Virtual Reality Instruction Followed by Enactment Can Increase Procedural Knowledge in a Science Lesson

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ABSTRACT

A 2X2 between-subjects experiment (a) investigated and compared the instructional effectiveness of immersive virtual reality (VR) versus video as media for teaching scientific procedural knowledge, and (b) examined the efficacy of enactment as a generative learning strategy in combination with the respective instructional media. A total of 117 high school students (74 females) were randomly distributed across four instructional groups – VR and enactment, video and enactment, only VR, and only video. Outcome measures included declarative knowledge, procedural knowledge, knowledge transfer, and subjective ratings of perceived enjoyment. Results indicated that there were no main effects or interactions for the outcomes of declarative knowledge or transfer. However, there was a significant interaction between media and method for the outcome of procedural knowledge with the VR and enactment group having the highest performance. Furthermore, media also seemed to have a significant effect on student perceived enjoyment, indicating that the groups enjoyed the VR simulation significantly more than the video. The results deepen our understanding of how we learn with immersive technology, as well as suggest important implications for implementing VR in schools.

Keywords: Virtual Reality, generative learning strategy, enactment, learning, procedural knowledge.

1 INTRODUCTION

With recent advances in immersive technology and proliferation of VR devices in today's technosphere, novel ways of enhancing student learning have emerged in the educational scene [2],[4],[7],[9]. This growing availability of immersive VR technology for education also creates the need to determine if and how immersive VR affects and shapes learning and comprehension [6],[9]. Although the technological upsurge certainly has proposed a paradigm shift in education, research suggests that learning with VR only works in terms of learning outcomes when the technology is appropriately implemented based on scientific learning principles, where students construct knowledge through class-room activities, contextualized to their social and material world [1],[3],[8]. Preliminary research shows that activities, such as generative learning strategies in combination with VR in a science lesson.

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[5],[9]. The present study addresses these issues by comparing student learning about DNA polymerase chain reaction (PCR) procedures through immersive VR with learning through a video, containing identical content, both with or without a generative learning strategy. The generative learning strategy chosen for this study was enactment. It involves engaging in task-relevant actions during learning by manipulating respective objects in coordination with the lesson content, making it particularly relevant for learning procedures in simulated environments[5].

Based on previous research on generative learning strategies [5] and enactment [8], we specifically predict that students will exert more generative processing in the immersive VR conditions, which will lead to deeper learning and better knowledge transfer, particularly for procedural knowledge, as compared to the video condition. Furthermore, we hypothesize that students in the enactment conditions will use more time to reflect on the material which will lead to deeper learning and transfer and more procedural knowledge than in the non-enactment conditions. An interaction between media and method for the outcomes of procedural knowledge and transfer, where the immersive VR with enactment condition outperforming the other groups, is therefore expected.

2 METHOD

A total of 117 Danish high school students (74 females) from three different schools in Denmark participated in a 2x2 between-subjects experiment with random assignment to four experimental groups – VR and enactment, video and enactment, only VR, and only video. Participants learned about the PCR technique through either a video or an immersive VR simulation, with or without enactment as a generative learning strategy. Data from 7 students were excluded from the analysis due to technical problems; resulting in the following sample distribution: VR (n = 27), VR with enactment (n = 26), Video (n = 29), Video with enactment (n = 28).

2.1 Materials

An interactive immersive VR learning application (see Figure 1a) "Polymerase Chain Reaction Virtual Lab simulation" by Labster was used. The simulation revolves around a crime-scene investigation involving forensic analysis of the collected DNA sample in a realistic laboratory environment and supplementary animations of micro-level biological processes such as DNA replication. For the VR conditions, the simulation was administered with a Samsung Galaxy S8 device using Oculus' Samsung Gear VR headsets. For the video conditions, a high-quality recording of the simulation was used. The interactivity in the VR groups occurred through movement of the head, allowing the learner to control where they focused their attention in the 360-degree virtual environment, at their own pace.

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For the video groups, students were able to click pause/play if needed. To support students in the enactment conditions, specialized props where provided in the form of printed out lab tools (see Figure 1b).

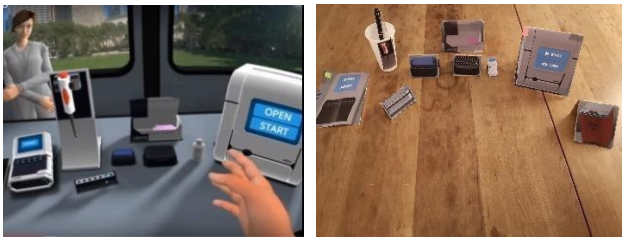

Figure 1a-b: (a) Screenshots from the Labster "Polymerase Chain Reaction Virtual Lab Simulation" (left), and (b) Specialized props in the form of printed pictures of lab tools (right).

The pre-session survey included demographic questions and a prior knowledge scale. The post- test included a three-item perceived enjoyment scale, and three tests for evaluating the participant's learning outcomes: Declarative knowledge (22 multiple-choice questions); procedural knowledge (3 open-ended, and 3 multiple choice questions measuring student retention of specific procedures); and knowledge transfer (1 open-ended question designed to measure how well participants were able to use the knowledge from the lesson in a different context).

2.2 Procedure

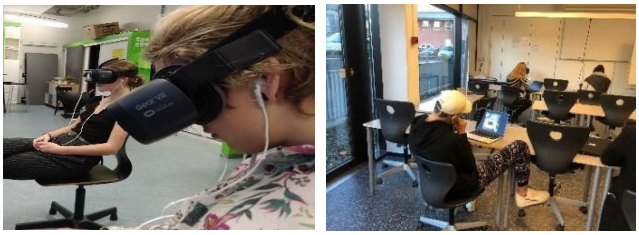

Figure 2a-b: (a) VR condition (left) and (b) video condition (right)

Experimental procedure. Experimental procedure was as follows: 1) briefing, signing of consent forms, random assignment to experimental conditions, 2) pre-session survey, 3) student reallocation to different classrooms (one per experimental condition), 4) introduction to the instruction condition (e.g. VR controls and mounting for VR groups; video controls for video groups), 5) instruction/intervention (VR or video), 6) individual enactment drill (only for VR enactment and video enactment conditions), 7) post-session survey (all the four treatment conditions), 8) debriefing and discussion regarding the experiment.

Enactment procedure. In the enactment conditions (see figure 3) students were asked to manipulate the provided props to enact the laboratory procedure they had observed during the instruction, as accurately as possible. The enactment took a total of 6 minutes and was performed individually in supervised, uninterrupted sessions.

Figure 3: Enactment Condition

The specialized props were not visually present during the intervention to prevent priming the students.

3 Preliminary Results and Conclusions

There were no significant gender differences between the groups based on a chi-square test, X^2 (3, N = 110) = 0.734, p = .059, or the mean prior knowledge score based on a t-test, t (106) = 0.922, p = .433. Mixed model ANOVAs with media (immersive VR vs. video) and method (enactment vs. no enactment) as independent variables, and retention, procedural knowledge and transfer as the dependent variables were conducted. The results indicated that there was no significant interaction between media and method for the outcome of retention $F_{(1,106)}$ =2.884, p =.092. Furthermore, there was no significant effect for media $F_{(1,106)}$ = 0.852, p =.525, or method $F_{(1,106)}$ = 0.703, p =.556. The interaction for the outcome of transfer was also not significant $F_{(1,106)}$ =1.116, p =.293. Furthermore, there was no significant effect for media $F_{(1,106)}$ = 0.490, p =.611, or method $F_{(1,106)}$ = 0.225, p =.718. Conversely, there was a significant interaction between media and method for the outcome of procedural knowledge $F_{(1,106)}$ = 4.028, p =.045. Post-hoc independent samples t-tests run to investigate the source of the interaction indicated that within the immersive VR condition, the group that trained the procedure through enactment (M = 13.81, SD = 7.01) scored significantly higher on the procedural knowledge test than the group that did not enact the procedure after using the VR simulation (M = 9.07, SD = 6.03) $t_{(51)}$=2.637, p = .011, d = 0.73. Finally, a main effect of media on perceived enjoyment was found $t_{(108)}$ = 3.589, p =.001. Results indicate that procedural knowledge acquisition in VR could benefit from added enactment generative strategies. These findings deepen our understanding of how we learn in VR and provide important guidelines for using VR in schools.

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