for game application and target users. While in traditional game development, the whole phase of game design is described as creative process, in TARGET approach, game design is segmented into three stages: knowledge elicitation, knowledge representation and game design (Seager et al. 2010).

The knowledge elicitation phase objectives are to clarify cognitive models of experts, leading to high performance in tasks execution. Thus interviews with subject-matter experts establish the broad high-level structure for decision model competences, concerning specific knowledge domains. The knowledge representation phase includes codification of data in a way appropriate for incorporating in game design. The game design phase consists of scenario building, identification of critical incidents and learning situations, and description of non-playing characters and their role in the process. The game design phase is the most complex phase as it involves as well conception, design and development of software environment and other game elements.

In Target are developed 3 games scenarios- for Sustainable global manufacturing, for stakeholder analyst and social architect. The game scenarios are process based, and follows specific business cases. The TARGET stories aim to develop specific soft competences, based on number of human interactions, and that is why there are created a number of Non-playing characters with specific roles and background. The success in TARGET stories depends on how well the player will interact with NPCs.

4.2 Knowledge transfer models

The use of the ACTA method produced valuable data for the initial phase of SG and the goal is to learn about the task, the cognitive challenges associated with task performance.
The outputs of the first component of the ACTA interview is a task diagram interview, that provides useful insights of most challenging cognitive tasks and subtasks. The Knowledge Audit phase aims to identify how the expertise is used in the application domain and provides cognitive difficult elements, why difficult, potential errors and cues& strategies. They can provide useful information about critical incidents and learning situation in game dynamics.

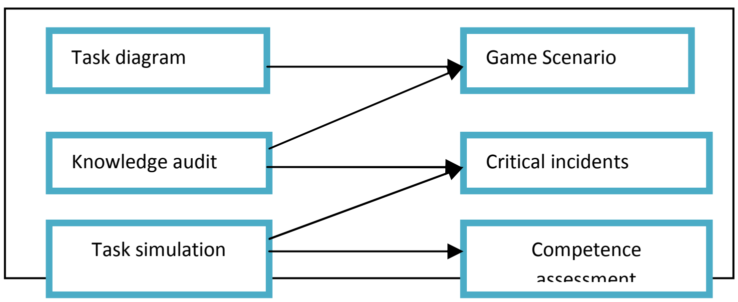


Fig. 1. Application of ACTA methodology to Serious game design

The third step is a task simulation, where the SMEs are asked to imagine particular organizational role and to describe how they would think and act in this situation. They will identify the key events, the possible actions, the models to assess situation, and potential errors. Very important is analysis of critical cues of the event and potential errors, that novice can make. This information is summarized in a table that can be used in SG design, skills performance levels and potential errors identification.

4.3. Application of ACTA and discussion of the results in Sustainable global manufacturing knowledge domain.

In order to identify specific competence set in the field of sustainable global manufacturing there were organized several semi-structured interviews with SME experts. The interviews included sections for critical incidents technique and job analysis. In total there were performed 14 interviews with SMEs from business and academia in 5 countries – Germany, Italy, Poland, Bulgaria and Slovenia. The outcomes were analyzed and allowed project partners to identify general level of understanding of the domain. There was realized that subject matter experts are mainly focused on their specific experiences and context and rarely provided summarized information that can be directly used in game development. Moreover, the information obtained from SMEs about critical incidents was hardly comparable in scope and importance. Therefore, much of this information remained unused on practice.
On a second stage, it was used the ACTA methodology to elicit expert knowledge for development of scenario for serious game in the field of Sustainable global manufacturing. Therefore 5 narrow-domain experts were identified in 4 of the countries, and interviews were performed using structured ACTA templates and tables. As result, there was quickly produced a

general framework, allowing project partners to structure the game process and the game flow, to identify difficult cognitive elements and potential errors, and finally – to identify possible game paths. Proper identification of tasks contributed for better structuring of the game scenario. An emphasis is made on cognitive difficult elements and potential errors. As final output all collected structured data is accumulated and stored in unified tables, allowing project partners to have access in later stages of game development.

The application of ACTA facilitated TARGET team to (Seager et al. 2010):

- Generate a scoped task model of the domain. (and integrate it in the story building)
- Identify task elements that novice learners often find particularly challenging. (and specific competences)
- Generate information about the knowledge, thought process and goal structures that underlie observable task performance in the domain.

Therefore, the application of ACTA method for knowledge elicitation in TARGET was successful, as it enabled SG designers to approach SME without deep knowledge in subject domain. It was easy to use, fast for application and not specific training was needed to apply it on practice. Moreover, the obtained results are comparable, storable and can be easily transferred to SG design specifics.

4.4. Limitations for application of ACTA methodology in SG design

ACTA can be easily used for knowledge elicitation in the case of SG and TEL, because it enables SG designers to approach SME without deep knowledge in subject domain. However, when applying ACTA on practice, SG designers should take in consideration several limitations. ACTA methodology prioritize knowledge gained through first-hand experience and there should be identified SMEs with practical experience. Thus SMEs with theoretical knowledge (for example Lecturers) could not provide useful results as they lack practical insights for task execution. Another limitation of the model is that it requires decomposition of expertise on structured task processes. This could be difficult in complex and broad areas as sustainable global manufacturing and innovations. Thus before applying ACTA to scope knowledge domain, there should be identified basic task structure and working processes. This can be used in defining the game scenario further.

5 Conclusions and future works

More and more learning experts think about developing Serious games for learning. On the market there are available different game-developing software tools designed for non-programmers as e-Adventure, Adventure maker and other. It can be expected more educators and e-learning experts to be tempted to develop new SG. In this case, development of specific knowledge transferring models in for SG is very important for its further success. ACTA methodology can be successfully used for design of SG and training simulations. ACTA methods permit SG designers to capture more accurate and complete descriptions of how experts succeed at complex tasks. It enables SG designers to identify critical phases of task execution and to capture SGM assessment of cognitive demanding sub-tasks, where will be concentrated most of the learning processes and challenges in Game scenario. Therefore, ACTA enable SG designers to identify specific knowledge transfer models and mechanisms as game scenarios, scenes, NPCs, knowledge objects, quizzes, critical incidents and others. This facilitate SG designer and allow him to produce faster and easier SG.

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