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GAME-BASED LEARNING AND THE ROLE OF FEEDBACK. A CASE STUDY

Daniel Burgos[1], Christof van Nimwegen[2], Herre van Oostendorp[2] and Rob Koper[1]

[1] Open University of the Netherlands, Educational Technology Expertise Centre
Valkenburgerweg 177, 6401DL, Heerlen, The Netherlands
{daniel.burgos, rob.koper}@ou.nl

[2] Utrecht University, Center for Content and Knowledge Engineering
Padualaan 14, 3584CH, Utrecht, The Netherlands
{christof, herre}@cs.uu.nl

Abstract

Educational electronic games and simulations (or simply educational eGames) engage players. They are attractive to awake and keep the focus of a user, and are useful for learning while covering learning objectives and playable goals. In eGames, feedback can improve learning and help the learner to take decisions about his strategy and it also encourages the learner's motivation. However, too much feedback can in some situations lead to a weaker strategy by the learner to solve the problem presented, resulting in a lower performance.

In this paper, we first show the relevance of eGames for learning and its relation with feedback. We introduce the need for appropriate feedback in order to get a better performance, but we also state that feedback depends on the context and on the game and that it is not always required in order to achieve the best performance while solving a problem. We carried out a case study (Planning Educational Task) with real learners/players, to study the differences between having and not having instant destination feedback while solving a problem. We discuss the results and implications of the case study, namely that in the context of our planning game, leaving feedback out improved performance.

Keywords

Feedback, destination feedback, eGames, problem solving, program interface

1. Introduction and background

1.1. Electronic educational games and simulations

Gaming and learning can become a perfect marriage. In order to achieve educational goals, several interactive learning techniques can be used in, or in connection with games. Some examples are learning from mistakes, goal-oriented learning, role playing and constructivist learning [1]. When playing games, one of the most commonly applied *strategies* is trial-and-error. Trial-and-error behaviour of a learner during playing is characterized by the absence of a systematic strategy [2], although at the same time it is a primary way to learn and to keep the player motivated. The mentioned learning techniques can be implemented in games, so that the game itself becomes fully integrated in the learning process, instead of remaining an isolated stand-alone resource. In doing so, any generic game can be an educational game if fully integrated in a learning process [3]. Furthermore, teachers are able to make good use of generic games, educational games and simulations in their daily teaching activities. However, a better development of an integrated model is needed in order to achieve learning goals better and to fully take advantage of the power and potential of games in education [4].

EGames are attractive, addictive, fashionable and elicit emotional reactions in players, such as wonder, the feeling of power, or even aggression [5]. Engagement and educational goals can mutually support each other in the same environment to achieve specific targets focused on, i.e., learning content, researching human relationships, improving personal and social skills and working on strategies [6]. This last topic, strategy, is at the base of the case study presented in section 2.

1.2. What is feedback

Feedback is critical for learning as it provides support on the educational process and motivation [7] and feedback is also an important feature of games. Several authors stress the importance of feedback in learning and eGames. They state that specific, contextual and instant feedback based on goal commitment increase the effort, the performance and the motivation of the learner. They also advocate the use of feedback to support game-based learning as a way to provide the learner with useful and immediate information about his performance.

In the definition of Mason & Bruning [8] feedback is defined as *any message generated in response to a learner's action*, usually after something is done. It implies that there is an interactive flow between the learner and the system, coming from some information collected or generated by the learner and coming back to him as an output after some processing. Furthermore, this information flow is seen as a series of frequent inputs and not as a single one, because it is a part of the entire learning flow [9]. Through appropriate feedback, the learner is able to receive some information concerning the way he acts and learns. This enables him to assess his own progress regarding his goals and actions, and he is able to make a consequent choice about the next action to take or even about the strategy to follow.

Since the widespread introduction of Graphical User Interfaces (GUI), it was common to stick to guidelines such as for example the ones that Apple started to provide from 1992 onwards [10]. One of the guidelines is to keep users informed about what is happening by providing appropriate feedback and enabling communication with the application. A few years after GUI's and WYSIWIG interfaces became common however, Gentner and Nielsen [11] considered to bring some flexibility into the feedback and dialogue provided by the system. They pondered that the computer could provide detailed feedback to familiarize the user with operations and instill confidence. Later, the feedback could be scaled back over time and restricted to unusual circumstances or times when the user requests more feedback.

Furthermore, not all authors agree on the positive effects of feedback. Halttunen and Sormunen [12] stress the different perception that users have about performance feedback and how users can be distracted on their strategy trying to improve on their results automatically, without analysis. In addition, educational eGames and simulations are usually played in an unpredictable way by the player, which provides some values based on performance with feedback that could be too complex or not specific enough to make it useful or even easy to understand or to apply [13]. In addition, once some feedback is provided its use by the learner is uncertain, meaning also a reduction of the performance [14].

1.3. Types of feedback, destination feedback and eGames

There are several ways to provide feedback based on the learner's performance, the learning history or the learning goals. Mory [15] describes two main types of feedback: instructive and informative. Instructive feedback is related to the knowledge domain and informative feedback is related to the context where learning takes place. While instructive feedback leans on a corrective intervention on the learning process, informative feedback is focused on self-regulation. In addition, there are four main types of indicators in informative feedback: 1) related to performance, 2) related to process, 3) related to social interactions and 4) related to environmental interactions.

There are still other types of feedback, such as *destination feedback* [10]. For instance, when a user drags an item from its place to a destination, the application provides feedback that indicates whether it will accept that item. This type of feedback informs the user about the possible actions that can be taken, for instance, externalizing information by *greying-out* items. In this sense, only *recognition*, not *recall*, is needed here for task performance, and this can relieve working memory [16]. In the opposite situation, when no such features are provided, a user has to *internalize* the information himself, and store this information in his/her memory.

The concept of *destination feedback* can be interesting in Game-based learning. Providing guidance or assistance in complex situations and trying to relieve the working memory of students so that they can devote attention to development of proper strategies can seem promising in this context. However, instead of beneficial properties, one can also ponder that having this kind of destination feedback might cause users to behave less proactive and lazy, and do less *thinking before you act*. Research by O'Hara and Payne [17] provides support for this notion using a similar approach to internalization and externalization and stating that a too strong reliance on external information leads to negative effects regarding planning and transfer of skills. Also, Svendsen [18], who used the Towers of Hanoi problem, showed that a high-cost interface yielded improved understanding of problems. The notion that too much feedback could be counterproductive while playing a game based on planning, led us to do a case study with real learners, as we show in the next section.

2. The case study: Planning Educational Task (PET)

2.1. Game description and setting

There are several definitions of what a game is but there is no concluding agreement. We define a game as a structured activity with rules, challenge and interactivity pursuing an outcome, that provides enjoyment and entertainment and can be used for educational purposes [19]. In this sense, a game can be called a puzzle when there is no active agent to compete against [20]. Bearing this definition in mind, and based on previous research by van Nimwegen et al. [21], we developed a puzzle called Planning Educational Task [22], which simulated the planning of speakers for a conference. There were two versions: A *feedback* version, and a *no feedback* version. The feedback version provided visual destination feedback related to the learner's actions and moves so far. In the Planning Educational Task, students can first be expected to start to explore the application and in the meanwhile work towards the imposed goal: solving the problem. A routine or strategy will not be available in the beginning. Therefore, students will need to explore and discover in a probably non-structured manner, which can be compared as the absence of a systematic strategy when a learner plays [2]. The Planning Educational Task focused on the opposition between externalization and internalization of information in the interface, corresponding to the difference between respectively providing and hiding visual feedback as long as the player tries to solve the problem. This feedback is fostering orientation on what to do next and is guiding the player in the sense that it shows which choices are available. However, when moves are made, the player is at all times allowed to undo the taken action(s) and to go backwards to establish a new strategy to follow. This strategy is partially based on trial-and-error movements, although the level of risk that a player takes in every movement could be different depending on the level of provided feedback, as we show in the coming sections.

The study was conducted in the Usability Lab at the Center for Content and Knowledge Engineering, Utrecht University. 43 students participated (17 male, 26 female, 19 to 32 years old). The experiment took at most one hour and subjects received a €5 reward. We developed an Open Source software application called *Conference Planner* which simulated the planning of speakers for a conference. The software logged all the moves participants made. The *Conference Planner* was developed by The Open University of The Netherlands and funded by the European UNFOLD Project [23]. It consists of four different components. The first one is the dynamic interface that shows each set of demands for a conference and allows the end-user to solve the problem in an easy way, based on drag & drop movements. The second one is the core of the application itself: the set of rules and related algorithms. Here is defined which actions are permitted, based on the requirements of the experiment and which are the subsequent consequences. The third component is a database, with all the scenarios used in the experiment. The fourth component is the logging-module that writes all the clicks and drag & drop moves and their associated timestamps, as well as waiting times during non-activity to an external spreadsheet. The logs provide data for analysis of the results.

In the experiment, the students had to solve 5 different conference scheduling situations. The conference speakers each had different demands, and they had to be scheduled into one of three available rooms (each with its own facilities and availability). This type of task requires a certain approach to solve the situation in an efficient manner. When facing the problem, subjects can take multiple (correct) approaches to schedule the speakers. Even with more correct solutions existing, without some degree of planning, the scheduling will not be optimal and extra moves (corrections on the assignments so far) will be needed.

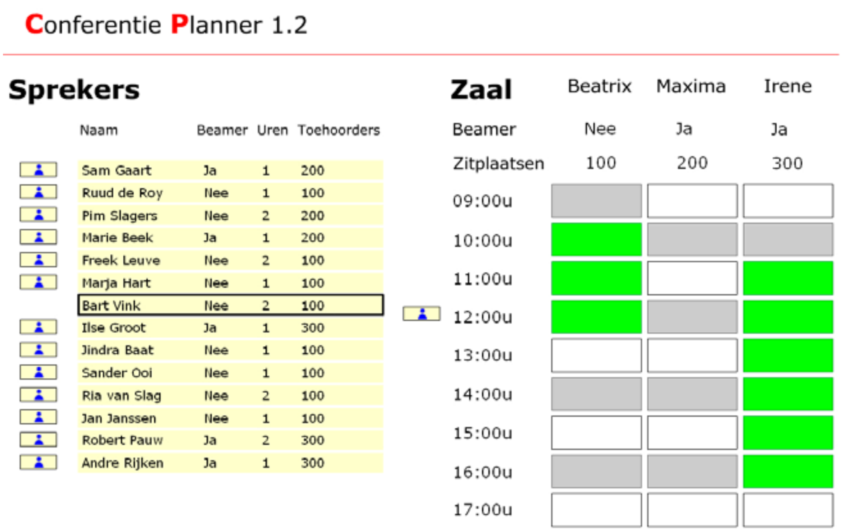

Figure 1: Conference Planner, *feedback* version: (when a speaker is picked up, legal timeslots turned green)

The difference between *feedback* and *no feedback* was implemented by highlighting all legal slots in the *feedback* version where a person can be placed. In this version (fig. 1), when one clicks on a speaker in the list on the left, the legal slots (those satisfying the constraints and being available) in the timetable turned green. Note that this does not show the best slot to place a speaker, but simply which slots are possible. To move a speaker from the left to a slot on the right, the little boxed icon in front of each speaker's name had to be *picked up* and *dragged* to its destination slot with the mouse. Not all the timeslots in the grid are always available. Some where unavailable all the time, indicated with light-gray, for example the timeslots during lunchtime (13:00), but also some arbitrary other slots. The empty available timeslots were shown in white, and the ones that were already occupied by a speaker would display the name of a speaker. In the internalization condition the green feedback was absent, and one has to look up information and constraints by one self all the time (fig. 2). No other differences existed between the two conditions.

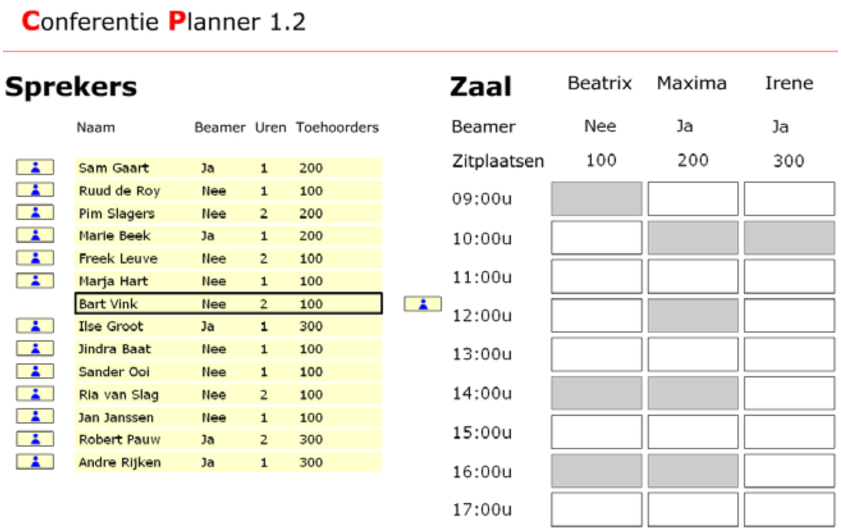

Figure 2: Conference Planner, *no feedback* version

In both conditions, a list of speakers who had to be scheduled was given on the left. Each speaker had his/her own constraints displayed next to them, which could vary on a maximum of three variables: Projector (*beamer* in Dutch), Number of hours and Number of attendees. The assignment was to place all the speakers on the schedule timetable, while taking the different constraints into account. A solution where each speaker was scheduled (and all the constraints were met) always existed. The students had to perform 5 tasks with different settings. We collected several time-based and move-based measures (table 1).

Table 1

Time-based and move-based measures

Total time needed	The average time needed to solve the tasks
Time before first move	The time between the moment the problem appears on-screen and the first move. It is an indicator for planning, telling how long subjects analyzed the problem before they started solving it
Inter-move latency	The time that passes between having placed a speaker, and picking up the next. We interpret this measure as a planning indicator
Superfluous moves	The problems have a shortest path solution, with an optimal amount of moves (speakers dragged from left to right) to solve them; any other movement is superfluous. We use this measure as the main performance measure, because it reflects the efficiency with which the task has been solved
Knowledge	Assessment afterwards with essay questions about pictures of situations that were either legal or illegal given the constraints. It had to be decided whether or not certain situations could occur, and why (or why not)
Strategy	We looked (per task) at whether or not subjects started solving the problem with the best strategy, by first moving the speakers who had the most stringent constraints. When this is done, one can assume that some amount of planning has happened

2.2. Results of the PET case study

We statistically analyzed the effects of having feedback vs. no feedback using ANOVA. We report on significant effects using a significance level of $p < 0.05$. Results with p-values between 0.05 and 0.10 are reported as tendencies. All the tasks were eventually solved correctly by all the students in the two versions of the task. Table 2 shows the results, followed by the interpretation of the data in table 3.

Table 2

Scores on dependent variables split between *feedback* and *no feedback*

Dependent variables	Feedback		No feedback	
Average per task * indicates significant difference at α = 5%	Mean	SD	Mean	SD
Total time needed to complete the task	132.7	33.4	139.7	34.3
Time that passed before the first move was done *	14.4	7.4	18.9	7.1
Inter move latency: time that passed between moves*	3.9	1.3	4.8	1.4
Superfluous moves: the amount of unnecessary moves done *	4.3	3.1	2.5	2.6
Other measures (not per task)				
Answers correct on questions after finishing the five tasks	7.7	0.7	8.0	0.2
How many of 5 tasks were started with "speakers with most stringent constraints" strategy	1.5	1.5	2.4	1.8

Table 3

Interpretation of the results

Total time	The marginal difference in average total time was not significant. Students in both groups took equally long to complete the tasks
Time before first move	The main effect of feedback vs. no feedback on the time that passed before students made their first move was significant $F(1,41)=4.15$, $p<0.05$. Students who had feedback took more time to think than students who had no feedback, M=18.9, SD=7.1 vs. M=14.4, SD=7.4
Inter-move latency	There was also a significant main effect of having feedback on the average time taken between moves $F(1,41)=4.79$, $p<0.05$. Students who had no feedback took more time between moves, M=4.8, SD=1.4 vs. M=3.9, SD=1.3
Superfluous moves	There was a significant main effect of feedback on the number of superfluous moves that were made $F(1,41)=4.37$, $p<0.05$. Students who had no feedback made fewer superfluous moves than students who did have feedback, M= 2.5, SD=2.6 vs. M=4.3, SD=3.1

Knowledge	The effect of feedback on answers to knowledge questions afterwards, was practically significant at F(1,38)=3.73, p=0.06. Students who worked with the feedback version answered less of those questions correctly than students who worked with the no feedback version (M=7.7, SD=0.7 vs. M=8.0, SD=0.2)
Strategy analysis	Also video recordings of the students' performance were analyzed. We looked (per task) at whether or not subjects started solving the problem a smart strategy, in this case first moving the speakers who had the most stringent constraints. Students who had no feedback showed a tendency to use the 'most constraints first' strategy more often than students who did have feedback (F(1,39)=3.21, p=0.08). Students who had no feedback used that strategy 2.4 times (SD=1.8) out of 5 (tasks) whereas students who did not have feedback used it only 1.5 times out of 5 (SD=1.5)

3. Discussion

In our case study we explored the influence of providing versus leaving out visual destination feedback. We saw that the feedback as it was implemented was not beneficial in any way. In the two versions, students solved all the planning problems, and more importantly in the same amount of time. However, the version that provided *no feedback* resulted in longer thinking times *before* starting to solve the problem and to more time *between* moves. We take it as an indication that more contemplation was provoked and the students pondered longer before acting, so they studied the planning problem more effectively. Students who worked with the *feedback* version made *more* superfluous moves thus they solved the problems with more errors and lower economy. This explains the time differences mentioned above: having *feedback* lead to shorter time taken before moves, but making error (unnecessary) moves, also costs time. Similar results were also found by O'Hara and Payne [17] who found that a more display-based approach resulted in more moves than a plan-based approach, and that *backtracking* (undo a move and return to the previous situation) occurs more during display-based behaviour. Regarding the strategy that students chose, the results also indicated a more plan-based approach by students who worked with the *no feedback* version. They filled the timetable by first scheduling speakers with the most constraints more often. This strategy again suggests planning, because students think about whom they are going to schedule *before* starting with the task. The effect of feedback on declarative knowledge was almost significant; having feedback resulted in less correct answers.

Against the use of games in learning, one could argue that what occurs in popular games is probably often what Rasmussen [24] refers to as skill-based action, which is not very knowledge intensive. Besides engagement, what is needed is insight in how to provoke high mental effort and deep, not shallow processing from learners. Also Guttormsen Schar et al. [25] recognized the importance of other interface design standards than *only* those suggested by common guidelines.

4. Conclusion and future work

An appropriate and contextualized feedback helps the learner actually to learn and to reach educational and playable goals. Feedback in games is usually based on the user's performance. According to how the user acts, some related information is collected and processed, and some kind of report is given back to the user. However, feedback can also be different. *Destination feedback* stresses the relevance of providing information about the next action to come, before it occurs. It results in a kind of *feedforward* that also supports the player's decision, based on the player's actions but guiding the next movement. However, this feedback is not always positive for learning.

In this paper, we have presented some background on feedback and eGames and we have shown the results of the case study PET based on how a number of actual users play an educational simulation. The results show that too much feedback can be counterproductive as it provides too much information that makes the player lazier, discourages deeper contemplation and consequently provokes an inferior strategy. One has to realize that this was true for the type of problem solving task as the ones we used, where planning and effort are crucial for efficient solutions. Limitations of the study could be found in how far findings can be generalized to more realistic task domains, or tasks where learning itself, and not only problem solving strategy is more crucial. The effects of adaptively varying the amount of feedback over time, based on performance, are worthy of research. Lastly, the assistance as implemented is only one way to assist a user, and it is interesting to look into other ways. More research is needed to see to what extent our findings can be generalized.

In summary, there was no case where having *feedback* resulted in better performance. On the contrary, we found only positive effects of having *no feedback*: It led to more plan-based behaviour, smarter and more economic solution paths and better declarative knowledge. We argue that one has to be careful with providing interface cues that give away too much and must be designed in such a way that learners think and act is optimally supported. Designers could consider making interactions *less assisted* to persuade learners into specific behaviour. When certain types of behaviour are the aim, with learning as the target, engagement resulting in deep processing from the learners side is a prerequisite.

5. Acknowledgements

This paper is partially supported by the European projects TENCompetence (IST-TEL/2004-2.4.10, www.tencompetence.org) and ProLearn (IST Contract number 507310, www.prolearn-project.org). We also thank Dr. Hermina Schijf from Utrecht University for her involvement and assistance during this research project.

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Biographies

Daniel Burgos works as an Assistant Professor at The Open University of The Netherlands, after working fourteen years as a teacher, multimedia developer and academic manager in Europe and South America. He is mainly focused on IMS Learning Design, Adaptive eLearning, Educational eGames and Learning Networks. More information at www.open.ou.nl/dbu.

Christof van Nimwegen received his master degree in Cognitive Ergonomics at Utrecht University, The Netherlands. He worked several years a usability engineer and interaction designer in Internet related businesses in The Netherlands and abroad. Currently, he works as a Ph.D. student at the same university, focused on representations in interfaces, and Human Computer Interaction in general.

Herre van Oostendorp works as an Associate Professor at the Center for Content and Knowledge Engineering at the Institute of Information and Computing Sciences, Utrecht University. His research interests lie in the areas of text processing, updating of mental models, cognitive models for navigating the Web, and learning from screen.

Rob Koper is a full professor of educational technology and the head of the Development Programme at OTEC, Open University of The Netherlands. His research is focused on personalised instructional, web-based learning environments and self-organized distributed learning networks for lifelong learning, including the use of interoperability specifications and standards. More information at www.learningnetworks.org.