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Is Game-based Learning as a Computer Game a Benefit for Teaching?

Abstract

Game-based learning (GBL) has gained increasing attention in different areas of school and university teaching and industrial training. We apply game-based learning to laboratory exercises in microbiology. These are composed of a complex ensemble of interconnected parallel processes. Using a game-based simulation, students should get the opportunity to independent and realistic preparation for the experiments. This asks for special requirements in the graphical user interface of the game-based learning application. It should promote independent learning and render the virtual operations in the game transferable to the real laboratory. To do this, the user interface must provide context-sensitive help, give immediate feedback, and contain an evaluation and reward system. We demonstrate the realization of the user interface of the game-based learning application as a virtual laboratory including an assistant as an avatar. The application has been evaluated quantitatively in a field trial with students in a real laboratory. The analysis of the results shows the added value of the application for the participants. It demonstrates in particular the ease of learning and the usability of the interface, as well as an increase in effectiveness for participants using the game-based application.

Keywords

Game-Based Learning, Virtual Laboratory, Evaluation

1 Introduction

Game-based elements are introduced into a learning application by means of playful engagement (Subhash 2018, Koivisto et al., 2019 ; Zainuddin 2020). A more active insight into topics is often achieved than with purely theoretical reading activities (Koivisto and Hamari, 2019). We use GBL to prepare laboratory exercises in microbiology. To complete the experimental workload in the given time frame, it is necessary to strategically plan the se-

quence of steps in concurrent subprocesses so that they interlock optimally. In order for students to optimize the process sequence for themselves before the course begins, we provide a GBL application as preparation (Gers and Prowe, 2014). If the result of this preparation is sufficiently good, the experiment takes place as usual in the laboratory under personal supervision. The GBL application is intended to provide the most realistic preparation possible for microbiology laboratory exercises. The realistic representation and animation of working environments are essential to the learning process (Sailer, 2020) and for transferring what has been learned to the real laboratory. We formulate the requirements for the user interface of the GBL application, implement them as a Graphical User Interface (GUI), and evaluate the GUI and the overall effectiveness of the GBL application in a field trial.

2 The GBL application

The GBL application for preparing laboratory exercises contains a simulation of the procedures to be performed in the real laboratory. The GBL application is based on a form of logic that maps the complexity of the laboratory experiment procedures onto a network structure (Gers and Prowe, 2014). This network structure links strands of workflows that must be correctly processed and timed. Students must strategically plan the sequence of steps in concurrent subprocesses so that they interlock optimally. Only in this way can the experimental workload be completed successfully within the specified time frame.

2.1 The User Interface

The graphical user interface of the GBL application, as a realistic representation of the laboratory, is shown in Figure 1. The GUI allows direct manipulation of all displayed components using the computer mouse or other pointing devices. Initially, a virtual shelf contains all the initial products and the tools necessary for the experiment. In addition, in the course of an experiment, the intermediate products created are added. The display and position of each product in the virtual lab are determined by the application. The player can combine products, according to the hidden process logic, using drag & drop. By doing so, they apply a tool if necessary, or use laboratory apparatus, such as a centrifuge. For some steps in the process, such as stirring or shaking, small skill games must also be completed. A

lab assistant avatar accompanies the player throughout the experiment. He supports the player with praising and reprimanding comments as well as practical help, which are spoken and appear simultaneously in a speech bubble.

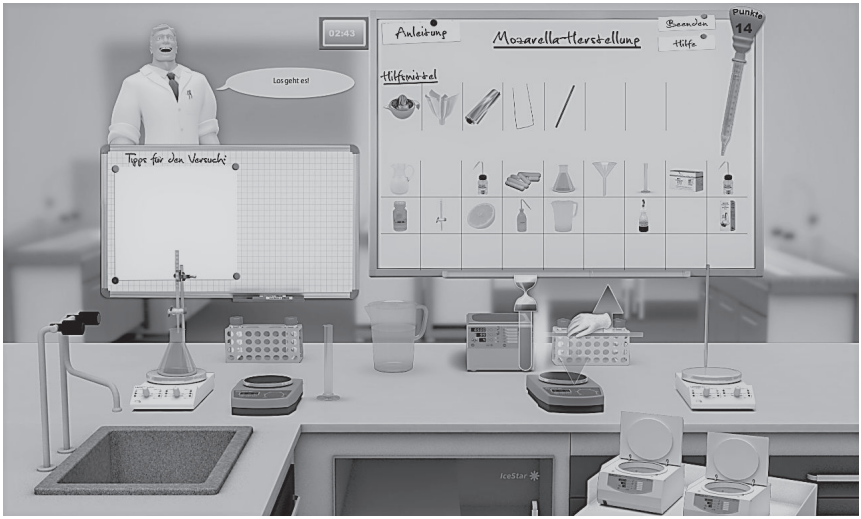

Figure 1: The virtual laboratory (text in German)

3 Field Trial

The GBL application was evaluated in a field trial with two study groups (Gers and Prowe, 2014). Both groups completed the experiment simultaneously in the same laboratory. All participants were from the same semester of study and were randomly assigned to the groups. One study group prepared using the GBL application in addition to the printed instructions. They repeated the GBL application until each participant felt well enough prepared before the experiment in the laboratory took place (which was a maximum of five repetitions of the virtual experiment). The instruments used for quantitative evaluation were a questionnaire, observations by the laboratory supervisor, and the results achieved in the GBL application.

3.1 Results

The learnability, usability, and design of the GBL application were rated as positive. The students rated the application as very helpful for planning the workflow in the laboratory. If we compare the two test groups, the study group with the GBL preparation made significantly fewer errors and completed the laboratory experiment faster.

4 Summary

A GBL application was developed for the preparation of laboratory experiments for students. Its GUI is a realistic representation of a laboratory, in which all steps of a real experiment can be virtually reproduced by direct manipulation. A lab assistant avatar accompanies the user with praise, reprimands, and hints. The learner is supported by context-sensitive help regarding all components and tools used in each particular experiment. The context of the help is not only object-related but also time-related, i.e. it also refers to the current state within the workflow of an experiment. In a field experiment, the GBL application was evaluated positively overall; this is especially true for the learnability, usability, and design of the user interface (GUI). Participants indicated that the GBL application helped them in planning the laboratory experiments. By preparing using GBL, they made fewer mistakes when conducting experiments in the lab.

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