Learning to collaborate: Designing collaboration in a 3-D game environment

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Abstract

To respond to learning needs, Computer-Supported Collaborative Learning (CSCL) must provide instructional support. The particular focus of this paper is on designing collaboration in a 3-D virtual game environment intended to make learning more effective by promoting student opportunities for interaction. The empirical experiment eScape, which encourages learners to solve problems collaboratively, is also presented. eScape is a design experiment, comprising both the process of designing a collaborative game environment and an empirical study where data is collected using a variety of methods and analysed, after which the findings and conclusions serve as a basis for further design work. By designing and testing game-players’ activities, this study attempted to find out whether the characteristic features of 3-D games can be used to create meaningful virtual collaborative learning environments. The results revealed that the scripted game persuaded student teams to enter into collaboration, but the actual processes varied.

Keywords: Computer-Supported Collaborative Learning; 3-D games; Scripting collaboration

1. Introduction

New technological applications offer tools for supporting collaboration within teams. There have been many attempts to use network-based technology, for example, in virtual university courses (Strijbos, Martens, & Jochems, 2004) or in a work-based learning context (Leinonen, Järvelä, & Häkkinen, in press). Although knowledge of Computer-Supported Cooperative Learning (CSCL) processes makes it possible to develop new technological

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environments designed to promote collaboration, basing interactions on textual elements has been the most dominant feature of these environments. However, environments that make virtual group interactions visible may offer one future method for supporting participants’ awareness of group processes and helping them to build shared understanding (Fischer & Mandl, 2001). 3-D virtual environments, which are being constructed at the moment, may also be one way to meet CSCL needs.

The last few years have witnessed a rise in interactive gaming, though this growth has taken place mainly in the field of entertainment games (Hämäläinen, 2005; Kiili, 2005). This has recently aroused a discussion about whether collaborative virtual gaming could also foster learning. The use of gaming and different game elements may lead to new learning innovations and enhance participants’ commitment to collaborative learning activities. Our thesis is that collaborative games can be seen as one of today’s innovations in learning because at their best they make it possible to design environments that promote students’ higher-order cognitive skills. Accordingly, in the future the aim should be to use learning games to create a broad range of sophisticated pedagogical solutions that guide students towards collaborative learning activities and studying practices where the objective is deep understanding. At present, there is very little research on collaborative learning games, and reported studies cover mostly individual cases (Janssen, van der Meijden, & Winkelmolen, 2003; Klopfer, Perry, Squire, Jan, & Steinkuehler, 2005; Lantz, 2001). This calls especially for learning research focused on the potentials and limitations of collaborative learning games.

Games are a highly promising learning resource because in many computer games gameplay teaches players lessons that can be applied to other aspects of their life. This may mean that they can draw on enhanced problem-solving methods in their work, employ their improved spatial skills to arrange their furniture better, or perhaps even learn greater empathy by assuming game roles. Gameplay, in this context, can be defined as the component of computer games known as interactivity. A game’s gameplay is a function of how much and what kind of interaction is available within the game, that is, of how the player is able to interact with the game world and how it reacts to the choices that the player makes (Rouse, 2000). Thus, interactivity, allows the player to exert some control over the outcomes of the game and actively change the course of game events (Smith & Mann, 2002).

At their best, well-designed multiplayer games may enable lively communication and collaboration between players during the game. Reciprocal activities are crucial in virtual environments because they provide the user with feedback on their own actions, making them feel that they are able to influence the game processes. Game worlds have the potential to draw on the feeling of presence and immersion which outstanding virtual worlds are able to generate (McLellan, 1996). It is typical of computer games that players find them alluring and that they want to play them together with other players. Despite the high-tech image of contemporary games industry, rich interactions between participants do not necessary require technically elaborate user interfaces because in play and games, it is the communicative, cultural and social aspects that are important (Manninen, 2003a).

One of the main benefits of a game world is that a 3-D space opens up new dimensions for virtual interactions. Within the virtual world players appear as avatars, promoting interaction with the game world and the other players and enhancing commitment to the game. More sophisticated technical applications will make avatars increasingly capable of supporting non-verbal communication between players, which may also make player interaction more efficient (Cassell & Vilhjámsson, 1999; Taylor, 1999). Fluent interaction in the game world makes it easier to depart, during the game, from real-world role behaviours. In such a situation a virtual world may, at its best, activate processes which would be impossible in face-to-face learning (Talamo & Ligorio, 2001).

2. Review of literature

In the last few years, many researchers have reported on the beneficial effects of making use of different interaction processes in collaborative learning. In general, Computer-Supported Collaborative Learning (CSCL) (Koschmann, 1996) often arouses positive expectations. Collaborative learning combines individual and social processes. In a collaborative learning process, a group of people construct a new understanding of the topic they are working on. Thus, collaborative learning can be seen as a process of meaning construction. The main idea of collaborative learning is that collaborative knowledge construction, co-ordination of different perspectives, commitment to joint goals, and shared evaluation of group activities enable a group to create something that goes beyond what any one individual could achieve alone (Bereiter, 2002; Stahl, 2003).
However, despite the many positive aspects of collaboration researchers have also pointed to problems with CSCL, such as surface-level discussions, lack of engagement, and unequal participation in group processes (Dillenbourg, 2002; Häkkinen, Arvaja, & Mäkitalo, 2004; Roschelle & Pea, 1999). Moreover, collaboration is a less frequent feature of learning than is commonly assumed (Järvelä & Häkkinen, 2002). Learning through collaboration is not something that simply takes place whenever learners come together. Therefore, designing a collaborative virtual environment is a demanding task. To improve the quality of interaction in learning, different tools and pedagogical models have been developed to support collaboration. Careful pedagogical design seems an effective way to improve the outcomes of collaboration (Lehtinen, 2003; Lipponen, 2000). Structuring the interactions taking place during a virtual learning period is one particular way to make collaborative activity more fruitful. Structures that construct collaborative processes are called collaboration scripts (Dillenbourg, 2002; Weinberger, 2003). Current research on scripting CSCL is derived partly from earlier work on the approach based on scripted cooperation (Derry, 1999; O’Donnell, 1999).

The main idea of basing CSCL on scripts is to promote participants’ engagement in group activities that would otherwise take place rarely or not at all. Scripts are intended to facilitate collaborative learning processes and guide learners’ actions (Weinberger, 2003). There are certain key factors that have been found to foster collaboration in virtual environments and that may be put to use when scripting collaboration. The design of the script used in this study is grounded on theoretical ideas concerning CSCL described in the following chapters. Another important point related to scripting is that scripts must lead to pedagogically meaningful practice and that the environment itself must be such that the idea of scripting makes sense in the first place. Scripting interactions is a natural idea in game design because games are often based on different levels of activity (Hämäläinen, 2005).

Collaboration can be stimulated by, for example, providing environmental support for the adoption of other people’s perspectives, and by setting learners common goals or tasks that can be solved in a variety of ways. Several individual factors may also promote collaborative knowledge construction. Therefore, such factors as prior knowledge, learning strategies, social anxiety, uncertainty orientation, personal interests, computer-specific attitudes, and different learning tools should all be taken into consideration when scripting collaborative learning activities in a virtual environment (King, 1999; Weinberger, 2003).

Another consideration affecting scripting is that collaboration produces the best results when participants employ a variety of cognitive mechanisms, such as explaining their own actions, sharing knowledge, and observing the other participants’ actions and problem-solving activities (Barron, 2000). At the same time, individuals may also benefit from the group in many ways; different ideas may lead to a cognitive conflict, which can have beneficial effects on learning. At their best, such cognitive conflicts may force learners to turn to new ways of constructing knowledge, thus opening up the possibility that novel knowledge will be created (Piaget, 1985). In any detailed account of the foundations of cognition, social aspects play a central role. Theorising about developmental psychology inspired by Vygotsky (1978) has drawn attention to the socially grounded nature of cognition. It has been argued that a socially grounded perspective on learning must acknowledge a human capacity for a projective understanding of mental states in other people (Crook, 1994). Social processes can contribute to cognition also in more implicit ways. The mere presence of other people influences cognitive processes. Even when there is no opportunity for interaction, simply having other people around can affect a person’s cognitive activity, either facilitating or impeding it. In such a situation, some people can be seen as a source of general arousal while some others might enhance the learning process or cause cognitive overload (Levine, Resnick, & Higgins, 1993). The latest studies have identified the essential interaction processes underlying collaboration, such as joint goal orientation, negotiation, co-ordination of different perspectives and sharing information (Baker, 2002; Pinelle, Gutwin, & Greenberg, 2002). In summary, the expectation of abundant opportunities to engage in rich interaction processes is among the factors that stimulate collaborative learning.

Research has emphasised the importance of interaction design as a means of fostering interpersonal collaboration in multiplayer computer games (Manninen, 2003a). On the elementary mechanical level games should, just like other virtual environments, support small-scale actions and interactions, such as voice communication, gestures, and awareness of other players and shared access to resources, which enable players to cooperate on the performance of game task (Pinelle et al., 2002). According to Manninen (2003b) in game design, collaboration support relies on the low-level interaction mechanisms, which define what players can do in the game and how the game responds to their actions. The interaction processes are, thus, generated and executed by the participants on the basis of the interaction mechanisms providing support in the background. It may be concluded that in collaborative learning, games must be...
put to pedagogically reasonable uses and the play must go beyond aimless enjoyment, become a purposeful activity that requires mental effort.

3. Method

The Electronically Shared Collaborative and Pedagogical Experiment (eScape) game and study are a part of the Ecology of Collaboration (ECOL) research project, whose purpose is to examine collaborative learning as a motivated and co-ordinated activity. The empirical objective of the research project is to explore a variety of virtual environments designed for collaborative work, planning and studying activities. This study addressed three research tasks: (1) designing a theoretically reasoned scripted game environment of a new kind; (2) describing how the scripted game environment affects collaboration; (3) and answering the following questions: (a) What kind of interaction emerged during the game? (b) What were the player activities that hampered collaboration during the game?

This study is a design experiment encompassing both the process of designing a game environment and a parallel empirical study where data are collected by means of a variety of methods and then analysed, after which the findings and conclusions serve as a basis for further design work (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). The following section will give an account of the game environment, followed, in the next section, by a description of the data gathered during the empirical experiment and its analysis. The article concludes with a discussion, in their individual sections, of the results of the empirical study.

3.1. The eScape game environment

Knowledge of game design and development was applied to a learning context while paying equal attention to the fun factor and the requirement of purposeful learning. The aim was to avoid the traditional pitfalls of edutainment by finding a fruitful synthesis of a game system and a learning environment. The main design challenge was to script motivationally relevant, logical and demanding problems that would call for true collaboration. Theoretical and practical game design expertise was drawn on during the design and implementation of the game as a means of avoiding the construction of trivial, non-motivating or frustrating activities. However, since there are relatively few instances of truly collaborative games in the entertainment sector, the theoretical background behind eScape was a combination of game design, virtual environments, collaborative work and learning theory. With a view to harnessing the potential of multidisciplinary expertise, the eScape game was developed and the empirical study conducted in cooperation among three research units.

The eScape virtual game is a pedagogical innovation involving the development of a technological tool intended to create settings for collaboration and enhance participants’ awareness of the social processes going on during the collaborative process. The main focus was on constructing a game environment that would promote, and even enforce collaboration between team members and help teams learn to collaborate. The game includes puzzles, or scripted problem scenarios that can be solved only through the effort and commitment of every participant (see Table 1). This was meant to prevent “secret master plans” (Fischer & Mandl, 2001). The purpose of these problem scenarios was to establish the significant key points where collaboration was expected to emerge. In essence, shared workspace collaboration revolves around certain core activities that must be supported: (1) communication and negotiation between group members, (2) keeping track of other group members’ work, and (3) stimulated physical activities such as moving tools and objects (Pinelle et al., 2002).

eScape is a social action-adventure game for four players. The game concept involves an escape story where a group of players must solve a set of problems in order to flee from an ancient prison colony. The scripting was hidden from players behind the game’s escape story. Due to the limited duration of the experiment, the content of the game enables approximately 60 min of goal-oriented activities. Players interact and experience their surroundings by using avatars to move and act in an atmospherically captivating virtual world. Role play and player-to-player communication are supported through versatile non-verbal communication (expressions, gestures, etc.) and a voice-over IP speech system which allows free spoken dialogue between players.

The game puzzles form a mainly linear sequence. Players must solve all of them in order to complete the game. Game design knowledge was applied to scripting puzzles that required a team of players to perform a series of collaborative actions. They include, for example, organising objects in space (by using the avatars), exploiting individual resources (e.g. tools), reaching the correct solution through planning (promoted by, for example, rendering a trial-and-error procedure obviously useless), and coordinated procedures (e.g. initiating a sequence of actions in the right order and at the right moment). The scripted collaborative puzzles and the corresponding design criteria are described in Table 1.
The overall process of designing eScape was highly iterative. The difficulty level and features of the game were developed, tested, analysed and refined in cooperation with representatives of the target group, while the pedagogical experts provided design guidelines. The end result was a 3-D multiplayer game where players see their surroundings and the other players (avatars) from a first-person perspective (i.e. through the eyes of the game character). An example scene from the eScape game world is given in Fig. 1, where a group of players in the process of solving a puzzle are monitored via the virtual camera interface.

Table 1
Brief descriptions of eScape puzzles

<table>
<thead>
<tr>
<th>Puzzle</th>
<th>Description of actions</th>
<th>Design rationale and criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prison cells</td>
<td>Players start in isolation from each other. Voice communication is enabled, but there</td>
<td>Offers an isolation period intended to make the players focus on the basics and encourage group formation.</td>
</tr>
<tr>
<td></td>
<td>is no visual contact between the players. Players must pick up their tools by the cell door to start the predefined 2-min launch sequence.</td>
<td>Criteria: negotiation, planning, sharing information, co-ordination</td>
</tr>
<tr>
<td>Balloon parts</td>
<td>Higher-level puzzle, where the players must collect four sets of balloon parts and bring them to a non-player character (NPC). The NPC tells the players how they are progressing.</td>
<td>Combines four puzzles. Provides overall status information.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criteria: joint goal orientation, negotiation, planning, sharing information, joint rule-making</td>
</tr>
<tr>
<td>Climbing</td>
<td>The platform must be reached either by building steps from boxes or by using a seesaw and launching one player on the top of the platform.</td>
<td>There are different solutions, and it is possible to change the order of the puzzles.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criteria: planning, sharing information, co-ordination</td>
</tr>
<tr>
<td>Bees</td>
<td>Players collect bees’ nests from a field. Entering the field requires the use of a protective barrel, which blocks the view. Other players guide the one in the barrel in the right direction.</td>
<td>Co-ordination essential.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criteria: planning, sharing information, co-ordination, joint rule-making</td>
</tr>
<tr>
<td>Drums</td>
<td>Players must guide a blind man off the pier by playing their drums in the correct order and at a correct pace.</td>
<td>Co-ordination involving a time-related challenge.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criteria: joint goal orientation, negotiation, planning, sharing information, co-ordination, joint rule-making</td>
</tr>
<tr>
<td>Rocket pattern</td>
<td>Players must combine red and blue rockets, launch them in a correct timed sequence and form the required fireworks pattern.</td>
<td>Coordination involving a time-related challenge.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criteria: joint goal orientation, negotiation, sharing information, co-ordination, joint rule-making</td>
</tr>
<tr>
<td>Balloon building</td>
<td>After acquiring all four boxes, the players must use their personal tools in synchrony to prevent the building process from breaking off.</td>
<td>Coordination involving a synchronisation challenge.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A changed UI metaphor introduced to make the task more difficult.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criteria: joint goal orientation, negotiation, planning, sharing information, co-ordination, joint rule-making</td>
</tr>
<tr>
<td>Balloon lift-off</td>
<td>All players must enter the balloon in order to start the escape sequence.</td>
<td>Requires the definition of a common goal and common status.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Criteria: joint goal orientation, negotiation, joint rule-making</td>
</tr>
</tbody>
</table>

Fig. 1. eScape players working out a possible solution to the balloon-building puzzle.
3.2. Data gathering

A special laboratory environment was constructed to capture all the relevant data during the experimental game sessions. As a multiplayer game eScape required extensive data collection arrangements since every player’s actions had to be recorded. In order not to compromise the research setting, movable partitions were used to physically isolate the subjects from each other. The player cubicles were constructed in a way that prevented the subjects from being disturbed or intimidated by the world outside the virtual environment. This made it possible to have a broad array of data-recording devices and personnel within the research setting at the same time as the subjects were experiencing realistic computer-mediated collaboration.

The empirical experiment was carried out in November 2003 with the participation of university students chosen from the non-gaming community. Six groups of four students (N = 24), four of them composed of Finnish students, two of foreign students, took part in the experiment. On the first day the students were given a half an hour’s training session in the game environment. On the second day they played the game, immediately followed by a stimulated recall interview. The data were gathered using several methods: background information questionnaires, video feed from each of the players (over-the-shoulder view), combined views from all the four players (over-the-shoulder views), video feed from a virtual camera (inside the game world, handled by one of the game operators), audio recording of spoken dialogue, demo recording within the game platform (enables free camera movements during playback), observation notes, stimulated recall interviews, and the players’ personal notes. After the game experiment the observation notes were verified (by cross-checking the notes of four different observers) and sorted into categories. And the interviews and conversations conducted during the game sessions were transcribed.

3.3. Data analysis

The qualitative analysis was driven both by theory (Berger & Calabrese, 1975; King, 1999; Webb, 1989) and by the data, yielding three data classifications. A first step in the classification process was to categorize all the different kinds of data according to the problems (key collaboration points) that were scripted into the game environment. This step involved, for example, analysing the first key problem by (a) watching game feeds several times; (b) reading the game transcripts several times; (c) comparing four different series of observation notes; (d) comparing the combined analysis of the observation notes with the video feeds; (e) comparing student experiences of this phase of the game (as elicited through interviews and recorded in the students’ personal notes) with the video feeds and the observation notes.

The second step focused on the significant collaboration situations identified on the basis of the script. There were two stages. The first stage pinpointed those interactions that served as the central facilitators of game progress, for example the negotiation situations (Table 2).

In the above situation, the importance of negotiation becomes obvious as Leila tells the other players what is going on. Tuija agrees with her assessment of the situation and suggests that they need everyone to work together. This makes

| Table 2 |
| Example of a significant negotiation situation during the game |

Leila: Look, there are several places over there. How about going there all together and guiding him away from there.
Tuija: I expect we’ll need everyone here. Here in this place. I’ll go and stand in the doorway over there.
Leila: Hi there, who’s there, come here.
Mira: Where are you?
Leila: ... is running over there by the church. I’m here in the doorway a little farther on, do you see me?
Mira: No.
Leila: Look, there’s this shed here, here where there’s level ground. Come down here to the level ground, was it left where it lies. Not there, not there. Don’t go up, come down again and walk here in exactly the opposite direction, where you came from. Not there, here, well then, good, do you see me now?
Marja: We must all go to the drums and play it so he’ll get somewhere.
Leila: Yes, but there’s this thing that everyone must find their way here. Hi there, you over by the church, come here. Which direction would it be again. Do you see me?
Marja: And me?
Mira: Yes, a moment, yes, you are over there.
Leila: Come here.
Mira: Coming.
them realise that Mira must be guided to where the others are, and they start helping her to find them. Collaboration continues as Maria joins the conversation and establishes a new idea about how to proceed in the game. Leila argues with her, but only after seeing to it that all the players are able to find their way to where they should be. Finally all the players are together and able to undertake the next action, set by Maria.

After this, the situations (such as the one described above) thus identified were analysed to find out, on the basis of observations, what were the individual or group activities that the players engaged in, followed by an examination of their contribution to collaborative group activity (Table 3). In the following table, for example, Simon’s actions are identified in terms of whether they represent, primarily, personal or group activities. Players engaged in personal activities do not share information, trying, instead, to play the game on their own. Group activities involve, among other things (as shown in the following table), the creation of rules shared by the team as a whole.

The final stage involved classifying the environmental elements and player actions that hampered collaboration during the game. Players can hamper collaboration by, for example, hiding important information from their fellow players. During each stage, the different research materials were cross-compared to enhance the reliability of the research results (Cohen & Manion, 1994).

4. Results

The next section discusses scripted collaboration processes unfolding during gameplay, going on to describe the main mechanisms used to solve the game problems. Finally, player actions which hampered collaboration in the non-collaborative group are identified.

4.1. How scripted game environment affects collaboration

The findings of the companied data analysis indicate that most groups achieved a high level of scripted collaboration during the game. At the same time, despite the scripted environment group and individual actions varied a great deal.

<table>
<thead>
<tr>
<th>Phase 1—Prison cells</th>
<th>Encouraging the group members to communicate (required: negotiation, planning, information-sharing, co-ordination)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 2—Balloon parts</td>
<td>Planning the activities and getting to know the 3-D environment (required: planning, goal-setting and -seeking, negotiation, co-ordination and rule-making, information-sharing)</td>
</tr>
<tr>
<td>Phase 3—Climbing</td>
<td>First problem: getting a box from a high scaffold (required: a working plan + goal-setting and -seeking, planning, following the example of avatars, information-sharing, negotiation, co-ordination and rule-making)</td>
</tr>
<tr>
<td>Phase 4—Bees</td>
<td>Second problem: getting nests from a colony of bees (required: forming dyads + planning, information-sharing, goal-setting and -seeking, negotiation, feedback, co-ordination and rule-making)</td>
</tr>
<tr>
<td>Phase 5—Drums</td>
<td>Third problem: helping a blind man to get away from the dock (required: forming groups of three or four members + goal-setting and -seeking, planning, negotiation, information-sharing, co-ordinated action, feedback and rule-making)</td>
</tr>
<tr>
<td>Phase 6—Rocket pattern building</td>
<td>Fourth problem: firing a rocket pattern into the sky (required: goal-setting and -seeking, information-sharing, planning, negotiation, feedback, co-ordination and rule-making)</td>
</tr>
<tr>
<td>Phase 7—Balloon building</td>
<td>Fifth problem: constructing a hot-air balloon (required: contribution by all four players; joint goal orientation, negotiation, planning, information-sharing, co-ordination, joint rule-making)</td>
</tr>
<tr>
<td>Phase 8—Balloon lift-off</td>
<td>All players must enter the balloon (required: goal orientation)</td>
</tr>
<tr>
<td>Phase 9—Stimulated recall</td>
<td>Reflection (30 min)</td>
</tr>
<tr>
<td>Game situation</td>
<td>Interview</td>
</tr>
<tr>
<td>----------------</td>
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</tr>
<tr>
<td>2: Can I lift this up, can I jump and lift [3: I cannot] at the same time? I don’t know. [3: I think that maybe we could lift one barrel onto the top of the other barrel and then we could lift it up.] How on earth can you lift it? 3: Could you lift it in the same way. [2: Yes.] [1: ... somehow.] 4: Yes but [2: ymm in a funny way .. you see.] ymm I see well .. do you have any picture [1: Here are boxes, here are.] can you see, [3: Are these boxes easier?] do you have the assembly instructions on your parchment .. those instructions ... anyone? That what kind of pieces you [1: I’ve only this one.] can you gather up?</td>
<td>2: I at least thought good ideas were coming up, like, coming up all the time. 4: That’s just it, we were getting ideas all the time. 2: Yes, always there was someone suggesting a solution. 1: maybe we really were in an equal starting line situation I mean.</td>
</tr>
</tbody>
</table>

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Fig. 2. An example of student experience and an actual game situation (Group 3) confirming that the game problems encourage teams to work together.

Tom: What is ger?
Max: It’s like in marina, the eh, where the ships come.
Demi: Ok, so let’s go to this (?) because, ah I think we ...
Tom: But I’ve seen some man outside this house. And ...
... Sanna: On which side?
Tom: It was somewhere here.
Demi: Yeah, here. Where?
Tom: Yeah, it’s here.
Sanna: I don’t see anyone anywhere, heh. (3)
Tom: What ball? ... Balloon.
Sanna: I don’t see any ...
Max: And on my pergament there are some instructions how to make this balloon. We have some stove, axe and some oven or stove... and from four hmm four boxes.
Demi: Ok, so we have to just find the boxes.

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Fig. 3. An example of a practical problem-solving situation.
The groups differed in the time spent on the game, the degree of collaboration shown and the roles assumed and attitudes displayed by their members. Scripting guided team members towards collaboration and shared problem-solving. Despite the scripting, the time spent on the game varied from about 45 min to 1 h and 20 min. The companied data analysis revealed that five of the six groups had achieved a high level of collaboration at some points of the game at least, while even the non-collaborative group had managed some teamwork. The five collaborative groups followed the predefined order of scripted game tasks (Table 4).

The five groups that followed the script attained at least some degree of cooperation during the game although the quality of their collaboration varied a great deal even in groups immersed in game situations. After the game the players reported feeling that the game environment had supported their collaboration and distributed teamwork. Observation notes and video feed from inside the game confirmed that the game problems did indeed encourage teams to work together (Fig. 2).

For the purposes of collaboration, it was essential that the first problem that the members of a team encountered in the virtual environment encouraged them to communicate with each other. Collaboration emerged mostly in the problem-solving situations, and more often on the level of practical activities than on the cognitive level. Below is Fig. 3 illustrating a practical problem-solving situation.

The results indicate that in order to obtain collaboration it was crucial to construct tasks that compelled players to work together. In eScape, most of the problems were set in a way which made it impossible to solve them alone. However, most players first attempt to carry out the tasks on their own, joining forces with the other players only when they realise that they are stuck. With many of the players, perceptions of collaboration clashed with observation notes: students felt that they had mostly tried to solve the problems as a team, but observations indicated that most of them contacted other players only when they actually needed their help. Only one of the six groups made, in the early stage of the game, a joint decision that they would work as a team to get through the game.

The real-time observation notes and student experiences showed that this group, which decided to work as a team right through the game, was more strongly committed to collaboration and teamwork than the other groups. The group members also spent more time negotiating among themselves, co-ordinating their activities and giving feedback to each other than the members of the other groups. They also put in a great deal of time playing the game, and after the game they were highly positive about their experience. All players in this group had very little playing experience; none of them was an “expert” player. They also kept track of each other’s activities throughout the game. Thus, it can be said that they were the players who most needed the help of their fellow players. They also had a shared background history and fairly good communication skills.

The observation notes and the players’ perceptions suggested that all players were strongly committed to the game itself. Only one of the players lost interest when he drifted out of the game. A lower level of commitment affected his communication activity, his use of his avatar in the game environment and even his physical posture outside the game world. The player resumed active participation as soon as he was helped back into the game.

In all teams, the scripted game environment enhanced the value of distributed teamwork. The players felt that they had been in the same world operating as a team, and observation notes confirmed this subjective finding. No team reported feelings of being alone or engaged in aimless interaction. Inexperienced players in particular found spoken communication easy. The game’s functional design and logical structure had a positive effect on both the playing experience and the quality of collaboration. However, players with some gaming experience in particular were annoyed by game elements that they thought illogical (Fig. 4).

The example in Fig. 4 illustrates a task which introduced a user interface mechanism that was completely new to the players. Some of them were bored and others became frustrated as they worked on the solution. On the other hand, this puzzle spurred the teams, in their attempts to solve it by trial and error, to try many different approaches. In comparison to the other analysed puzzles, this one brought into play the most diverse range of solution strategies. When the expected solutions did not work, most groups began showing various degrees of frustration. While this generally indicates bad game design in the sense of illogical structures, in a collaborative context such a situation would seem to intensify the sense of togetherness and heighten anticipation.

The experiment integrated distributed CSCL and face-to-face interaction. The students met before the game, and afterwards, during the stimulated recall interview, they were shown extracts from the game video and asked to watch and comment on them. After the game, the students were very eager to talk with each other about it and discuss those
aspects of the game environment that they had not understood during the game. This showed that post-game reflection was important. Although the stimulated recall interview was originally designed as a data collection method, it had also an important pedagogical role.

4.2. Solving the scripted problems: main interaction processes

During the game, the groups used different modes of interaction to solve the game problems. All the groups set themselves goals, but the actual decision-making process ranged from group decisions to leader-oriented ones. The group decisions affected the game and the team formation process in different ways at different stages of the game session. The players had roles although many of them were clearly not themselves aware of these, as was revealed in the post-game interview. For example, in some groups the game was dominated by one or two players who worked out the plans and told the others what to do, but in some situations leadership shifted according to the players’ level of expertise. Interestingly, all groups felt that they had collaborated as reasonably equal partners even when their group had actually had a leader without their being aware of it.

All groups employed interaction mechanisms to solve the game problems. These mechanisms were applied mostly in problem situations and at points where the team members were about to pool their mental resources to solve a problem. Groups formulated low-level action plans, but no group used much time to devise their plans. All

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**Transcription of the game situation**

JL: Suddenly this system is no longer working for me, wait.
- Don’t any of you let go of that button. Now we have the saw and the torch locked here.
JL: Why cannot I make my pickaxe visible. I cannot make it come any longer, that "just... ."
- You must move [the cursor] over the pickaxe.
JL: That’s where it is. I don’t understand.
- Point it at the fireplace. I’ll check if you have the pickaxe visible.
- I cannot get any closer to the fireplace either. I’m holding the left button down all the time on the bare hand.
- I’m looking from the top of the fireplace and you are not close enough. Could Paula and Jane give way a little so Mervi’ll get through. Well now, that looks better. Well now, [got it].
- Yes, all we need now is the saw.
- Now we have all the stuff, now it happened. Yes, yes.
JL: That was a tricky one.

**Interview**

JL: it was such a dumb task that it was purely by chance
2: well what may have helped there finally was that when someone went close enough it became visible to him [1: mmm] there that . menu I mean all the same things were supposed to appear there and then he knew how to guide the others there too, say to them, hi there, now you must come here [1: and there] just close enough [1: yes] to that fireplace
JL: the basic problem here was that we thought that those boxes were supposed to use
3: [mmm] [2: yes] use tools there [3: just so] or because they were there close by the fireplace I mean . it was the fireplace finally that we were supposed to use
1: and there too it took time, there we were for ever. We thought we were close but I suppose not close enough [2: close enough yes] then there was this Jari saying, hold it down for a long time . [JL: yes, if you just clicked it they flickered] the left button
Others: yes, yes
1: so then you, like, realised that when they all

**Experiential student note**

JL. The most unforgettable point was absolutely the last task by the fireplace. That was the most illogical task I’ve come across since Tomb Raider I. The parts suggest a hot air balloon, but you must use them in the fireplace! Just as though you should burn them in the fireplace. We never managed to get any real sensible collaboration going during the fireplace task because nobody quite understood what we were supposed to do there – the solution turned up as if accidentally.

Fig. 4. An example of using several methods to monitor an illogical factor in the game environment that hampered a group’s goal-setting activities, agent interaction and game progress.

the groups negotiated among themselves and co-ordinated the activities they engaged in to advance the game. Throughout a game, group members shared information and followed the example of each other’s avatars to further the game. They shared information and learned from each other in a great variety of situations, such as when working out how certain tools functioned, how to use the avatars, what kind of individual knowledge the different players had and so on. During the game, the groups also made rules on how to act in certain situations. Few of the rules were intended to limit the actions of the avatars during the game, and those made for this purpose related mostly to the last problem, which required group members to employ certain tools simultaneously. All the teams also gave feedback to and encouraged their members. There was no negative feedback in the form of personally disparaging remarks in any of the groups. The negative feedback that was given focused on the environment in situations where it did not work in the way the players expected. Feedback was most frequent in problem-solving situations and after a problem had been solved.

In all groups, there were situations in which players found it difficult to give up their own ideas even when their proposed solution did not make sense in the game environment. In many such cases, the players kept advising each other or attempted to solve the problems on their own. The most collaborative group was also the one most open to mistaken ideas. Conflict situations during a game were rare. When conflicts did arise it was because the players did not understand or find each other. Thus, the game environment failed to create significant cognitive conflicts. However, there were occasions during the collaboration process that involved tacit conflicts. For example, records show instances where a player seemed to become increasingly frustrated when nobody paid any attention to their suggestions.

All the groups used humour to establish relations between players even though it was not necessary for solving the game puzzles. Fig. 5 displays language-related humour. Humour was employed to make contact with other players, get through surprising situations and enliven the atmosphere. Humour was most evident in those groups which had some history of being together, least evident in one of the foreign student groups. How much and what kind of humour there was varied both between the groups and within each group. For example, during one game the players tried to work out the similarities and differences between the game world and the real world: will avatars break when they jump from a height? Some ethical issues also arose, such as whether one can open the church door using a rocket.

4.3. The effect of non-collaborative player actions on the game process

One of the groups in the study failed to develop, at the beginning of the game, into a collaborative team, share information and work together. Because of this, the members drifted into a crisis and found themselves in a great many dead ends during gameplay. This group needed outside help from the operators to finish the game. The group broke down because the players pursued a goal which was outside the boundaries of the game. While this indicates that there were loopholes in the design, the players displayed creativity and lateral thinking in their approach to solving the game problems and exploring the game world. The group also had to work hard to persuade non-collaborative players to share information and function as a team. Interestingly, afterwards even these players were convinced that they had been collaborating with the rest of their group. Thus, it may be assumed that well-designed collaborative game environments can generate feelings of collaboration. The conclusion that the group collaborated little in the game is

Tuula: Pekka? with me to the pier, [Nina: Yes.] 16:44:09 - Uses humour
remember to come and help me back later. Matias!

Aha, Matias has gone, what’s “pier” in English? Pee

ii ee är, I don’t mean for a beer. Ha-ha.

Nina: That’s where it is all the same. [Tuula:
Remember to come and help me back later, Matias.]

Game situation | Observation note
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16:44:09 - Uses humour

Remember to come and help me back later, Matias!

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Nina: That’s where it is all the same. [Tuula:
Remember to come and help me back later, Matias.]
Based on observation during the game, which indicates that the players had many communication problems, kept losing track of each other, engaged in teamwork only when it was indispensable, and that even when there was teamwork some members were often left out of the action.

The problems affecting this group were triggered at the scripted collaboration key points. The players in the group had many language problems, which made collaboration more difficult (Fig. 6). However, the language problems were a less serious obstacle to collaboration than the roles assumed by the players. Three of the four players applied models of action which block collaboration. One of the group members failed to share information, which prevented the group from solving one of the key problems, and their game session came to a dead end. Player 2 can be identified as a “lonely rider”, who always tried to solve the problems by himself. He was the most experienced player in the group but did not offer to share his background knowledge with the others. Player 3 tried very hard to work collaboratively and was extremely supportive towards her fellow players. The problem was that she could not hear the other players’ suggestions with the result that she was very supportive about their ideas even when the game environment did not work as she expected. As one result, one of the key problems (Phase 6—Rocket pattern) was solved despite of rather than thanks to her guidance. By this phase, the other players had ceased to listen to her attempts to co-ordinate their actions even though she continued to advise them all the time. The others solved the task in their own way, doing their best to ignore her. In the stimulated recall interview, she was still unable to understand what had happened at that point of the game.

5. Conclusions

The study produced encouraging results on the possibilities of scripted edugames, but some dangers were also identified. When considering the findings, all the limitations of a case-study approach should be kept in mind. Accordingly, what follows are some initial suggestions concerning and preliminary implications identified regarding game design.

A scripted game environment persuaded the student teams to enter into collaboration, but the actual quality of collaboration processes varied. It was found that obtaining collaboration on practical problems was easy but that higher levels of collaboration were difficult to reach in a game environment. In the game used here, this result may have been due, among other things, to a design involving relatively simplistic and unthreatening problems that could be addressed through risk-free trial-and-error procedures. In the future, a higher level of collaboration can be promoted by scripting for collaboration subject to more intense pressure, involving greater risks, and/or requiring more creative behaviours. In a game environment of this kind, a tangible feeling that one is engaged in beneficial or purely enjoyable collaboration serves as a natural inducement to pursue such strategies. An explicit construction process provides participants with endless representational variations that they can use to express themselves. When this is combined with the challenge of collaboration, participants are enabled to creatively enrich each other’s experiences. For example, the study’s findings indicate that in the game examined here, the participants found highly innovative ways of overcoming the game obstacles—sometimes even exceeding the boundaries set by the designers of the game. In comparison to the destructive features evident in contemporary games, constructive features, while difficult to design, offer a broader range of possibilities.

At its best, a game environment can offer a setting that can trigger several processes of collaboration. This study supports some of the previous findings about the essential mechanisms of collaboration, such as joint goal orientation,
negotiation, co-ordination of different perspectives, and information sharing (Baker, 2002; Dillenbourg, Baker, Blaye, & O’Malley, 1995; Häkkinen et al., 2004; Puntambekar & Young, 2003), but a game environment may also generate new forms of collaboration. The 3-D game world used in the study affected collaboration processes, such as information sharing, because players were able to draw on the example of the avatars to pool their knowledge. In this game, the collaboration context was enhanced by a game-like thematic setting which bound the subjects together. In general, multiplayer problem-solving scenarios should encourage and enforce collaboration by balancing solo efforts and teamwork. Puzzles might even be scripted to require action from all group members provided that potential deadlocks can be prevented. However, it is hard to design challenging, rational and non-destructive puzzles that require concrete collaboration while excluding all single-player solutions. In the design experiment reported here, some of the puzzles failed, despite the predefined objectives, to fully meet this requirement.

In game environments, attention must be paid to the variation across player groups in the quality of collaborative activity as revealed in the study and to the unequal interaction relationships found in some groups, which pose new challenges to designers of game environments. While the eScape game did support pedagogical criteria for collaboration processes, it was clearly necessary to provide support also for low-level collaboration mechanics. For example, spoken dialogue and avatar-based non-verbal communication are critical collaboration media and must be made available. However, even in the most communicative settings, players are repeatedly found attempting to solve game puzzles by trial and error. If the threat of punishment is not feasible and if the application domain is other than that of mainstream gaming, one option is to design highly difficult and even frustrating puzzles. In fact, apparently impossible tasks seem to be one of the strongest factors promoting player collaboration. After all, games are all about facing challenges and succeeding after a series of failures.

In eScape, collaboration was crucially dependent on team members’ need for each other’s help, for at first individual players often tried to solve the game tasks on their own. This suggests that scripting social modes of interaction is an effective means of promoting collaboration in virtual gaming. Moreover, despite the positive influence of such scripts, there are also some critical issues such as the danger of over-scripting learning (Dillenbourg, 2002) and the relationship between the internal scripts guiding the players and external scripts underpinning the game environment (Kollar, Fischer, & Slotta, 2005). This study used scripting representing a very high macro-level. Therefore, more empirical research should be conducted, for example on the effects of variously detailed scripting on collaboration processes. Furthermore, the question concerning the type of scripting most suitable for use in game design and implementation needs more attention. More experiments should be carried out in order to find out whether scripting should emphasise epistemic considerations, looking for ways of approaching the problem-solving process, or whether it should, rather, pay attention to social factors, focusing on how different groups of players should interact with each other (Weinberger, 2003).

The results of the study also indicated that from the perspective of learning, scripting reflective activities into games needs to be made another central research objective in the future. In this study, reflection was a natural part of the stimulated recall interview, but a future challenge might be to incorporate reflective activities into the synchronous environment itself as support mechanisms for distributed teamwork. Another challenge for the future is combining reflective learning with the flow of action in rapidly changing situations that is characteristic of games. As Salomon and Perkins (1996) pointed out a decade ago, technology alone does very little to aid learning. Learning depends crucially on the specific character of the activities that learners engage in as they employ technology, the character of the tasks that they face, and the nature of the intellectual and social activities that they become involved in as they interact with the functions that technology makes available. At present, collaborative edugames form a very little researched area in CSCL. Therefore, it is important to identify the type of collaboration that can serve as a successful learning mechanism. There is an urgent need to find out whether 3-D computer games, for example, involve new forms of collaboration. Furthermore, more edugames are needed to determine the potentials and limitations of games. In our future research on CSCL environments with edugame effects, the major challenge is to consider how these environments could be turned into effective settings for collaborative learning.

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