Collaborative Learning Through Games – Characteristics, Model, and Taxonomy

Alf Inge Wang, Terje Øfsdahl and Ole Kristian Mørch-Storstein

Abstract— **Educational games have been around for some time, but there are still many areas that need to be explored. One of the main challenges when developing educational games is that the highest educational value is gained from games developed for one specific subject. Such games are very expensive to develop and they cannot be reused in others subjects. In this paper, we suggest to utilize collaborative gameplay to improve the learning capabilities of educational games for more than one subject. More specific, we search for the answer to the following three research questions: which properties characterize a good educational game; how can collaboration improve learning in educational games; and how to classify educational games that also can take the multiplayer aspect into account? The results presented are based on analysis of previous research on educational games as well as our own experiences from developing a multiplayer educational game. The contribution of this paper is a characterization of what makes good educational games, a theoretical model for how collaboration can improve learning in games, and the Lecture Games taxonomy of educational games.**

***Index Terms*— Educational Games, Collaborative Learning Tools, Multiplayer Games, Taxonomy.**

I. Introduction

EDUCATIONAL games have been around for some time, and games are now commonly used in schools as an alternative to traditional teaching methods. Research shows that use of games in children's classroom can be beneficial for academic achievement, motivation and classroom dynamics [1]. Teaching methods based on educational games are not only attractive to schoolchildren, but can also be beneficial for university students [2]. Research on games concepts and game development used in higher education is not unique, e.g. [3-5], but we believe there is an untapped potential that needs to be explored. In the project Lecture Games, we explore how games and game technology can be utilized to a larger degree in higher education. Games can mainly be integrated with higher education in three ways. *First*, games can be used instead of traditional exercises motivating students to put extra effort in doing the exercises, and giving the teacher and/or teaching assistants an opportunity to monitor how the students work with the exercises in real-time [6-8]. *Second*, games can be used within lectures to improve the participation and motivation of students [9, 10]. *Third*, the students are required to develop a game as a part of a course using a game development framework to learn skills within computer science (CS) or software engineering (SE) [11-15]. In primary and middle schools, games and game technology are most commonly used in exercises where the children play games in computer labs. However, there are also examples that games have been used as a part of a lecture at elementary and middle schools (quiz games where the teacher and the children participate), and that visual game development environments such as Alice [16] have been used to teach children programming through developing games. This paper aims to provide new inputs to how games used as exercises or as a part of a lecture can be improved in terms of effectiveness in learning a subject, and how collaborative learning can contribute in educational games.

One of the main challenges in development of educational games is how to make educational games with high learning potential that can be reused in many subjects? The main problem is to overcome the hurdle that the highest educational value is gained from games developed for *one specific subject*, which makes them very expensive to develop. In this paper, we suggest to introduce collaborative gameplay to improve the learning capabilities of educational games made for more than one specific subject. More specifically, in this paper we search the answer to the following three research questions: which properties characterize a good educational game; how can collaboration improve learning in educational games; and how to classify educational games that also can take the multiplayer aspect into account? The results presented are based on analysis of previous research on educational games as well as our own experiences from developing the multiplayer educational game Lecture Quiz.

The rest of the paper is organized as follows. Section II describes the theoretical background for the contribution presented in this paper, and describes examples of multiplayer educational games. Section III presents characteristics a good educational game should have. Section IV describes our theory for how collaboration can improve learning in educational games. Section V describes the Lecture Games taxonomy of educational games that also takes the multiplayer aspect into account. Finally, Section VI concludes the paper.

Manuscript received June 19, 2009.

A.I. Wang, T is with the Norwegian University of Science and Technology (NTNU), 7491 Trondheim, Norway (corresponding author: phone: +47 7359 4485, fax: +47 7359 4466, e-mail: alfw@idi.ntnu.no).

T. Øfsdahl, was with Norwegian University of Science and Technology, Trondheim, Norway. He is now with Steria, Norway, (e-mail: terje.ofsdahl@gmail.com).

O.K. Mørch-Storstein, was with Norwegian University of Science and Technology, Trondheim, Norway. He is now with Comperio, Norway, (e-mail: okstor@gmail.com).

II. Theoretical Background

This section presents the theory that was used to propose the characteristics (Section III), the model (Section IV) and the taxonomy (Section V) presented in this paper.

A. Effective Computer Instruction

By reviewing the previous influential philosophical and psychological studies in computer-based instruction up until 2005, Lowe and Holton, have aligned modern theories and created a framework to explain and predict quality learning in a computer-human setting [17]. In their research they describe the variables considered to be important in planning and evaluating computer instruction software. For our case, the main variable to consider is the *main design*, which can be decomposed into several variable points of interests: instructional control, instructional support, screen design, instructional strategy and external support.

The *instructional control* describes the trade-offs between giving control of events to the end-user and restricting the user from deciding the flow of events. In cognitive philosophy, a debate is in progress regarding the benefit of adding behavioral theories where the user is in full control. In this fashion, the game takes form of an exploratory toy rather than a traditional game, e.g., the goal may be for the end user to become aware of how he learns.

The *instructional support* describes to what extent information, hints or solutions is available to the user. It is argued that new modes of cognition appear when full instructional support is given. When everything is visible, it is not the short-term memory being tested, but the way of thinking. Having the screen as a visual cache a computer can improve the quality of thinking [18].

Good *screen design* is shown to have an important impact on the motivation of users. The framework also advises to consider a practice strategy. Users spending time training generally obtains a higher learning outcome [18].

The *instructional strategy* deals with the pedagogic tactics of the software and is of paramount importance. The application of quality instructional principles is the basis for any effort to teach using desktop computers. To achieve specific learning goals, the content is sequenced according to learning theory. Boocock & Coleman [19] argues that new technology can address the main defects in contemporary education by first and foremost release the students from having to deal with content to which they do not identify themselves. Theoretical studies of potential future problems become intriguing when the theory is perceived as real and future tasks are played out in the present. The sense of accomplishment is instant as opposed to in some potential work situation years later. It is considered effective in games with simulated environments when users feel as if they are facing a real situation. This is arguably the most important feature of such games. As part of the instructional strategy the grouping strategy describes a choice of individuals or groups as the participating units. Empiric studies show that for computer games in specific, grouping students in couples, benefiting in particular the lower achieving students, may increase the learning outcome. Students have expressed satisfaction of having someone with whom to discuss their understandings and opinions [17]. Schik has investigated the learning possibilities drawn from computers and identifies ten cognitive skills teachable through computer simulations [20]: *interpreting* – ordering facts and generalizing about cause and effect; *analyzing* – breaking the topic down in constituent parts; *translating* – finding different ways to represent the ideas; *applying* – using generalizations or facts in solving a problem; *synthesizing* – drawing out the key elements of a topic; *evaluating* – explicit criteria to make a decision about a topic; *communicating* – reporting findings in a clear concise manner; *imagining* – employing new ways to understand a topic; *reprocessing* – changing the context of facts or generalizations; and *I-witnessing* – putting yourself into a situation removed from you by time, distance, culture or other factor.

After determining the design of the software, the *external support* of the application needs to be addressed. Empirical studies show that when there is lack of initial motivation, the need for external support is of increasing importance [17]. Examples of external support are human assistance, designated computers or follow-up lectures.

B. Making Games Intriguing

Enjoyable situations or rather the characteristics of enjoyable activities can be divided into three categories: challenge, fantasy and curiosity [21]. These are properties in games that are enjoyable and captivating. In the following, we will further explore this topic.

1) Goals and Challenges

Malone defines a classification of intrinsic motivation, such as the driving force that makes people play games over and over [21]. Games that lack proper goals are less likely to be challenging over time. Once the novelty factor is over, the game might be forgotten. Where there is no objective, there is also a lack of the desire to finish the unfinished. Malone writes that:

"... In a sense the, very notion of "game" implies that there is an object of the game" ([21], p.1)

Goals can be practical, fantasy or the goal of using a specific skill. Malone recommends the use of practical and fantasy goals, rather than the goal of just using a skill. An example of this can be the goal of accumulating a certain score versus the goal of the player using his arithmetic skills. It is not common to know exactly in which way a task will be carried out in real life. Providing the player with more than one path to achieve the goals is important. The added uncertainty will provide the feeling of dynamically created and more realistic content.

2) Instructional Control

As the player completes goals, there will be an effect on their self-esteem. As with any challenge, mastering that challenge can give a self-esteem boost. Malone argues that failing such a challenge can have the opposite effect. A solution to this is the opportunity for the player to attain tasks of variable difficulty, adapted to the player's skill level. There

are three approaches to this: The *first approach* is to let the player statically specify a difficulty at some point during the game. Typically the player will have the choice between easy, normal and difficult. Most schemes are instances of this with varying granularity. The *second approach* is to let the game dynamically adapt to the players skills. E.g. the difficulty will be adjusted if the players' accumulated score diverge from an expected value within a given threshold. The *third approach* is to let the difficulty depends upon the skill of an adversary. In the case of a human opponent, this will to a lesser extent take into consideration the skill of each other, so in the case of a big discrepancy between the two players, the game will be very uneven. If the game provides user profiles and store statistics of the player's skills, the game can try to find players with similar player skills. On the other hand, if the opponent is computer controlled, this approach will be synonymous with one of the first two or a combination of both.

As the player gets more training, and possibly becomes better at the game, the difficulty increases. Thus the player will ideally have a constant feeling of mastering, and will have the same drive towards improving himself. Malone strongly emphasizes the importance self-esteem plays in relation with a player's experience of a computer game. With success, self-esteem can increase, and likewise failure can cause a decrease in self-esteem. In addition, a severe discrepancy between the players' skills and the required skill of the game can cause the player to lose interest in the game. For example if the game is too easy, there will be no motivation for the player to continue playing, and if it is too difficult, the player will lose self-esteem and be discouraged. This implies that there exists a "sweet spot" unique to every player, where the game is challenging enough so that the player stays interested, but not to the extent that that the player thinks he will be unable to complete it.

3) Intrinsic and Extrinsic Fantasies

An aspect of computer games, and games overall for that matter, is the use of fantasies and abstractions to enhance and make them more interesting to the players. These fantasies can vary from the completely plausible to the impossible. Examples of the extremes can be running a store versus assuming the role of a hero with superhuman strength. Malone introduces two different ways of using fantasies in games: extrinsic and intrinsic [21]. *Extrinsic fantasies* are fantasies that only depend on the use of a set of skills, but the skills are not influenced by the fantasy.

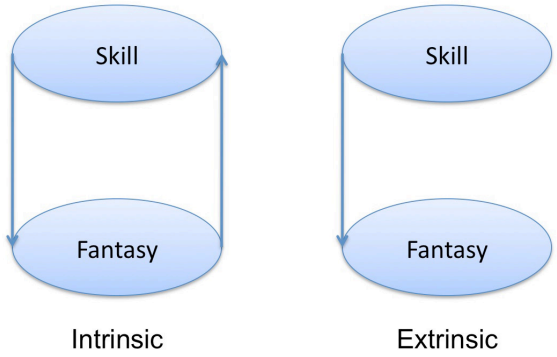

Fig. 1. Intrinsic and Extrinsic Fantasy in Games

The idea is illustrated in Fig. 1. An example of extrinsic fantasy is hangman where you save a crudely drawn man from being hung by guessing a word. The player does not have to take into considerations any factors of the fantasy when using his skills. The fantasy of saving the man from certain death does not correspond to the skill, in this case vocabulary and logic reasoning. The only feedback from the fantasy is that the letter or word the player guessed is wrong.

Intrinsic fantasies on the other hand have skill and fantasy influencing one another. A simulator of running a store is an example of an intrinsic fantasy, where the player have to interact with the fantasy of the game and the player get feedback from the game rooted in the fantasy. This means that the player must adapt his skills according to the fantasy to progress in the game (run the store successfully doing things you need to do in a store). Another example of an intrinsic fantasy game is a darts simulator. There is a very short feedback loop, similar to that of a real game of darts. In the game, the player will get instant visual feedback if for instance he miscalculated and aimed to far off too the right. To improve her accuracy the player will have to adjust the aim based on this feedback. The feedback from the game is very similar to the feedback you would have in the real dart game.

Malone argues that *intrinsic fantasies are more interesting and educational* than extrinsic fantasies [21]. He argues that intrinsic fantasies can suggest how a given skill can be applied in real life, like in the darts simulator. Further, that a close relation between the game itself and the material being learned will give players the opportunity to draw from previous experience in the real world. The player can also use information from the fantasy to improve his skills directly, without any intermediate steps, like e.g. consulting a textbook.

4) Trigging Curiosity

In this paper, *curiosity* is defined as the motivation to learn and to investigate. Malone distinguishes between two types: sensory curiosity and cognitive curiosity [21]. A change in patterns, sounds and other stimuli that attracts attention is called *sensory curiosity*. Audiovisual effects are commonly used in television shows and movies. The usage spans from pure decorative purposes, to enhance a fantasy, to reward the player and finally as a way of conveying information. A typical way of using sensor curiosity is recent games is to let the player win decorative items or prices (e.g. a player wins costumes for his avatar or paint-decor for his car in the game). *Cognitive curiosity* is people's desire to bring completeness, consistency and parsimony to their knowledge. The classical example is that if you read all the chapters of a murder mystery, then you will have the desire to read the last chapter, thus giving your knowledge completeness. The importance of feedback cannot be underestimated; indeed it is imperative to the success of a computer game. A classical problem for some educational games is the lack of feedback on user actions and confusing user interfaces [22].

C. Technology and Trends

Traditionally users of computer games have been isolated, either playing alone or with a very limited number of players

connected to the same computer or console. With the emergence of the Internet, computer games have gradually shifted focus from the isolated gamer to multiplayer games where 64 or more players can play against each other at a time [23]. Indeed, with the advent of the Internet, there has been spawned a whole new culture in gaming with a continuing expected future growth [24]. Collaboration in learning is considered the most important field of research in educational games by Angela McFarlane [23].

At the same time in the sphere of educational games, the traditional approach has been to develop drill and practices games where the player is presented with a number of exercises, often in the form of multiple-choice questions. These exercises are very similar to the exercises found in textbooks, and thus not very innovative. These exercises build on well-proven methods, which have been refined throughout the history of educational institutions. However, in [23] it is questioned whether theses tasks should occupy a big part of the school day. When at school, the students have access to teachers and other qualified personnel, and it is imperative that these resources do not become wasted, and that the teacher's role in the classroom is not reduced to the role as a mere instructor.

Recently, there has been an increase in the creation of more imaginative educational games. This is mainly due to of a closer collaboration between the computer game industry and academic institutions [23]. New innovative educational games have been born out of combining new game technology with recent research in educational theory. One example of such a game is Kar2ouche [25]. Immersive Education has developed this heavily awarded game with the assistance from Oxford University's Department of Educational Studies. The game lets the player develop storyboards, animations and role-plays in a 3D environment, and is intended as a cross curriculum game.

An alternative approach is to use mainstream computer games in classrooms. There are some issues surrounding this, amongst others the cultural acceptance of games as a means for teaching and the strict hardware requirements for schools. Albeit there are some pitfalls, this is a topic that is in need of further exploration. One example of such a game is the Buzz! The schools quiz [26]. An alternative approach to the use of mainstream computer games in classrooms is to use "lite" or stripped down mainstream games as a compromise [23, 27]. However, theoretical understanding of edutainment is not as productive as innovative attempts at producing fresh concepts to support learning in games [28].

Another trend in computer games is the emergence of popular titles on handheld devices such as dedicated gaming devices such as Nintendo DS and Playstation Portable or PDAs and mobile phones [29-31]. One example of how new mobile technology can change educational games, is the touch-based interfaces introduced on Nintendo DS and iPhone/iPod touch. Such interfaces enable the player to interact in a more direct way with objects in the game world that can be utilized for learning. New technology opens new doors to game developers and the market is expected continuous growth. This trend reveals possibilities for new modes of learning through context sensitivity and improved collaboration [32]. In addition to the separate advances and trends mentioned, there is a convergence between different gaming hardware. Home-based game consoles, PCs and handheld devices implement common interfaces for communication, new to the gaming scene. Examples of this are Bluetooth and WiFi wireless connectivity and open Internet standards allowing collaboration and communication across heterogeneous hardware [32].

Evidence of benefits from computer games when correctly integrated in a teaching environment is becoming clear through anecdotal, empirical and pedagogic evidence. However, within a longer perspective it is hard to predict the future trends.

D. Collaborative Gaming

The advances made in communication technology have lead the way to the development of and research in Collaborative Virtual Environments (CVE). This field of research has received a lot of attention in academic circles in recent years [33, 34]. The driving force behind these applications is the ever-growing need to bridge geographical gaps between people. In addition to the development in CVEs, there is on-going research on collaborative gaming or Computer Supported Cooperative Play (CSCP) [35]. Wadley et al. also introduces the metaphor "the third place" [35], previously used by Sony in the marketing campaign for one of their consoles. The third place is an appropriate metaphor for online gaming, where players meet each other on neutral ground. According to [35, 36], the playful mood and regular clientele of these "third places" act as a vehicle for the participants to display their personality and individuality together as well as sociability [36]. Pseudonyms or nicknames are used to separate the participant's real identities from their online alias. Conversation, be it voice or text is the primary activity in these third places. Recently, with the incorporation of voice over IP technology, the "third space" has become an increasingly rich communication medium, especially when combined with increasingly realistic 3D graphics. An alternative emerging approach to learning and games is to use general virtual world environments like Second Life [37] or role-playing games such as World of Warcraft [38] as a learning arena.

Collaborative does not necessarily mean competition between teams, or otherwise an adversarial approach [39]. A goal that requires a collaborative process, like solving a puzzle does create a conflict in the form of the interaction within the game [40], but it is not a contest amongst adversaries. The team has to cooperate to reach a common goal. That being said, there is always the potential for a conflict amongst the members of the group as a result of varying or indeed conflicting visions, motivation and strategies.

Up until recently, the lack of proper means of communication and interaction has made it difficult to support collaboration in computer games, and there exist few actual true collaboration games on the marked. Notable exceptions are arcade two player cooperation games. But these are on the

periphery of true collaboration games, where the players cooperate to solve puzzles and difficult tasks, not merely helping each other to defeat a violent and powerful enemy. Collaborative gameplay has received more attention the last couple of years in commercial entertainment games and the support for collaboration is used as a major sales arguments. Examples of some games that have used collaborative multiplayer gameplay as in advertising the game are the Lego Starwars games [41], Boom Blox Bash Party [42], Uncharted 2: Among Thieves [43], and Army of Two [44]. In the Lego Starwars game, the collaborative gameplay is the main game mode, and two game characters are required to proceed through the levels of the game. If only one player plays the game, the player needs to change back and forth between game characters in order to proceed.

E. Examples of Multiplayer Educational Games

There are not many existing Multiplayer Educational Games available, but we want to give examples of some existing ones.

Breast Cancer Detective (BCD) [45] is a drill and practice game introducing X-ray photos inspection and factual recall for medical students. Extrinsic fantasy is added by emulating the game show Jeopardy, and a two-player mode as well as artificial opponent mode is available. In evaluation of BCD, medical students preferred learning the material by playing an on-line game instead of studying a paper handout. The efficacy of the game was presumably inferior to the hand out, but the students preferred spending more time with the game than saving their time.

Internal Force Master (IFM) [46] is a game where students are put to test their mathematics skills through drill and practice genre. The game depends on competition as a motivator, being stripped of fantasy elements. Competition at individual, university, national and European level is available. The user can hide her true identity by using a nickname and choose from 6 different levels of difficulty. The learning outcome in IFM was studied in two isolated groups, and the evaluation concluded that the learning outcome was at least as high as with traditional learning. The key factor to success was the game's ability to motivate students. The evaluation concludes that the high motivation stems from the competitive aspect and relevance of the game to the students.

"Age of Computers" (AoC) game combines a simple quiz games and with multiple game genres [4]. AoC takes a historical approach to computer science by combining collaborative possibilities; simulations; and quiz games framed in a massive multiplayer online role-play game. An evaluation of the game showed that the students found the game more motivating than paper exercises, and that a majority of the students also perceived the game to have a higher learning effect than paper exercises or textbook reading. However, the result of a controlled experiment comparing the learning effectiveness of game play with traditional paper exercises and textbook reading showed that learning effect was equal with the same time spent. This result is encouraging, as the students learned the same, but more motivated [6]. The evaluation results of AoC shows that games can compete with traditional methods, and that mixing various game play elements and adding a multiplayer option will increase the motivation of the student. High motivation presupposes credibility, which is achieved here by separating the fantasy aspects from the actual theory. Fig. 2 shows a screenshot from Age of Computer game.

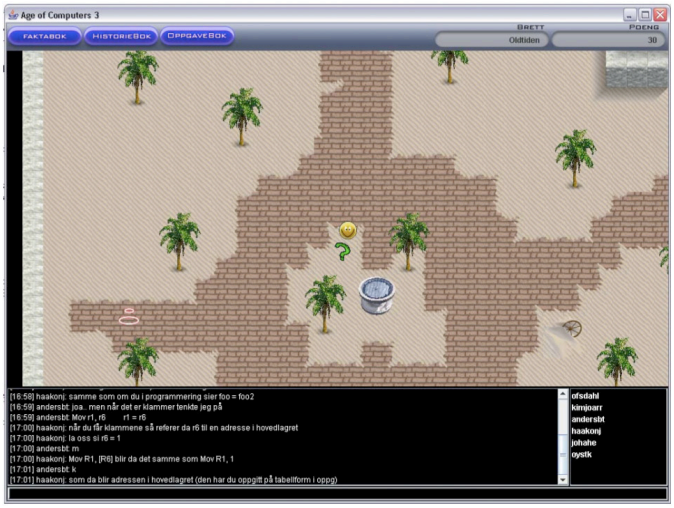

Fig. 2. Screenshot from the Game Age of Computers

Another innovative attempt is the collaborative puzzle game eScape [39]. The game confronts traditional understandings of puzzle games by focusing on the possibilities inherent through the presence of multiplayer support. Four players mutually engage in challenges demanding common participation to achieve successful outcome. Challenges are presented as puzzle-like obstacles that the team has to overcome. The concept is a prison break story in the form a 3D first person game with verbal communication supported by voice over IP. The players have to agree upon goals and negotiate strategies. They also have to share information amongst themselves and co-ordinate their actions carefully. Empirical studies of the game showed that the players enjoyed the game, were able to use the verbal communication features with little effort, but that it was hard to recognize other players merely by their voice. The collaboration proved successful with players following each other throughout the game, even though some players tended to become superfluous as a fraction of the group solved the puzzles internally. One of the issues the developers recognized was the difficulty in making meaningful puzzles designed for team cooperation.

Lecture Quiz was developed by the authors of this paper and is a multiplayer quiz game where multiple players can participate using their own mobile phones, and the teacher moderates the game using his own PC and a video projector [9] (see illustration Fig. 3). The game provides two game modes: *score distribution* – the presentation of the students answers distributed on the various alternatives is shown in an animated 3D bar diagram and the correct answer is highlighted; and *last man standing* – the players have to answer correctly to make it to the next round and the winner is

the last man standing. The evaluation of Lecture Quiz showed that the students perceived that the game contributed to increased learning and motivation, and that they would more likely to attend lectures if such games were used [10] regularly. The evaluation also showed that the game gave important input to the teacher in how much the students had learned about the subject being tested in the quiz game.

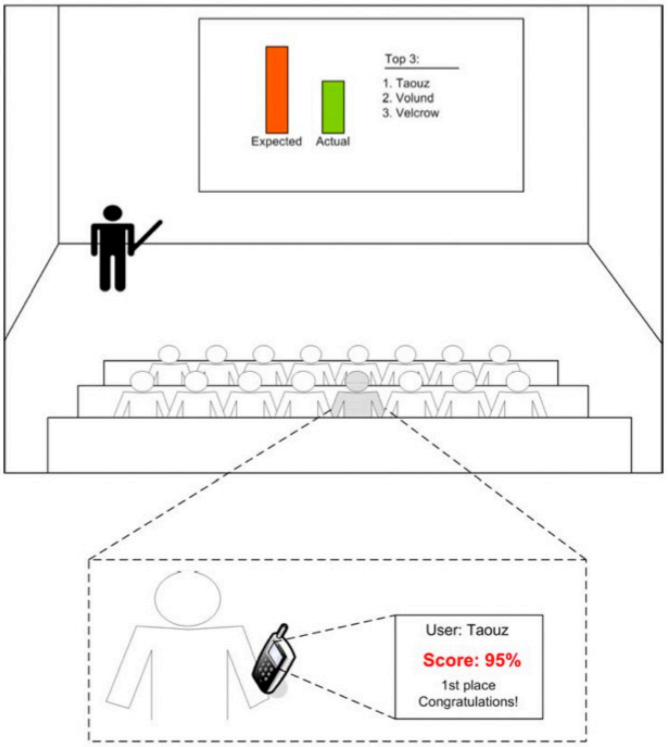

Fig. 3. Shows an illustration of how Lecture Quiz works

Angela McFarlane [47] stresses the importance of pushing technological limits to obtain the best possible educational games. Her prime example is the flight simulator used to train professional pilots. The pilots are tested in face of disastrous events without compromising their own security. The hardware and software are considered realistic to such an extent that gameplay counts as hours flown. Several realistic simulations have proven successful, also without mimicking the hardware input device: Such an example is Americas Army (AA), passing implicit knowledge, warfare theory and political views by simulating armed forces operations from at first person view. Subjects being taught differ from theoretic knowledge such as hand signals and rules of engagement to precision shooting and mission planning. Realism is a key feature simulating detailed situations as gun jams and rocket back blast injuries [48], often ignored in simulation games.

The results from the evaluations of games described in this section indicate that multiplayer educational games have a good learning potential if they are done right. This area of research is still unexplored and so there is plenty of opportunities for research in this area.

F. Pitfalls & Issues

Elder argues that credibility is the very essence of educational games [27]. Credibility contradicts validity, as it describes the end-user experience and not the observations from a detached observer. To achieve credibility, designers need to evaluate the capabilities of the students, with challenges of incremental complexity based on related experience and knowledge from outside the game. Unnecessary abstractions should be avoided, and with growing complexity comes diverse and diffuse experiences. Thus, there needs to be symmetry between real life and game environment in its variables, relations, roles, structure and starting conditions. Keeping in mind that captivating games should have intrinsic fantasy goals [21], the tradeoffs between fantasy stimuli and credibility becomes a challenging designer task. Elder suggest that simpler and limited games are desired in education to meet these demands. As the game grows in complexity, the grasping of new concepts become smudged and the game risk becoming counter-productive [27].

Burdensome administration is another major pitfall and need to be avoided. The game must not depend on administrative verbal communication with the teacher. Another common pitfall is to oversell the game. It is important to give organizations realistic expectations of abilities of the game to gain appreciation and acceptance [27].

Burg & Cleland [49] throw light on a major pitfall in games and learning. Their claim is that researchers are mostly writing about the positive effects, and most articles are written by advocates of educational games. It is agreed among researchers that gaming for educational purposes may indeed be ineffective, but its efficiency is completely ignored. Compared to time spent, it is claimed that the learning outcomes are limited. However, the claim does not distinct between different game genres or products, but generalizes over the entire specter.

III. Characteristics of Good Educational Games

In this paper, we wanted to give answers to three research questions. The first research question was: “Which properties characterize a good educational game?” In the search for answers to this question, we have looked at multiple sources on educational games that could contribute to answer this question (see Section II). We have not considered the technical and artistic issues of educational games, as they are mostly independent of the game concept. We acknowledge that the game concepts are restricted by what you can do artistically and technically, but these issues are not covered here. By combining theoretical knowledge with empirical experiences found in the literature, we have identified eight characteristics that should be considered when designing a good educational game:

- **Variable instructional control** – the level of difficulty is adjusted to the skills of the player or the player himself can adjust complexity [17, 21]. In the case of multiplayer games, the skills of the players should be used to match player of similar skills.
- **Presence of instructional support** – whenever the player is incapable of solving a task, some sort of hints or supplementary background information is available to the

player [17, 18]. For multiplayer games, support for chat or forums among the players should be provided so the players can learn fro each other.

- **Necessary external support** – successful use of computer games in an educational setting demands careful considerations of external factors [17]. For instance availability of hardware, personal follow up and available guidance might be necessary for everyone to have a positive experience.
- **Inviting screen design** – users feel they are playing a game in contrast to operating a program. The screen design might motivate players by being playful and inviting without affecting the credibility of the game negatively [17]. For multiplayer games, it is important that the players can customize his avatar uniquely to be able to differentiate between different players.
- **Practice strategy** – players may practice without affecting their score or status negatively [17, 18]. For multiplayer games, a single player practice mode should be provided whenever appropriate.
- **Sound instructional principles** – this characteristic might be obvious but nonetheless an important quality attribute. Examples of such principles are motivating abstractions of theoretical syllabus [19], collaborative learning [17, 46] or use of recognized cognitive psychological principles such as repetition and incremental learning [20].
- **Concept credibility** – the theory or skills need to be abstracted in a way that maintains the integrity of the instruction. Empirical studies show that when abstractions become too conceptual or the game becomes too focused on abstractions instead of instruction, players find the game silly and loose interest [27].
- **Inspiring game concept** – the game concept should inspire the player for investing time into the game. The only way of determining this characteristic is through empirical studies of the specific concept. Ideally the players loose track of time, experience curiosity, have an enjoyable experience and want to continue playing whenever they need to stop [21, 23].

The eight characteristics listed above are probably not a complete list of characteristics a good educational game should have, but we believe we have identified the most important ones. However, to make a successful game other things like appropriate hardware platform, a solid software implementation and inviting artistic graphics play a major role. We like to think of these characteristics as a very good starting point for making such games. These characteristics have also been important inputs for the model and taxonomy presented in the two following sections.

IV. Collaborative Learning

The second research questions we wanted to find an answer to was: "How can collaboration improve learning in educational games?" Our answer and proposal to this question is described in this section.

As suggested by Angela MacFarlane [50], a further research on the strategic use of collaboration in educational software is a necessity. In this paper we suggest how one can overcome one of the most important barriers when making good educational games by exploiting the potential of collaborative learning. Collaboration is extensively used with great success in recent commercial games, as most newly released commercial AAA games come with a multiplayer component. The immense success of titles such as Buzz [51] and World of Warcraft [52] exemplifies this trend.

A. *Fighting the Intrinsic Fantasy Gap*

The perfect educational game has high credibility and captivating gameplay. Realizations of such games are often games involving intrinsic fantasy with interesting and amusing abstractions from the real world domain. However, making games of intrinsic fantasy presupposes that the game is custom-made for one particular subject. This is very expensive and diminishes re-use possibilities in other subjects. We argue that through creative use of collaboration in educational games, they can be engaging and captivating even if they do not contain intrinsic fantasy.

B. *Extended Malone Model*

Section II-B-3 described how a tight feedback loop between skill and fantasy is desirable in computer games, yet the making such games is usually hard and expensive to develop. Fig. 4 shows how Malone's model (see Section II-B-3) can be extended with the entity *social interaction*. Our extended model shows that the feedback from fantasy to skill can be reproduced through social interaction.

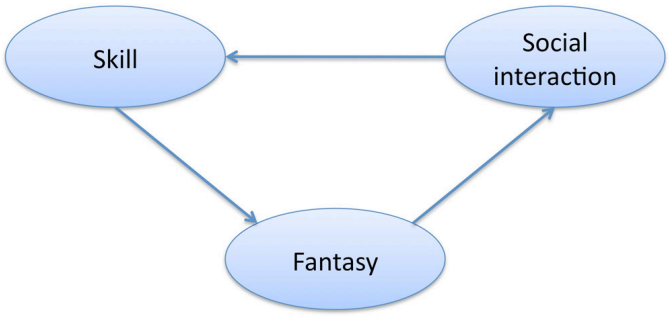

Fig. 4. Extrinsic Fantasy and Social Interaction

This means that even though the fantasy of the game is irrelevant to the skill, the players are provided with direct feedback from the contribution of other players. A barrier in making good educational games is the fact that a player is trained in a skill needed on his final exam or in real world future challenges. By providing constant feedback through collaboration, the theory remains the same. However, the real challenge takes place there and then instead of in a potential future. A simple, yet illustrating example might be a straightforward quiz game compared to the group quiz game Buzz! [51]. A quiz game is independent of its contents and extrinsic by nature. By adding multiplayer possibilities, the challenge is no longer just answering the questions, but to cooperate with or beat your opponents. The social element of the game provides a context, where the player receives a great deal of information from his opponents. To give an example, imagine a group of friends playing a group quiz. One of the

participants tries to answer a question, but he gives the wrong answer and one of the others will be allowed to try. This person then gives the correct answer. The first person can then interact with the person with the correct answer and ask his follow up questions to obtain possible additional information relevant to the question. Thus the important feedback from the game is indirect, obtained via the other players. This feature turns a simple idea into an amusing experience that proves successful even competing with mainstream console games.

In addition to improving educational games with extrinsic fantasy by adding the multiplayer aspect, we also suggest two additional models to improve intrinsic fantasy educational games. Throughout our research, we have only come across one product, eScape [39], implementing these concepts, but we are convinced these are models that are worth considering despite the complexity of making such games.

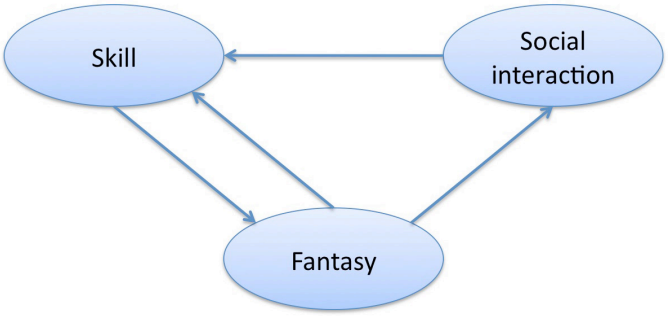

Fig. 5. Intrinsic Fantasy and Social Interaction Outside the Game

Fig. 5 illustrates how social interaction outside the game and intrinsic fantasy can increase the feedback to the user in the same manner as illustrated for extrinsic fantasy games in Fig. 4. Here the actual interaction is not part of the game, but takes place in the real world (typically the players are located in the same room). Examples of this model include party games, where competition or cooperation in the real world is facilitated through a game. This model of interaction is realized in the game Wii Sports [53] bundled with the Nintendo Wii console.

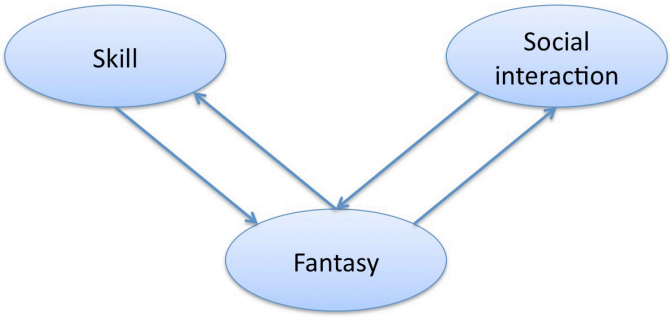

Fig. 6. Intrinsic Fantasy and Social Interaction Within the Game

Fig. 6 shows another model where feedback through social interaction stimulated through the fantasy of the game. An advantage of this model is that one may relief demand for high bandwidth communication channels as the social aspect is founded in the game concept. An example of this variant might be a game teaching decoration skill, for instance interior design, where work is rated by the social community through the fantasy. The feedback from the game will mostly consist of technical information from the game dynamics, while the feedback from the other players will provide domain specific knowledge. The game itself acts as a facilitator for this feedback, and a medium in which the players can experiment freely without having to concern themselves with the cost of the materials or tools. The feedback from the other players is authentic and sudden, and we believe further research might discover synergetic effects in combining fantasy and multiplayer possibilities in such a manner.

The extension of Malone's model presented in this section can be used as an inspiration to explore new kinds of educational games that experiment with different ways of utilizing the fantasy of the game and how the players interact. As there are few examples of educational games exploring this area, game concepts from entertainment games can be used as a starting point for new educational games.

V. Lecture Games Taxonomy of Educational Games

The third and last research question pursued in this paper was: "How to classify educational games that also can take the multiplayer aspect into account?" This section presents our Lecture Games taxonomy of educational games.

A. Existing Game Taxonomies

There is no widely accepted standard on categorizing computer games in general. A taxonomy used by several researchers is the Herz system [23], which divides games into eight categories: action games, adventure games, fighting games, puzzle games, role playing games, simulations, sports games, and strategy games. The Kasvi system is a similar categorization but does not include the puzzle, adventure and fighting categories [54]. Crowford has a totally different classification consisting of only two categories [54]: 1) *Skill and action games* that rely on hand-eye coordination and reaction; and 2) *Strategy games* that rely on human reflection and involve strategy, adventure, puzzle, simulation and role-playing games. In addition to these characterization systems described above, game magazines and game websites have defined their own systems. All the existing taxonomies share weaknesses in describing the multitude of games available today. Some games do not fit into any of the defined categories, while other games fit in many categories. Today, it is common that games mix various gameplay elements and game genres, making classification of games very hard. Also, the multiplayer concept is not taken into account, yet is an important feature to consider in educational games that can change gameplay and learning effect drastically.

The taxonomy most related to games and learning, is Maier and Größler taxonomy of computer simulations [55]. A subset of this taxonomy, named "Gaming oriented simulations", is relevant to educational computer games. Here gaming oriented simulations are divided into two categories: 1) *Simulators* that can be decomposed into the sub-categories *business simulators* and *other simulators*; and 2) *Planning games* that can be decomposed into *corporate planning games* and *other planning games*. Simulators are defined as single player

simulators, while planning games are multiplayer simulations. Maier and Größler's taxonomy only covers a very limited subset of educational games.

B. Background of the Lecture Games Taxonomy

The Lecture Games taxonomy of educational games was inspired by the early work by Malone [21] and other existing taxonomies especially the work of Maier and Größler. The purpose of defining the Lecture Games taxonomy was to provide a tool to identify and classify the various existing educational games. Historically, computer games have been categorized by its concepts genres such as adventure, action, and simulator. Dealing with educational games, other properties are of higher priority as the learning potential of entities may be described to a fuller extent by categorizing them according to other properties. However, the genre of a game is natural categorization criterion and gives important information about the nature of any game. We also see the social aspects of games getting more important through collaborative learning in multiuser systems. Perhaps the most important criteria for categorization of educational games, is whether the fantasy of the game is extrinsic or intrinsic to the skills being trained. Extrinsic games are easier to produce, as the rendered fantasy is independent of the learning goals. However, such games can have limited usefulness in achieving certain learning goals. Intrinsic fantasy games depend on integrating the fantasy with the learning goals often in some variation of the simulator genre.

C. Presentation of the Lecture Games Taxonomy

The Lecture Games taxonomy has been categorized according to following three criteria:

- **Player interaction** – does the game provide player-to-player interaction?
- **Fantasy and skills interaction** – does the game provide fantasy, which is integrated with the learning goals or not?
- **Game concept type** – what is the main game concept is used in the game?

Fig. 7 shows the Lecture Games taxonomy of educational games consisting of three levels.

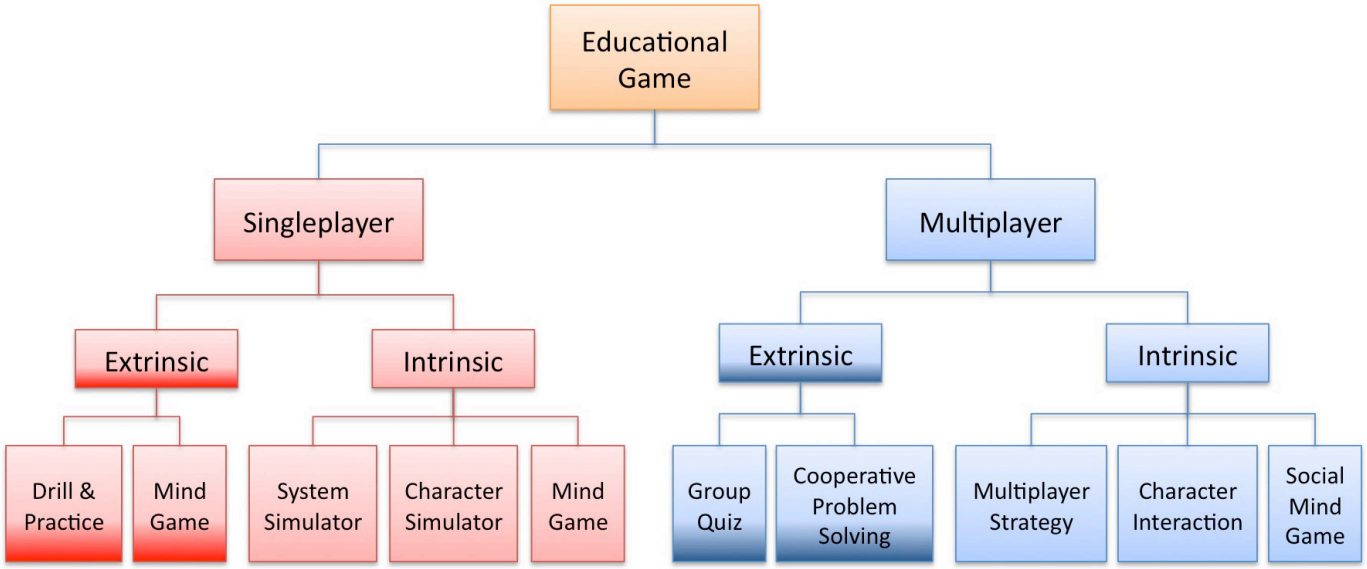

Fig. 7. The Lecture Games Taxonomy for Educational Games

Flattening the taxonomy presented in Fig. 7 will give ten unique categories of educational computer games (note that the examples of games are also from well-known non-educational games to easier link the category to a game):

- **Drill & Practice:** The user answers questions from alternatives, visual recognition or textual input. The user is tested in factual recall and recognition.
  Example: Internal Force Master, quiz games, most educational games for kids.
- **Extrinsic Mind Game:** Presents challenges including reasoning of some sort. The fantasy of the game does not affect the reasoning challenge.
  Example: Minesweeper, Mastermind, Cuboid.
- **System Simulator:** A complex system consisting of many parts and different set of rules is simulated, and the user input parameters affect the simulation. Typical for a system simulator is that the player controls more than one character or aspect of the game at any time.
  Example: Civilization, Sim City, The Incredible Machine, Nintendo Dogs.
- **Character Simulator:** Simulation from the point of view of a personified character/avatar. The player controls only one character or very limited number characters. Control of the environment where these characters exist is beyond the immediate control of the player.
  Example: Americas Army Training Missions (single player).
- **Intrinsic Mind Game:** Presents challenges including

reasoning of some sort relevant to the fantasy in a way where the fantasy gives feedback to the challenges.

Example: Illustrated math games, the niche of elementary learning.

- Group Quiz: Drill & Practice game where interaction among players in the game itself or outside the game is strongly encouraged and is an essential part of the game.

Example: Buzz!, Scene it?

- Cooperative Problem Solving: Mind game where the parameters affect the game of other users without the fantasy of the game affecting the challenge at hand.

Example: Battleship.

- Multiplayer Strategy: Multiplayer games where the input from the different players affects the game of one another and the fantasy of the game is relevant.

Example: Command & Conquer, Civilization (multiplayer).

- Character Interaction: Multiplayer character simulator where different players control separate characters. These interact within the game.

Example: Americas Army (multiplayer).

- Social Mind Game: Game involving reasoning where the players interact actively in the challenges. The fantasy of the game gives feedback to the challenge at hand.

Example: Multiplayer illustrated math games.

The taxonomy was designed to be easy to use, yet express the most important aspects of educational games.

A. Applying the Taxonomy

The Lecture Games taxonomy is fairly straightforward to use, but we would like to give a short introduction to how to use it.

The *first step* of the process is to determine if the game is single player or multiplayer. For a game to qualify as a multiplayer game, the game needs to offer actual interaction of players in the game during gameplay. This interaction must affect the process of playing the game, so the presence of a multiplayer high-score list is not sufficient to qualify as a multiplayer game. If a game supports both multiplayer and single player, a category can be found in two ways: 1) by focusing on the most relevant mode, the game can be categorized in the most appropriate category; or 2) the game can be categorized as two separate games (one single player and one multiplayer game).

The *second step* of the categorization process is to determine whether the fantasy in the game can be classified as extrinsic or intrinsic. Games can be classified to provide *extrinsic fantasy* if the fantasy of the game only depend on the use of a set of skills, but the skills are not influenced by the fantasy (the fantasy is independent of what the player do). Examples of such games are typical drill and practice games for learning the alphabet where the player can write letters in a fantasy world. This means that the fantasy is not integrated with the gameplay. Games can be classified to provide *intrinsic fantasy*, if the skill of the player and the fantasy influence one another (both ways). Examples of such games are physical puzzle games such as IncrediBots [56] and Crayon Physics Deluxe [57], where the player manipulates a game world of physical objects and the objects responds according to physical laws.

The *third step* is to determine the game concept of the game. For extrinsic fantasy games, one only needs to consider whether the game require reasoning or not. For intrinsic fantasy games, one needs to settle whether the game is a simulator or not. If it is a simulator, one needs to decide whether the simulation of the game is presented through controlling a character or a system.

B. Using the Taxonomy on Existing Educational Games

As a part of our research on multiplayer educational games, we wanted to get an indication of what kinds of educational games available. There exist no overview of existing educational games, and it is very hard to get one as many games are only available in certain countries and languages. We decided to focus on commercial educational games and classified the 26 commercial educational games running on current hardware platforms found at GameSpot's archives [58] according to the Lecture Games taxonomy. Note that the two games eScape and Tractor Multiplication were not found at GameSpot, but were added to give example of the categories not covered by the games found at GameSpot website. Table I shows the characterization of 28 educational games according to the Lecture Games taxonomy.

From Table I, we can see that the majority of major commercial educational games can be classified as single player, extrinsic, drill & practice games. This was not a surprise, as most educational games available fit into this category. We also found one example of a single player mind game. Although, we found some examples of games that could be classified as single player, intrinsic fantasy games, theses games are in the borderline for what can be accepted as educational games. Some of the games can hardly be regarded as educational games (the games in the system simulator and mind game category), but have some learning aspects. The games classified in the character simulator category have intrinsic fantasy, but the learning aspects of the games are questionable.

We found only three commercial educational games at GameSpot that could be classified as multiplayer games. Most existing educational games that can be classified as multiplayer games are developed at research institutions. Educational games in this category is largely unexplored. In our project, Lecture Games, our goal is to develop various multiplayer educational game concepts and to evaluate these games according to how they motivate the students, usefulness for the teacher, and the learning effect and effectiveness. In process of doing so, we will use the characteristics identified in Section III as a foundation for the design, consider our options related to the collaboration models as described in Section IV, and use the Lecture Games taxonomy to choose between the various categories of games.

TABLE I
CHARACTERIZING EDUCATIONAL GAMES FROM GAMESPOT USING THE LECTURE GAMES TAXONOMY

Player interaction	Fantasy	Game type	Games
Single	Extrinsic	Drill & Practice	Spanish for Everyone (DS), The Incredibles: When Danger Calls (PC), Spider-Man and Friends (PC), Driving Theory Training (DS), Brain Quest Grades 3 & 4 (DS), Konami Kids Playground: Dinosaurs Shapes & Colors (PS2), Konami Kids Playground: Toy Pals Fun with Numbers (PS2), Brain Quest Grades 5 & 6 (DS), Konami Kids Playground: Alphabet Circus (PS2), Dimenxian (PC), Skools Out (PC), Beliefnet Spiritual Trivia (MOBILE), Math Patrol: The Kleptoid Threat (GBA), Blue's Clues: Blue's Kindergarten (PC)
		Mind Game	Zoombinis Logical Journey (PC)
	Intrinsic	System Simulator	Ice Cream Empire (MOBILE), Making History (PC), Microsoft flight simulator (PC)
		Character Simulator	Franklin: A Birthday Surprise (PS2), Carmen Sandiego: The Secret of the Stolen Drums (Multi), Finding Nemo: Learning With Nemo (PC)
		Mind Game	Crayon Physics Deluxe (PC), Ingredibots (Web)
Multi	Extrinsic	Group Quiz	BUZZ! The schools quiz (PS2)
		Cooperative Problem Solving	eScape [39]
	Intrinsic	Multiplayer Strategy	Civilization II Multiplayer Gold Edition (PC)
		Character Interaction	Americas Army (Multi)
		Social Mind Game	Tractor Multiplication [59]

VI. CONCLUSION

In this paper, we investigated the use of multiplayer gameplay in educational games to overcome the high expense and difficulty in designing and implementing educational games with intrinsic fantasy elements. We have proposed eight characteristics a good educational game should have, a new model for how collaboration can improve learning in games and the Lecture Games taxonomy of educational games. We believe that introducing collaboration or competition between players in educational games gives the players a richer learning experience where the player not only learns from the game but also through other players interacting. Our model and taxonomy show that collaborative gameplay can be introduced in two ways in educational games: 1) The interaction of players can be independent of the fantasy provided in the game; or 2) the interaction of players can be provided through the fantasy of the game. Utilizing intrinsic fantasy is more costly to develop as games can be only developed for one specific subject, but can give a richer learning experience. Extrinsic fantasy makes it easier to develop games that are independent of the subject being taught, but might suffer in the way the students learn through interaction in the game. Introducing support for collaborative gameplay can compensate for the lack of intrinsic fantasy and in addition make learning a more social experience. In addition, it is possible to combine collaborative learning and intrinsic fantasy to provide a new kind of educational games. Both approaches bring interesting player-to-player mechanisms into the game that need to be explored.

The Lecture Games taxonomy can be used in various ways. *First*, the taxonomy can be used to classify various educational games according the ten unique categories defined. *Second*, the taxonomy can be used to compare the effectiveness of learning by comparing various the categories. *Third*, the taxonomy can be used to identify what types of games that are best suited for specific subjects. *Forth*, the taxonomy can be used to identify types of educational games that need to be explored further and validated. *Fifth*, the taxonomy can be further extended to classify educational games at a finer granularity. And finally, *sixth*, the taxonomy can be used together with e.g. the Hertz system for categorizing games [23] to map relationships between game genres and the categories defined in the Lecture Games taxonomy.

We believe that the characteristics, the model and the Lecture Games taxonomy can contribute to a framework for research on future educational games. Our hope for this research is that it will ignite other researcher to explore the area of multiplayer educational games.

ACKNOWLEDGEMENT

We would like to thank Richard Taylor and Walt Scacchi at the Institute for Software Research (ISR) at University of California, Irvine (UCI) for providing a stimulating research environment and ideas for visiting researcher from Norway. This work has been sponsored by the Leiv Eriksson mobility program offered by the Research Council of Norway.

REFERENCES

[1] R. Rosas, M. Nussbaum, P. Cumsille, V. Marianov, M. Correa, P. Flores, V. Grau, F. Lagos, X. López, V. López, P. Rodriguez, and M. Salinas, "Beyond Nintendo: design and assessment of educational video games for first and second grade students," Computer Education, vol. 40, pp. 71-94, 2003.

[2] M. Sharples, "The design of personal mobile technologies for lifelong learning," Comput. Educ., vol. 34, pp. 177-193, 2000.

[3] A. Baker, E. O. Navarro, and A. v. d. Hoek, "Problems and Programmers: an educational software engineering card game," in Proceedings of the 25th International Conference on Software Engineering Portland, Oregon: IEEE Computer Society, 2003.

[4] L. Natvig, S. Line, and A. Djupdal, "Age of Computers: An Innovative Combination of History and Computer Game Elements for Teaching Computer Fundamentals," Proceedings of the 2004 Frontiers in Education Conference, 2004.

[5] E. O. Navarro and A. v. d. Hoek, "SimSE: an educational simulation game for teaching the Software engineering process," in Proceedings of the 9th annual SIGCSE conference on Innovation and technology in computer science education Leeds, United Kingdom: ACM, 2004.

[6] G. Sindre, L. Nattvig, and M. Jahre, "Experimental Validation of the Learning Effect for a Pedagogical Game on Computer Fundamentals," IEEE Transaction on Education, vol. 52, pp. 10-18, 2009.

[7] B. A. Foss and T. I. Eikaas, "Game play in Engineering Education - Concept and Experimental Results," The International Journal of Engineering Education vol. 22, 2006.

[8] R. F. Lyvers and B. R. Horowitz, "A unique instructional tool for visualizing equipotentials and its use in an introductory fields course," IEEE Transaction on Education, vol. 36, pp. 237-240, May 1993.

[9] A. I. Wang, T. Øfsdal, and O. K. Mørch-Storstein, "Lecture Quiz - A Mobile Game Concept for Lectures," in IASTED International Conference on Software Engineering and Application (SEA 2007) Cambridge, MA, USA: Acta Press, 2007, p. 6.

[10] A. I. Wang, T. Øfsdal, and O. K. Mørch-Storstein, "An Evaluation of a Mobile Game Concept for Lectures," in Proceedings of the 2008 21st Conference on Software Engineering Education and Training - Volume 00: IEEE Computer Society, 2008.

[11] A. Barella, S. Valero, and C. Carrascosa, "JGOMAS: New Approach to AI Teaching," IEEE Transaction on Education, vol. 52, pp. 228-235, May 2009.

[12] W.-K. Chen and Y. C. Cheng, "Teaching Object-Oriented Programming Laboratory With Computer Game Programming," IEEE Transaction on Education, vol. 50, pp. 197-203, Aug 2007.

[13] R. Lawrence, "Teaching data structures using competitive games," IEEE Transaction on Education, vol. 47, pp. 459-466, Nov 2004.

[14] M. S. El-Nasr and B. K. Smith, "Learning through game modding," Computer Entertainment, vol. 4, p. 7, 2006.

[15] B. Wu, A. I. Wang, J.-E. Strøm, and T. B. Kvamme, "An Evaluation of Using a Game Development Framework in Higher Education," in Proceedings of the 2009 22nd Conference on Software Engineering Education and Training - Volume 00: IEEE Computer Society, 2009.

[16] C. Kelleher, R. Pausch, and S. Kiesler, "Storytelling Alice motivates middle school girls to learn computer programming," in Proceedings of the SIGCHI conference on Human factors in computing systems San Jose, California, USA: ACM, 2007.

[17] J. L. Lowe, I. Lowe, F. Elwood, and A. Holton, "A Theory of Effective Computer-Based Instruction for Adults," Human Resource Development Review, vol. 4, pp. 159-188, 2005.

[18] P. M. Privateer, "Academic Technology and The Future of Higher Education: Strategic Paths Taken and Not Taken," The Journal of Higher Education, vol. 70, pp. 60-79, 1999.

[19] S. S. Boocock and J. S. Coleman, "Games with simulated environments in learning," Sociology of education, vol. 39, pp. 215-236, 1966.

[20] J. B. M. Schick, "The Decision to Use Computer Simulation," The History Teacher, vol. 27, pp. 27-36, 1993.

[21] T. W. Malone, "What Makes Things Fun to Learn? Heuristics for designing Instructional Computer Games," in The 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems Palo Alto, California, United States: ACM Press, 1980.

[22] A. Amory, K. Naicker, J. Vincent, and C. Adams, "The use of computer games as an educational tool: identification of appropriate game types and game elements," British journal of Educational Technology, vol. 30, pp. 311-321, 1999.

[23] J. Kirriemuir and A. McFarlane, Literature Review in Games and Learning: Futurelab, 2004.

[24] J. Kirriemuir, "Video Gaming, Education and Digital Learning Technologies: Relevance and Opportunities," in D-Lib Magazine. vol. 8, 1999.

[25] Immersive-Education, "Kar2ouche," in Web: http://www.immersiveeducation.com/kar2ouche/. 1999.

[26] Rentless, "Buzz! The School Quiz," Web: http://www.relentless.co.uk/games/?product=buzzschoolsquiz, 2008.

[27] C. D. Elder, "Problems in the Structure and Use of Educational Simulation," Sociology of Education, vol. 46, pp. 335-354, 1973.

[28] K. Squire, "Video Games in Education," International Journal of Intelligent Simulations and Gaming, vol. 2, pp. 49-62, 2003.

[29] E. Klopfer, Augmented Learning: Research and Design of Mobile Educational Games: The MIT Press, 2008.

[30] S. Kurkovsky, "Engaging students through mobile game development," SIGCSE Bull., vol. 41, pp. 44-48, 2009.

[31] M. Denk, M. Weber, and R. Belfin, "Mobile learning challenges and potentials," Int. J. Mob. Learn. Organ., vol. 1, pp. 122-139, 2007.

[32] J. Kirriemuir, "Video Gaming, Education and Digital Learning Technologies: Relevance and Opportunities," in D-Lib Magazine. vol. 8, 2002.

[33] S. Benford, C. Greenhalgh, T. Rodden, and J. Pycock, "Collaborative Virtual Environments," Communications of the ACM, vol. 44, pp. 79-85, 2001.

[34] O. H. Graven and L. M. MacKinnon, "A Consideration of the Use of Plagiarism Tools for Automated Student Assessment," IEEE Transaction on Education, vol. 51, pp. 212-219, May 2008.

[35] G. Wadley, M. Gibbs, K. Hew, and C. Graham, "Computer Supported Cooperative Play, "Third Places" and Online Videogames," in Australian Conference on Computer Human Interaction (OzChi 03) Brisbane, Australia, 2003.

[36] J. Preece and D. Maloney-Krichmar, "Online Communities: Focusing on sociability and usability," in The Human -Computer Interaction Handbook, J. A. Jacko and A. Sears, Eds.: Lawrence Erlbaum Associates, 2003, pp. 596-620.

[37] M. Leidl, G. R, and ling, "How will future learning work in the third dimension?," in Proceedings of the 12th annual SIGCSE conference on Innovation and technology in computer science education Dundee, Scotland: ACM, 2007.

[38] D. Whitcomb, "World of Warcraft as a teaching tool," Web: http://www.wow.com/2008/10/04/world-of-warcraft-as-a-teaching-tool/, October 4 2008.

[39] T. Manninen and T. Korva, "Designing Puzzle for Collaborative Gaming Experience - CASE: eScape," in DiGRA 2005 Conference: Changing Views - Words in play 2005 Vancouver, Canada, 2005.

[40] C. Crawford, The Art of Computer Game Design: Osborne/McGraw Hill, 1982.

[41] LucasArts, "LEGO Star Wars: The Complete Saga," Web: http://www.lucasarts.com/games/legostarwarssaga/, 2009.

[42] ElectronicArts, "BOOM BLOX Bash Party," Web: http://boomblox.ea.com/, 2009.

[43] Playstation.com, "UNCHARTED 2: Among Thieves," Web: http://www.us.playstation.com/PS3/Games/UNCHARTED_2_Among_Thieves, 2009.

[44] ElectronicArts, "Army of Two Home Page," Web: http://games.ea.com/armyoftwo/, 2009.

[45] M. Roubidoux, "Breast Cancer Detective," Web: http://www.med.umich.edu/lrc/breastcancerdetective/, 2002.

[46] M. Ebner and A. Holzinger, "Successful implementation of user-centered game based learning in higher education: An example from civil engineering," Computers & Education, vol. 49, pp. 873-890, 2007.

[47] A. McFarlane, "The games people play," in eLEARNING AT BRISTOL, 2005, p. 3.

[48] Army-Game-Project, "Americas army Training Manual," Web: http://www.americasarmy.com/downloads/manuals.php, 2004.

[49] J. Burg and B. Cleland, "Computer-Enhanced or Computer-Enchanted? The Magic and Mischief of Learning with Computers," in ED-MEDIA 2001 World Conference on Educational Multimedia, Hypermedia & Telecommunications Tampere, Finland, 2001, p. 8.

[50] A. McFarlane and J. Kirriemuir, "Use of Computer and Video Games in Classroom," in Level Up Digital Games Research Conference Universitet Utrecht, Netherlands, 2003.

[51] Rentless, "BUZZ! [Website]," Web: http://www.buzzthegame.com/, 2009.

[52] Blizzard, "World of Warcraft Community Site," Web: http://www.worldofwarcraft.com/, 2009.
[53] Nintendo, "Wii Sports at Nintendo :: Games," Web: http://www.nintendo.com/games/detail/1OTtO06SP7M52gi5m8pD6CnahbW8CzxE, 2009.
[54] J. J. Jyrki, "Not Just Fun and Games - Internet Games as a Training Medium," Skidoo: Helsinki University of Technology, pp. 22-23, 2000.
[55] H. Maier and A. Größler, "What are we talking about? - A taxonomy of computer simulations to support learning," System Dynamics Review, vol. 16, pp. 135-148, 2000.
[56] Grubby-Games, "IncrediBots - Online Robot Physics Game!," Web: http://incredibots.com/, 2009.
[57] P. Purho, "Crayon Physics Deluxe," Web: http://www.crayonphysics.com/, 2009.
[58] GameSpot, "GameSpot: Video Games PC Playstation 2 Xbox 360 Wii PS3 GameCube PSP DS GBA PS2 Playstation 3," Web: http://www.gamespot.com, 2009.
[59] ArcademicSkillBuilders, "Tug of War - Tractor Multiplication," Web: http://www.arcademicskillbuilders.com/games/tractor-multiplication/tractor-multiplication.html, 2009.