Examining the Efficiency of Feedback Types in a Virtual Reality Educational Environment for Learning Search Algorithms

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Abstract. Feedback constitutes a fundamental aspect of educational systems that has a substantial impact on students learning and can shape their mental models. The delivery of appropriate feedback in terms of time and content is crucial for facilitating students' knowledge construction and comprehension. In this paper, we examine the complex nature and the efficiency of feedback in the context of a virtual reality educational environment. More specifically, we study the effect that different types of feedback such as feedback with visualized animations of procedures, can have on students learning and knowledge construction in a virtual reality educational environment for learning blind and heuristic search algorithms. An experimental study was designed where participating students were engaged with learning activities and solved exercises in different feedback conditions. Results from the study indicate that visual types of feedback can have a substantial impact on students' learning, assisting them in better understanding the functionality of the process studied with respect to performance and mistakes.

Keywords: Feedback Efficiency, 3D Virtual World, Learning Analytics, Search Algorithms

1 Introduction

Learning is a very complex mental process which is scaffolded and affected by a wide spectrum of factors. A factor that has a substantial impact on the efficiency of learning procedures and the construction of learners' mental models is the type of feedback offered to them [18]. Indeed, feedback is one of the most powerful factors to enhance learning and via feedback the behavior and the mental models of students can be enhanced and properly shaped. In this context, feedback can serve on mental level as reinforcement that shapes behaviors and supports learning [12] [17].

In educational environments the delivery of the appropriate feedback to learners which will assist the construction of their mental model and their understanding is highly desirable [5][19]. Various studies have examined the functionality and the effectiveness of types of feedback in tutoring systems [10] [15] [16] and research

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findings point out that different types of feedback can have effect on a different level and degree to the learning processes of students [1] [2] [11].

Over the last decade, educational environments that are based on virtual reality have the potential to offer innovative learning activities and training procedures to learners. The 3D virtual reality environments naturally allow more complex interactions and increase interactivity and also scaffold more constructive models of learning [3] [4]. Although intelligent educational systems have been used for a long time and the effects of feedback have been widely studied, the delivery of appropriate feedback in virtual environments and the examination of their efficiency and impact on students learning are yet to be explored.

In this work, we examine the efficiency and the effect that different types of feedback have on comprehension and knowledge construction of students in a virtual reality educational system for learning search algorithms. More specifically, we analyze students learning actions and performance with respect to the feedback type they received by the system. In this context, to do this, participating students were engaged with learning activities and solved problems in different feedback conditions and after that they were assessed in their ability to transfer their knowledge and understanding to different problems and exercises that had the same underlying structure. The main finding indicates that the delivery of visualized feedback to learners can have a substantial impact on their learning and assisted them in understanding and connecting abstract concepts such as heuristics and backtracking to concrete examples.

The reminder of the paper is structured as follows: Section 2 presents the virtual reality educational environment, describes its capabilities and illustrates the types of feedback offered to learners. In Section 3, the experimental study designed and conducted with the aim to assess the efficiency of the feedback types is presented and the main findings of the study are examined. Finally, Section 4 concludes the paper and provides directions for future work.

2 The 3D Virtual World Environment for Teaching Search Algorithms

2.1 Learning activities in the virtual world educational environment

The 3D virtual world environment offers immersive learning processes to the students and gives them various opportunities to explore how algorithms operate via a wide range of learning activities [7]. Students in the virtual world can participate in learning activities and solve exercises that necessitate them to correctly apply algorithms. In this context, students can solve predetermined mazes in the virtual world under different conditions and in a specific amount of time. The various learning activities are designed in the spirit to necessitate students to apply a specific search algorithm and properly move in a maze by simulating the way that the algorithm functions in order to accomplish the level's requirements. The mazes require in general from the learner to reach a specific point in the maze by moving according to a specific algorithm. In this approach, students are requested, starting from a random position in a maze, to reach the goal (e.g. exit, specific item etc.) by moving based on the specific search algorithm that the maze specifies.

Fig. 1. An example learning activity in a maze

The learning activities and the mazes are designed based on the principle of active learning that maintains that the more the users directly manipulate and act upon the learning material, the higher the mental efforts and psychological involvement and therefore the better the learning outcome [13]. Also, learning activities have been designed in a way that supports students forming appropriate mental models of involved concepts, by visualizing them and allowing interactions with the virtual phenomena and processes.

2.2 Feedback in the Virtual Reality Educational Environment.

Various types of feedback have been designed and offered to learners. In general, feedback during the learning activities comes as messages that appear in a text area in the users' interface. These messages that are delivered to the user can vary in the information that they contain and also in the way they are presented. For example a message can inform the user about the correctness of an action that he/she made, present the corresponding theory involved in the learning activity or even present a visualization of the algorithm's functionality.

More specifically, the types of feedback offered to students in virtual reality educational environment are Knowledge of Result (KR), Knowledge about Concepts (KC) and Knowledge of Correct Response (KCR). Knowledge of Result is offered to student to inform whether the selection/action/move based on the learning activity is correct or not. Knowledge about Concepts provides students with appropriate hints and explanations on the terms and the processes involved in the learning activity. The content of Knowledge about Concepts feedback can vary based on the characteristics of the learning activity and the search algorithm involved. Indeed, two types of KC feedback are designed and offered to learners. The first type is the textual KC feedback where textual messages of the corresponding concepts are delivered to students. The second type is the visual KC feedbacks, where the involved aspects and concepts in the learning activity are delivered to students via proper visualized animated examples. The aim of the visual KC feedback is to help students connect abstract concepts and procedures to concrete experiences and examples. Indeed, it can be hard for students to learn new abstract concepts, without appropriate connection to concrete examples [14]. Finally, the third type of feedback examined Knowledge of Correct Response is used to provide students with the correct answer or a part of it. The KCR feedback type can be provided to a student after a request for help or after consecutive errors on an exercise.

3 Experimental Study

3.1 Method

An experimental study was conducted in order to assess the learning effectiveness of the feedback types offered in the virtual reality educational environment and the degree to which they affect student's learning. The participants were 65 students that were in the 4th year of their study. The participants were randomly divided into two groups, named GroupA and GroupB respectively. GroupA consisted of 32 students, where 15 were female and 17 were male and GroupB consisted of 33 students where 16 were female and 17 were male.

To assess the learning effectiveness and the effect of feedback on students learning a pre-test and post-test study design was followed. The experimental study consisted of three main phases which are the pre-test, the learning phase and the post-test. The overall structure of the evaluation study is illustrated in Figure 2. Initially, all the participants were given a pre-test on search algorithms. In the pretest, the students' were asked to apply blind and heuristic search algorithm on various problems and cases and the duration of the test was 60 minutes. The pretest was used to ensure the two groups had equivalent prior knowledge on AI search algorithms.

After the pretest, the learning phase took place. The duration of the learning phase was three weeks and the students of the two groups were given access to the 3D virtual world educational environment where they participated in the same learning activities and solved the same sets of exercises under different feedback conditions. More specifically, the students of GroupA interacted with the virtual world in a concept were the Knowledge about concepts type of feedback was provided to them via proper textual messages. On the other hand, the students of GroupB interacted with the virtual world and studied in a context were the Knowledge about concepts type of feedback provided them with appropriate visualizations with respect to the algorithm studied in the learning activity.

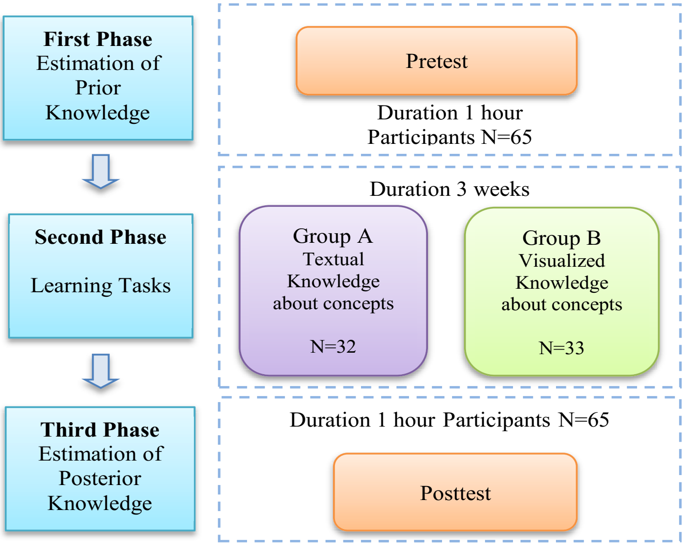

Fig. 2. The phases of the experimental evaluation study

Finally, the students of the two groups took the posttest and were assessed in their ability to transfer their knowledge and understanding to different problems and exercises. The duration of the posttest was 60 minutes and it consisted of exercises and activities that were of the same difficulty level and complexity compared to the pre-test [8][9]. All the students' answers were assessed automatically in a consisted manner by automated assessment mechanisms [6].

3.2 Results

A preliminary analysis of the pre-test was performed using one-way analysis of variance (ANOVA) to investigate that here was no significant difference between two groups on the pre-test performance. The participants of GroupA had a mean pre-test score of 4.11 (SD=0.50) and those of GroupB a mean pre-test score of 4.31 (SD=0.71). The results show that there were no significant initial differences between the pretest group means ($F=1.87>1$, $p=0.176 > 0.05$).

In addition, an Analysis of Covariance (ANCOVA) was conducted to extract the difference between the groups using the pre-test scores as the covariate and the post-test scores as dependent variables. The ANCOVA results indicate that the differences in post test scores are statistically and significantly different between the two groups ($F(1, 62)=125.6$, $p=0.000 <0.01$). The effect size (Cohen's d) is 0.818, which is a significant enhancement. Table 1 summarizes the results of the pretest and post-test where the mean of posttest scores were 6.47 for GroupA and 8.44 for GroupB respectively.

Table 1. Results of Pretest and Posttest for two groups

Group	N	Pretest		Posttest		Normalized Gain
		Mean	SD	Mean	SD	
Group A (Textual KC)	32	4.11	0.50	6.47	0.65	0.40
Group B (Visualized KC)	33	4.31	0.71	8.44	0.73	0.72

Moreover, the results showed that the performance of the students of GroupB, who studied in the educational environment with the assist of KC feedback in terms of visualized animations, was better than that of GroupA who studied with the assist of textual only KC feedback.

4 Conclusions

Feedback is acknowledged to be a fundamental aspect of learning and the design and provision of appropriate feedback type in terms of content and presentation is crucial for the learning capabilities of educational systems. In this work we examined the efficiency of feedback in a virtual reality environment for learning search algorithms. Specifically, we examined the effect that knowledge about concepts feedback provided in visualized and in textual form have on students learning. The main findings of the experimental study indicate that the delivery of visualized feedback can have a greater impact on learners understanding and their knowledge construction compared to textual form.

There are various directions that future work will examine. Firstly, a bigger scale evaluation study could be designed to provide a more analytical understanding of the efficiency of additional feedback types. In addition, learning analytics methods could be examined with the aim to analyze learners' behavior after the delivery of each type of feedback in terms of mistakes and also shed light on learners' metacognitive behavior. Finally, additional types of formative feedback based on the analysis of the types of the errors made by the student will be designed and integrated into the educational system with the aim to enhance the learning capability of the system.

References

1. Attali, Y., & van der Kleij, F. (2017). Effects of feedback elaboration and feedback timing during computer-based practice in mathematics problem solving. *Computers & Education*, *110*, 154-169.
2. Butler, A. C., Godbole, N., & Marsh, E. J. (2013). Explanation feedback is better than correct answer feedback for promoting transfer of learning. *Journal of Educational Psychology*, *105*(2), 290.

3. Christopoulos, A., Conrad, M., & Shukla, M. (2016). How Do Students 'Really' Interact with Virtual Worlds? - The Influence of Proper Induction for Virtual Interactions. In *CSEDU (1)* (pp. 43-54).
4. De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology*, *41*(1), 69-85.
5. Goldin, I. M., Koedinger, K. R., & Aleven, V. (2013). Hints: You Can't Have Just One. In EDM (pp. 232-235).
6. Grivokostopoulou, F., Perikos, I., & Hatzilygeroudis, I. (2017). An educational system for learning search algorithms and automatically assessing student performance. *International Journal of Artificial Intelligence in Education*, *27*(1), 207-240.
7. Grivokostopoulou, F., Perikos, I., & Hatzilygeroudis, I. (2016). An innovative educational environment based on virtual reality and gamification for learning search algorithms. In Technology for Education (T4E), 2016 IEEE Eighth International Conference on (pp. 110-115). IEEE.
8. Grivokostopoulou, F., Perikos, I., & Hatzilygeroudis, I. (2017). Difficulty Estimation of Exercises on Tree-Based Search Algorithms Using Neuro-Fuzzy and Neuro-Symbolic Approaches. In *Advances in Combining Intelligent Methods* (pp. 75-91). Springer International Publishing.
9. Grivokostopoulou, F., Perikos, I., & Hatzilygeroudis, I. (2015, November). Estimating the Difficulty of Exercises on Search Algorithms Using a Neuro-fuzzy Approach. In *Tools with Artificial Intelligence (ICTAI), 2015 IEEE 27th International Conference on* (pp. 866-872). IEEE.
10. Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research*, *77*(1), 81-112.
11. Koedinger, K. R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review*, *19*(3), 239-264.
12. Le, N. T. (2016). A classification of adaptive feedback in educational systems for programming. *Systems*, *4*(2), 22.
13. Lee, M. H., & Rößling, G. (2010). Integrating categories of algorithm learning objective into algorithm visualization design: a proposal. In Proceedings of the fifteenth annual conference on Innovation and technology in computer science education (pp. 289-293). ACM
14. Ma, T., Xiao, X., Wee, W., Han, C. Y., & Zhou, X. (2014). A 3D Virtual Learning System for STEM Education. In Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality (pp. 63-72). Springer International Publishing.
15. Mory, E. H. (2004). Feedback research revisited. Handbook of research on educational communications and technology, 2, 745-783.
16. Narciss, S., Sosnovsky, S., Schnaubert, L., Andrès, E., Eichelmann, A., Goguadze, G., & Melis, E. (2014). Exploring feedback and student characteristics relevant for personalizing feedback strategies. *Computers & Education*, *71*, 56-76.
17. Perikos, I., Grivokostopoulou, F., & Hatzilygeroudis, I. (2017). Assistance and feedback mechanism in an intelligent tutoring system for teaching conversion of natural language into logic. *International Journal of Artificial Intelligence in Education, 27(3),* 475-517.
18. Shute, V. J. (2008). Focus on formative feedback. *Review of educational research*, *78*(1), 153-189.
19. Woolf, B. P. (2010). Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning. Morgan Kaufmann.