Machineers: Playfully Introducing Programming to Children

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Abstract
In this document, the authors present the concept of the design experiment Machineers, a game that is intended to serve as an example of a good educational game by combining a set of game design principles with beneficial learning approaches.

Author Keywords
Educational Game; Stealth Learning; Experiential Learning; Procedural Literacy;

ACM Classification Keywords
K.8.0 [Personal Computing]: General – Games.
K.3.2 [Computers and Education]: Computer and Information Science Education – Literacy.

General Terms
Design.

Overview of the Game
Machineers is a puzzle adventure that teaches logical thinking, problem-solving and procedural literacy to children from 10 to 14 years as a preparation for learning programming. Its core design merges learning content with game mechanics to increase intrinsic motivation. Puzzles are enclosed in a compelling story with stimulating visuals to deflect from its purpose in order to avoid a negative mindset of the player.

The game was developed as part of a Master thesis [6] at IT University Copenhagen, Denmark.

Background Research/Related Work

According to the model of 'three generations of learning games' [1], many educational games follow the behavioristic learning approach from the first generation. Hereby players are conditioned in a drill-and-practice manner to adapt a certain behavior.

Second-generation learning games follow the cognitivistic learning theory and incorporate player attention, focus, curiosity and fantasy. Thus, they enhance motivation of players and enable them to develop a deeper understanding of the learned content.

Most beneficial are 3rd-generation instructional titles based on the constructivist approach whereas players construct understanding through experiences and interaction with the learning content. This is similar to the term experiential learning.

We also determined the approach of scaffolding [7] to be relevant for good learning games, as they guide the learner from supported to autonomous learning.

Design and Development

We assume that merging the learning content and game mechanics enables engaging and intrinsically motivating gameplay. We further claim that educational games need to cater for a broad range of different player types and their needs.

In our research [2, 3] we determined a set of design principles that can have a beneficial affect on the learning experience and attempted to incorporate them into the design of Machineers: agency, immersion, narrative / fantasy, intrinsic motivation, audio-visual stimuli and clear goals [6].

We established the stealth learning approach by presenting the player with an appealing puzzle adventure setting and a polished visual and sound scheme, which can be compared to commercial titles.

Figure 1. Screenshot of Crane Scene in Machineers

Puzzle elements directly represent the behaviour of programming concepts and at the same time appear and behave like familiar everyday objects. This way, players can interact intuitively with learning content and instantly experience behaviour of programming concepts.

The player is guided through the game with a set of different help options that range from pop-up information to on-demand accessible hints in order to please different player types as well as non-gamers.

The design of Machineers involves an advanced mode where players receive more control and freedom over puzzle elements and can use them to build and program their own vehicle. This feature represents

	Boys	Girls
# Test Subjects	12	9
Completion Ratio	10 ~83%	5 ~56%

Table 1. Average completion ratio divided by gender

Option	#	% of Testers
I would like to keep playing and solve more puzzles	11	52%
I would like to build my own machines	3	14%
I would ask my parents to get this game for me	5	24%
I would not play this game at home	4	19%
I would enjoy playing this game at school	8	38%

Table 2. Questionnaire answers to the question "Keep on playing?"

the constructivistic learning approach, and is currently being implemented. Please view our thesis [6] for further details.

Testing and Evaluation

We conducted three tests at different stages during the development of the game with a focus on usability, immersion and motivation. All tests were executed with representatives of the target audience, students from Copenhagen International School.

The tests involved mainly qualitative methods such as Observation, Think-Aloud, and a method we call peer-play. Here two or three children would play together so they would voice problems and strategies.

Figure 2. Children at Copenhagen International School playing Machineers

The results of the tests indicate a positive affect of our approach on immersion and intrinsic motivation. 52.38% of the participants expressed the wish to keep playing after an average completion time of more than 65min. Body postures and facial expressions monitored during playtest suggest that the players were deeply immersed and engaged in the game, which causes high intrinsic motivation.

Our results show that only a very low number of players were bored or overchallenged. The large amount of players stating that the game was fun, ok and/or tricky and challenging implies that the majority of playtesters were challenged, well-guided and in a state of flow.

To further evaluate the game, we asked professionals in the field of educational games, teaching and programming for feedback on Machineers. Amongst others, James Paul Gee pointed out the importance of a network of other media and peers: "*For me, a game needs to be embedded in a whole learning system connecting to other media, curriculum, and social media. Games like [Machineers], it seems to me, are good for what has been called 'preparation for future learning' (a form of transfer). […] The game does look promising*" (Gee, personal communication, July 31, 2012).

"*The central idea of adopting a stealth learning approach to 'experience' logic and programming concepts is greatly articulated. With no explicit reference to what is being learned, developers enable players to undergo a deeper and most valuable learning experience, actively 'constructing' knowledge by solving increasingly challenging mechanical puzzles, set in a story-driven game world with robotic elements." (Anonymous evaluator from Serious Games Showcase & Challenge at I/ITSEC, Orlando, Dec 2012*).

Figure 3. Screenshot of Machineers' Owl puzzle

Conclusions

Our results indicate that integrating good design principles with the appropriate learning approaches helps making advanced learning content easily accessible to a very young audience. The stealth learning approach can facilitate the learning process and minimize a potential bias against educational games while intrinsically motivating the player.

Future Work

It would be interesting to examine how the game could be integrated into a classroom setting and used within a group of peers. Our tests showed that using traditional test methods interferes with the stealth learning approach and can create resistance. In order to avoid this effect, the test needs to be stealthily integrated into the actual game. As an ideal test of understanding of the learned knowledge, an earlier mentioned feature needs to be implemented: The Vehicle Workshop. Here the players will have full access and control over all puzzle elements to build their own vehicle from scratch, and maneuvre it to the next city.

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Links

Trailer: http://youtu.be/LxHKmiIuG5c
Commented Walkthrough:http://youtu.be/LVtOgnpEFXI
Download the Demo:
http://machineers.tumblr.com/download/

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