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Abstract. Games can be powerful learning devices because of their interactive and multimedia capabilities, and their abilities to keep students motivated, active, deeply immersed and engaged for sustained periods of time. Yet the extent to which this translates into more effective knowledge and skill acquisition is not clear from the research reported so far. Several researchers have stressed that support tools should be added to game environments to ensure that learning takes place.

In this paper we will elaborate on this issue and will report data from experiments with a simulation game called KM Quest. In these experiments the effectiveness of several (learning) support tools was investigated. The data give indications that particular types of support (like advice) limit learning while others (feedback, just-in-time information) might enhance learning. Based on these data at the end of this paper it will be discussed whether (intelligent) support within educational games is necessary.

Keywords: simulation games, learner support, modes of learning.

Introduction

Games in potential are interesting educational tools because players (sometimes in cooperation with others) are actively solving challenging situated problems. In that sense they have elements in common with learning theories like constructivist learning, situated learning and collaborative learning. In these theories it is stressed that learning is an active social process in which meaning is given to experiences while solving situated realistic problems. Games can be powerful learning devices because of their interactive and multimedia capabilities, and their abilities to keep students motivated, active, deeply immersed and engaged for sustained periods of time. Yet the extent to which this translates into more effective knowledge and skill acquisition is not clear from the research reported so far. Klawe [1] concluded that relatively small changes in game design could strongly influence the extent of the learning effectiveness of the game. Garris, Ahlers and Driskell [2] agree that the potential for instructional games as platforms for training is appealing but they also state that "there is little consensus on game features that support learning, the process by which games engage learners, or the types of learning outcomes that can be achieved by game play. Ultimately we run the risk of designing instructional games that neither instruct nor engage the learner (p. 442)". So, little is known about the way students learn while playing a game and about game features that support learning. In this paper we will elaborate on this issue and will report data from experiments with a simulation game called KM Quest. In these experiments the effectiveness of several (learning) support tools was investigated. Based on these data at the end of this paper it will be discussed whether (intelligent) support within educational games is necessary.

1. Learning within games

We assume that players use different types of information processing while playing a game and that these different modes lead to different types of learning outcomes. This distinction is based on research by Berry and Broadbent [3], Norman [4] and Taatgen [5].

Berry and Broadbent [3] used a dynamic system, the Sugar Factory computer simulation, in which participants had to reach a certain level of sugar production by changing the number of employees. The behaviour of the simulation is based on a rule that is non-linear and contains a random component. Berry and Broadbent noticed that participants could achieve a good level of control of the system even though they remain unable to describe precisely the rules of the system in post-experimental structured questionnaires. They concluded that a task like this under certain conditions might be performed in some implicit manner. Berry and Broadbent observed a similar finding using a different task. On the basis of these results they suggested that two modes of learning could be distinguished, an implicit unselective mode (U-mode) and an explicit or selective one (that is effortful and reportable). U-mode learning is probable in situations in which there is much information in the learning environment and the key variables and their interrelationships are not salient. Especially in "rich" low transparent, interactive discovery simulations this leads to intuitive knowledge that is difficult to verbalize. Berry [6] states that these two modes of learning should be seen as the two extremes on a continuum, while Swaak and De Jong [7] assume that these two types of learning can be seen as two parallel, at least partly independent learning systems.

Taatgen [5] however, has a slightly different view. In his view implicit and explicit learning are a result of two competing modes/strategies: a search mode and a reflective mode. These are two competing strategies whose evaluations depend on the expected outcomes of the strategies. The expected outcome is determined by three elements: the estimated probability of reaching the goal using a specific strategy, the expected value of the goal, and the estimated cost of reaching the goal using the strategy. These estimates change in time due to increasing knowledge and the successes and failures of applying the strategy. In most cases people will start with a search strategy because reflective reasoning has a high cost, and it is not evident that the search strategy will be unsuccessful. Especially when one has little task relevant basic knowledge, the costs of a reflective strategy will be even higher. If the search strategy is not effective, and the estimated chance of reaching the goal will get lower, people might consider changing to a reflective strategy.

When using a search strategy implicit learning is a "by-product" of normal information processing. People are actively performing a task and while doing that unintentionally learn certain things (facts, procedures, instances, examples, sequences of actions). When using a reflective mode, learning is based on information processing based on learning strategies aimed at explicitly learning, comprehending or memorizing something.

The distinction made by Taatgen resembles the one made by Norman [4]. Norman describes two modes of cognition: an experiential mode and a reflective mode. "These two modes do not capture all of thought, nor are they completely independent (p.16)". The experiential mode is one of perceptual processing, it is a pattern or event driven activity. It requires some thought but the information processing is data driven and reactive. It leads to an accumulation of facts, it reactivates information that is already present in the memory system and it leads to a tuning and shaping of knowledge structures already available.

"The reflective mode is that of comparison and contrast, of thought, of decision making (p. 16)". It is slow and laborious. "Reflective thought requires the ability to store temporary results, to make inferences from stored knowledge and to follow chains of reasoning backward and forward, sometimes backtracking when a promising line of thought proves to be unfruitful……The use of external aids facilitates the reflective process by acting as external memory storage, allowing deeper chains of reasoning over longer periods of time than possible without the aids (p. 25)". According to Norman effective reflection requires some structure and organization and is greatly aided by systematic procedures and methods and the aid of other people.

This implies that the use of tools (inside or outside the environment) or the help of other people can facilitate the reflective process. Garris, Ahlers and Driskell [2] confirm this: "simulation games may be ineffective stand-alone training tools because people do not learn from simple exposure or experience alone to understand complex relationships …… Although our goal is to achieve self-directed, self-motivated learners, we must provide support for knowledge construction. The role of the instructor in debriefing learners is critical (if somewhat overlooked) component in the use of instructional games, as are other learner support strategies such as online help, cues/prompts, and other activities (p. 460)". A review of games research revealed that the following tools may be effective in supporting learning with games: cooperation and collaboration, debriefing and group discussions, hints and prompts, a help or advice system, additional assignments, feedback, monitoring facilities and the specification of goals.

2. KM Quest: A collaborative Internet based simulation game about knowledge management

In our research we used KM Quest: (http://www.kmquest.net) a collaborative Internet based simulation game about knowledge management. Several universities and institutions for higher education in the Netherlands like the University of Twente, the Radboud University in Nijmegen, the University of Utrecht, and Hogeschool Zuyd in Maastricht have used the KM Quest learning environment in courses on knowledge management. Furthermore, the Yeditepe University in Istanbul (Turkey) has used it. Goal of the game is to learn basic knowledge management concepts and actions and the steps of a systematic approach to solve knowledge management problems. Furthermore to learn to assess the KM situation of an organisation and to advise/implement appropriate interventions.

The simulation game can be played by three players who all play the same role of knowledge manager in a fictitious large product leadership organisation named Coltec for three years in the lifespan of the company (divided in 12 quarters). Collaboratively they have the task to improve the efficacy of the company's knowledge household. This is not an aim in itself but is related to objectives for the (management of the) company in general. The general goal of the simulation game is to optimise the level of a set of general organizational effectiveness variables: market share, profit, and the customer satisfaction index (that are in the top level of an underlying business simulation model that is used to simulate the behaviour of the company) by influencing the effectiveness and efficiency of knowledge management processes (knowledge gaining, development, retention, transfer and utilisation) that are in the lower level of the business model. These processes can be influenced by choosing and implementing interventions from a pool of 57 possible interventions.

In the game, players can use several resources while performing their task. They can inspect the status of business process indicators and knowledge process indicators (in three general domains) that are incorporated in the business simulation model, they can ask for additional information, and they have to choose knowledge management interventions to (try to) change the behaviour of the business simulation indicators. Most of these indicators are characterized by a decay factor. This means that the value of the indicators decreases over time when no interventions are implemented. The implementation of interventions involves costs, as well as several other activities that the players can perform. Players receive a limited budget that they can use to implement interventions and buy information.

Changes in the status of the business indicators will only be computed at the end of each quarter. There is no time limit to playing the simulation game. Teams set their own pace. When players think they know enough to solve the problem they indicate that they agree with the proposed interventions (by using a voting tool). After they have reached agreement the simulation game proceeds to the end of the quarter and the business simulation will calculate new values for each of the business indicators. The game ends after the players have indicated that they have implemented the last intervention(s) in the fourth quarter of the third year in the life span of the company.

To trigger activities from the players and to make sure that players are confronted with different types of knowledge management problems, at the beginning of each quarter an (unexpected) event is introduced that could affect the knowledge household of the company. Players have to decide if and how they want to react on these events. Events are generated from a pool of 50 events. Different types of events can be distinguished based on two dimensions: the locus of the event (internal or external), and the effect of the event (direct, delayed, or no effect). Effects either can be positive or negative.

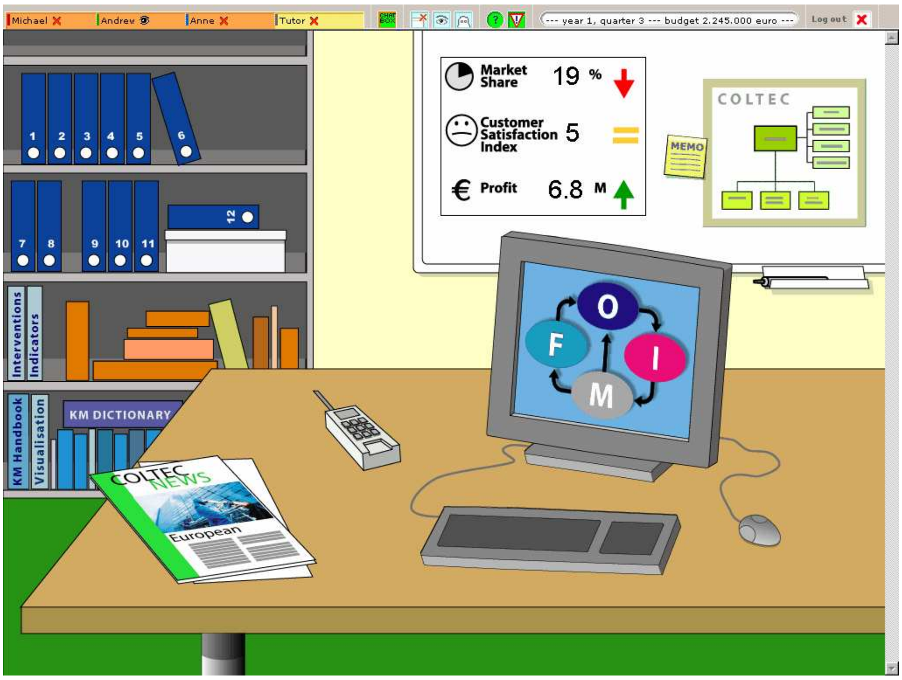

Figure 1. Virtual office interface of KM Quest.

Players can interact with the environment and with each other by using tools and resources that are presented in an Internet environment, based on a "virtual office metaphor" (see Figure 1). Clicking on a specific element in the "office" will open a window with additional resources or tools. To support the learners in performing their task and to support learning while playing the game several features have been implemented in the environment:

- A knowledge management model that describes a systematic approach to solving KM problems.

- Shared worksheets related to the steps in the knowledge management model (accessible by means of the computer).
- Just-in-time information (mainly in books on the bookshelf).
- Feedback (consisting of dynamic data from the simulation model and pre canned conceptual knowledge about knowledge management that is based on the experiences from KM experts and is coupled to certain events).
- Advice (only available when the value of certain indicators gets below a threshold value).
- Visualisation tools (different types of visualisations to display the data from the business simulation model).
- Monitoring tools (to be able to monitor their own behaviour and to reflect on it 12 quarterly reports are available on the top bookshelves).

To support collaboration and communication at a distance tools are implemented like a chat box, monitoring facilities, a voting tool, shared worksheets, and embedded forums. These tools support synchronous as well as asynchronous communication between team members.

3. Data from experiments with the learning environment

In the KM Quest simulation game several tools/resources were embedded to support learning as stated above. Logfiles from a first experiment with this game showed that from these resources the advice functionality was used most often. Advice was available when the value of certain knowledge process indicators in the business simulation model went below a threshold value.

It appeared that in 83% of the cases where advice was available it was actually consulted. Most of the time it was the first resource players consulted when they entered a new quarter in the game. Based on the available data from that experiment however it was hard to say whether the use of advice supported learning and game play.

A literature review also did not lead to many cues about the role of advice on learning in these kinds of learning environments. There is a study by Leutner [8] that also focuses on advice in a simulation game. In this research in the advice groups, during the game the players are provided with warnings if their decisions are likely to lead to problems. Results of the experiments (with 7th grade students and with university students) showed that advice increased verbal domain knowledge, but decreased game performance. Furthermore the data indicated that system-initiated adaptive advice had short-term effects (measured directly after game play), while learner requested non-adaptive background information had long-term effects (measured by a test that was administered a week after game play).

The type of advice given in the KM Quest environment is slightly different from the type of advice that was available in the Leutner study. In that study warnings were provided. In the KM Quest environment a warning is also given, but this is accompanied with general suggestions to improve the status of the specific indicators. An example of the advice is given below:

“The value of "Efficiency of knowledge gaining in research" has dropped below a value of 4.5. This may be a reason for concern. It is possible that you overlooked this decrease of this variable because you focused to much on the event or did not include it in your measurement system. If you want to improve the value of "Efficiency of knowledge gaining in research", you could consider interventions that influence this value. Most of the time several interventions are available. In this case you could take a look at interventions of the type listed below (see Interventions handbook). Note that there maybe other interventions also.

- Interventions that aim at cooperation with partners, implementation of new projects or hiring services

- Interventions that aim at the implementation of Information Communication Technology
- Interventions that aim at recruiting and hiring people".

When a player clicks on a class of interventions the chapter of the interventions handbook will be opened in which additional information about these interventions is given.

To explore the effects of the advice on learning in another experiment two versions of the simulation game were used: one with the advice and one in which this resource was removed. A pre-test, post-test design was used with an additional transfer test. It was hypothesized that students in the advice group would gain more explicit knowledge (in line with Leutners findings) and would perform better in the game because they receive hints about possible solutions. This last hypothesis is not in line with Leutners findings, but this is because the type of advice given in this experiment is somewhat different than the advice given in the experiments performed by Leutner.

3.1 Method

In this section the subjects that participated in the research will be described as well as the instruments that were used and the experimental procedure.

The students who participated in the experiment did so because the use of the simulation game was an assignment within a third year course "Knowledge management in learning organizations" at the University of Twente. All students were from the Communication Studies department and had followed a preliminary course on Knowledge management in the second year. 29 Students participated in the course (18 women and 11 men).

The game environment that was used in both conditions was slightly different than the standard version that is described above. In this case players played individually, the order of the events was not random but fixed and the same for all students, and the starting values of the indicators were lowered (several are below 5 on a ten point scale). This is done to create a situation in which events can occur that refer to internal problems related to knowledge processes. In the original game set up in the beginning of the game a lot of events are generated that have to do with external (opportunity) events because knowledge processes within the company still were running smoothly (score of 6 or higher on a ten point scale). Observations in try-outs showed that players found these kinds of events difficult to deal with when they had limited domain knowledge.

Knowledge gain is measured by comparing the score on a pre-test and a post-test. Each consisted of 26 items that contain questions to measure explicit (18 items) as well as implicit knowledge (8 items). Explicit knowledge of knowledge management concepts and principles is tested by giving students textual multiple-choice questions that refer to declarative knowledge about concepts used in the learning environment like the knowledge processes, and steps within the knowledge management model. Furthermore, questions are included that refer to relationships between indicators and interventions. Implicit knowledge items are included to measure intuitive knowledge that is difficult to articulate. These items are based on the guidelines given by Swaak and de Jong [7] who characterize intuitive knowledge by a "quick perception of anticipated situations". In the test a situation is given, an action is described and a set of possible post action situations is given. In each item the textual information is kept to a minimum and a picture or chart is used to present the alternatives.

A transfer task was administered after the game and the post-test were completed. The transfer task used a different type of company: a small customer relationship type of company. In the task a case description was presented with four event descriptions. For each event 4 questions were presented.

Player performance in the game was logged into a database. These data make it possible to see for each of the twelve quarters within the game, which resources people used (and in which order), which interventions they implemented and what the values of the business and knowledge process indicators were.

3.2 Procedure

In the first lecture of the course the set up of the course was described and KM Quest was introduced. In four consecutive weeks following on this lecture four two-hour sessions were planned to work with the KM Quest environment. The sessions were located in a computer room with a large set of computers. Each student had a computer. In the first session the pre-test was administered. After the game was completed the post-test was administered in the fourth session. After the students finished the post-test they received transfer task, which they had to make at home. Students were not able to get access to the game environment while they were making the transfer task.

3.3 Results

First data will be presented from the tests and about game performance. After that data will be presented about the use of advice and the other resources.

In Table 1 the test results are summarised. It shows that on the average students answered 39.6% of the questions of the pre-test correctly. For the post-test the average score was 50.3%. A paired samples t-test shows that this knowledge gain is significant (T=-4.62, df=28, p=0.00).

The data show that both groups have gained explicit knowledge. This gain is mainly in the conceptual domain. There is no significant gain in knowledge related to the knowledge management model, nor on explicit knowledge concerning relationships between indicators and interventions. The No-advice group however, has also gained implicit knowledge, while the advice group did not show any gain in this domain. The difference between both groups on the score on the implicit knowledge items of the post-test is nearly significant (Anova: F=4.18, df=1, p=0.051).

Table 1. Average number of correct answers (and standard deviations) on the explicit and implicit knowledge items of the pretest and posttest and the score on the transfer test for the whole group and for the groups with and without advice.

	Pre-expl Max=18	Pre-impl Max=8	Pre-tot Max=26	Post-expl Max=18	Post-impl Max=8	Post-tot Max=26	Transfer Max=10
Advice N=15	6.80 (1.86)	3.80 (1.61)	10.60 (2.87)	8.80 (2.04)	3.67 (1.35)	12.47 (2.77)	7.20 (1.53)
No adv. N=14	6.86 (2.88)	3.14 (1.56)	10.00 (3.35)	9.07 (1.97)	4.64 (1.22)	13.71 (2.30)	6.98 (1.71)
Total N=29	6.83 (2.36)	3.48 (1.59)	10.31 (3.07)	8.93 (1.98)	4.14 (1.36)	13.07 (2.59)	7.10 (1.59)

Looking at game performance there are hardly any differences between the experimental groups (see tables 2 and 3). Both groups have managed to improve the business and knowledge management (process) indicators significantly.

Table 2. Average values for some important business (process) indicators in the business simulation model at the end of the game for the whole group and for the groups with and without advice. At the bottom row the starting values.

	MS*	CSI	Profit	JSI	PQI	ATM
Advice	23.79	8.15	64.73	9.60	8.77	1.34
	(3.76)	(0.90)	(23,26)	(0.88)	(0.99)	(0.77)
No adv.	24.43	8.33	68,58	9.50	9.04	1.14
	(3.18)	(0.61)	(19,54)	(0.76)	(0.66)	(0.55)
Total	24.10	8.23	66,59	9.55	8.90	1.24
	(3.45)	(0.77)	(21,25)	(0.81)	(0.84)	(0.67)
Start values	20.0	4.40	-	4.22	4.80	2.40

* MS = Market share, CSI = Customer satisfaction index, Profit = Total profit in 3 years in millions, JSI = Job satisfaction index, PQI = Product quality index, ATM= Average time for new product to market,

Table 3. Average level of competence in three knowledge domains for the whole group and for the groups with and without advice. At the bottom row the starting values.

	Competence in marketing	Competence in R&D	Competence in production
Advice	8.63	8.27	6.43
	(1.22)	(1.29)	(0.79)
No advice	8.72	8.60	6.40
	(1.00)	(1.02)	(0.71)
Total	8.68	8.43	6.41
	(1.10)	(1.16)	(0.74)
Start values	4.93	4.38	5.34

Advice is only available when certain indicators get below a certain threshold value. On the average advice was available in 9.33 quarters and was consulted in 7.07 quarters. This means that in 77% of the cases where advice was available it was actually consulted.

Table 4 gives an indication about the frequency of use of the other resources available in the learning environment. The Intervention handbook, the feedback and the visualization tool were the most used resources. The indicator handbook and the history books were used less frequently, and the other resources are sparsely used.

Although there are differences in the use of tools between the two experimental conditions, most of them are not significant, except for one. The no-advice group consulted the indicator handbook significantly more (Anova: $F=5.22$, $df=1$, $p=0.03$) than the advice-group.

Table 4. Average number of quarters in which some of the standard resources were used by the learners for the whole group and for the groups with and without advice. The resources are: feedback, the intervention handbook, the indicator handbook, history files, what and how files related to shared worksheets, and visualisation tools.

	Feedb	Intv HB	Indc HB	Hist	What	How	Help	Visual
Advice	5.73	6.13	3.13	3.67	0.80	1.00	0.47	6.73
	(4.33)	(4.36)	(1.99)	(2.19)	(0.86)	(0.76)	(0.52)	(4.93)
No adv.	5.93	4.57	5.43	3.14	1.00	1.14	0.50	5.29
	(5.08)	(4.50)	(3.30)	(1.29)	(0.55)	(0.86)	(0.52)	(3.99)
Total	5.83	5.38	4.24	3.41	0.90	1.07	0.48	6.03
	(4.62)	(4.42)	(2.90)	(1.80)	(0.72)	(0.80)	(0.51)	(4.48)

4. Discussion

The data indicate that the players appreciated the advice functionality, but there are also indications that the effectiveness of the advice given was low. Players in the no-advice condition score equally well on game performance, on the explicit knowledge items of the post-test and on the transfer test. The fact that in the no-advice condition there is a significant knowledge gain on test items that measure implicit knowledge while there was no gain in the advice condition even seems to indicate that advice (as it is given within the game) prevents the gain of implicit knowledge and the transfer of this type of knowledge into explicit knowledge. This could be due to the fact that players in the advice condition put in less mental effort in solving the knowledge management problems within the learning environment and rely too heavily on the suggestions given by the advice functionality. The players in the no-advice condition seem to be seeking more actively for data that could support problem solving. This is indicated by the fact that players in this group consulted the indicator handbook significantly more than the other group. A counter indicative finding could be that the advice group consulted the intervention handbook more often (although not significantly). This however, is probably caused by the direct links between the content of the advice and the content of certain parts of the intervention handbook.

There are some indications that players who are actively searching for information in the games resources are learning more or performing better within the game. Frequent use of feedback or the intervention handbook improved learning in a previous experiment. This finding was not replicated in this experiment. Frequent users had higher post-test scores but did not have a larger knowledge gain. This could be due to the fact that in the reported experiment the players who used these resources often already had a "high" level of prior knowledge, while this was not the case in previous experiment. The data reported in this paper however showed that frequent use of the indicator handbook lead to higher scores on the explicit knowledge items of the post-test and on game performance measured by the level of some of the business process and knowledge process indicators included in the business simulation model.

The data are in line with findings of other experiments with the same learning environment that are reported by Purbojo and de Hoog [9] and Shostak and de Hoog [10]. These data show that the availability of certain types of support resources like certain types of visualisations or certain types of indicator values, per se does not have an influence on learning results or game performance. These experiments however also show that a briefing session before game play is important as well as the fact that players have to cooperate. There are indications that a certain types of support (like the advice that is available) limit learning. When there is less directive support students are more actively searching for information in the resources available and while doing this gain more conceptual and implicit knowledge. Discussion with others during or after game play seems to support learning with games the most, as is also reported by Kirriemuir [11]. Since relatively simple support within the game seems to make players "lazy", it can be questioned whether more advanced intelligent types of support will be effective in supporting learning within these kinds of environments. In the case of KM Quest more intelligent support could take the following form: A new version of KMQuest stores all user actions in a well-structured data base. As the program works with fixed quarters after which the values in the business model are adjusted, the moment of a quarter change also allows an analysis of the content of the data base. This analysis can lead to advice about visiting certain activities in the knowledge management model that were overlooked but are necessary for better learning. Another option is to predefine certain preferable learning trajectories and check the actual behaviour of the learners against these trajectories and give tailored advice about what to do next. A vision of the future could even be an online analysis of the content of the chat (which is also stored) to detect certain characteristic utterances that could signal learning difficulties or misconceptions that could be redressed by specific suggestions given by the system.

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