Educational games in chemistry education

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Educational games are a splendid learning method, if pupils are desired to be the ones responsible for their own learning. Executing the idea of an effective constructivist classroom. In this article, educational games are discussed from the standpoints of a pupil and a teacher. Also a tool for designing and evaluating educational games for lower-secondary chemistry education purposes is presented.

About play, playing and games

Current chemistry education leans on a social constructivist perspective of learning: pupils construct new knowledge by discussing and exploring together. Every pupil has an active and accountable role in the learning process. A teacher´s role, in turn, is to guide and support this process. (e.g. Eilks, Prins, & Lazarowitz, 2013; Powell & Kalina, 2009) A positive perception of one´s capability and of chemistry as a school subject has been proved to enhance learning. This is one reason why it is necessary to use teaching and learning methods, which promote both the pupils´ capability in chemistry and the fact that they like chemistry as a school subject. (Kärnä, Hakonen, & Kuusela, 2012) Educational games are this kind of a teaching and learning approach.

Play and playing are an inseparable part of childhood, youth and adulthood. Play turns into game, whenever strict rules, an aim and permitted tricks to achieve the aim are added into play. Winning is a typical aim, affecting competition between the players. (e.g. Kelley, 1988) In general, playing a game is about acting and making decisions: every decision made by players results a change, which changes the whole game system and creates new meanings. Playing requires a lusory attitude, meaning that a player accepts the game rules and its articifial world. (Salen & Zimmerman, 2003)

Also games for educational purposes have been developed. *An educational game* is a game, which can be used and adapted for improving, enhancing and supporting the teaching and the learning process for certain knowledge or a skill. (Tuomisto, 2015)

Educational games and pupils

The pupil is acting the role of a player. Playing educational games provides pupils with opportunities to take a responsibility for their own learning. These games also enhance an interplay between pupils as well as a construction of meaningful knowledge together. (Lujan & DiCarlo, 2006; Ke, 2008) In other words, with educational games it is possible to execute a social constructivist way of learning. But it is the teacher, who should find the suitable game for a certain task, phenomenon, skill or knowledge to be learned (Rastepargour & Poopak, 2012).

Even though a competitive element is typically included in the games, it is noticed that a cooperative, collaborative or an individual aim helps the progress of learning more than competitiveness. In cooperative or collaborative play, pupils focus on a shared aim and because of that, they play more rationally and make less mistakes. Often choice-makings in cooperative or collaborative play differ from individual play. (Bornstein, Kugler, & Ziegelmeyer, 2004; Zagal, Rick, & Hsi, 2006; Ke, 2008) It also seems that boys are engaged in cooperative game and problem-solving during the play better than girls (Ke, 2008).

Not only luck, but also knowledge should play a role in winning the educational game. There should be a degree of uncertainty and unexpected events in every game: then the one who masters the content knowledge will not be the obvious winner (Gredler, 2004; Salen & Zimmerman, 2004). When rewards and positive feedback are alternating with challenges and conflicts in actual game situations, players will achieve alternating feelings of anxiety and boredom. These two emotions (for its part) engage pupils in the play and in learning during the play. Both, the feeling of attendance and the feeling of achieving the game objective, have a similar effect as feelings of anxiety and boredom. (e.g. Annetta, 2010; Tüysüz, 2009)

It has been proven that low-achieving pupils, pupils under special education and those, who lose their motivation and interest quickly, benefit most from the educational games. For higher-achieving pupils, educational games do not have similar effects, yet they also enjoy playing (Ke, 2009; Virvou, Katsionis, & Manos, 2005). The effects of gender have also been studied, and based on results the gender has an influences on how a pupil plays rather than what a pupil learns in the game session (Ke, 2009).

The younger the players are, the easier, shorter and unambiguous game rules should be. (Galus, 2003; Tsai, Tsai, & Lin, 2015) And short educational games are preferred, because then it is possible to play the game more than once during a lesson (e.g. Bayir, 2014).

Educational games and the teacher

A mere educational game does not enhance learning, but the teacher is essential. The teacher is one to determine why to use an educational game in teaching, to specify what and when to learn, how to prepare pupils for the play and how to control the fact that an aim for a game-based learning has been achieved. (Kangas, Koskinen, & Krokfors, 2016)

Using educational games for learning should follow the orders of the national curriculum. The teacher decides, which of the objectives in the curriculum are implemented by playing. For instance types of bonds, cooperation and critical thinking could be the three aims for a chemistry-related educational game, based on the Finnish National Curriculum for Basic Education (Finnish National Board of Education, 2014). It is important to prepare and orientate pupils before the actual game session. The teacher can do it shortly by introducing pupils into the game rules, or can do it more detailed by teaching the key concept of the topic before the game. Then the educational game will help pupils to rehearse or/and apply these concepts. (Costa, 2007; Kangas et al., 2016)

By using educational games, the teacher may map and collect pupils´ conceptions about the learned topic or key concepts. During the game, the teacher has a possibility to follow the choices, decisions, discussions and other action applied in the playing groups. In parallel also guidance and support is provided and as well feedback is given, whenever the teacher

sees it necessary. Sometimes it might be appropriate for the teacher to stop the game for a while and to sharpen a certain concept or some key points of the game, or to create a discussion about the topics that are being learned. After the game, it is sensible to keep a teacher-guided compaction session. (Costa, 2007; Kangas et al., 2016)

That is to say, the teacher has many responsibilities when integrating an educational game into education. But at the same time, the teacher offers pupils possibilities to see and learn one topic in many perspectives and in different contexts. The teacher acts as a guide between the real world and the artificial world of a game by asking relevant questions during the game, answering the pupils' questions and strengthening dialogues between pupils or between a pupil and the game (Barab et al, 2010; Kangas et al., 2016).

Derived from the research, there are teachers who assess educational games as an unknown area, where they have no time or courage to explore. Some of these teachers see games as a waste of time, because they have not found a suitable game for a certain topic, their own knowledge or experience about games is insufficient, or they are not aware of the methods and products available. (Lean, Moizer, Towler, & Abbey, 2006; Rastegarpour & Poopak, 2012)

Designing and evaluating educational chemistry games

Quality educational games give quality for learning chemistry: with them interest and enjoyment in learning will increase. New educational games should be developed especially in order to underpin a learning process for a certain phenomenon or a concept (e.g. Tüzün, Yilmaz-Soylu, Karakus, Inal, & Kizilkaya, 2009). Also criteria of quality should be set for an educational evaluation of games (Dondi & Moretti, 2007).

A process for designing and executing a new game will take more time than expected, and this might be a problem for teachers with lots of work to do (Galus, 2003). One solution for that is a novel tool in order to develop and evaluate educational card and board games for chemistry education on lower-secondary level (Figure 1) (Tuomisto, 2015). This tool consists of classes and subclasses, which describe features of quality educational chemistry games. Additional details in subclasses ease an interpretation by showing alternative possibilities. Alternatives in bold are the best choices according to the research literature.

Features for a quality chemistry game presented in figure 1 are in consistent with criteria for a quality game in general, with demands for an effective learning environment (Norman, 1993), with the social constructivist perspective for learning and teaching chemistry (e.g. Eilks et al., 2013) as well as with aims for the 21st century skills and with the objectives in lower-secondary chemistry curricula in different countries. Based on this perception, it can be said that both digital and non-digital educational games are one suitable method for teaching chemistry (Tuomisto, 2015).

DESIGN AND EVALUATION TOOL FOR CHEMISTRY-RELATED EDUCATIONAL CARD AND BOARD GAMES ON THE LOWER-SECONDARY LEVEL		
CLASS	SUBCLASS	SUBCLASS DETAILS option for best learning results in **bold**
LEARNING OBJECTIVE	Game has a clear learning objective	
	Knowledge	remembering or repetition, concept or phenomenon, rules
	Skills	motor skills (dexterity, accuracy), application of knowledge, decision making or problem solving,
	Attitudes	social interaction, self-assessment emotional, moral (values)
PREREQUISITES	What pre-knowledge is the student required to have?	
STRUCTURE	Game paraphernalia	playable, visual
	Coherence between game's look and context	
	Availabilty (at the same time)	for one, for one group, **for all**
	Mobility	school, home
	Playing time	**15 min, 30 min**, 45 min
	Clear rules	easy to read, explicit, goal is easy to understand
PEDAGOGY	Unpredictability and uncertainty	
	Multiple difficulty levels	different ways to play, increasing difficulty within game event
	Making thinking visible	discussion, explanation, argumentation, evaluation
	Suitable challenges (zone of proximal development)	
	Problem-solving	
	Coherence between game content and learning objective	
CHEMISTRY CURRICULUM FOR LOWER-SECONDARY LEVEL	Concept or topic included in chemistry curricula	
	Representational levels	macro, sub-micro, symbolic
	Connection to the living environment and everyday life	
	Application of knowledge	
	Critical thinking and multiliteracy	
SOCIALITY ACTIVITY	Number of players	single player, **multiplayer**
	Student interaction	competitive, cooperational, **collaborative**
	Student involvement	rare, **continuous**
	Possibility of assessment	self-assessment, peer assessment
INSTRUCTIONS SUPPORT FEEDBACK	Pregame	instructions, discussion
	In-game	in-game instruction, peer support, teacher support, discussion, feedback, rewards
	Postgame	discussion, feedback
ASSESSMENT	Pregame	preconceptions
	In-game	in-game assessment self-assessment, peer assessment, teacher assessment
	Postgame	questionnaire, self-assessment
FLOW-STATE can be evaluated after playing	Feeling of being present during playing	0-5 (0 = not at all, 5 = continous)
	Feeling of being able to achieve the goal	0-5
	Interest in playing	0-5
	Alternation between feelings of frustration and satisfaction	0-5
	Engagement for playing (intrinsic or extrinsic motivation)	0-5

Figure 1. A novel design and evaluation tool for chemistry-related card and board games on the lower-secondary level helps a teacher. If any of the detail options are in bold, according to the research, it is a better choice than the other quality alternatives (Tuomisto, 2015).

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