BRIDGING THE GAP:
Transforming Knowledge into Action through Gaming and Simulation

Proceedings of the 35th Conference of the International Simulation and Gaming Association, Munich, 2004

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Learning Knowledge Management in a Collaborative Game: Effects of Player Preparation and Visualization of Variables

RIJANTO PURBOJO & ROBERT DE HOOG

1. Introduction
The general idea that underlies this paper is investigating learning effects of the use of a simulation game in a business management domain. Since the first business game was produced by American Management Association in 1956 the use of business games has grown among business schools throughout the world (Ellington & Early, 1998). However, research that can show benefits of using games to promote learning is infrequent and inconsistent (Druckman, 1995; Pierfy, 1977). In the field of educational science, games/simulations have not been widely accepted as learning tools (Corbeil, 1999). This paper contributes to education and training research into the effective application of simulation games as learning tools in business management.

Knowledge management (KM) as a new approach conceptually addresses activities and perspectives required to manage knowledge in corporate business operations. KM intends to define a set of distinct and well-defined methods and processes for dealing with the positive and negative aspects of knowledge in different kinds of business operations in order to achieve important business objectives (Wiig, 1995). In practice it turns out to be difficult to address KM problems in a systematic way and therefore people do not choose the right activities and solutions (Christoph, van der Tang & de Hoog, 2001). This seems to be related to two observations: (1) a coherent and well-supported methodology in KM is lacking (Wiig, de Hoog & van der Spek, 1997); (2) knowledge as a concept is abstract and not clearly definable. As a consequence learning KM falls into the category of learning ill-defined and fuzzy problems. In educational science it is assumed that a constructivist approach, that provides learners with a generic problem solving strategy and encourage the learners to collaboratively apply the strategy to the problem and learn the consequences, is the preferred way to support learning in these types of domains.

KM Quest for learning KM was created to apply this approach by providing a collaborative internet-based simulation game. The game combines a simulation and a case description to stimulate player’s joint decision-making process, which is practicing applying KM problem-solving strategies in KM and learn from the consequences of their decisions. This stimulates problem-based learning in which players in a team jointly learn to solve (unpredicted) events by using a given KM strategic problem-solving model. This collabora-
tive situation is very similar to the real work situation. In our perspective, this will also offer opportunities where players can learn to share visions, exchange individual mental models in groups, teamwork, and team learning that typically is necessary in learning organization (Senge, 1990). Another objective that the game would like to encourage is a learning context where players can learn KM interactively and overcome physical and geographical boundaries among players and tutors/trainers.

Whether these goals can be achieved in practice must, of course, be investigated. From research thus far two main problems emerged:

- Players had problems in assessing the effects of the events and interventions based on the large set of numerical business indicators. Players preferred to have visualization of the game indicators (Leemkuil, de Jong, de Hoog & Christoph, 2003).

- There were no significant learning outcomes and a minimal use of game indicators.

Based on these data, we hypothesize that players need a substantial level of prior knowledge -both domain specific and general knowledge- before playing the game. We decided to add an extensive introduction and instructional session prior to the playing session. This is to help players build prior knowledge before entering a meaningful playing session. From this, better learning outcomes should result. In addition extensive visualization of game indicators was included, in order to improve the accessibility and understandability of crucial game information for geographically dispersed players using limited band-with means of communication.

To test these improvements we conducted an experiment in which three hypotheses were investigated: will significant learning outcomes occur after playing KM Quest that is prepared by extensive briefing to improve players' domain specific knowledge and is there any significant difference of learning outcomes for visualization of game indicators? In addition the effect of visualization on decision making satisfaction was tested.

The next section gives a brief overview of the KM Quest learning environment, followed by some theoretical consideration that underpins our hypothesis. After presenting the design and the results of the experiment, conclusions and suggestions for further research are stated.

2. **KM Quest™ in brief**

Generally, KM Quest consists of three components: a case description, a game simulation and a KM model. The case description illustrates a fictitious company called Coltec which is a product leadership type of company (Treacy & Wiersema, 1995) that manufacture adhesive, coating, and so forth. The simulated business model adds to the case description by simulating business processes of Coltec. This triggers game events, processes the input
from the players and reports the consequence back to the learners by changing the value of business indicator in every cycle of the game. The visualization essentially filters the data stream of the game indicators from the business model to the game interface. The KM model is an interactive schematic model which can guide players to follow step-by-step a strategic KM problem-solving process that ends with deciding on game interventions.

These components are coupled by an instructional envelope, that mediates between players and the components. The interaction between the players and the system, and among 3 players in a team is realized by a common interface. Each player in the team receives a partially shared interface, which means that not all player's action can be seen or modified by other players. The interface is fully implemented in WWW technology, required MS Internet Explorer version 6.0.

The three players in the team should work collaboratively to solve the game events in while located at different places, without visual and voice-based communication. Their communication is maintained by text-based chat boxes and “follow-me” buttons. The follow-me button can be used if one of the players would like to call other players to open a certain page or section of the system.

At the beginning of every quarter of the game, a game event is triggered. The events are characterized by an unexpected KM event that may create internal or external KM problems, or offers business opportunities to the company. Players can follow the steps and sub-steps of the KM problem-solving model and try to make unanimous decisions about interventions. This game runs in 12 cyclic game quarters, there is no limit of actual time to finish it.

The players have to play a role in a team of knowledge managers who work collaboratively to improve the condition of the company by paying attention to the company’s knowledge household. Improvement or an optimal level of business indicators is an indication of appropriate players’ performance in the game but not an indication of learning performance. The learning goal is to learn to apply the KM model strategically to the KM event and for long-term goals. In other words, the key of learning is to find relationships between strategies for KM problem solving and the business processes. Therefore, the game does not label explicitly right or wrong performance, but encourages players to learn the consequence of their actions.

Detailed information about KM Quest environment can be obtained from http://www.kmquest.net and in Leemkuil et al. (2003).

3. Theoretical considerations

In principle, problem-solving involves the use and application of skills for finding solutions, making decision, and thinking inventively (Leshin, Pollock & Reigeluth, 1992). To solve problems in a domain, Gagne (1980, 1985) and de Jong & Ferguson-Hessler (1986) said that learners must possess and
apply three kinds of knowledge: principles, declarative knowledge, and cognitive strategies. The ability to apply principles seems to be the most critical component to problem solving; however it is clear that without declarative knowledge and cognitive strategies, the learner may not able to adequately identify or search the problem space. (Smith & Ragan, 1999).

As described in the previous section, KM Quest tries to encourage this type of learning process. However, the instructional support does not guide and prompt players to look for particular clues and information to solve the problem. It is limited to advise players to follow the given problem-solving strategy, and the system will warn players if relevant indicators are below a certain threshold. This leaves it to the players to collaboratively discover more information to support or revise the strategy and link it to possible consequences of their actions.

The process of collaborative playing can be seen as a group decision making process of three knowledge managers who try to solve KM problems and learn whether the problem is solved with the decisions observing their consequences. The characteristics of the playing situation and its instructional supports does not fall exactly into the category of closed (rigid rules) or open simulation games (free-form rules) from Kriz (2003) and Stahl (1983). This creates another complexity in the gaming process because players tend to perceive the game in their own subjective way, leading to problems like playing too fast (Corbeil, 1999) or “floundering” behavior (Veermans, 2003) which appears to be common in problem-based learning where learners who have little prior knowledge, experiment with a simulation without having a clear idea of what has been done, and what to do next. Smith and Ragan (1999) observe that the prerequisites (principles and their associated concepts, declarative knowledge, and cognitive strategies) for problem solving can be taught in lessons prior to the problem-solving lesson.

The considerations above lead us to the hypothesis that improving the original introduction and instructional session substantially will contribute to better learning outcomes. Other extra activities are a classroom session that teaches players explicitly about theoretical foundation of KM and on how to use the KM problem-solving strategy in KM Quest properly. Further, an extensive technical briefing is also given. This session is given by an expert in KM and one of KM Quest’s designers.

Our other hypothesis is that visualization of game indicators has a better chance to improve learning and decision making because it provides a language that could unify disparate perspectives and even merge different interest into common objectives (Asakawa & Gilbert, 2003). Visualization fosters interpretation of data from different conceptual perspectives. Visualization is also found to be supportive to make appropriate decisions and better solving problems in organizations (Senge, 1990). Visualization, such as graphs and diagrams, supports heuristic processes in learning and decision-making because it provides ways to visualize relationships between variables graphi-
cally and providing feedback to the learners concerning consequences of their actions (Veermans, 2003).

Based on these theoretical considerations we expect that improved preparation and informative visualizations will have a positive effect on learning outcomes and group decision making satisfaction.

4. Research Methodology

In order to test the hypotheses, the investigation should permit a comparison between differences in preparation and differences in visualisation. For the second aspect it was decided to have three independent groups:

1. C teams played the game using only charts and diagrams (see Figure 2 and Figure 3)
2. T teams played the game using only spreadsheet tables (see Figure 1).
3. TC teams played the game using charts, diagrams and spreadsheet tables.

Figures 1, 2 and 3 below show the differences between the experimental conditions.

Figure 1: An example of the spreadsheet table displaying the game indicators
The preparation aspect is covered by comparing learning results between teams which were not extensively briefed before the game, and those who
were. For this we will use an experiment that had the same design as the one described in this section, but without the advance briefing.

**Subjects**

The recruitment of participants only considered the novice learners in KM and KM Quest. The population is a mixture of international graduate students and Dutch regular under-graduate students. Twenty-seven students of graduate and undergraduate programs in The Behavioural Science Faculty, University of Twente, registered voluntarily. They received a financial reward after finishing the experimental session. The participants were matched into 9 teams based on their educational background and specialization studies (psychology, management, and education) to obtain equal distribution of team’s ability for each team. Later, each team was randomly assigned to one of the experimental conditions. The majority of the subjects were female with an average age of 28 years, educational background was quite similar.

**Procedure**

The experiment was carried out in synchronous playing mode. The procedure went as follows:

1. Two weeks prior to the playing phase, an online training module and the reading materials were available at the internet. Each player was asked to read the paper and follow this training module at their own pace.

2. One week prior to the playing session, a classroom session was given (90 minutes).

3. The playing session took place in the computer laboratory. Each player in a team was seated separately and informed to communicate only by the communication tools provided in the game. They received “virtual” identities before playing and asked to hide their original identity during playing the game. The purpose of this procedure is to reproduce the condition of geographical dispersion. The session took about 7 hours, including pre- and post-test session, 45 minutes lunch breaks and two times coffee breaks.

**Hypotheses**

The first hypothesis concerns the effects of a similar preparation but different visualisations on the learning outcomes for each experimental condition. It is expected that due to preparation, post-test scores for learning outcomes will be higher than pre-test scores for all conditions, but that due to visualisation the post-test scores, given equal pre-test scores, will be higher for the TC condition than the C condition, and the C condition post-test scores will be higher than the T condition.
The second hypothesis addresses the effect of a difference in preparation with different visualisations for the different experimental conditions. It is hypothesized that a better preparation will lead to much better post-test scores on learning outcomes than those resulting from a very limited preparation.

The third hypothesis states that satisfaction with group decision outcomes, process and support facilities is higher for the TC condition than for the C and T condition, and higher for the C condition than for the T condition.

Measurement instruments

The measurement instruments below were used to test the hypotheses:

- Pre- and post-test of KM knowledge were administered to measure learning outcomes. We used two parallel tests that have two sections: a 20 question multiple-choice test and a 2 question case-based test. The first section measures generic declarative knowledge of KM, for instance definitions and conceptual models of KM. The second section measures strategic knowledge related with the KM problem-solving model.

- A pre-test of TOGS+ that measures generic knowledge and specific graphing skills was administered to check whether players in different experimental conditions have comparable graphical abilities. This test is a combination of the standard version of TOGS (McKenzie & Padilla, 1986) and a sub section of TIPS (Burn, Okey, & Wise, 1985) that measures graphing skills.

- An adapted version of the Group decision making satisfaction inventory (Briggs & Vreede, 1997) that measures players’ subjective judgments on group decision making process, outcomes, and support facilities during the playing phase, was administered at the end of the playing session.

5. Results

Because the sample size in this experiment is relatively small (N = 27, n = 9), we decided to analyse all results with non-parametric statistic tests (Wilcoxon signed rank and Kruskal-Wallis) and use other qualitative information taken from the measurement instruments.

General ability and graphing skills test

The mean scores for these tests are almost equal; each experimental condition achieved 65% to 72% from the total score. Non-parametric statistical analysis Kruskal Wallis test confirmed that there is no statistically significant difference between conditions ($\chi^2 = .909$, df =2). This result shows that the experimental conditions have equal general ability and specific skills in graphing, which rules out their role in causing differences between conditions.
**Effect of visualisations on learning outcomes**

The pre- and post-test of KM knowledge were administered in two sections: a multiple-choice declarative test and an essay case-based test. As the essay test is an open question, 14% of the answers were given to a second coder to check inter-coder reliability. The Wilcoxon Signed Rank test showed that there is no significant difference of the essay test scores between the first and second coder.

Table 1 shows the results for the learning outcomes.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Pre MCa</th>
<th>Pre CBb</th>
<th>Totalc</th>
<th>Post MCa</th>
<th>Post CBb</th>
<th>Totalc</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (N=9)</td>
<td>10.00 (1.58)</td>
<td>4.06* (2.71)</td>
<td>14.06* (2.93)</td>
<td>10.22 (2.64)</td>
<td>9.83* (3.07)</td>
<td>20.06* (4.62)</td>
</tr>
<tr>
<td>T (N=9)</td>
<td>8.78 (2.22)</td>
<td>4.61 (3.30)</td>
<td>13.39* (2.83)</td>
<td>10.67 (1.50)</td>
<td>6.83 (2.61)</td>
<td>17.50* (3.42)</td>
</tr>
<tr>
<td>TC (N=9)</td>
<td>10.56 (1.59)</td>
<td>6.50* (5.14)</td>
<td>17.06* (5.70)</td>
<td>11.33 (3.04)</td>
<td>11.11* (3.22)</td>
<td>22.44* (5.27)</td>
</tr>
</tbody>
</table>

Table 1: Mean and standard deviation of the KM knowledge test scores; Notes: a = Multiple-Choices section (Max = 20); b = Case-based section (Max = 24); c = total score (Max = 44); *p < .05 Wilcoxon signed rank test comparison difference between pre- and post-test sessions.

The first hypothesis predicts that, given equal pre-test scores, on the post-test the TC condition will do better than the C condition and the C condition will do better than the T condition. As can be seen from Table 1, the pre-test scores are almost equal. Though there are differences in the last column in Table 1, they are not significant, so we have to reject the hypothesis. From Table 1 we can see that there are significant differences between the pre- and post-test in C, T, and TC conditions with respectively 6 (z = -2.549; p < .05), 4.11 (z = -2.077; p < .05), and 4.8 (z = -2.312; p < .05) score. Further statistical analysis of the sub sections of the test show that there are no differences between the multiple-choices test scores from all conditions, but there are significant differences between the C and TC condition for the case-based test, respectively 5.77 (z = -2.666; p < .05) and 4.61 (z = -2.016; p < .05).

**Effects of preparation on learning outcomes**

Comparing the result of the KM knowledge test of this experiment and the previous one was done by using the percentage of correct answers on the multiple choice test, because the tests used were slightly different.

Figure 4 shows the results for the experiment in which only a limited preparation took place. It can easily be seen that post-test results were almost the same, or even worse, as the pre-test results. Learning outcomes were worse after playing the game than before playing it.
Figure 4 shows the percentage of correct answers for the experiment in which elaborate preparation took place. As already is known from Table 1, there occurred a significant learning effect for all conditions, and from Figure 5 it can be seen that the pre-test scores were almost the same as in Figure 4. Though we cannot test hypothesis 2 statistically due to different samples and measurements, it seems not too bold to assume that it is corroborated by the data. It also interesting that in Figure 4 there are no differences whatsoever between the conditions, but there are in Figure 5 and Table 1, though they are not significant.
**Effect of visualisations on group decision making**

Table 2 shows that players in all conditions are generally satisfied with the overall process of group decision making during playing. The process of making decision, support during making decision, and decision outcomes are judged positively. However, players in the C and TC conditions judged the outcomes of decision-making process more positive than players in the T condition. Thus the third hypothesis is partly correct: it holds for C and TC versus T, but not for TC and T.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>N</th>
<th>Process</th>
<th>Support</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>9</td>
<td>3.80 (.89)</td>
<td>3.70 (.63)</td>
<td>4.14* (.53)</td>
</tr>
<tr>
<td>T</td>
<td>9</td>
<td>3.80 (.71)</td>
<td>3.81 (.78)</td>
<td>3.36* (.75)</td>
</tr>
<tr>
<td>TC</td>
<td>9</td>
<td>3.95 (.88)</td>
<td>3.56 (.85)</td>
<td>4.25* (.56)</td>
</tr>
</tbody>
</table>

Table 2: Mean and standard deviation score of the judgements of Group Decision Making; Notes: Judgements were made on 5-point scales (1 = very negative to 5 = very positive). Mean scores of the Outcomes judgment do differ at *p < .05 in Kruskal Wallis Test.

6. **Conclusions**

The conclusions can be grouped around the three hypotheses that were tested in the previous section. Before this, a general remark on the effectiveness of KM Quest must be made. Statistically, most of the players in all experimental conditions with elaborate preparation, gain significant learning outcomes. We conclude that the contribution of playing KM Quest is positive. However, qualitatively we see that the achievement of the learning outcomes is still far from optimal: less than 51% from the total score (see Figure 5.), or, in other words a 5 on a 10-point scale. Thus there is still quite some room for improvement of learning with KM Quest.

Concerning the effect of visualization there are no significant differences between having tables, tables and chart or only charts available during playing, though there is a tendency for charts and tables to do better than tables alone. When looking at the profile of test scores in both subsections (see Table 1), they indicate that players who were supported with charts and diagrams scored low in the multiple-choice test, which means that they did not gain any declarative knowledge after playing. However, statistically these players showed much better scores in the case-based test subsection, which indicates gaining of strategic knowledge of problem-solving. This finding supports the major learning goal of the game and shows that learning strategic KM may be difficult without the support of visualization as learners in the table only condition experienced. Maybe learning problem-solving skills for ill-defined problems is better served by giving symbolical information than only numerical information.

As for extensive preparation, the comparison of qualitative results between two similar experiments indicated that the extensive preparation does not lead to better domain knowledge before playing the game (30 to 38% from the overall score, see Figure 5.), but has a substantial effect when combined...
with playing the game. Or to summarize: playing only does not help, extensive preparation only does not help, only the combination seems to make a difference.

All players judged the overall group decision making process positively. Yet, the players that played the game only supported by the tables perceived the decision outcomes as less positive than players in the other two conditions. This may be due to the representation of the game indicators in this condition, which tends to depict detailed and discrete numerical information which could create more uncertainty about the nature of decision outcomes (Leigh & Spindler, 2004). However, this must be further investigated by analysing the communication process of making joint decisions in the log files.

The analysis in this paper is limited, due to statistical reasons. Two approaches can be followed to overcome this: (1) focusing on analysing the records of player’s activities and the collaborative communication process; (2) replicating the experiment with larger samples. Both will be followed in the future.

All along we will be developing of KM Quest not only for practical applications but also for the ongoing investigation of the effectiveness of gaming to support collaborative learning in other ill-defined problems in business management studies.

Notes

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References


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