# REVIEW OF EDUCATIONAL USE OF GAMES AND SIMULATIONS

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# Executive summary

This study examines the theoretical analyses and empirical results from research in the area of instructional use of games and simulations. It mainly focuses on approaches taken in designing game(-like) learning environments and distils a list of characteristics of games from the instructional theory. It also tries to find evidence concerning the appropriate learning approaches and measures which can optimise the learning effects of games and simulations. In this analysis we also look at a related instructional methods: *the use of case studies*, a method that is very common in the training of management techniques. A second analysis that is made in this study concerns *solving ill-defined or wicked problems*. In the KITS context the knowledge management situations can be characterised as being ill-defined. Both analyses result in a set of requirements for the KITS learning environment. The starting points of the KITS project are shortly introduced in Chapter 1.

Chapter 2 starts by defining the concept of 'game' and gives a list of characteristics of 'games' based on a literature study. This resulted in the following definition: Games are competitive, situated (learning) environments based on a set of rules and/or an underlying model, in which, under certain constraints, some goal state must be reached. Games are situated in a specific context that make them (more or less) realistic, appealing and motivating for the players. Important elements that are related to the situatedness of games are validity/fidelity, complexity, risk, uncertainty, surprise, unexpected events, role-play, access to information, and the representation form of the game.

Games as learning environments are closely related to simulations, microworlds, adventures and case studies. The definitions of these environments partially overlap. For instance, the distinction between simulation and games is often blurred, and many recent articles in this area refer to a single "simulation game" entity.

The educational goals of games depend on the setting in which they are used and can be very diverse like: development of consciousness and motivation, training of skills, development of knowledge and insight, training in communication and co-operation, integration of learning experiences, and assessment.

Much of the work on the evaluation of games has been anecdotal, descriptive or judgmental, but there are some indications that they are effective and are superior to case studies in producing knowledge gains. However, there is general consensus that learning with interactive environments such as games, simulations, and adventures is not effective when no instructional measures or support is added. Support can be added by implementing model progression, prompting, assignments, feedback, additional information, monitoring facilities, reflection, debriefing, explication and different problem formats.

Problem solving is seen as the main activity for the acquisition of knowledge and skills in working with games and simulations. In Chapter 3 it is concluded that the kinds of problems that humans solve vary dramatically, as do the nature of the problem situations, solutions and processes. On the one hand the domain, goal and processes entailed by a problem may be very well structured and on the other hand they may be very ill structured. What is clear at the moment is that knowledge management is an area where problems are multi-faceted, complex, and without univocal outcomes. Therefore, the problems in this domain can be categorised as ill-structured or wicked problems.

Training to solve those kinds of ill-structured problems requires different instructional settings than training to solve well-structured problems. An instructional design model for in ill-structured problems is introduced. In this model there is a prominent place for context, constraints, cases, knowledge base and argument construction, and for assessment.

In Chapter 4 a set of preliminary requirements for the KITS learning environment is presented based on the information in the previous sections. In a later deliverable these initial requirements together with the user requirements that are specified in Deliverable 4, will be specified in a description of the instructional envelope that is one of the two main elements (together with the domain model) of the KITS learning, which is the final objective in the project.

# 1. Introduction

The KITS project has two starting points. First, the project builds on psychological and pedagogical developments in learning and instruction that are based on a shift from “instructivist” approaches towards “constructivist” approaches. Second, the project sees a need for better training of people working in the emerging field of knowledge management.

*Developments in instructional design*

During the last decade in the field of instructional design, there has been a shift from “instructivist” approaches towards “constructivist” approaches (Van Merriënboer, 1997). Instructivistic theories assume that formal concepts and systems can be transmitted to students by giving them formal descriptions in combination with the presentation of examples (following certain design procedures). After that, problems are given to apply the new knowledge, to practice and to test if the new concepts, procedures or principles are mastered (see for example Merrill, 1994).

Constructivistic approaches emphasise the idea of an active, experiencing student in a situation where knowledge is not transmitted to the student, but constructed through activity or social interaction. Well-designed instruction should offer experiences to learners that enable them to construct useful cognitive schemata and which allow them to understand a new domain. For instance, situated cognition (Brown, Collins, & Duguid, 1989) stresses the importance of context in learning, because the context becomes an important part of the knowledge associated with that learning. In a related cognitive apprenticeship approach (Collins, Brown, & Newman, 1987), it is argued that instruction should focus on realistic real-world problem solving rather than the transmission of pre-structured pieces of knowledge. The role of an instructor or instructional materials is then to coach and support the learner while these problems are solved. Constructivistic approaches stress that cognitive processes and knowledge are mainly the result of actively constructing meaning by learners.

Games, simulations, and case studies have an important role in education and training in putting learning in a context, albeit a contrived one, which creates demands on the student’s personal competence, values, and attitudes (Jaques, 1995). Jaques (p. 22/23) states “Games and simulations change the balance of power (in comparison with conventional teaching). They provide students with a framework of rules and roles through which they can learn interactively through a live experience and to tackle situations they might not be prepared to risk in reality; to express feelings in respect of learning and to experiment with new ideas and strategies. In short, they get students to involve themselves personally as they interact with a set of events, both real and contrived. They also reactivate the sense of fun and play associated with many of the most vivid experiences of childhood. Games and simulations are also likely to create demands on the student’s capacity, values and attitudes. They involve individual and group interpretations of given information, the capacity to suspend disbelief and a willingness to play with the components of a situation in making new patterns and generating new problems; and these require an ability to tolerate a great deal of ambiguity. These elements are socially and psychologically risky and high levels of anxiety may be generated. But in games and simulations it is the anxiety of the roller coaster – it may feel dangerous but there is an awareness of the structure supporting the trip and a foreseeable end to the experience when feelings can be shared; thus the risk which could be traumatic becomes fun”.

*Knowledge management an ill-structured domain*
Knowledge management is a domain that recently has received increasing attention. However, as a knowledge domain it is still lacking a well-established theoretical and logical background, and, therefore, a coherent and well-developed methodology is still missing. As a consequence many knowledge management activities are more guided by opportunistic (IT) solutions than on a thorough understanding of the nature of the relations between the initial problem (or opportunity) statement and the organisational solutions available. This implies that there is a need for more formalised knowledge in the domain of knowledge management. What is clear at the moment is that knowledge management is an area where problems are multi-faceted, complex, and without univocal outcomes. Therefore, the problems in this domain can be categorised as ill-structured or wicked problems. Several authors have claimed that training to solve those kinds of ill-structured problems requires different instructional settings than training to solve well-structured problems. A further analysis can be found in Section 3.

This study examines the theoretical analyses and empirical results from research in the area of instructional use of games and simulations. It mainly focuses on approaches taken in designing game(-like) learning environments and distils a list of characteristics of games from the instructional theory. It also tries to find evidence concerning the appropriate learning approaches and measures which can optimise the learning effects of games and simulations. In this analysis we also look at a related instructional methods: *the use of case studies*, a method that is very common in the training of management techniques. A second analysis that is made in this study concerns *solving ill-defined or wicked problems*. In the KITS context the knowledge management situations can be characterised as being ill-defined. Both analyses result in a set of requirements for the KITS learning environment.

# 2. Using games for learning

## 2.1 Introduction

This chapter starts by defining the concept of 'game' and it lists characteristics of 'games' based on a literature study. The main constraint in this analysis is that we have looked at games in an 'instructional', or better, 'learning' context. In making this analysis we have compared games to related learning environments such as simulations, adventures, and case studies. We also have looked at combinations of games, simulations, and case studies. An analysis is made of the effectiveness of games and on how to enhance games by including extra support measures.

## 2.2 Games, a general definition

Games have played a role in instructional situations already for quite some while. The first field in which such applications took place was military training (Hays & Singer, 1989). Here, serious use of simulation and gaming began at the end of the eighteenth century, and the techniques have since been developed to a high degree of realism and sophistication.

"The next field in which important developments took place was business management training, where the use of games, simulations and case studies as vehicles for developing decision making skills was introduced in the mid-1950s. Here, there was a need to find a teaching method that could gap the bridge the gap between formal, academic instruction (which often lacked direct job relevance) and on-the-job training (which could be slow, and was generally restricted to a limited area). Around 1955, it was recognised that gaming and simulation methods could help provide a solution, and, in 1956 the American Management Association produced the first business game. This was a decision making simulation exercise for potential executives. Led by the Harvard Business School, which made the 'case-study-method' one of the mainstays of its teaching, the use of such exercises soon spread to business schools throughout the world (Ellington & Earl, 1998, p. 5)".

> "AMA Top Management Decision Simulation provides an environment in which two teams of players could represent officers of firms and make business decisions. Each of up to five teams with three to five persons each produced a single product which they sold in competition with other teams (Hays & Singer, 1987, p. 197)".

Originally, games were played in non-computerised environments, nowadays games can also be played through the support of computers with as the latest developments, that internet connections allow players to be at separate locations (Dasgupta, 1999).

First of all we have to set a general definition for games. Holsbrink-Engels (1998) points to a complicating factor in giving a definition of games: "Non-English languages tend to have just one term for what the English call 'play' and 'game'. In Dutch, for instance 'spel' is used for both play and game, and so are 'jeu' in French, 'Spiel' in German, 'gioco' in Italian and 'juego' in Spanish. The English word 'play' is related to the experience of pleasure. The word 'game' is related to the notion of competition. Games are contests among adversaries (players) operating under constraints (rules) for an objective (winning, victory or pay-off)". The Dutch philosopher Huizinga already recognized this problem in his famous work about "The play element of culture" in 1938, titled "Homo ludens". Huizinga (1955) stated however that a contest is also play. He distinguished the following crucial elements of a game ("spel"):

- an informal act or activity,
- occurring within certain temporal and spatial boundaries,
- developing according to freely chosen, but afterwards committing rules.
- the goal is the activity itself.
- the activity is accompanied by a feeling of tension and/or enjoyment and the consciousness that the activity is different from real life.

Dempsey, Rasmussen and Lucassen (1996*)* define gaming in a basic sense as "any overt instructional or learning format that involves competition and is rule guided (p. 4)". Several types of games can be distinguished: adventure games, simulation games, competition games, co-operation games, programming games, puzzle games, business and management games, etc. Below we describe this last category into more detail because these types of games are of interest for the KITS project because of their content.

*Business and management games*

Carson (1969) gives a few definitions of business games:

- ♦ “Business games are simplified mathematical abstractions of a situation related to the business world. The game participants, either individually or in groups, manage a whole firm or an aspect of it, by making business decisions for successive periods.
- ♦ A business simulation game may be defined as a sequential decision making exercise structured around a model of a business operation, in which participants assume the role of managing the simulated operation.
- ♦ Business games are case studies with feedback and a time dimension added (Carson, p. 39)”.

He states that these games generally fall into two classifications: general management or total enterprise games, and functional games.

*"General management games* are designed to teach decision making at the top management level where all major functional areas of the total enterprise are involved in achieving fundamental organizational objectives, such as maximum profit, return on investment, or attainment of certain sales levels or a certain share of the market. Generalized games of this type are designed to teach objective decision making through experimentation, evaluation, and modification (Carson, 1969, p. 40)”.

> "MARKSTRAT3 is a simulation that has been designed for teaching strategic marketing concepts. Course participants are grouped in industries, where four to six teams of around five members are in direct competition against each other. The instructor and the participants will usually run through six to twelve decision cycles, intermixed with conceptual sessions, case studies and application work.
> Each period, the teams managing the simulated firms must make the decisions, which are usually made by marketing managers. These decisions are organized in five easy-to-use self-explainable dialogue boxes such as:
> - Research & Development. The team must interface with the R&D department to specify new research projects. Specifications encompass the physical characteristics of future products and the target unit cost.
> - Brand Portfolio. When completed, R&D projects can be used to launch new brands, to target new segments in existing markets or to enter entirely new markets. Alternatively, teams can decide to upgrade existing brands.

- Production, Price &Advertising. A number of more tactical decisions must be made for each marketed brand. Teams must plan production batches carefully in order to avoid stock-out while minimizing inventories. Prices must be set according to the expectations of target segments. Finally, communication budgets must be allocated to marketed brands according to their position in the product life cycle, to their sales potential, etc.
- Sales Force & Distribution. Sales force decisions include the size of the sales force, and its allocation on distribution channel. Guidelines can also be set regarding the effort to dedicate to individual brands.
- Market Research Studies. More than twenty market studies can be ordered each period. Teams must select the most appropriate studies to purchase in order to avoid information overload (http://www.insead.fr/~gatignon/Markstrat.html)."

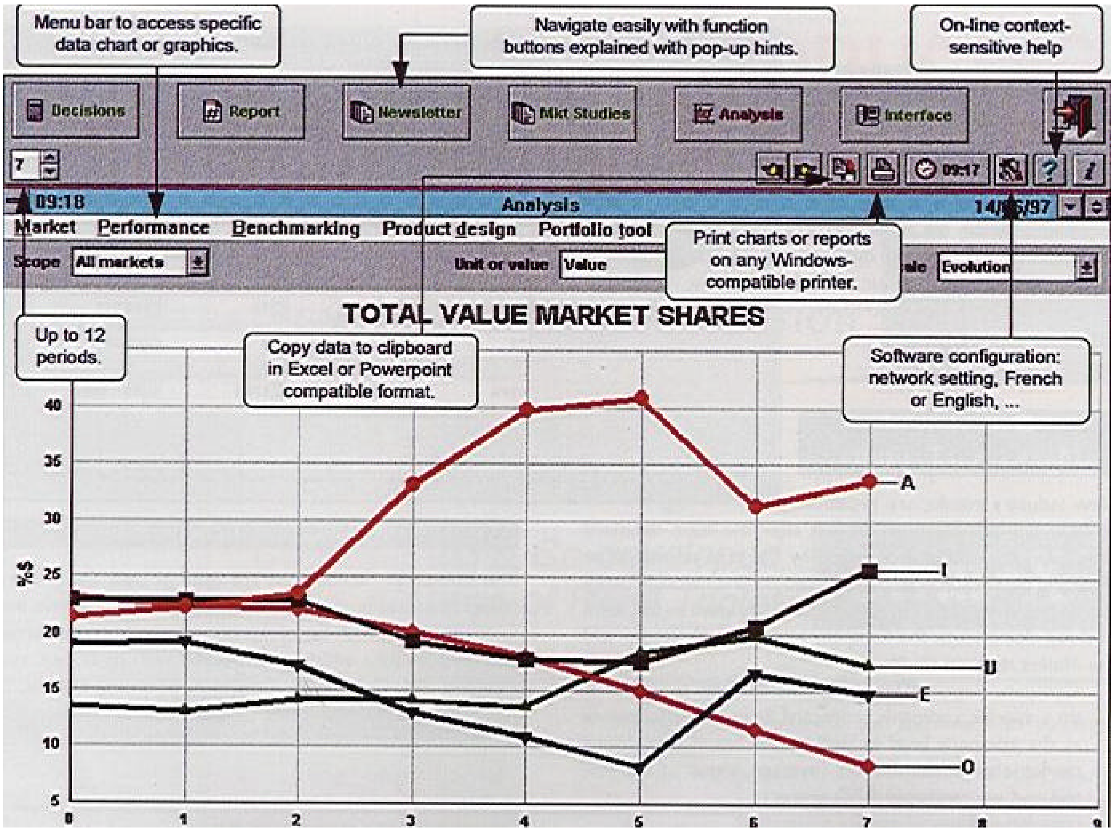



**Figure 1.** *MARKSTRAT3 screen. Source: http://www.insead.fr/~gatignon/Markstrat.html*

*"Functional games* are intended to teach specific skills in a particular management area such as marketing, production, inventory control, finance or some other. They are aimed at teaching better decision making at the middle and lower levels of management.

In these games, instead of trying to maximize attainment of some organizational goal, the players are usually working to minimize costs through efficient operation. This type of game is most useful in teaching the value of a specific set of decision rules such as EQQ in inventory control. Teams normally do not compete with one another in a market, but try to get the highest possible score relative to a perfect operation (Carson, 1969, p. 40)."

Although a wide variety of management games have been developed, they share several general features. Hays and Singer (1989) mention the following features:

- They allow the presentation of feedback of the results of players' actions.
- The environment represented in management games is expressed in logical or mathematical relations. Some of these relations are known to the players as rules while others are only vaguely qualified and become known during play.
- They allow interaction between the players (sometimes representing different functional areas within a company) and the environment.
- They provide a simplified view of reality. These simplifications are due to the desire to make the games manageable and sometimes because our understanding of the world is lacking.

Carson (1969), as well as Hays and Singer (1989) point to the importance of the elements of *risk and uncertainty* in the real business world and in management issues. Therefore these have to be introduced into business games through inclusion of some chance elements in the results fed back at the end of a decision cycle. "The use of random or stochastic rules provide higher functional fidelity and allow the trainee so see how a given decision may have different consequences depending on the other players or chance occurrences" (Hays & Singer, 1989, p. 1999).

Carson also mentions the use of different types of *time variation* in games, being time compression, time lag, and time cumulation. "Through use of computers it is possible to simulate years of business experience in a matter of hours. This comprehension of time makes it possible for the player to see long run, as well as immediate, results of his decisions.

Many games have time lags built into them so that decisions must be made in one time period in order for their results to be achieved several periods later in answer to problems expected to arise then. This teaches the need for future planning in management.

Time cumulation lets the player see how his decisions build on one another and hence should be based on long-run policies and objectives (Carson, 1969, p. 41)."

*Characteristics of games*

Based on the definitions above we come to the following characteristics of games:

- some goal state must be reached
- there are constraints and rules involved
- there is some form of competition
- they are situated in a specific context

The following sections will be used to elaborate these characteristics.

### *2.2.1 Reaching goal states*

An important feature of games is that there is some kind of goal that has to be reached. Those goals can be very different. The goal can be:

- To reach the highest level of proficiency and/or efficiency.

- To solve a particular problem or a series of problems.
- To be the best amongst the competitors.

In the last case the goal is not to reach the highest level or a predefined (goal)state, but the goal is related to the actions of the other players. This is closely related to the element of competition (see Section 2.2.3).

Goals can be the same every time the game is played, or they can change every time the game starts, or even during the game. In the well-known game "Risk" at the beginning of the play every player draws a mission card from a pile of 14 cards that all have different assignments. So the goals for the individual players are different and the goals can de different each time the game is played.

> The game of risk in its original form is a board game of world domination. The Board is actually a map of the world in the 1880's. The object of the game is to destroy the others players or achieve your mission. The players can do this by acquiring territories by using their armies to battle opponents. Each participant is allotted a number of armies at the beginning of the game. Additional armies are also allotted at the beginning of each turn depending on the number of territories and continents the player has conquered. The players then take turns rolling dice as they attack their neighbors in an attempt to eliminate them from the map.

In some games the (sub)goals can change during game-play because the player has reached a certain proficiency level and advances to a higher "playing" level. At this level new or more complex constraints may be introduced (see also Section 2.7.1).

> Tango is a business simulation designed by Celemi in Sweden for all decision makers in knowledge organizations. Tango provides a model which clarifies the business logic behind the knowledge organization and defines the specific factors which enhance profitability. These include familiar tangible factors such as pricing and capacity, as well as critical intangible factors such as image, know how, personal chemistry and individual competence.
>
> Tango participants see how these intangible factors are directly linked to financial results, and learn practical strategies to manage them.
>
> Participants are divided into four-member management teams. Each team is given a company to run for seven annual cycles, pursuing its business strategy in order to maximize profitability. Each team competes with the other teams for the same customers and key personnel. The simulation takes one day or two days (advanced level) to complete. After a dry-run in the first "year" to give players a feel of the game, the teams are required to make their own decisions about the kind of people they want to recruit, and the kind of clients they want to attract, and then to plan and execute projects. The most important decision, at this stage, is what strategy to adopt.
>
> At the end of each "year" the facilitator asks the teams what they have learned, and what conclusions they have drawn from their results. About halfway through the simulation, some of the control indicators that measure intangible assets and the flows of knowledge to, from, and within the invisible balance sheet are introduced. Thereafter, the groups use these control indicators to monitor their operations (http://www.tangonow.net/index2/index.html).

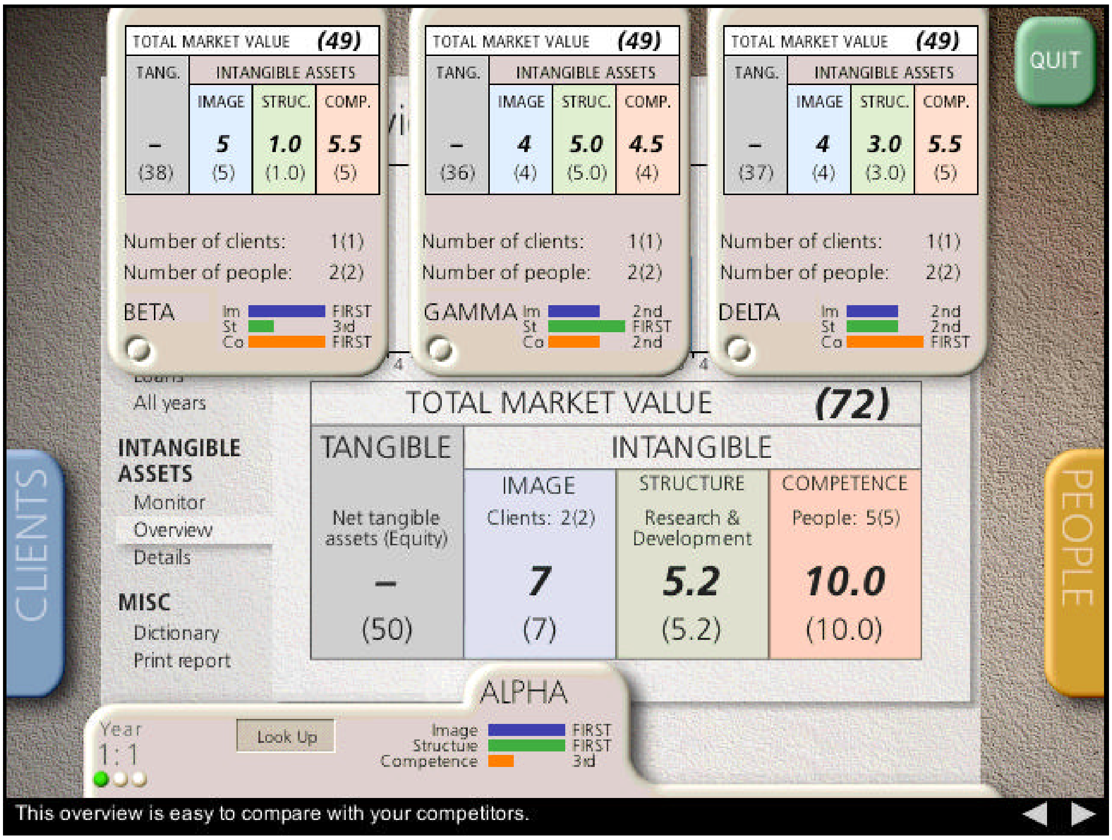



**Figure 2.** *An example of control indicators used in Tango. Picture taken from [www.tangonow.net](http://www.tangonow.net)*

The goals can be preset or left open, so players can set their own goals. For instance in "Virtual U" a computer simulation game for university administrators and others interested in managing a university, players can set their own goals as long as they stay between certain boundaries (in this case the game can continue as long as the institution remains financially viable), or they can select certain scenarios with preset goals (see: http://www.virtual-u.org/educause.html).

> "Virtual U provides a powerful, convenient, and user-friendly tool by which institutional professional and interested laypersons can participate in leadership challenges in a college or university setting. Users set, monitor, and modify a variety of institutional parameters and policies, allocate resources as they see fit, and watch as results continually unfold. The simulation provides an opportunity to experiment and succeed or fail in a safe and entertaining fantasy environment. While Virtual U is necessarily a caricature of real academic life, it is grounded in authentic conceptual structures and data. It will provide serious lessons in higher education (Massy, 2000)".

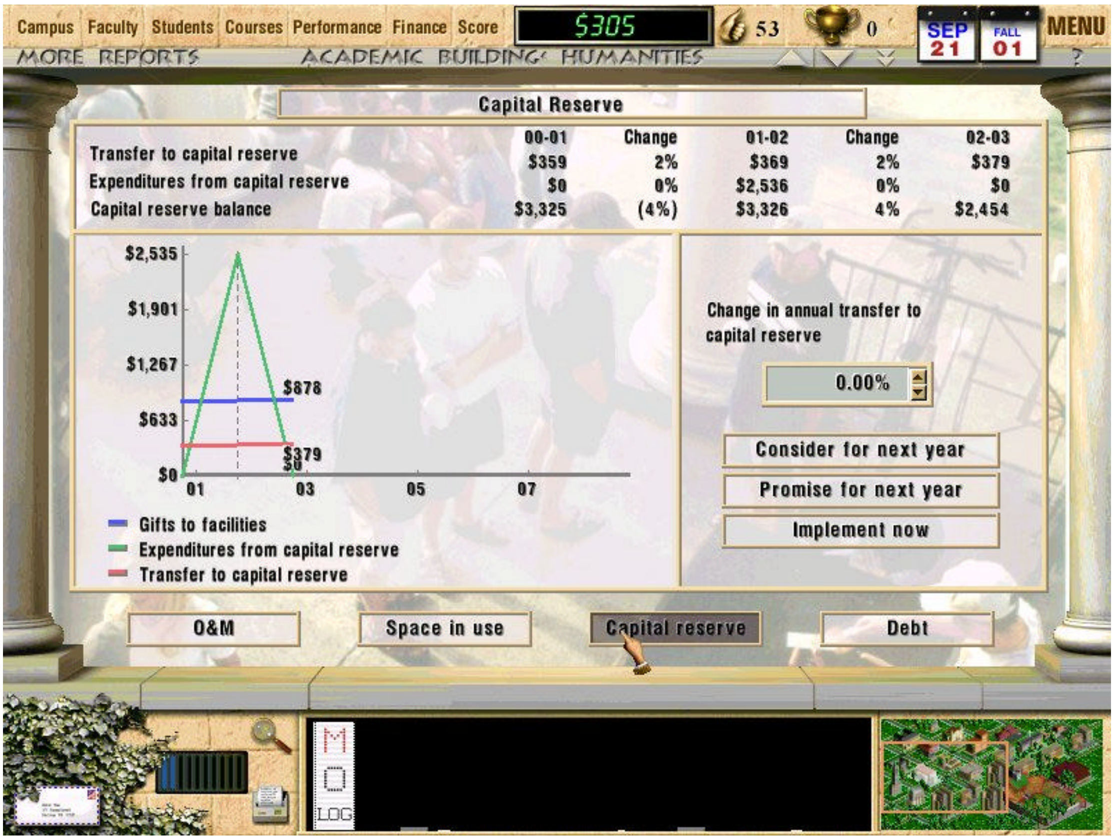



**Figure 3.** *Screendump from Virtual-U, showing how players can monitor their capital reserve (taken from http://www.virtual-u.org/screens.html).*

Quite often players have to reach their goals with a limited set of resources. At the start they have a specific number of resources and during the play they can consume or loose resources or acquire new ones.

### *2.2.2 Constraints, rules and incentives*

Each game consists of a basic set of rules that define which actions are allowed and which are not, and that define the setting and goals of the game. Additional constraints may be introduced by implementing resources/incentives that can be used (lost/won or acquired) for instance money, armies, “lives”. Cooper (1978) states "A well designed game has to be surrounded by constraints such as production costs, market trends, seasonal factors, availability of finance, industrial relations, stock holding costs and so on (p. 80). Some business games, for instance, enable teams *to obtain information (like market research information) at a price*. Cooper (1978) also thinks this is an important constraint. He advises that relatively little information should be fed back automatically to the participants and that relatively great opportunities should be given to them to buy information.

For example in Magnus, a management game used at the National University of Singapore (http://www.comp.nus.edu.sg/~yeogk/MAGNUS/game.html) players have the option to purchase information concerning their competitors. This information reveals the competitor's performance for the last period. With the additional information, players can make better judgement in their decisions. The cost of this information will be determined by the game administrator. There is no limitation how much information the player wishes to purchase. Players are allowed to buy any number of company's information as they desire, but the more information they buy, the more they pay and this will affect their profit (see Figure 4).

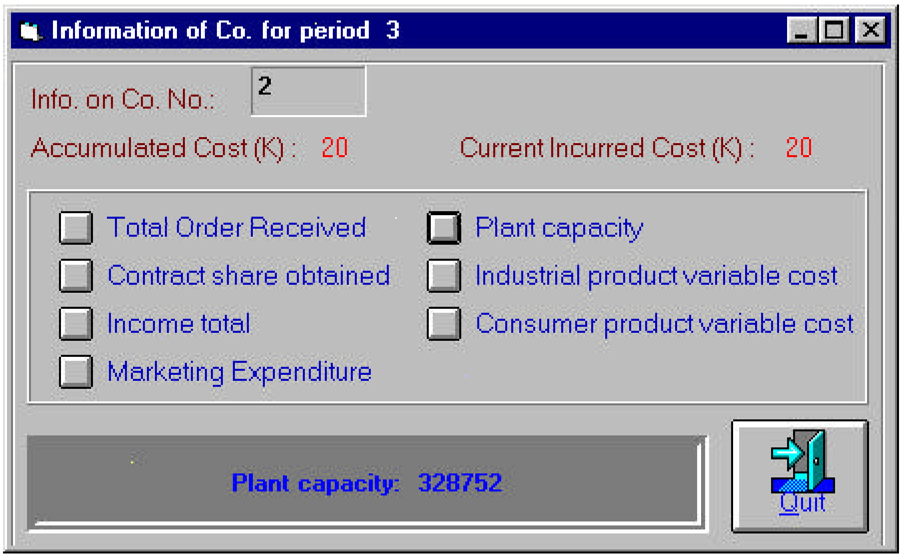



**Figure 4.** *Screen from Magnus concerning the buying of information. Taken from http://www.comp.nus.edu.sg/~yeogk/MAGNUS/game.html*

Constraints can also be induced by setting *time limits* to certain actions. For instance, in a knowledge management (board) game that is developed by “Inside games” (www.inside.hu) in Hungary there is a limited time for decisions so within the team organisation, teamwork and co-operation is needed.

In MARKSTRAT3 (see Figure 1), a business game developed by Insead in France and Strat*X in the United Kingdom, the marketing budget of each team is set each period according to the team's past results. In addition, a time constraint can be set to emphasize the importance of group dynamics and organizational behavior. A typical time limit for a MARKSTRAT3 decision is two hours (http://www.insead.fr/~gatignon/Markstrat.html).

Another form of constraints can be build into games is by using *conditions*. These conditions have the form of IF….. THEN …. actions. This means that a player can only perform certain actions if certain conditions have been fulfilled.

In a game that is used in the Department of Educational Science and Technology of the University of Twente students have to manage the process of implementing educational changes in an organisation. One of the actions that they can take, is to plan a meeting with certain persons to discuss the implementation of changes. However, planning such a meeting does not make sense when the different persons involved, are not in a certain state of awareness of the new possibilities. In that case the meeting probably will not be successful. If players plan a meeting under these conditions, they will loose the resources they have used to plan the meeting without getting any results/incentives.

*Trade-off and an underlying model*

When resources and incentives are used in games, as in the example given above, in most cases there is a kind of trade-off involved: every action a person takes uses some resources and resources are limited. Successful actions may lead to new resources. So the question for the players is "When to use their resources?" In certain cases they will have to take risks (see section 2.2.4) to accomplish their intermediate or final goals.

The use of resources and incentives in those games is based on a predefined set of (decision)rules, or in more complex cases, on an underlying model that computes the number of resources available (for every player of team ) at a certain point in time. Such a model will always be part of games in which certain processes are simulated (see section 2.3).

### *2.2.3 Competition*

Games require a sense of "winning" or "losing. This can be accomplished by:

- beating other players/teams,
- outperforming the others/teams,
- beating the system,
- outperforming your self (by improving your performance).

In most general business games several teams try to outperform the others in achieving fundamental organizational objectives, such as maximum profit, return on investment, or attainment of certain sales levels or a certain share of the market. This is the case in "Tango" which is described in the previous section.

There can de *different forms of competition* in a game: one in which the actions taken by one player/team directly influence the general state of affairs (the market) for all the others; and one in which the teams act in their "own world" and after a certain time period the performances of the different players/teams are compared to each other and a "winner" is indicated (for that round, or over-all).

As already mentioned in the section on functional games (see Section 2.2), in strategic management games teams normally do not compete with one another in a market, but try to get the highest possible score relative to a perfect operation (Carson, 1969). This is also the case in "Virtual U".

> "Virtual U players are scored in several ways. All runs produce annual "performance evaluations" and an "ultimate score" that the president may wish to maximize. Scenario simulations bring additional goals that add bonus points to the ultimate score if achieved. Players can view their scores using the *Performance* tool. Additional devices such as the annual trustee evaluation letter and plaques for achieving scenario goals add emphasis and interest.
>
> Maintaining financial viability represents the threshold criterion for presidential success. The university goes bankrupt if deficit spending triggers short-term borrowing needs in excess of what bankers will lend. The player will be warned in time to take remedial action. Failure to do so will terminate the game and negate all other accomplishments.
>
> The president's annual performance evaluation depends on four groups of factors: output measures, institutional performance indicators, attitudes toward the institution, and

> financial indicators. There are sixteen factors in all, each of which enters with a particular weight. For example, the *performance indicator* group counts for 35% of the overall evaluation. It consists of institutional prestige (20% of the 35%), educational quality (20%), scholarship (20%), student and faculty diversity (10% each), and the percent of alumni who have given anytime during the last five years (20%). Help definitions are provided and players can track their performance by looking at time series. Each year the simulated Board of Trustees sums up the president's performance in a letter that lists the areas needing improvement.
> The ultimate score is calculated according to the following formula, which is displayed prominently.
> Ultimate score = current trustee evaluation x (number of gaming years) + (current trustee evaluation – initial trustee evaluation) x 10 + total bonus points
> The formula recognizes improvements relative to the game's initial conditions, and it also rewards longevity and cumulative accomplishment. Voluntary termination of the game posts the score in the Virtual University Hall of Fame (Massy, 2000)".

### *2.2.4 Situatedness of games*

Games are situated in a specific context that make them (more or less) realistic, appealing and motivating for the players. An important concept related to the situatedness of games is the concept of validity/fidelity of the game and the context. "A very general definition of the concept of validity in relation to games is that the validity of a game is the degree of correspondence between the reference system and the simulated model thereof (Peters, Visser & Heijne, 1998, p. 23)". Several criteria can be used to assess the degree of correspondence between "reality" and the game situation. Elements that play a role in this process are:

- Complexity
- Surprise, unexpected events, risk and uncertainty
- Roles and (differential) access to information
- Representation form and type of interactions

The following sections will be used to elaborate these elements and the concept of validity/fidelity.

*Validity/fidelity of simulations/games*

An important characteristic of a simulation/game is its validity. Different types of validity can be distinguished. *Content* validity expresses the degree in which a simulation/game environment captures the relevant aspects, activities and parameters of the real-life operational environment it simulates or refers to. *Construct* validity expresses the degree in which the constructs, knowledge and skills the learner has to use/develop in a simulation/game environment resemble the ones that one has to use in the real world.

Jacobs and Dempsey (1993) point to the fact that the underlying content and activities presented within the context of a simulation/game will never exactly emulate the operational environment. However, the simulated or gaming environment can offer distinct advantages over the operational environment during training. This is especially so when the activities being trained are complex or have situational constraints which inhibit the training process in the operational environment (e.g. occur infrequently, or have associated risk, danger, or expense). Other researchers have made similar arguments.

A great deal of time, energy and money is spent in trying to simulate as accurately the physical components of the operational environment as close as possible (given the technology available), to optimize simulation fidelity. Simulation fidelity, according to Hays and Singer (1989), "is the degree of similarity between the training situation and the operational situation that is simulated. It is a two-dimensional measurement of this similarity in terms of:

- The physical characteristics, for example, visual, spatial or kinaesthetic; and
- The functional characteristics, for example, the informational and stimulus and response options of the training situation."

MacCallum Stewart (1981) points to the fact that most management games and exercises simulate some aspect of the management process. However they represent only some of the features or reality and others are omitted. The choice of which features to include and which to omit will determine the reality and the complexity of the exercise. In the process the designer should take into account what the (s)he wants the participants to learn (see also section 2.6). MacCallum Stewart lists six features that indicate how close an exercise is to reality:

- "The extent to which the game is based on a real-life organization or product.
- The extent to which complex processes in real-life are represented by stochastic operations, such as random number generation or dice throwing, in order to simplify the situation.
- The extent to which participants feel the same pressure and emotions within the simulation as they would in reality, for example, time pressure or conflict purposely engendered by the exercise.
- The participants' perceptions of the relevance and realism of the exercise. Some aspects deliberately contrived by a designer may be perceived by the participants as aspects only of the game and not of reality.
- The possible use of the simulation for strategic planning. Where an exercise is also used for such a purpose it is likely to be very realistic but its associated complexity may reduce its value as a teaching aid.
- The quantitative reality of the model. As well as an initial realism in this area games with a high financial content must be updated in line with inflation (MacCallum Stewart, 1981, p. 62)."

*Complexity*

Game realism and complexity have long been connected in the literature when considering games for teaching and training. Especially since the introduction of computer-based games this issue has got new attention because the computer introduced new possibilities to simulate complex processes in a short time against relatively low costs. Furthermore, developments in computer technology have created ways to give the games a high degree of realism. The danger, however, of implementing complex models in games is that they may get unplayable.

When exploring game complexity of business games, often the focus is on the number of decisions to be made in each game cycle. This complexity measure is often accompanied by some degree of recognition of the influence of decision types or the impact of the interrelatedness of the different decisions (Burgess, 1995).

Wolfe (1978) distinguished two criteria that could be applied to judge the degree of complexity of (computer based) business games: playing complexity and program complexity. *Playing complexity* entailed the amount of sophistication and intricacy faced by the learner. This was further desegregated into three components:

- Decision type (for instance concerning: number of products, territories available, number of raw materials, pricing decisions, sales promotion budgets, R & D expenditures, financial moves, capacity changes, maintainance expenditures, production scheduling element),
- Number of decisions per cycle, and
- The size of the players' manual in number of words.

Program complexity entailed the relative size of a game's program as determined by its number of executable statements. Wolfe states that these criteria are only rough indicators of complexity.

Burgess (1995) tried to operationalize game complexity by formulating a quantitative measure of dynamic complexity that takes into account the number of decisions per cycle, but also other aspects of complexity such as the interactions between individual players (operationalised by the number of players per team and the number of competing teams), and time pressure. He notes that the effects of the number of players per team and the number of competing teams are problematic and require further examination.

MacCallum Stewart (1981) gives some other indicators of a game's complexity:

- "The quantity of information that is included in the exercise, which may be indicated by the volume of the participants' notes or the amount of presenter's input.
- The number of variables that are represented to the participants and whether this increases as the game progresses.
- The number of actions required of the participants. This is indicated by the number of decisions to be made in model-based games but varies with the actions of participants in most situation-based games.
- The number of possible strategies that participants may adopt and the extent to which they are enumerated by the presenter.
- The mathematical complexity of the model and whether this can be varied on different occasions of play (MacCallum Stewart, 1981, p. 62)."

Surprisingly, in none of the articles reviewed, the number of constraints/rules was mentioned as a factor contributing to the complexity of the game.

*Surprise, unexpected events, risk and uncertainty*
Risk and uncertainty are characteristics of games that make them realistic, appealing and motivating. Uncertainty can be induced in a game by introducing unexpected events, chance, random responses, or by leaving part of the rules and underlying models implicit. Risk can be introduced by these factors to, but also by using resources/incentives that can be used. People can loose or acquire resources depending on their own action, chance or the actions of others.

In the game "RISK", for instance, uncertainty is accomplished by the fact that the missions of the players are secret and because the other players do not know which extra hidden resources a player has not yet placed on the map. Risk is accomplished by introducing the element of chance in a "battle between players" because the players have to throw dices to see who wins the battle.

In the before mentioned game "Virtual U" presidents of the university are confronted with chance events: for example, the governor makes a sudden change in the state appropriation, Congress adjusts research funding, or there is a serious fire or scandal on campus. The events may have good or bad consequences, and they may or may not call for an explicit response.

This same strategy is used in the "Coltec game" (De Hoog, Van Heijst, Van der Spek, Edwards, Mallis, Van der Meij, & Taylor, 1999). Unexpected events are introduced to teams of players. They have to react to these events by applying appropriate knowledge management actions.

> "Coltec is a manufacturer of adhesives, coatings, headquartered in Utrecht, The Netherlands. Coltec was established in 1968. Initially, Coltec operated in the market of custom formulated adhesives and coatings. During this period the company developed a unique competence in the development and manufacturing of coatings and adhesives for extreme temperatures. Based on this competence, Coltec developed in the seventies a series of standardized products for the industrial market. In 1981 Coltec was acquired by the Namco Group, a leading USA-based consortium in the chemical industry. In the eighties, Coltec extended its activities to include consumer products (do it yourself glues etc.). Within the Namco Group Coltec operates as an independent company. It develops, manufactures and sells its own products. Since the acquisition by Namco, Coltec has steadily extended its range of products. In 1997, Coltec offers over 250 products, ranging from high performance adhesives used in space engineering to D.I.Y. products. Coltec currently operates in 23 countries in Europe and the Middle East. It has production plants in 12 European countries, and it employs over 5000 people.
>
> Event 3
> Because of new environmental legislation, from 1 January 1999 on it is no longer allowed to use polyethydimydyl in adhesives manufactured and sold in countries of the European Union. This is a major threat for Coltec, because polyethydimydyl is used in all its adhesives to prevent premature coagulation. Coltec has no immediate replacement for polyethydimydyl. Shortly after the announcement of the new legislation, Gluco, a smaller competitor has put on the market a tiling adhesive that does not contain polyethydimydyl , which is rapidly gaining market share (De Hoog, Van Heijst, Van der Spek, Edwards, Mallis, Van der Meij, & Taylor, 1999)".

*Roles and (differential) access to information*

"In one sense all gaming involves role playing since the individual participants are asked to assume the situation assigned (Graham & Gray, 1969, p. 18). For the time of the game, the players or teams assume a certain role. For instance, they take over the management of a production company. Strategy must be set up, goals must be reached, information must be analysed and decisions must be made.

In the game "Virtual U" players take the point of view of the university's president. They choose the kind of institution they wish manage: e.g., public or private, large or small, prestigious or not. They can make decisions or view operating and financial reports at any time, and they can drill down to the department or even the individual professor level. They determine policies for resource allocation, faculty hiring, enrollment management, and many other decisions faced regularly by college and university administrators. They can set policies consistent with long-term strategies or intervene in specific decisions as desired (see Figure 5).

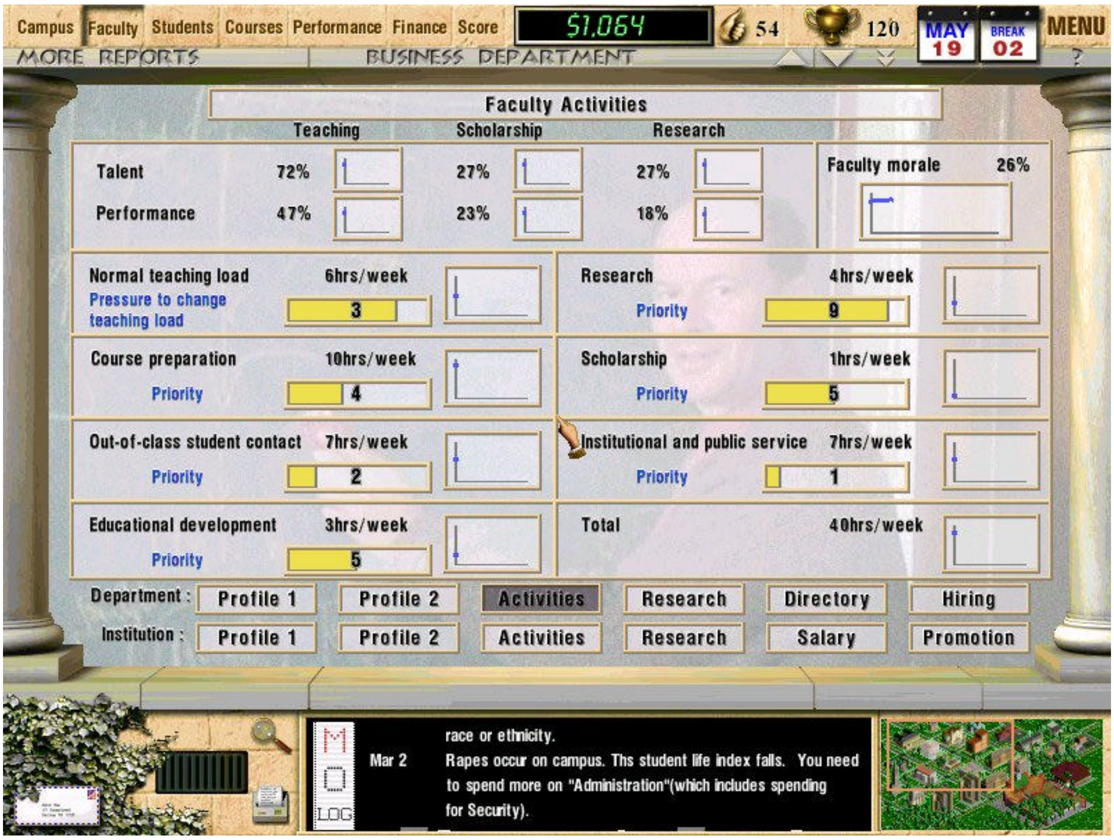



**Figure 5.** *Screendump from Virtual-U, showing how a player can direct a faculty by defining how the people working in it should prioritize their time (taken from http://www.virtual-u.org/screens.html).*

By playing a role the participants get more deeply involved in a game. The gaming situation becomes *intrinsically motivating*. In some cases, players are so deeply involved in their role, that they stick to their roles even in situations that are not related to the game. For instance, persons involved in a business game refuse to sit on the same table with players of other teams during a coffee break; or are discussing strategies with other teams to obstruct the team that is in the lead at that moment.

In games where no clear roles are given to the players often extrinsically motivating factors are introduced. For example, the winning person or team will get a price or an award. These prices/awards, however, are not a part of the game.

In most games the different players assume the same role, although their goals not necessarily are the same (see section 2.2.1). However, when playing in teams, the teams as u unit may have the same roles (and goals), but within the teams roles could be different. A form of task differentiation could be introduced. In a general business game, for instance, one player in a team could assume the position of a marketing manager, others the role of logistics-, production- or knowledge manager. A form of differentiation is used in Capstone (see below).

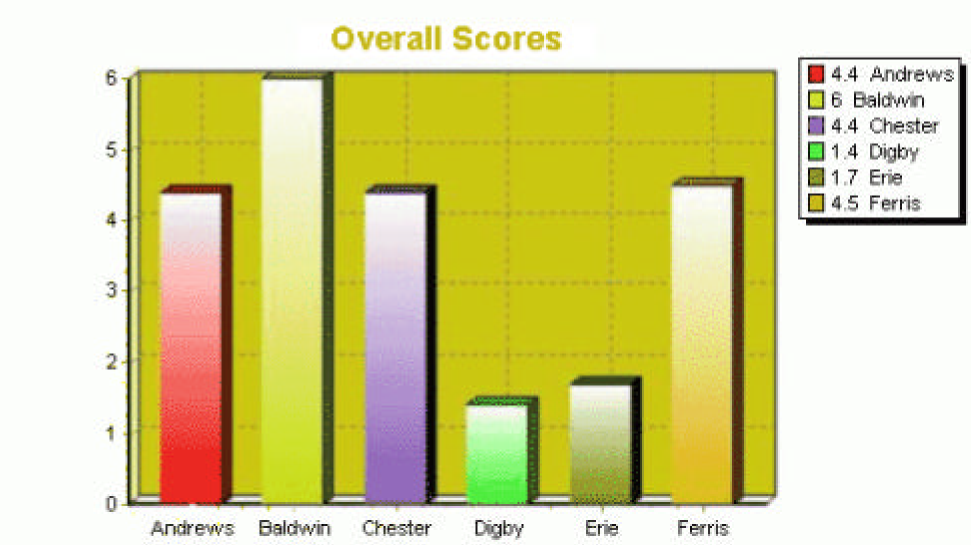
In the last case, the type and amount of information that is available during game-play for every player not necessarily will be the same.

Capstone™ is a business game from Management Simulations Inc. in the USA, It creates a hands-on environment where students learn to run — and coordinate — several business functions: marketing, R&D, production, human resources, and finance

Capstone™ participants divide into competing teams of four to seven players. Each team acts as an executive committee responsible for running a $100M electronic sensor company. The game consists of two components:

- A Web site — where players download starting market conditions, communicate with team and class members, and upload corporate decisions.
- Decision Support Software — which runs in Microsoft® Excel. Using the software, players determine product positioning, price, sales and promotion budgets, production levels and financing requirements.

Capstone™ offers methods for groups to organize by function, by product, by segment, or as a board of directors. Much thought has gone into shaping the conversations within a team. For example, tactical questions are resolved through what-if analysis, while graphs and charts foster discussion of the strategic implications (http://www.capsim.com/).




Weightings by team must add up to 100% or 0%. Weightings are currently due by Round 3 and the importance of each round is prorated.

| Team | Cumulative Profits | Ending Market Share | Avg ROS | Avg Asset Turnover | Avg ROA | Avg ROE | Ending Stock Price |
|---|---|---|---|---|---|---|---|
| Andrews | 5% | 20% | 5% | 25% | 15% | 20% | 10% |
| Baldwin | 35% | 0% | 35% | 0% | 30% | 0% | 0% |
| Chester | 40% | 40% | 0% | 0% | 0% | 0% | 20% |
| Digby | 0% | 35% | 15% | 10% | 10% | 10% | 20% |
| Erie | 15% | 20% | 10% | 10% | 10% | 15% | 20% |
| Ferris | 10% | 25% | 10% | 25% | 10% | 10% | 10% |

**Figure 6.** *Capstone uses a web page to display success graphs as a form of feedback to the teams. Taken from http://www.capsim.com/*

Regardless of the roles participants play in a game, the *acces to information* may be different between games. In some games all relevant information will be available at the beginning of the game, while in others certain elements only become available during the course of action. The latter certainly holds for games in which information is treated as an important resource.

*Representation forms*

Another feature of games is that there are differences in the representation form: the way in which the material is presented to the players. The game can be text-based, a game-board may be used, or a computer to display materials. Furthermore, there might be a real-life game leader/trainer/instructor that controls the actions that the players make and/or gives feedback based on certain specified rules or an underlying (computer)model. In other cases the role of the game leader may be taken over by paper- or computer-based rules and/or models.

For instance, in a knowledge management game developed by the Dutch firm "Recense" each team that exits of four to eight players has an own game board. Each team has a coach who accounts for the instruction, coaching and leading the evaluation (www.resense.com).

**Figure 7.** *A typical situation in which Tango is used in the traditional representation form. Picture taken from www.tangonow.net.*

> In a Tango simulation, up to 24 participants sit in groups of four at separate tables, each with an identical game board in front of them. For two days (covering up to seven 'years'), they act as the management of their own knowledge company, in competition with the other groups. A 'facilitator' is present to clarify the rules, organize the 'market', and act as referee. The game board is divided into three sections: one for the ordinary income statement and balance sheet, one for the invisible balance sheet and one in the form of a calendar on which projects are planned and executed. Recently the representation form of Tango has been changed from aboard game to a computer based environment, an example of which is presented in Figure 2 (www.tangonow.net).

Reigeluth and Schwartz (1989) distinguish four different types of representations for computer based simulations, that are similar to the description given above for games in general:

- The enactive form uses equipment along with the computer to provide the most realistic simulations.

- An iconic form consists of video or graphic displays
- A visual symbolic form uses symbols or icons
- A verbal symbolic form is composed of words and numbers.

All four representation forms may be used to produce a dynamic presentation that requires learner participation, but the degree of realism will differ depending on the nature of the content and the instructional objectives.

When a game is played by multiple players a distinction can de made *between synchronous and asynchronous games*. In synchronous games all players have to be available (at the same place) at the same time. In asynchronous games players act whenever they have the time, and they do not have to be available at the same time and place. Asynchronous play of games always has been possible, think for instance of "chess by correspondence", but has got new attention since the world wide web has opened new ways of communication between people (see for instance how a web page is used by Capstone in Figure 6).

Based on the the representation form that is used in games, and on the fact that it is stand-alone game, a game with players that opreate seperately of each other, or players that act on the same board/market, *different types of interaction* may de distiguished.

## *2.3 Games, simulations, microworlds, adventures, and the like*

In the preceding section we have given a general definition of games and we have listed characteristics of games. Next to games we find instructional and training systems that are similar to games in a number of respects. In the present section we present a number of such systems including simulations, microworlds, and adventures. The reason for doing so is twofold. First, it helps to clarify a terminological issues, in any case it will make clear that there is no straight terminology and that terms are often used in different ways. Second, from the educational embedding of game-like systems we can learn lessons on how to design the KITS game.

A type of system that is very close to games is *simulations*. Simulations resemble games in that both contain a model of some kind of system and learners can provide both with input (changes to variable values or specific actions) and observe the consequences of their actions. According to Gredler (1996) the deep structure of games and simulations differs in three important ways:

Instead of attempting to win (the objective of games), participants in a simulation are executing serious responsibilities with the associated privileges and consequences.

The event sequence of a game is typically linear, whereas, according to Gredler, a simulation sequence is non-linear. The player or a team in a game responds to a stimulus, typically a content-related question and either advances or does not advance, depending on the answer. This sequence is repeated for each player or team at each turn. In a simulation, however, participants at each decision point face different problems, issues or events that result in mainly from their prior decisions.

A third difference is the mechanisms that determine the consequences to be delivered for different actions taken by the players. Games consist of rules that describe allowable player moves, game constraints and privileges and penalties for illegal (non permissible) actions. Further the rules may be imaginative in that they need not relate to real world events. In contrast the basis for a simulation is a dynamic set of relationships among several variables that (1) change over time and (2) reflect authentic causal processes (i.e. the relationships must be verifiable).

Jacobs and Dempsey (1993) stated that the distinction between simulation and games is often blurred, and that many recent articles in this area refer to a single "simulation game" entity. "After all a game and a simulation generally may be assumed to have goals, activities, constraints and consequences. A distinction could be made between simulations and games in the following way. Where the task-irrelevant elements of a task are removed from reality to create a simulation, other elements are emphasised to create a game. These elements include competition and externally imposed rules, and may include other elements such as fantasy and surprise".

Both Gredler (1996) and Jacobs and Dempsey (1993) emphasise similar resemblances and differences between simulations and games. Games and simulations both have some kind of underlying model, allowable actions to be taken by the learner, and constraints under which these actions should take place. Games add to this some kind of "winning" or "losing" characteristics, participants need to reach a kind of goal state and quite often have to do so with a limited set of resources. The latter means that in games participants have to think about the trade-off between costs and profits of actions.

In this respect it is important to make a distinction between two kind of simulations. De Jong & Van Joolingen (1998) divide computer simulation into two types: simulations containing conceptual models and those based on operational models:

- *Conceptual* models hold principles, concepts and facts related to the (class of) system(s) being simulated.
- *Operational* models include sequences of cognitive and non-cognitive operations (procedures) that can be applied to the (class of) simulated system(s).

In similar vein Gredler (1996) distinguishes experiential simulations and symbolic simulations. *Experiential* simulations establish a particular psychological reality and put participants in defined roles within that reality. Participants, in the context of their roles, execute their responsibilities in an evolving situation. Experiential, simulations, in other words, are dynamic case studies with the participants at the inside. In *symbolic* simulation the behaviour that is simulated is usually the interaction of two or more variables over time, and the learner can manipulate these variables in order to discover scientific relationships, explain or predict events, or confront misconceptions (Harper, Squire, & McDougall, 2000). In contrast to the experiential simulation in a symbolic simulation the learner is not a functional element of the situation. The student acts but stays external to the evolving events, so the reinforcement on the actions is different. Operational or experiential simulations are closer to games than are conceptual or symbolic simulations. In operational simulations (e.g., a flight simulator) the participant has specific goals to reach (e.g., take off the plane, keep it in the air for a certain while, and land it safely) under specific constraints (e.g., a specific quantity of fuel). For conceptual or symbolic simulations these elements are often not present. Here, learners interact with a simulation to understand the underlying model (e.g., collisions in physics, see de Jong et al., 1999), they do not need to reach a certain goal state. There are also no specific constraints in the form of resources the learner has to take into account. Conceptual simulations can be changed into more game like environments by adding specific goals. For example Miller, Lehman, and Koedinger (1999) designed a simulation in which the topic is electricity, more specifically electrically charged particles. In the simulation that is called "Electric field hockey" students are expected to gain an intuitive feel for the qualitative interactions of electrically charged particles by playing a game in which they have to place charged particles in such a way on a hockey field that another particle that is given an initial speed and direction form a certain point hits a hockey goal.

Environments like the above mentioned “Electric field hockey’ are often labelled ‘microworlds’. They are mainly used in the field of physics. A microworld is an idealized world that represents ideas/models in a theoretically ideal form (White, 1984). White used such an idealized world to let students develop a basic understanding of Newton’s laws of motion. (see also diSessa, 1979). The real world is confusingly complex. It includes friction and gravity and has nonrigid bodies that do not correspond to the point masses of the formal physics. In the microworld she used there is just Newtonian motion in a pure and simplified form. There are no extraneous complications, such as friction, to distract and confuse the learner. This should provide students with the kind of experience which would permit the induction of the correct beliefs about force and motion. Within the context of a microworld one could either set the learners free to explore as they choose, or one could give them some activities to pursue. Setting a goal, such as hitting a target or navigating a maze creates a game-like challenge (White, 1984).

This way of creating ‘microworlds’ or ‘games’ with copnceptual simulations still misses one essential aspect of games, namely that the participant is an integral part of the environment and that there is a sense of involvement, as for example in the case in a simulation such as a flight simulator. In games, participants do get a certain ‘role’ that they have to play. In conceptual simulations or microworlds the participant is still ‘external’ to the simulated domain.

A type of environment in which this ‘involvement’ is also present, are ‘adventures’. In adventures the participant receives a certain role and has to achieve a certain goal. In their way to the goal learners have to perform all *kinds of actions* and *take specific decisions*, which often includes *asking for specific information*, actions and decisions often have their *specific cost* (in the form of certain abstract tokens, or more concrete ones as lifes, money, and other resources), on the way to the final goal substages can be reached by *gaining points* (which also can be made more concrete in the form of money or some other gadgets). A game takes place in a kind of artificial world (quite often having a ‘horror’ or ‘science fiction’ type of setting), but in a learning context these worlds can be replaced by ‘real worlds’. An example of such a learning adventure is ‘Khufu’s Quest’ developed at the Educational Technology Department of the San Diego State University (see http://edweb.sdsu.edu/courses/edtec670/index.html). In Khufus’ Quest the *setting* is ancient Egypt and the *goal* of the participants is to find a missing ‘thether ball” that is hidden somewhere in the great Pyramid. In taking *actions and decisions* on their navigation through the pyramid participants encounter personages such as village people and guardians who may help or try to prevent the reaching of the goal. On their quest participants have to earn points on their way to achieve certain subgoals and the *trade-off* they encounter is that they may loose the content of their back-pack interact with guardians before they have acquired certain objects. On their way participants are support by certain clues that they receive (e.g., “get the Rosetta stone. It will help you undertand hieroglypics”). In the words of the authors:

> “The player must first navigate their way through the Great Pyramid using their personal knowledge about the environment of Giza, Egyptian art and architecture, and a series of educational clues given along the way. In the mazes of the pyramid, the player is given clues to where objects (including the location of the tether ball and rope) are hidden and what point value is associated with each object. The player must acquire enough objects to total 30 points to be allowed entrance into Khufu’s Tomb. The player then takes possession of the tether ball and rope from within Khufu’s Tomb, navigates their way out of the Great Pyramid, attaches the ball to the pole at the top of the Great Pyramid, and

plays a game of Tether ball to return home. Along the way the player may encounter obstacles that prevent them from reaching their goal of returning home.”

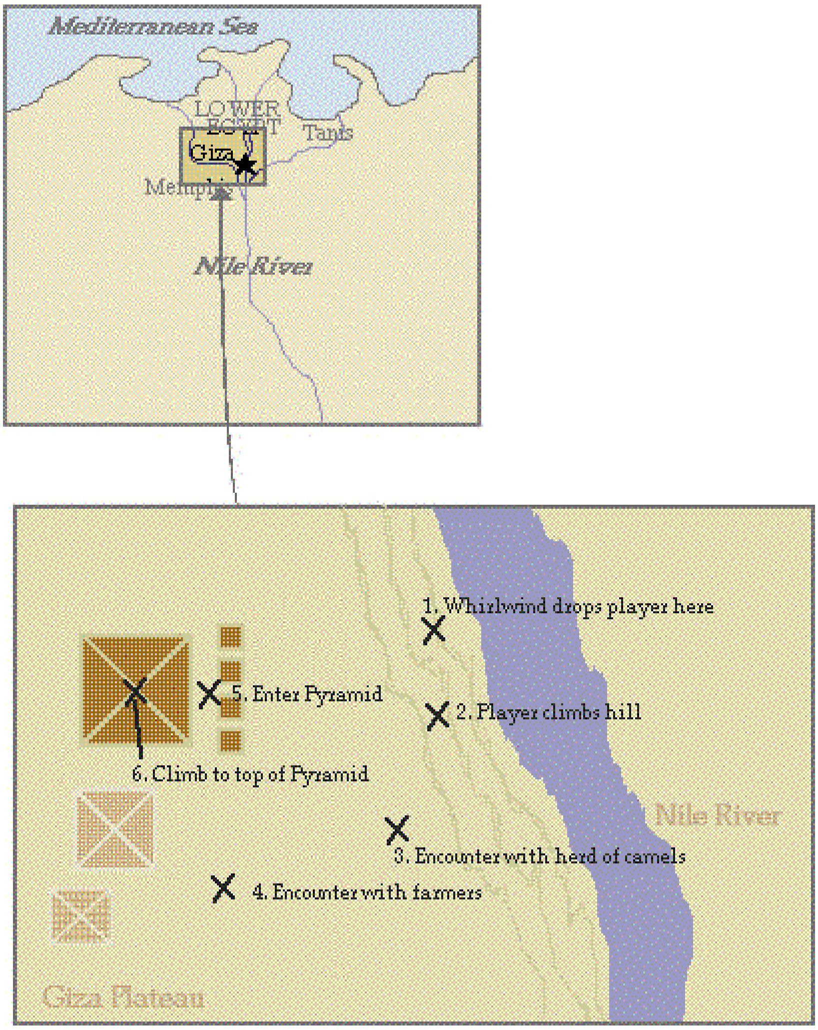



**Figure 8.** *Overview of maps from ‘Khufus’ Quest’ (taken from http://edweb.sdsu.edu/courses/edtec670/index.html)*

The overall educational goal of the adventure is to reinforce knowledge about geography and history of ancient Egypt (including for example knowledge about the Giza plateau and the Nile river and knowledge about social ordering in ancient Egypt). Though an adventure as Khufus’ Quest shares many characteristics with games, the main difference is that Khufus’ Quest misses a model of ancient Egypt that calculates or reasons so that a full adaptive response to actions of the participants can be given.

To summarize the data presented in the previous sections the main differences between simulations and games are given in Table 1.

**Table 1.** *The main differences between simulations and games.*

| | Underlying model | Goal | Competition | Constraints | Involvement |
|---|---|---|---|---|---|
| Operational Simulations | Yes | Yes | No | Yes | Yes |
| Conceptual Simulations | Yes | No | No | No | No |
| Adventures | No | Yes | Yes | Yes | Yes |
| Games | Yes | Yes | Yes | Yes | Yes |

## *2.4 Case studies*

In the sections above case studies play an important role. They are used in (combination with) games and simulations to provide learners with a specific context. Percival and Ellington (1980) suggest that these three “instructional methods” are closely related and overlap each other (see Figure 9). They identify three basic types (games, simulations, and case studies) and four ‘hybrid’ types (games used as cases studies, simulation games, simulated case studies and simulation games used as case studies).

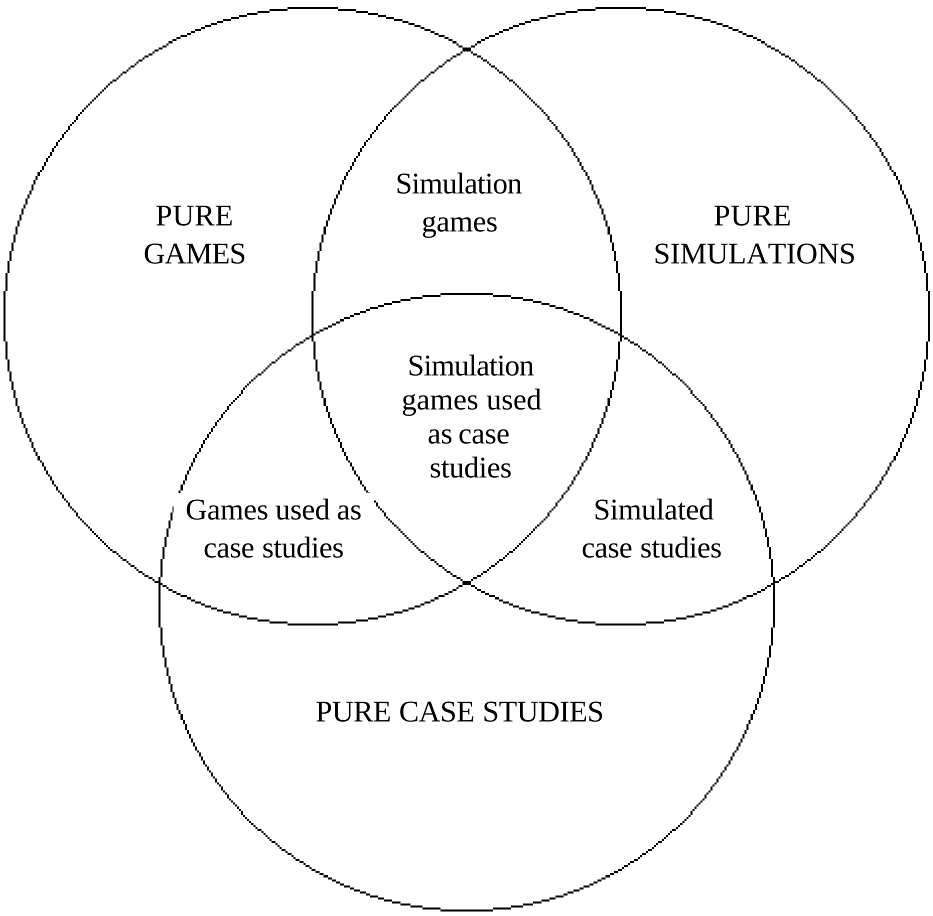



**Figure 9.** *Relationship between games, simulations and case studies (according to Percival & Ellington, 1980).*

Van Merriënboer (1997) sees case studies as a central part in his "Four component instructional design model for training complex cognitive (technical) skills". The basis for the design of a training program according to this model, is whole-task practice, offering non-trivial, realistic, and increasingly more authentic cases and problems to the learners. Schema acquisition by induction and mindful abstraction from these concrete cases are the key learning processes.

He gives the following description of case studies: "Well designed case studies require learners to actively participate in actual or hypothetical problem situations situated in the real world. Often, such a case study will describe a spectacular event in order to arouse the learners' interest: an accident, a success story, a disputed decision that turned out all right, and so on (Van Merriënboer, 1997, p. 245)". He distinguishes three different kinds of case studies, which may be distinguished on the basis of the type of knowledge they illustrate.

- ♦ Case studies that illustrate conceptual models will typically describe a concrete object, event or situation that exemplifies the conceptual model.
- ♦ Case studies that illustrate goal-plan hierarchies will typically be artificially designed objects (or be descriptions of those objects) that have to reach particular functions or goals.
- ♦ Case studies that illustrate causal or functional models will describe real-life processes that illustrate a number of principles or a causal or functional model.

The last two forms of case studies may take the form of computer based design or process simulations, according to van Merriënboer.

He makes a distinction between *case studies* and *modeling examples*. "Case studies typically describe how things take place or are organized in the real world. They focus on a description of objects, problem situations, events, natural processes, etc. Modeling examples (see also Section 2.7.8), on the other hand, pay explicit attention to the problem solving processes an expert task performer goes through while working on a particular case problem. They illustrate the application of SAPs[1] and heuristics that may be helpful to find a solution (Van Merriënboer, p. 249). This does not mean however, that case studies and modeling examples can not be integrated.

Ertmer and Russell (1995) state that although there are many variations in both form and style, case-based instruction tends to involve complex problems situated in the real world of practice. They describe four common components of *case-based instruction* (based on a distinction made by Wassermann):

- ♦ *A case report* containing relevant (but not conclusive) data centered around specific topics, but which may take students across disciplinary lines in their search for viable solutions.
- ♦ *Study questions* that require the students to examine the issues, assumptions, evidence and counter-evidence that are relevant to the case.
- ♦ *Small group work* gives students the opportunity to discuss cases and questions with each other, to analyse the data, evaluate the nature of the problem(s), decide upon applicable principles, and recommend a solution or course of action in a "safe context".
- ♦ *Whole group discussion* (or debriefing) in which the experiences from the students are discussed to guide students through a reflective process about their learning.

[1] SAP stands for Systematic Approach to Problem solving.

Van Merriënboer (1997) also states that questions are an important part of case based learning. Leading questions may require the learner, for example, to:

- Come up with a more general idea or organizing framework for a set of similar ideas.
- Compare and contrast a set of similar ideas.
- Analyse a particular idea into smaller ideas.
- Provide a description of a particular idea in its main features or characteristics.
- Find a well-known, familiar example or counter-example for a particular idea.
- Find an analogy for a particular idea.
- Explain the relative location of elements in time or space.
- Re-arrange elements and predict effects.
- Explain a particular state of affairs.
- Predict future states.

"Whereas such questions may be used in all different instructional strategies, they play a dominant role in an inductive-inquisitory strategy or guided discovery approach (Van Merriënboer, p. 247).

## *2.5 Learning goals of games, simulations, and case studies*

Games serve many functions such as tutoring, amusing, helping to explore new skills, promoting self esteem, practicing existing skills, drilling existing skills, automatizing or seeking to change an attitude (Dempsey, Rasmussen, & Lucassen, 1996*)*.

Hays and Singer (1989) give an overview of the way games can be used to train cognitive skills. They state "games can de used *in* training to: assess entry level behavior; measure criterion performance; aid in formative and summative evaluations; provide instruction in specific knowledge and skills; and to teach attitudes. Games can be used *before* traditional instruction to provide advanced organizational information to trainees so that they are better prepared for traditional instruction. Games can used *in place of* traditional instruction to transmit facts, teach skills, and provide insights. Games can also be used interspersed with or *after* traditional instruction for drill and practice, to integrate and maintain skills, or to illustrate the dynamics or abstract principles of a task (p. 194)".

Ellington and Earl (1998) describe ten ways games, simulations and case studies can be used in tertiary education:

- To reinforce teaching of basic facts and principles
- To demonstrate applications of theory
- To develop higher cognitive skills of all types.
- To support and supplement laboratory and studio work
- To develop library and research skills.
- To act as an 'icebreaker'
- To develop communication skills
- To develop interpersonal skills
- To develop multi-faceted work related skills
- To achieve affective objectives of all types.

*Educational use of business and management games*

Carson (1969) asked himself “What if anything do business and management games teach?”. He mentions three aspects. They teach the importance of planning and timely decision making; the art of working through and with people; and the importance of the control function and control devices.

Hays and Singer (1989) mention several additional educational properties of business and management games:

- They can provide training on the interactions of functional specialities within companies. The players can learn how their speciality is dependent on others, and to learn to interact more effectively to reach common goals.
- Playing the game sensitizes trainees to the fact that in the real world they must take particular actions solely for the sake of information gathering.
- They offer the trainee the opportunity to learn and refine a variety of analytic tools.
- They allow trainees to become aware of the psychological and organizational interactions and interdependencies in business.
- Players learn that most decisions are made by teams of several players and that these decisions are constrained by a variety of variables, such as time, complexity of the decision, and personality factors of the players.
- They can teach institutional facts about the trainee’s company (standard operating procedures etc.).
- They teach the importance of establishing policies and making long range plans.
- They can act as a powerful motivating force for the trainee and can maintain that motivation by being interesting and involving.

> The learning goals of MARKTSTRAT3 are: "At the end of the course, participants will have a better understanding of the following subjects:
>
> - Strategic marketing concepts. Students will be confronted with real problems and will better understand key concepts such as: the relationship between market share and profitability, the experience effect, product/market portfolios, allocation of resources, market segmentation and product positioning, barriers to entry, competitive advantage, etc.
> - Business integration. Students will have to use the knowledge acquired in many different business courses in order to succeed fully. Topics from finance, accounting, production, economics and marketing will all have to be integrated to form a coherent course of action.
> - Marketing tools. Students will make an extensive use of a number of marketing tools which have been built into MARKSTRAT3 : perceptual mapping, conjoint analysis, portfolio analysis, marketing planning, multiple regression analyses, etc.
>   Market and competitive analysis. To be successful, teams will have to analyze changes in markets, anticipate the moves of competitors, evaluate different courses of action, plan long-term and secure competitive advantages (http://www.insead.fr/~gatignon/Markstrat.html)".

De Caluwé, Geurts, Buis & Stoppelenburg (1996) distinguish six categories of goals of using simulation games that are related to changes in organisations: development of consciousness and motivation, training of skills, development of knowledge and insight, training in communication and co-operation, integration of learning experiences, and assessment.

According to Celemi participants in Tango learn:
- "To formulate and implement strategies that incorporate both key people and customers.
- To find the balance between increasing your company's effectiveness and profitability for the short run and enhancing its strength over the long run.
- How your company's profitability (short-term and long-term relates to investments in personnel, competence and confidence building) measures with your customers.
- The value of "indirect" marketing, such as customers care attitude and service to influence the company's reputation. Your customers make their decisions to purchase based in large part on your computer's image.
- How to measure success when your product, professional competence, is intangible. Why? Because decision making has very little to do with computers. Also because human beings learn through the body. Learning is enhanced by actually being able to physically touch the environment (www.tangonow.net)".

## *2.6 Effects on learning*

Gaming is considered to produce a wide range of learning benefits like, improvement of practical reasoning skills, higher levels of continuing motivation, and reduction of training time and instructor load (Jacobs & Dempsey, 1993). Some authors however have questioned some claims due to a lack of sufficient empirical support (Bredemeier & Greenblatt, 1981). Much of the work on the evaluation of games has been anecdotal, descriptive or judgmental. There are some studies, however, that give some insight in the effectiveness of games/simulations compared to other forms of instruction.

Randel, Morris, Wetzel, and Whitehill (1992) examined 68 studies directly or indirectly (review studies over the period of 1963 - 1984, and separate articles published between 1984 and 1991) on the difference between simulations/games and conventional instruction in student performance. Business games were *not* included because, according to the authors, "they do not cover traditional academic subjects and because of the difficulty of specifying exactly what subject matter was taught, especially in management games (p. 264)".

A summary of findings:

- "Of the studies reviewed
  36 (56%) found no difference
  22 (32%) found differences favoring simulations/games
  5 (7%) favored simulations/games, but their controls were questionable
  3 (5%) found differences favoring conventional instruction
- Seven out of eight studies involving math found that the use of games is superior to traditional classroom instruction for improving math achievement. Subject matter areas where very specific content can be targeted and objectives precisely defined are more likely to show beneficial effects for gaming.
- The greatest number of studies on simulation/gaming is in the area of social sciences. The majority of these studies (33 out of 46) showed no difference in student performance between games/simulations and conventional instruction.
- Five out of six studies demonstrated that games can not teach language arts effectively, particularly when specific objectives are targeted.
- Social science games tend not to use a computer, while math, physics, and language arts games tend to use a computer.

- Simulations/games show greater retention over time than conventional classroom instruction.
- In 12 of 14 studies, students reported more interest in simulation and game activities than in more conventional activities (p. 269)".

Wolfe (1997), in contrast to Randel et al., reviewed only studies in which a computer based general management game was used to teach predefined strategic management learning outcomes. The studies had to be comparative in nature with at least one treatment and one control group. He found evidence for the effectiveness of business games. In every study citied in the article, the particular gaming application that was used, produced significant knowledge-level increases. When the business game approach was pitted against the case approach, which is the major alternative teaching strategy in strategic management courses, the game approach was superior to cases in producing knowledge gains.

*Affective learning*

According to Bredemeier and Greenblat (1981) simulation games are believed to have great potential in the area of affective learning. They are assumed to be more affective than traditional teaching methods for increasing empathy and might lead to changed perspectives and orientations. The results they report, however, are not conclusive. "The available evidence suggests that, under certain circumstances and for some students simulation-gaming can be more effective than traditional methods of instruction in facilitating positive attitude change toward subject and its purposes (p. 324)".

*Motivation*

Bredemeier and Greenblat (1981) report that numerous studies support the idea that simulation gaming leads to higher levels of motivation and interest than more traditional forms of instruction. However, little is reported about the "whys" of this effect.

Malone (1984) observes that games have three characteristics that enhance trainee motivation. Games offer a *challenge* with goals and uncertain outcomes. They enhance trainees' *curiosity* through audio-visual techniques, humor, and new information content, and they allow trainees to *fantasize* by providing an imaginative context and adventure scenarios. However, as the author pointed out, his studies focused on what made games fun, not what made them educational.

Few studies say something about the relation between game characteristics and learning outcomes. The available results are summarised below.

*Goals*

Within the context of a microworld or simulation one could either set the learners free to explore as they choose, or one could give them some activities to pursue (White, 1984). Setting a goal, such as hitting a target or navigating a maze creates a game-like challenge. By changing the goal the focus of attention can be changed. Miller, Lehman, and Koedinger (1999) report that several empirical studies suggest that training in connection with a microworld-specific goal, can detract from the microworld's pedagogically targeted objective.

On the other hand there are studies that conclude that students are able to achieve some success in a simulation/game without having completely understood the underlying rules/models: "A problem related to this kind of programs is its game like character. Students are very easily inclined to play it as a game only. As a consequence, we have to make sure that students reflect on what they do and experience, in order to make them switch over to thinking about the physics of the problem (Van 't Hul, Lijnse & Moens, 1990, p. 130)."

The findings reported above make that Miller, Lehman, & Koedinger (1999) come to the conclusion that "the learning outcomes achieved through microworld interaction depend largely on the surrounding instructional activities that structure the way students use and interact with microworlds (p. 306)". This issue will be adressed in Section 2.7.

*Situatedness*

Hays, Jacobs, Prince, and Salas (1992) performed a meta-analytic review of flight simulator training literature. They cite evidence indicating positive transfer can be accomplished using simulators that only slightly match the physical characteristics of the operational environment, but whose functional requirements provide for an effective learning environment. They argue that simulation design should optimal fidelity and that fidelity should not be treated as an end in it self. Effort should be made to determine the minimum acceptable fidelity level that still ensures adequate training outcomes, especially transfer.

Reigeluth & Schwartz (19890 give several suggestions concerning what factors should be considered when deciding on the level of fidelity of a simulation:

- The degree of complexity of the real world environment
- The potential for transfer to the operational environment
- The motivational consequences of incorporating the high fidelity characteristics, and
- The resulting expense involved in upgrading the realism of the simulation.

The study of Hays, Jacobs, Prince and Salas (1992) also found some indications that the type of task and the complexity involved did have some effects on learning outcomes. Normal takeoffs, approaches, and landings presumably less complex in nature, produced mean effect size outcomes at or above .57, whereas night carrier landings and selected aerobatic manoeuvres, thought to be more complex, often produced low or even negative effect size outcomes.

Wolfe (1997) reported contradictory data concerning the influence of game complexity on learning results in business games. In one study, knowledge gains were the same regardless of game complexity, whereas in another study, knowledge increase expanded with game complexity.

*Learner characteristics*

Dempsey, Rasmussen and Lucassen (1996) reviewed 99 sources on instructional gaming. They found that few articles considered variables related to learner characteristics. Academic ability was one of the characteristics that was most frequently reported (8 studies) along with sex. Jacobs and Dempsey (1993) state "One important finding in some of the gaming literature is that gaming ability may differ in significant ways from academic abilities, which rely on abstract thinking and verbal fluency (p. 202)".

According to Seginer (1980), gaming ability differs from academic ability in three respects: (1) the cognitive processes involved in gaming may include the ability to perceive relationships rather than language command; (2) gaming is more independent from self-perceptions of confidence and control; and (3) gaming is not affected directly by social background.

Windschitl and Andre (1998) investigated the effects of a constructivist versus objectivist computer simulation environment on students' conceptual change within the setting of a college human physiology class. The study provided some evidence that an exploratory (constructivist) simulation experience could be more effective in altering learners' misconceptions than a confimatory simulation experience.

"In addition, the results suggest that the epistemological beliefs of learners interact with the type of learning environment in determining achievement. Students with greater epistomological sophistication did better in the exploratory simulation environment, while students with less sophisticated beliefs about knowledge and learning achieved best in the more prescribed, confirmatory simulation environment (Windschitl and Andre, 1998, p. 158)".

## *2.7 Instructional support*

There is general consensus that learning with interactive environments such as games, simulations, and adventures is not effective when no instructional measures or support is added. Miller, Lehman, and Koedinger (1999, p. 306) for example stated that "the learning outcomes achieved through microworld interaction depends largely on the surrounding instructional activities that structure the way students use and interact with microworlds". Earlier, Knotts, and Keys (1997) in the context of learning from games asserted that "Early research in business gaming and experiential learning destroyed the notion that games were self teaching. Instructor guidance is critical and must be applied during crucial states in the game development to insure that learning closure takes place. Students must be guided, prompted, motivated, and sometimes forced to learn from experiences (p. 387)". Also, de Jong and van Joolingen (1998, p. 181) after reviewing a large number of studies on learning from simulations concluded, "The general conclusion that emerges from these studies is that there is no clear and univocal outcome in favor of simulations. An explanation why simulation based learning does not improve learning results can be found in the intrinsic problems that learners may have with discovery learning." After analysing a large number of studies de Jong and van Joolingen concluded that adding instructional support to simulations might help to improve the situation.

In the following sections we present a number of instructional measures that could play a role in learning from games. In a later deliverable more detail and specifications of these instructional measures will be given.

### *2.7.1 Model progression*

The basic idea behind model progression is that presenting the learner with the full complexity of a complex situation at once may be too overwhelming. In model progression the situation (or model or case) is introduced gradually, step by step. White and Frederiksen's (1990) work on QUEST is one of the best known examples where the idea of *model progression* has been applied. QUEST treats electrical systems and models of electrical circuits in QUEST differ in their *order* (qualitative or quantitative models), *degree of elaboration* (number of variables and relations between variables), and *perspective*. While learning with QUEST, learners are confronted with models that advance from a qualitative to a quantitative nature, that are more elaborated, and that transform from a functional to a physical perspective. In this respect the instructional sequence follows the (assumed) transition from a novice knowledge state to an expert one. As far as we know, no controlled evaluation of

QUEST has been undertaken. Model progression in which the model increases in complexity for the learner was studied in Swaak, van Joolingen, and de Jong (1998). SETCOM is a simulation on harmonic oscillation where the model develops from free oscillation, through damped oscillation to oscillation with an external force. Swaak et al. (1998) found that model progression was successful in enlarging the students' intuitive knowledge (but not their conceptual knowledge) as compared to an environment without model progression.

In learning from games model progression can be introduced by introducing different 'levels' in the game. At each level, the complexity of the game (e.g., by introducing more levels of choice, or more complex rules that govern the behaviour or by introducing more or more severe constraints) can be increased.

### *2.7.2 Prompting and assignments*

Learners can be helped in their planning process by having access to prompts or assignments or by receiving assignments from the system. The use of prompts has bee explored as a means to improve training effectiveness. Prompts may take a number of forms (Jacobs & Dempsey, 1993). "For example prompts may be given to help the learner respond to a question and take the form of an answer or partial answer. Prompts may be used in a less directive manner, such as providing a rule or mathematical formula. Prompts can also be used to promote the learners' self awareness or self-monitoring." De Jong et al. (1994) describe different types of *assignments* that can be used in combination with simulations, among others investigation assignments that prompt students to find the relation between two or more variables, specification assignments that ask students to predict a value of a certain variable, and explicitation assignments that ask the student to explain a certain phenomenon in the simulation environment. In De Jong et al. (1995) using a simulation on collisions, Swaak et al. (1998) using a simulation on harmonic oscillation, and De Jong, Härtel, Swaak, and Van Joolingen (1996) using a simulation on the physics topic of transmission lines it was found that students (who were free to choose) used assignments very frequently, and that using assignments had a positive effect on gaining what they call "intuitive" knowledge.

In games the overall assignment of learners is to reach a certain goal. Learners can be helped by providing them with smaller assignments that they can follow if their own planning process does not support them.

### *2.7.3 Feedback*

One of the primary forms of feedback a learner may get is the intrinsic feedback from the game: the "score" at the end of the game. Outcome measures reflect the learner's overall performance in the game. Outcome measures may simply document the final status of events, or may specify a cumulative performance measure. Comparative criteria may also be applied to a give outcome measure, thereby providing a relative scaling of performance in relation to others completing the simulation. In addition there may be all sorts of feedback on specific actions of learners. For example, the learning environment may check if all conditions for performing an action have been met, and if this is not the case report to the learner. Process measures, on the other hand, analyse critical step-by-step actions and decisions that eventually lead to the final outcomes. The feedback may come from the learning environment itself, from a "human mediator" who is observing and monitoring the game, or from co-participants.

### 2.7.4 Additional information

In games and simulations learners need to have sufficient background knowledge to be able to make right decisions. Sources of information that help understand crucial variables or, if necessary, specific rules may be essential to let the learning interaction progress in a meaningful way. It is known from the literature that this is most effective when the information is offered Just-in-Time (see de Jong & van Joolingen, 1998). In game like situations, part of the learning experience is to gather additional information. Normally, acquiring this information involves costs such as money and time.

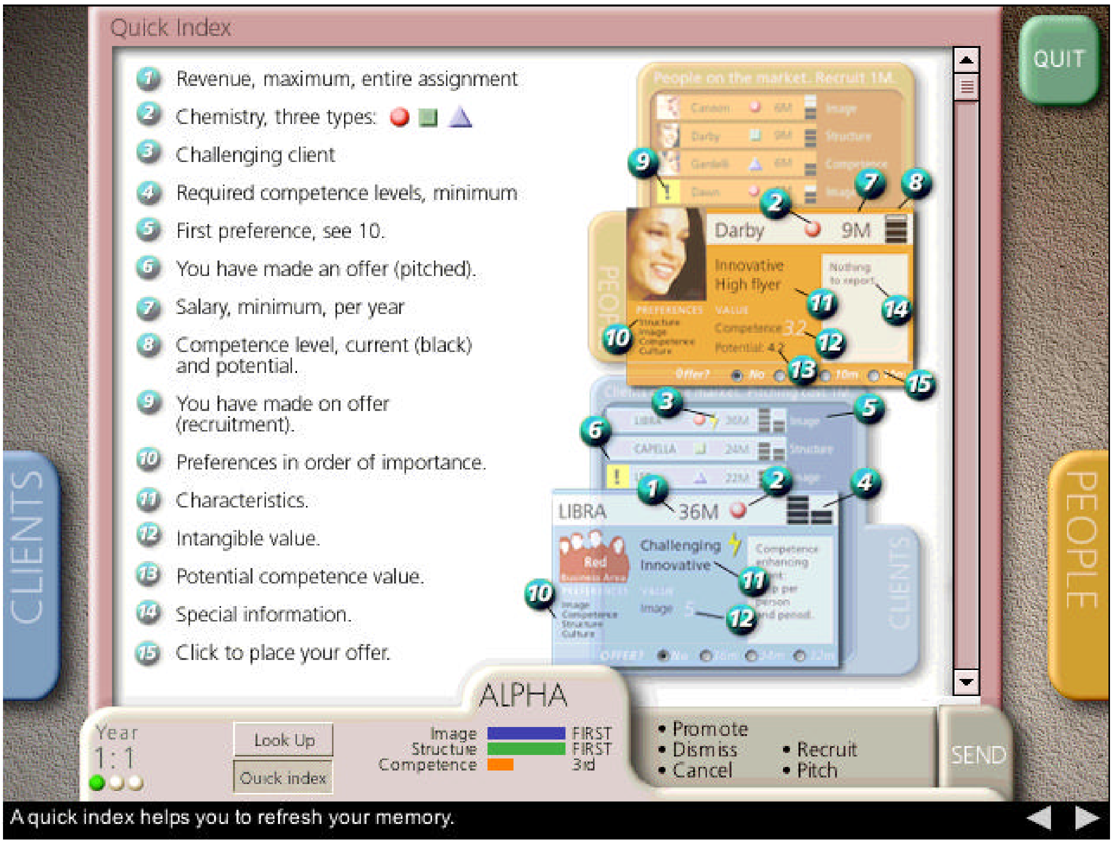



**Figure 10.** *The game Tango from Celemi uses a quick reference to refresh the participants' memory about the decisions tehy have to make. Taken from www.tangonow.net.*

### 2.7.5 Monitoring facilities

In the area of simulations several monitoring facilities have been offered. Support for *monitoring* one's own discovery process can be given by overviews of what has been done in the simulation environment. Reimann (1991) provided learners in Refract with a notebook facility for storing numerical and nominal data from experiments. Data in the notebook could be manipulated so that experiments could be sorted on values for a specific variable, experiments could be selected in which a specific variable has a specified value, and an equation could be calculated over experiments. Also the student could replay experiments from the notebook. Similar notebook facilities are present in Smithtown (Shute & Glaser,

1990) and Voltaville (Glaser et al., 1988) and SIMQUEST (Veermans, van Joolingen, & de Jong, in press). In SHERLOCK learners can receive upon request an overview of all the actions they have taken so far (Lesgold, Lajoie, Bunzo, & Eggan, 1992). Schauble, Raghavan, and Glaser (1993) presented monitoring support that not only provided an overview of students' actions, but also offered the opportunity to group actions under goals, and to ask for an "expert view" that gives the relevance of the student's actions in the context of a specific goal (e.g. to find the relation between two variables).

In games, especially in complex situation, it seems to be of great value to have the opportunity to inspect the history of the interaction.

### *2.7.6 Reflection and debriefing*

One of the issues in learning from simulations is that during the simulation "intuitive knowledge (see Swaak & de Jong, 1996) is acquired. By introducing a final phase of reflection and debriefing learners may acquire more explicit knowledge on the rules of the game and on the strategy that they have followed. Petranek (2000) states that several authors in the simulation and gaming field stress the value of oral defriefing. Written debriefing is, however, is rarely used. "The major hrdle is the time needed to write and evaluate the writing. However, the benefits far outweigh the costs. With written debriefing, participants can reflect about their behavior, facilitators can assess individual learning, and students can privately communicate with their professor (Petranek, 2000, p.108)".

### *2.7.7 Explicitation*

Making your knowledge and strategies explicit is also the idea behind introducing tools that help to formulate and note ideas or by introducing co-operative situations in which learners have to explain to each other what they intend to do or have done. Especially in the area of collaborative learning, the notion, that for collaboration ideas have to be made explicit is used as an argument pro collaborative learning (see e.g., proceedings of the 1999 CSCL conference, Palo Alto).

### *2.7.8 Problem formats*

There are several ways to provide problems to learners, who mainly depend on, which of the problem elements (givens, goals, and solutions; see Section 3.1) are actually presented to them. A distinction can be made between product-oriented and process-oriented problem formats. Product oriented problems only are focused on the (end) solution, while process-oriented problems also pay attention to the solution process (strategies, heuristics). Some examples of problem formats (Van Merriënboer, 1997):

*Conventional problems* are problems in which the learner is confronted with some givens and a (often)-specific goal, and the task is to find a solution. Many people identify whole task problems with conventional problems.

*Worked-out examples* contain a description of a given situation, a goal and a good solution to reach this goal. In addition it may be desirable to identify the critical features in the worked out-examples by annotating them with what they are supposed to illustrate. In contrast to conventional problems, worked-out examples focus attention on problem states and associated operators enabling learners to induce generalised solutions.

*Modelling examples* are worked-out examples that also contain a description of the problem solving process that leads to an acceptable conclusion, so that the application of systematic approaches to problem solving are illustrated (for example an annotated think aloud protocol of an expert solving a problem).

*Completion problems* are problems for which a given state, a goal state and a partial solution are provided to learners. The task of the learners is to complete (small or large parts of) the partial solution.

*Goal-free problems* refer to problems with non-specific goals. Compared to goal-specific problems, goal-free problems prevent learners from working backward from the goal, but forces them to move forward from the givens. This reduces cognitive load and may facilitate learning because learners can more freely explore the problem space. An example: conventional problems in the troubleshooting domain typically ask the learner to identify the cause of a particular malfunction. Alternatively, a goal-free problem would require the enumeration of all possible faults that are consistent with a particular type of system behaviour.

*Reverse problems* present both a solution and a given goal, and the learners have to trace the implications of different given situations. For instance in the context of software engineering, one might present an algorithm designed to reach a particular goal. Students then have to evaluate the strengths and weaknesses of the algorithm by predicting its behaviour in different situations (inputs).

*Imitation problems* are combinations of conventional problems and analogous worked-out examples. Students have to identify the analogy between the conventional and worked-out problem and use the example to map the new solution.

*Problems with performance constraints* refer to problems in which learners are required to apply the same set of heuristics or approaches as experts do.

*Problems with process worksheets and cognitive tools* are similar to the previous ones, but less directive.

The problem formats discussed above should not be seen as distinct alternatives, but as complementary approaches to scaffolding learner's behaviour.

## 2.8 Summary

This chapter started by defining the concept of 'game' and gave a list of characteristics of 'games' based on a literature study. This resulted in the following definition: Games are competitive, situated (learning) environments based on a set of rules and/or an underlying model, in which, under certain constraints, some goal state must be reached. Games are situated in a specific context that make them (more or less) realistic, appealing and motivating for the players. Important elements that are related to the situatedness of games are validity/fidelity, complexity, risk, uncertainty, surprise, unexpected events, role play, access to information, and the representation form of the game.

Games as learning environments are closely related to simulations, microworlds, adventures and case studies. The definitions of these environments partially overlap. For instance, the distinction between simulation and games is often blurred, and many recent articles in this area refer to a single "simulation game" entity.

The educational goals of games depend on the setting in which they are used and can be very diverse like: development of consciousness and motivation, training of skills, development of knowledge and insight, training in communication and co-operation, integration of learning experiences, and assessment.

Much of the work on the evaluation of games has been anecdotal, descriptive or judgmental, but there a re some indications that they are effective and are superior to case-studies in producing knowledge gains. However, there is general consensus that learning with interactive environments such as games, simulations, and adventures is not effective when no instructional measures or support is added. Support can be added by implementing model progression, prompting, assignments, feedback, additional information, monitoring facilities, reflection, debriefing, explication and different problem formats.

# 3. Solving ill-defined problems

## *3.1 Introduction*

As stated before problem solving is seen as a main activity for the acquisition of knowledge and skills in working with games and simulations. In the most general sense, a problem is an unknown that results from any situation in which a person seeks to fulfil a need or accomplish a goal. According to the influential work by Newell and Simon (1972) problem solving is described as a heuristic search process in a problem space. The problem space is defined by:

- The representation of the initial state of the problem.
- The set of operators available for processing a problem state.
- The criterion of an acceptable problem state.

Problem solving then refers to tentatively applying operators to states in order to find a sequence of operators or a solution that transforms the initial state into the goal state.

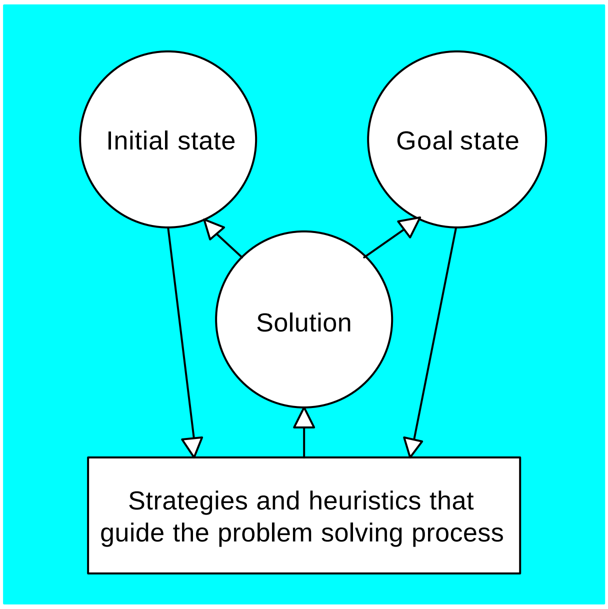



**Figure 11.** *General model for problem solving*

Figure 11 shows four elements that are relevant to describe problem-solving processes.

1. An initial or given state;
2. A criterion of an acceptable goal state;
3. A sequence of operators or a solution that transforms the initial state into the goal state
4. The strategies and heuristics that guide the problem solving process (i.e. tentatively applying operators to states in order to find a solution).

This general model can be used to explain qualitative differences in problem solving between experienced and inexperienced problem solvers. These differences are related to the process of tentatively applying operators. Beginners use general, domain unspecific strategies and heuristics (so called weak methods like means-ends analyses en hill climbing methods) to search the problem space. While experienced problem solvers use more powerful and domain specific strategies and heuristics (so called strong methods like recall of analogical problems and working forward). Advanced problem solvers are able to use those strategies because they have general knowledge of the domain, which is organized in cognitive schemata.

Jonassen and Tessmer (1996) state that “problem solving engages a variety of cognitive components such as

- Domain knowledge (propositional information, concepts, rules and principles).
- Structural knowledge (information networking, semantic mapping/conceptual networking and mental models).
- Ampliative skills (constructing/applying arguments, analogizing and inferencing).
- Metacognitive skills (goal setting, allocating cognitive resources, assessing prior knowledge, assessing progress/error checking).
- Motvational/attitudinal components (exerting effort, persisting on task, engaging intentionally)
- Knowledge about self (articulating prior knowledge, articulating sociocultural knowledge, articulating personal strategies, and articulating cognitive prejudices/weaknesses.”

## 3.2 Well- and ill-structured problems

The kinds of problems that humans solve vary dramatically, as do the nature of the problem situations, solutions and processes. On the one hand the domain, goal and processes entailed by a problem may be very well structured and on the other hand they may be very ill structured. Jonassen (1997) states that these problem types do not represent well-defined classifications, but rather represent a continuum from decontextualized problems with convergent solutions to very contextualized problems with multiple solutions.

*Well-structured problems* (also referred to as application or transformation problems) consist of a well-defined initial state, a known goal state, and a constrained set of logical operators. These problems:

- Present all elements of the problem.
- Are presented to learners as well-defined problems with a probable solution.
- Engage the application of a limited number of rules and principles that are organized in a predictive and prescriptive arrangement with well-defined, constrained parameters.
- Involve concepts and rules that appear regular and well-structured in a domain of knowledge that also appears well-structured and predictable.
- Possess correct convergent answers.
- Possess knowable, comprehensible solutions where the relationship between decision choices and all problem states is known or probabilistic.
- Have a preferred, prescribed solution process.

*Ill structured problems*, on the other hand:

- Appear ill defined because one or more of the problem elements are unknown or not known with any degree of confidence.

- Have vaguely defined or unclear goals and unstated constraints.
- Possess multiple solutions, solution paths, or no solution at all, that is, no consensual agreement on the appropriate solution.
- Possess multiple criteria for evaluating solutions.
- Possess less manipulable parameters.
- Have no prototypic cases because case elements are differentially important in different contexts and because they interact.
- Present uncertainty about which concepts, rules and principles are necessary for the solution or how they are organized.
- Possess relationships between concepts, rules, and principles that are inconsistent between cases.
- Offer no general rules or principles for describing or predicting most of the cases.
- Have no explicit means for determining appropriate action.
- Require learners to express personal opinions or beliefs about the problem, and are therefore uniquely human interpersonal activities.
- Require learners to make judgements about the problem and defend them.

*Tame and wicked problems*
This distinction between well- and ill-structured problems resembles the distinction that Buckingham Shum (1998) makes between *"tame" and "wicked"* problems.

*"Tame problems* are not necessarily trivial problems, but by virtue of the maturity of certain fields, can be tackled with more confidence. Tame problems are understood sufficiently that they can be analysed using established methods, and it is clear when a solution has been reached. Tame problems may even be amenable to automated analysis, such as computer configuration design or medical diagnosis by an expert system (Buckingham Shum, 1998)"

*Wicked problems* display a number of distinctive properties that violate the assumptions that must made to use tame problem solving methods. Wicked problems:

- ♦ Cannot be easily defined so that all stakeholders agree on the problem to solve;
- ♦ Require complex judgements about the level of abstraction at which to define the problem;
- ♦ Have no clear stopping rules
- ♦ Have better or worse solutions, not right and wrong ones;
- ♦ Have no objective measure of success;
- ♦ Require iteration-every trial counts;
- ♦ Have no given alternative solutions-these must be discovered;
- ♦ Often have strong moral, political or professional dimensions, particularly for failure.

## *3.3 Instructional design models for well- and ill-structured problems*

Jonassen (1997) presents separate instructional design models for well- and ill-structured problems. Both will be described below. The model for well-structured problems is based on Gick's (1986) simplified schematic of the problem solving process (see Figure 12).

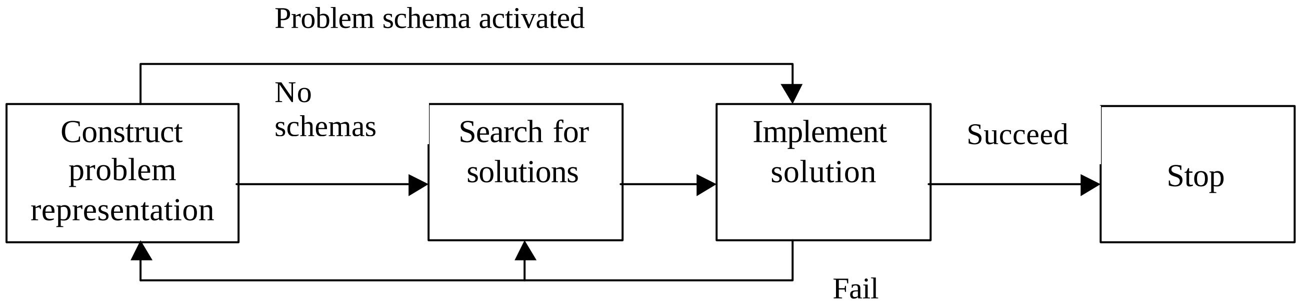



**Figure 12.** *Simplified schematic of the problem solving process (Gick, 1986)*

The model for well-structured problems consists of six steps:

1. **Review prerequisite component concepts, rules and principles**
   The concepts, principles and procedures that are required to solve a problem should be reviewed or presented as concept and rule lessons prior to beginning the problem-solving lesson.
2. **Present conceptual or causal model of problem domain**
   An effective means for helping learners construct appropriate problem representations is to provide a graphic organizer of the problem domain. The reason for intentionally illustrating the conceptual components in the problem space is to enhance learners' mental models of the content being studied. Another reason is because they explicitly represent the structural knowledge required to support problem solving.
3. **Model problem solving performance in worked examples.**
   The purpose of worked examples is to model required problem solving performance, including both a description by an experienced (though preferably not an expert) problem solver of how the problems are solved as well as the thought processes that are engaged by the problem solving experience. Worked examples help learners to construct useful problem schemas. They can help learners categorize problems with similar solutions and construct solutions to novel problems by analogy to the example (Sweller & Cooper, 1985).
4. **Present practice problems**
   Worked examples affect the acquisition of problem schemas first and only later improve rule automation. Therefore a combination of worked examples plus extended practice is most likely to facilitate the acquisition of problem schemas and the transfer of those schemas to novel problems.
5. **Support the search for solutions.**
   After having helped the learners to construct meaningful problem representations, it is now appropriate to provide supports that help learners to find and try different solutions. One approach is to provide analogical problems. Another support strategy is to provide advice or hints on breaking down the problem into sub-problems that can be more easily solved by highlighting relevant cues or providing a solution template. Finally it is essential to provide adequate feedback about learners attempts to solve the problem.
6. **Reflect on problem state and problem solution.**
   Since the cognitive load of problem solving interferes with the acquisition of appropriate problem schemas (Sweller, 1988), learners should reflect on initial problem conditions in order to facilitate the acquisition of relevant schemas. Learners should note the characteristics of the problem as presented: the situation, the knowns and unknowns, and

the problem as stated. They should then reflect on the solution processes that were most effective and ineffective in solving the problem.

*Scaffolding*
Elements like problem diagrams, concept maps, worked examples (see Section 2.7.8) and analogical problems are problem solving scaffolds: temporary frameworks to support learning in situations where learners would not be able to perform complex tasks without help. These scaffolds should be faded out as soon as possible. That is they should not be made consistently available to learners.

*Instructional design model for ill-structured problems*
The model for ill-structured problems also consists of six steps:

1. **Articulate problem context.**
   Ill-structured problems are more context dependent than well structured ones, therefore a context analysis is necessary. Another reason for articulating the problem domain is that well developed domain knowledge is essential to problem solving.
2. **Introduce problem constraints.**
   Instruction for well-defined problems would articulate the goals and solutions for the problem at this point. However, ill-structured problems seldom, if ever, have clear or obvious solutions or solution alternatives. What ill-structured problems do have are problem constraints or requirements (that are imposed by a client and/or the situation).
3. **Locate, select and develop cases for learners.**
   Having identified the skills needed by a practitioner, the next step is to select cases that necessarily engage those skills.
4. **Support knowledge base construction.**
   In order to construct useful knowledge structures learners need to compare and contrast the similarities and differences between cases.
5. **Support argument construction.**
   Getting learners to make reflective judgements about what can be known and what cannot is important to support in problem solving instruction. That support may take the form of modelling the arguments for the solution to a related problem or coaching or prompting learners to reflect on what is known.
6. **Assess problem solutions.**
   Solutions to ill-structured problems are divergent and probabilistic. Evaluating learners' solutions must consider both process and product criteria.

Jonassen finally notes that the models that are described are not recommended as definitive answers, but as works in progress.

## *3.4 Summary*

Problem solving is seen as the main activity for the acquisition of knowledge and skills in working with games and simulations. The kinds of problems that humans solve vary dramatically, as do the nature of the problem situations, solutions and processes. On the one hand the domain, goal and processes entailed by a problem may be very well structured and on the other hand they may be very ill structured. In Chapter 1 it is concluded that it is clear at the moment that knowledge management is an area where problems are multi-faceted, complex, and without univocal outcomes. Therefore, the problems in this domain can be categorised as ill-structured or wicked problems.

Training to solve those kinds of ill-structured problems requires different instructional settings than training to solve well-structured problems. An instructional design model for in ill-structured problems is introduced. In this model there is a prominent place for context, constraints, cases, knowledge base and argument construction, and for assessment.

# 4. Requirements for KITS

In this section a set of preliminary requirements for the KITS learning environment will be presented based on the information in the previous sections.

## *4.1 Game-characteristics*

- The KITS environment should include challenging goals for the learners. These goals are "real life' goals and concern outcomes of the business model affecting variables that signify a certain business model outcome (e.g., profit, reduction of scrap, increased safety etc.)
- The KITS environment should include the idea of coupling resources (e.g., time or money) to certain actions. Learners always have to make the trade-off between the effects of their actions and costs involved. Learner actions can be:
  - KM actions;
  - Actions to obtain additional information;
- The KITS environment should involve some form of competition. This could take the form of reaching a pre-set outcome, beating previous scores in KITS games, or beating other(s) team(s).
- The KITS environment should include realistic cases that lead to a feeling of involvement at the side of the learner. This is further accomplished by giving players a "role" in the game.
- The KITS environment should have the possibility to generate random or unexpected events.

## *4.2 Learning goals*

- Learning in the KITS environment should lead to knowledge about the *content* of KM actions and their consequences that has an *implicit, intuitive, character*. This means that learners learn which actions are applicable and they learn their consequences, but not necessarily need to be able to express precisely the rules that govern the KM model.
- Learning in the KITS environment should lead to knowledge about the *sequence* of KM actions (a so-called normative model).
- Learning in the KITS environment should lead to *explicit knowledge* on certain aspects of the domain. This explicit knowledge can be offered 'outside' the game in e.g., explanations, or reflections.

## *4.3 Instructional context*

- The KITS learning environment should contain support that helps the learner in the planning process (e.g., by providing the learner with assignments and prompts or to use model progression)
- The KITS learning environment should help the learner in the monitoring process (e.g., by providing "registration and log-tools").
- The KITS learning environment should prevent cognitive overload (e.g., by providing learners with model progression or a monitoring tool).
- The KITS learning environment should provide ample opportunities for reflection. This could be supported by, for example, registration of actions of learners that then could easily be 'revisited' or 'replayed' as input for reflection.

- The KITS learning environment should provide possibilities for discussion amongst participants.
- The KITS learning environment should provide the learner with sufficient background information (just in time) to understand the actions that can be undertaken in the game and that help to interpret the results.
- The KITS learning environment should stimulate and help the learner in reflecting on the problem solving process that has been followed.
- The KITS learning environment should stimulate and help the learner in expressing considerations behind actions and expected results.
- The KITS learning environment should support collaboration and exchange of information.
- In the KITS learning environment learners should be able to ‘mark’ elements of the learning scenario they want to be included in the reflection.
- In the KITS learning environment learners may be helped by providing them with a different problem format (such as, for example, worked out problems).
- In the KITS learning environment feedback should reflect not only be “single valued” responses but give extensive verbal accounts on the consequences of actions. (these do not necessarily be based on intrinsic feedback from the business or KM model, but could also be pre-defined.
- In a KITS learning environment the complexity (and thus reality) of a situation could be reduced in order to help the learners cope with the environment, reduce the cognitive load.
- In the KITS learning environment the knowledge management problems that need to be solved are ill-defined. Part of the problem solving process for ill-defined problems is acquiring the right information. Learners should have access to information and may choose this information form different sources.
- In the KITS learning environment the ‘involvement’ of participants is an important characteristic. This can be done by the set-up of the game, e.g., by giving the participant a specific role, or by introducing ‘personal consequences’ (loss of life is a good example) of actions and decisions

In a later deliverable these initial requirements, together with the user requirements that are specified in Deliverable 4 (Haldane, 2000), will be specified in a description of the instructional envelope that is one of the two main elements (together with the domain model) of the KITS learning. The KITS learning environment (and it components) which is the final objective in the project is depicted in Figure 13.

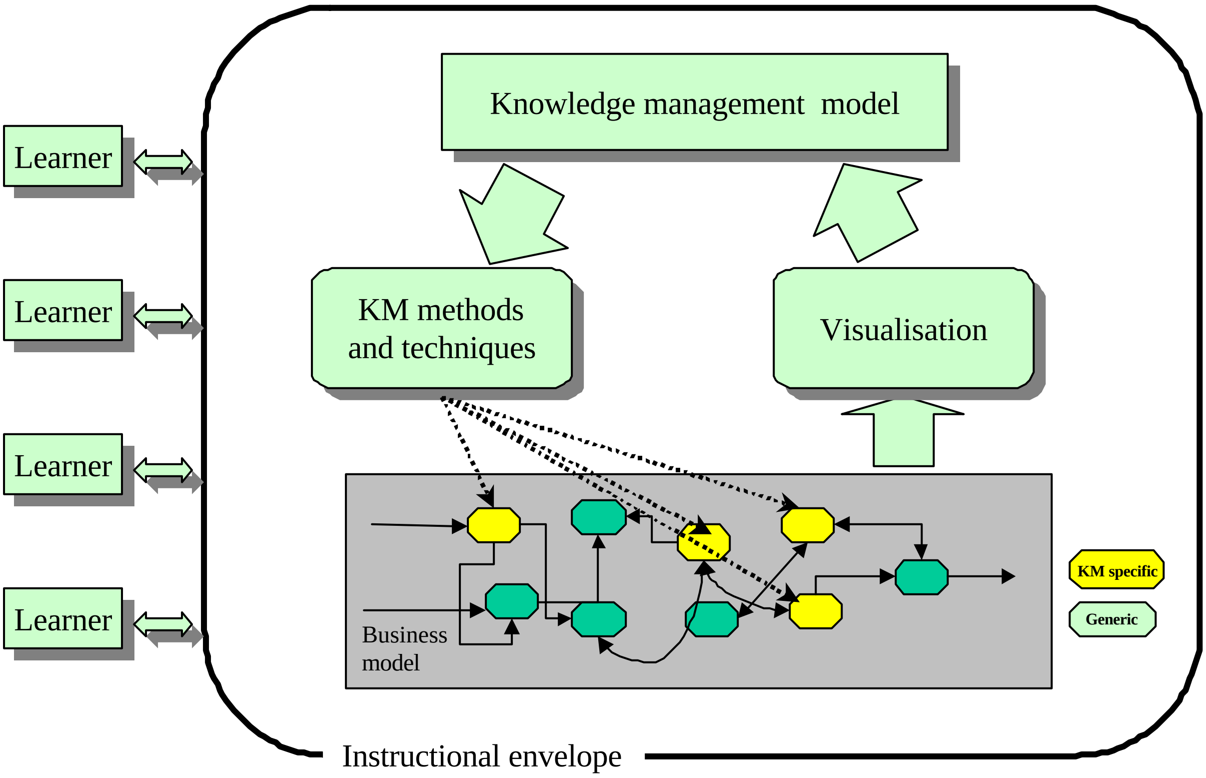



**Figure 13.** *KITS learning environment and its components*

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