Let's POLCA!

~ A simulation game for introducing POLCA ~

E.M. Epping

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Preface

In front of you lies the result of seven months of reading, observing, thinking, and writing about POLCA, learning, simulation games, and the POLCA simulation game: my final thesis. This thesis is part of the final project of my study at the faculty of Management and Organization at the Rijks*Universiteit* of Groningen. The aim of this interesting project was to develop a POLCA simulation game that can be used as a teaching tool.

I would like to thank Jan Riezebos and Martin Land, the supervisors of the University, for giving me the opportunity to work on a project that was perfectly designed for me: it combined knowledge, practice, and creativity with a trip to the USA! I would also like to thank them for their assistance, feedback, and suggestions during the research.

I would like to say special thanks to my parents, my brothers, my sister, my friends and the participants of the test game for all their support and assistance. Without you, the POLCA simulation game would not have been the same!

Evelien Epping,

August 2005

Executive summary

The aim of this research is to develop a POLCA simulation game for introducing POLCA to students and to people from organizations. Three sub goals are that participants of the game learn about the context and the application of POLCA, get insight in the main topics of POLCA, and learn to work with POLCA.

Before developing this POLCA simulation game, it is important to know what POLCA is, how participants learn, and what the features of effective simulation games are. Therefore, these three subjects are elaborated before the actual development of the POLCA simulation game begins.

POLCA (Paired-cell Overlapping Loops of Cards with Authorization) is the material control strategy for QRM (Quick Response Manufacturing), a concept with lead time reduction as its main goal. POLCA is developed for manufacturing companies in a high-variety environment. It requires a cellular organized production process in which each cell is responsible for a certain phase of production. POLCA cards represent available capacity in two succeeding cells. They are attached to an order during the operations in both cells and will be returned to the first cell when the operations are finished. This move through two cells and back is called a POLCA loop. An HL/MRP (High Level Material Requirements Planning) oversees all cells in the production process. This system decides when a cell is allowed to start working on an order.

Because POLCA has to be taught to participants of the game, the learning process is important. Learning takes place in repeating phases. First, somebody experiences something and thinks about it. In reaction, the learner develops principles and concepts and he is going to test the new insights, which will lead to new experiences, et cetera. Room should be created to let these phases pass several times. People learn best when the learning tool requires an active attitude. Participants of the POLCA simulation game need to understand why they have to learn about POLCA. In addition, the material has to be at the right level of difficulty and has to connect to the current knowledge and skills of participants.

Effective simulation games are part of a project that consists of three parts: an introduction, the simulation game, and a reflection. In the introduction instructions about the subject of the game and about the rules of the game have to be given. In the reflection, participants individually have to give the things they learned during the game a place in their cognitive structures. This can be done by writing a paper. The simulation game has to be challenging, imaginable and should have a clear layout. With a challenging case, a need for change can be created. Rules and goals should be obvious and participants should have some control over the game process.

The POLCA simulation game is developed in four stages: initializing, design, engineering, and operation.

In the initializing stage, the requirements of the POLCA simulation game are defined. The requirements are deduced from the requirements of effective learning and effective simulation games. In addition, relevant information about POLCA should be reflected in the game and the game should be suitable for students and for people from organizations.

In the design phases, the elements of effective simulation games are described. A Nestor Introduction is made to introduce the theory on POLCA. A manual and a presentation are made to explain the POLCA simulation game. The game itself will take place in fictitious factories that are run by teams of six persons. The case reveals typical POLCA problems. The reflection of the things learned by the game can take place by individually playing the Internet version of the POLCA simulation game and by writing down the knowledge obtained.

In the engineering phase, the elements discussed in the design phase are worked out in detail. The layout of the factory, the POLCA cards, the orders et cetera are chosen such that they reflect the features of POLCA.

The operation phase finally tests the game. Based on the results of the test game, the POLCA simulation game is evaluated and modified. The main improvement made, is the reduction of the opportunity to discuss the allocation of orders. In the real world, much communication namely is often not realistic and it can decrease the effect of POLCA shown by the game.

Table of Contents

1. Introduction

The research that is subject to this paper will be performed for the University of Groningen. For the project underlying this research, the University cooperates with Apollo. In this opening chapter, a description of the two focus organizations will be given.

1.1 University of Groningen

The University of Groningen has a long academic tradition extending back to 1614. This makes Groningen the oldest University in the Netherlands after Leiden. Many people in a variety of disciplines have studied or worked at the University during the almost 400 years of its existence, including a Nobel Prize winner, the first female University student in the Netherlands, and the first Dutch astronaut.

Figure 1.1 Academy building

Opportunities and threats followed on each other's heels during the centuries. In 1815, the University gained recognition as a national college of higher education. The Higher Education Act of 1876 had radically improved the position of the University, which was renamed the Rijks*Universiteit* Groningen (RUG). Teaching now took place in Dutch as well as in Latin and the University was given a *research* as well as an *educational* duty. This laid the foundations for the present research university. The number of students grew rapidly to reach about 21,000 students registered at the RUG at the present time with the number of foreign students also growing steadily.[1]

In 1979, the faculty of Management & Organization was founded and has developed to a national and international centre in the field of management and organization questions. Aim of the faculty is to create new knowledge concerning management and organization, and to share that knowledge with students and organizations.[2]

[1] www.rug.nl
[2] www.bdk.rug.nl

As part of the master Operation & Supply Chains, which is provided at the faculty of Management & Organization, students can follow the Field Course Operations & Supply Chains. For an improvement of an element of this course, the research is performed.

Figure 1.2 WSN building

1.2 Apollo Simulation and Gaming

In cooperation with the Hanzehogeschool Groningen, the University of Tilburg, and the Avans Hogeschool, the Rijks*Universiteit* Groningen started in 2002 Apollo with the aim to improve the integration of ICT in education. Apollo starts and supports projects with the goal to develop products that encourage this integration.[3]

In 2004 the project 'Apollo Simulation and Gaming' started. The research of this thesis is part of this project.

[3] www.apolloplatform.nl

2. Research design

~ A goal without a plan is just a wish ~

Antoine de Saint-Exupery

In this chapter the famous 'what' and 'how' questions will be answered. What the reason for doing this research is and 'what' will be accomplished by doing the research will be explained. After this, 'how' the research will be performed will be enlightened.

2.1 Introduction to the research

Universities have two primary functions could be read in chapter 1: research and education. These two interwoven functions are the basis of this research. Interwoven because without being taught, theory is not very useful. Education is the link between theory and practical implication, the final utility of research. Generally, there is a 'total' of general business[4] knowledge. By knowledge acquiring, research, this knowledge is translated into theories. In addition, by education people are taught to practically implement the theories. In a scheme, this looks as follows:

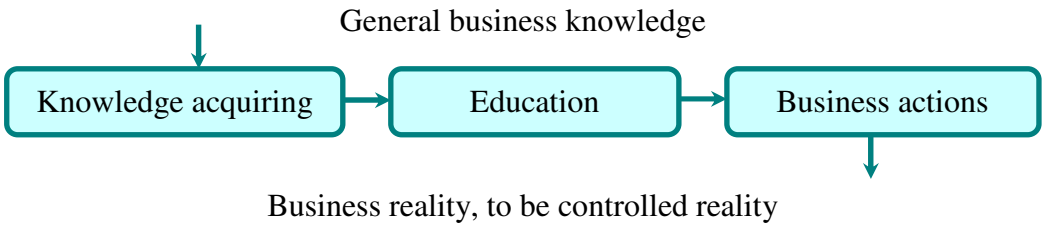


Figure 2.1 Reciprocal dependencies of research, education and application[5]

At the faculty of Management and Organization of the University of Groningen, the Field Course Operations & Supply Chains is taught. Currently a Just-In-Time (JIT) game is played as an element of this course. The reason for this is to show how a material control system (i.e. Kanban) can affect the outcomes of an organization. JIT is developed over thirty years ago and extensively applied since then. At the faculty researchers however are investigating a new concept, the POLCA material control system. To link the current research of the faculty (POLCA) better to the education (Field Course Operations & Supply Chains), the JIT game has to be substitute or completed by a POLCA simulation game. In a picture, this link looks as follows:

[4] Business is used as a translation of the Dutch word *Bedrijfskunde*
[5] Free interpretation of scheme 2.1 in De Leeuw, 2001: 17

Figure 2.2 Basic functions of the University in relation to the game

This POLCA game does not exist yet[6] and has to be developed. The development of the game is the subject of this thesis.

2.2 Problem statement

To develop a POLCA game, a research will be started. Research that produces useful results will not come about automatically and needs commitment, inspiration, creativity and a well-designed approach. This paragraph will elaborate on this last element by making a problem statement. In the next paragraph the methodology, the way to reach the goals, will be discussed.

The problem statement of a research is a careful reproduction of the questions that have to be answered by that research, the reasons why the answers are important, and the stated conditions.[7] The components goal, research question, and conditions will be detailed below.

2.2.1 Goal

The goal explains for whom the research is done, what the outcomes of the research should be (the knowledge product) and why these outcomes are important.[8]

The goal of this research is to develop a POLCA simulation game for the faculty of Management and Organization of the Rijksuniversiteit Groningen. The learning objective of this game is that participants master the material control system POLCA after playing the game.

The main reasons why it is important to introduce POLCA to the participants is to illustrate what effects applying the principles of the material control system can have and to improve the link between research and education, the two functions of universities.

2.2.2 Research questions

'The research question specifies the knowledge product a research aims to produce.'[9] 'The research question is associated to the goal, but is formulated in terms that are accessible for the research.'[10] To reach the goals stated above, the following main research question has to be answered:

[6] The University of Wisconsin developed a POLCA game, but this game does not fulfill the requirements stated for this research. More about this game can be read in chapter 6
[7] De Leeuw, 2001: 81
[8] De Leeuw, 2001: 85
[9] De Leeuw, 2000: 290
[10] De Leeuw, 2001: 85

In what way can, by means of a simulation game, the theory and reasoning behind the material control system POLCA be explained and the working of it be shown to the participants of the game such that these participants will be able to apply POLCA to an organization?

This main question is quite general and to explain the main question and to show the elements of the research the following sub questions are developed:

- What are the theoretical bases of the *POLCA concept*? What aspects of this theory are relevant for the target group (and thus have to be part of the game)?

- How does *learning* take place? How can POLCA be taught best to the participants of the game?

- What elements and aspects should be considered when constructing a *simulation game*?

- How can a *POLCA simulation game* be constructed that optimally satisfies the aims? What has to be prepared to play the game by both participants and game leaders?

- What are the *effects* of the game on the participants? How can, in reaction to this, the game be improved?

How these questions are linked will be described in the research set up.

2.2.3 Conditions

The first requisites are requisites for what the participants should learn by playing the game. They can be derived from the main research question.

- The game should make clear what the POLCA theory involves;
- The game should show how the POLCA system works in 'practice' and what influences parameters have;
- The game should make the participants of the game able to apply the theory of POLCA.

This last requisite is important, but cannot be tested. Because POLCA is not implemented by organizations that used the POLCA simulation game, no results of the game will be available when this thesis is ready.

The development of the game is also restricted by several conditions. One important condition is that the game can be played by two different groups of participants. The target groups are:

1. Students following the Field Course Operations & Supply Chains;
2. Members of organizations that consider implementing POLCA.

Another condition is very practical. The game will be played only a few times per year and on different locations. Therefore, it is important that the game is movable and easy to store.

Important is that the game should be motivating. The participants should like to play the game and they should know why it is important for them to play it.

Conditions concerning time are that the first version of the game is ready before the summer. In addition, that the game has to take place in not too much time. For example one afternoon, about three or four hours.

Finally, ICT should be integrated into the game. Internet (Nestor) should be used as part of the game.

2.3 Methodology

When conducting research, several choices have to be made. In the last paragraph choices where made about the focus, the content of the research. In this paragraph, choices will be made on the process of the research. First, the type of research will be explained and the implications of that for the research. Then the research design is on turn and at the end of this chapter, information gathering will be discussed.

2.3.1 Research type

Several research types can be used to come to an answer of the research questions, depending on the nature of these questions. Developing a game is a design activity. Therefore, the main research type for this thesis is design. This type is quite active, practical, and creative.

To support the design, first some information is needed we saw. This information will be gathered by doing descriptive research. Descriptive research is about a precise description of the features of the subjects.[11] This type of research will be used when answering the first three sub questions about the theory on POLCA, the theory on learning, and the theory on simulation games; in the conceptual model the left three circles. The last question, a description of the effects of the game on participants, will also be answered by doing descriptive research.

2.3.2 Research set up

First, as a kind of diagnosis, information will be gathered that is needed to start the development process of the POLCA simulation game. As could be derived from the sub questions, this is information about POLCA, learning and simulation games. The theory of POLCA will be looked at in detail in chapter 3. Then, a chapter will be dedicated to learning processes. In this chapter, chapter 4, it will be examined how POLCA best can be transmitted to the participants. Several learning theories will be explained. In chapter 5, the third sub question will be answered. Aspects of and requisites for effective simulation games will be elaborated. In addition, existing simulation games will be evaluated on what aspects of these games can contribute to the POLCA simulation game.

The ultimate goal of the research is to design the game. In chapter 6, the real design will start. All the things learned when answering sub questions one to three will be put together and a POLCA simulation game will be constructed.

[11] Baarda, 2000: 93

Finally, the proposed simulation game will be implemented. It is the transformation of a design into a concrete system. A test game will be held and the results of this game will be described. The last two sub questions will also be answered in chapter 6. Depending on the effects noticed in the test game the designed simulation game will be adjusted.

In a conceptual model, this looks as follows:

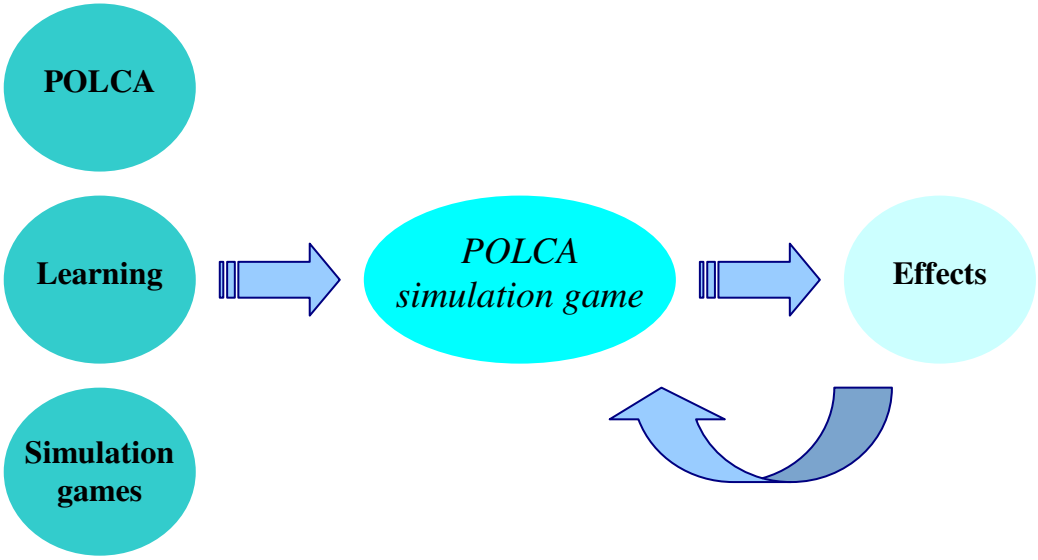


Figure 2.3 Conceptual model

As can be seen in the model, first the diagnosing sub questions will be answered independently. This is needed to have basic starting information for developing an educative simulation game. Then, on basis of this information, the POLCA simulation game will be developed. This mainly is a creative process. The process will be structured by using a framework for developing simulation games. When this is done, the game will be played and the effects will be noted. The feedback will be used to adjust the game. This will be done until the game is good enough to fulfill the aims.

2.3.3 Information gathering

Existing information, observations and interviews are used to get the information about POLCA, learning, and simulation games.

Information about POLCA is found by reading the book of Suri, the developer of POLCA. In addition, all available articles about POLCA are read and a workshop about POLCA in Madison, USA are visited.

Information about learning can be found in numerous books, articles, and Internet sites. The sources that relate to learning in (production) organizations is focused on.

Also about simulation games can be found much in literature. Interesting books and articles on developing simulation games and on existing simulation games are read and analyzed. In addition, some simulation games are visited and participated,

accompanied or observed. When doing this, both participating in a game and leading a game can be experienced.

Information about the results of POLCA will be found by testing the POLCA simulation game. To find out the opinion of participants of the POLCA simulation and to find out what they learned, a test game will be held. The results, elements and experiences of this test game will be discussed with the participants.

3. POLCA

~ There is nothing so practical as a good theory ~

Kurt Lewin

In the late 1980s, a new way of thinking about production strategies entered the scientific world: time-based competition (TBC). TBC is a broad corporate strategy focusing on lead time reduction that can not only benefit the shop floor, but that can benefit the whole company.[12] Scientist Suri was impressed by this approach; however, he also found some downsides. Based on the fundamentals of TBC, Suri developed a new, sharpened concept, particularly for manufacturing: Quick Response Manufacturing (QRM). Essentially, QRM pursues the reduction of lead time in all aspects of the operations of companies. QRM has refined TBC by:

- 'Focusing only on manufacturing;
- Taking advantage of basic principles of system dynamics to provide insight into how to best reorganize an enterprise to achieve quick response;
- Clarifying the misunderstandings and misconceptions managers have about how to apply time-based strategies;
- Developing a novel performance measure;
- Developing a whole new material planning and control approach.'[13]

This chapter will focus on the last refinement; the material planning and control approach. This approach is called paired-cell overlapping loops of cards with authorization (POLCA). In this chapter, first attention will be paid to why POLCA is needed and to the type of organizations POLCA is meant for. Then, in the second paragraph, a broad overview will be given about POLCA. Paragraph three goes deeper into the details of POLCA by means of an example. Paragraph four finally, summarizes the main findings and conclusions on POLCA.

3.1 Introduction to POLCA

In today's marketplace, there is an increasing demand for customized products. Customers can select from a large number of options, or they can even order custom-engineered products. Besides this, there also is the pressure to produce faster and faster.

For high-variety companies, this creates some challenges. You can imagine that a company, which produces a high variety of products, cannot keep every item in stock. The demand for one particular item can be very low; it can even be a unique order. On the other hand, companies have to deliver very quickly.

Manufacturing companies that have to supply such high-variety or custom-engineered products are struggling with questions like 'When should we start producing, do we have to forecast production?' and 'What products should we keep in stock?'

[12] Suri, 1998: xxi
[13] Suri, 1998: 5

To answer questions like these, material control schemes have been developed. They can be classified as push, pull, or hybrid strategies. Push and pull strategies are mainly developed for the more stable production situations. To see what makes them not suitable for the high-variety markets, the basics of those strategies will be outlined shortly.

'In a *push system*, activities are scheduled by means of a central system and completed in a line with central instructions, such as an MRP system. Each work centre pushes out work without considering whether the succeeding work centre can make use of it.'[14] Thus, in a push system, material is moved to the next stage as soon as it has been processed. Work centers are coordinated by means of the central operations planning and control system. According to Slack, the main problem with push systems is that actual conditions differ from those that are planned. This can lead to idle time, inventory and queues. Suri adds to this that it is a waste of time and effort to work on products not needed yet by the next workstation.

'In a *pull system*, the specifications of what is done are set by a workstation, which 'pulls' work from his preceding workstation. The customer acts as the only trigger for the movement. In a pull system, material is moved only when the next workstation wants it.'[15] Demands are satisfied from the removal of items from the output inventory buffers of workstations. The removed items then have to be replenished. To avoid long waiting times for customers, parts and finished products must be stored in buffers at every operation and for every product. This means that inventory is always needed to keep the process going.[16] Therefore, these strategies cause excessive inventories when the product mix is broad. An example of a pull strategy is Kanban.

In reactions to the shortcomings of push and pull strategies, *hybrid systems* where developed. Hybrid systems are more recent systems and are better suitable for high variety production environments. 'They are material control strategies that combine features of push and pull. These systems recognize that in certain markets, the ones we have discussed, responding to the variability may provide competitive advantage.'[17]

As told in the introduction, Suri was not contented with the existing (hybrid) systems. A main problem with these systems was that they overlooked important system dynamics. A lot of attention for example is paid to efficiency. According to Suri however, 'focusing on efficiency very often leads to longer lead times. This leads eventually to less efficiency. Not efficiency in itself is a problem, but most measures of efficiency work counter to lead time reduction.'[18]

It seems for example cheaper and thus also more efficient to buy material in large quantities. However, this leads to longer lead times in the supplier's factory, which leads lo longer lead times in your factory, et cetera. This effect is called the 'Response

[14] Slack, 2001: 326
[15] Slack, 2001: 327
[16] Gstettner, 1996: 3253
[17] Krishnamurthy, 2004: 124
[18] Suri, 1998: 19

Time Spiral for Purchasing from Suppliers'. How the effect takes place, can be seen in figure 3.1:

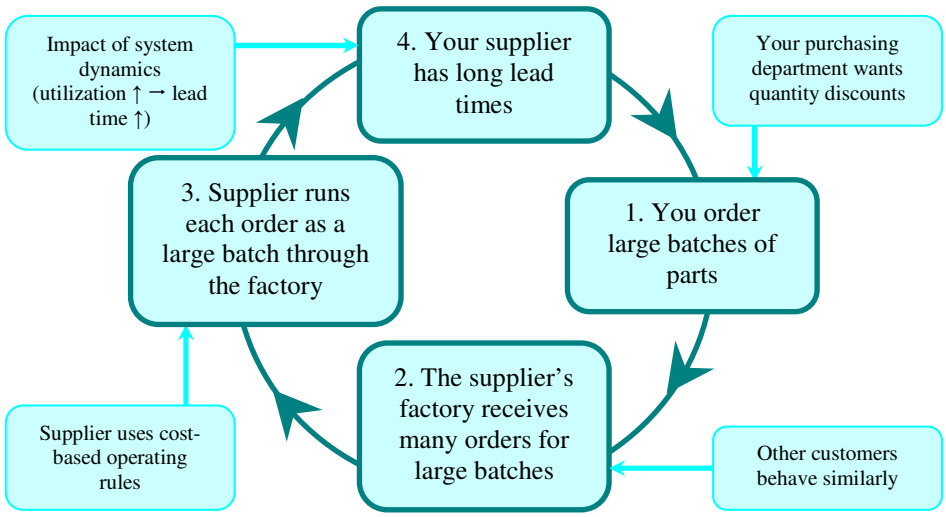


Figure 3.1 Response Time Spiral for Purchasing from Suppliers[19]

In reaction to dynamics like this, Suri developed the material control strategy POLCA, which is a hybrid one; it combines adjusted applications of MRP (push) and Kanban (pull). It is a material control system designed with the discussed high-variety situation in mind and therefore suitable for organizations that provide a broad, high-variety product mix and that have a high variety in demand. The remainder of this chapter will give a detailed description of the principles of POLCA.

3.2 POLCA in bird's-eye view

The central, covering objective of QRM and POLCA is *lead time reduction*. All the principles of POLCA are pointed at this central objective. Focusing on lead time reduction namely has several benefits from which the most obvious one is that responding fast to customers promotes customer satisfaction. And, in reaction, the performance reputation may assist in taking orders away from competitors. In addition, if customers have an urgent need for products, companies might be able to charge a price premium.[20]

'Less obvious, but more fundamental, is that implementing QRM and POLCA can improve the integration of the whole enterprise. The concept searches for ways of squeezing time out of the whole process, thereby uncovering sources of inefficiency, quality problems and wasted efforts.'[21] According to Suri, 'lead time reduction has a positive impact on quality, costs and waste reduction.'[22]

[19] Suri, 1998: 270
[20] Suri, 1998: 31
[21] Suri, 1998: xiv
[22] This in contrast to Just-In-Time management. Here, waste is eliminated in order to improve quality, decrease costs, and reduce waste.

The characteristics of POLCA will be explained by elaborating on the word POLCA. We already know that POLCA is an abbreviation for Paired-cell Overlapping Loops of Cards with Authorization. What these words exactly mean by will be explained.

Paired-cell…
Underlying the POLCA system is a *cellular organization*. This organization is not divided into functional departments, but into cells. Each cell does the operations for a certain production phase. The cells are quite independent; they have all the facilities needed to perform the required activities.[23] In principle, it is not allowed to share machines with another cell.

POLCA only coordinates the flows between the cells. Within the cells, the most suitable system for that cell is used. If the operations in a specific cell are routine like, for example Kanban can be applied.

In the POLCA system always two cells are connected. When for example cell 1 wants to start production, it only is allowed to do so if there is space in cell 2 when cell 1 will be finished. If not, cell 1 better starts working on another order. If there are no orders that do comply this rule, the people from cell 1 should not start working on other orders, but they can make themselves more useful by for example joining quality circles and thinking about ways to improve the production process.

Overlapping ***L***oops of ***C***ards…
The two connected cells are tied with a *POLCA card*. This card makes a *loop* when an order goes from cell 1 to cell 2. The card namely shares an order from the start of operation 1 until the end of operation 2. Then the card is turned back to the start of operation 1. When cell 1 is finished, cells 2 and 3 are the connected pair. The loops that the POLCA cards make are *overlapping*. It shows the routing of a certain order. How this exactly works, will be explained in the next paragraph.

POLCA uses Kanban-like cards to coordinate production. The difference between the two types of cards is that Kanban cards represent an order replenishment of a certain item and POLCA cards represent capacity. Thus, a Kanban card is linked to a certain product (which is impossible for a company with a high variable product mix) and a POLCA card is linked to capacity. If a POLCA card is available, then capacity to produce is available in a certain cell.

With ***A***uthorization
The POLCA cards are used at a quite detailed level. To get a more aggregated impression of the production process, the High Level Material Requirements Planning system (HL/MRP) is developed. This system oversees the whole production process and gives permission to start an order. This permission is given when all material to start producing is available and when it is the right time to start producing. The latter

[23] According to Suri, 'the aim of a cell is to start with raw material and to end with finished products, with all operations being completed in the cell.' (Suri, 1998: 90) This is a quite rough definition about cells that will not be applied in this chapter. Because, if the whole production, from raw material to finished products, would take place in one cell, there would not be needed a POLCA system to coordinate the order flows between cells.

is because not all customers want their products as soon as possible, but at a certain point of time. Then it is useless to start producing earlier (and build up inventory).

We have seen that for a cell to start working on an order, there are two prerequisites:
- Authorization by the HL/MRP;
- Availability of a POLCA card.

3.3 An example – MSD Printing Company

In the previous paragraph, a very short explanation of POLCA was given. In this paragraph, we will zoom in on the important aspects of POLCA. This will be supported by an example of a fictitious company that is going to implement POLCA. The activities that take place will be followed.[24]

In a small town in the east of the Netherlands a middle-sized organization, MSD Printing Company, serves the competitive local printing market. The company has a high variety product mix and is struggling with a high level of WIP and long lead times. Therefore it considers implementing POLCA. A POLCA team is established to prepare the implementation.

The implementation of POLCA can, as can be derived from the previous paragraph, be divided into the following elements:
- Cells;
- POLCA loops;
- POLCA cards;
- HL/MRP.

Now the several steps of implementing POLCA at MSD Printing Company will be elaborated to get a better understanding of the concept.

3.3.1 POLCA cells

First, the organization has to be split into several cells. We will look at the different parts of the MSD Printing Company and decide on how the cells will be structured.

Generally, the process at MSD Printing Company looks as follows:

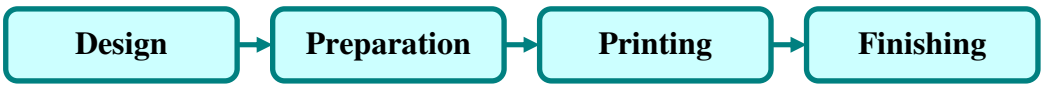


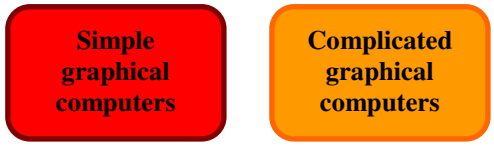
Figure 3.2 Printing process at MSD Printing Company

At the company, in most cases a design has to be made for a certain product. This can be simple or complicated and time consuming. Sometimes a customer already has a design; then this phase can be skipped. The department that makes the design and layout of orders and dummies (prototypes) is called the DTP department. In the current situation all the computers are in the same room. In the company the DTP department is, on the advice of the POLCA team, split into two cells: one cell for the

[24] This example is used in the Nestor introduction to the POLCA simulation game. The text will be less 'academic' then the text of the rest of the research.

simple orders and one cell for the complex orders. In the simple cell, there are only some simple graphical computers and a simple laser printer. In this cell, the lead time of an order is quite short, never more than one hour. The personnel of this cell does not need to have a very thorough understanding of a lot of graphical programs. In the complex cell, the more sophisticated graphical computers and printers are placed. Here the higher educated DTP-ers work.

We now have the following two DTP cells:



The DTP cells will abbreviated with respectively D1 and D1.

The next cell is the pre-press cell. In this cell the metal plates are made for the printing department. Only one person works in this cell. He makes the plates for both the complex and the simple products. He also checks whether the plates are good. This means for example that there are no little black points on the plate. He does not check the spelling and the page numbers et cetera; this is the responsibility of the DTP cells. A feature of POLCA is that every cell produces a certain type of wound up product. The cell has the responsibility that his attribution to the product is perfect. In this way, a lot of rework and a lot of (double) checking are prevented for the other cells.

Pre-press cell:

The pre-press cell will be abbreviated with R1.

Then the printing is on turn. MSD Printing Company has five presses. Two for one-color orders, two for two-color orders and one for the full-color orders. The full color press of course, can be used to print a one-color advertisement folder, but that is not a very smart thing to do. This press namely takes a lot time to clean and set up. The one-color presses are used very often and are the main bottleneck in the organization.

The POLCA team decides to split the printing department into three cells. One cell for the one-color presses, one cell for the two-color presses and one cell for the full-color press. The team also decides to acquire an additional one-color press.

The next three cells are thus:

Abbreviations for these cells are P1, P2, and P3.

Finally, there are some finishing operations. These operations include cutting, folding, stapling, putting together the pages of a magazine, gluing, and packing. The machines and the tools for performing these operations are now spread across the organization.

The POLCA team chooses to make two finishing cells and puts all the required resources together in these cells. One cell is for the orders with large products like

posters. The other cell has to perform operations for the smaller products like cards and books.

Finishing cells:

The finishing cells will be abbreviated with F1 and F2.

In total, this gives the following picture:

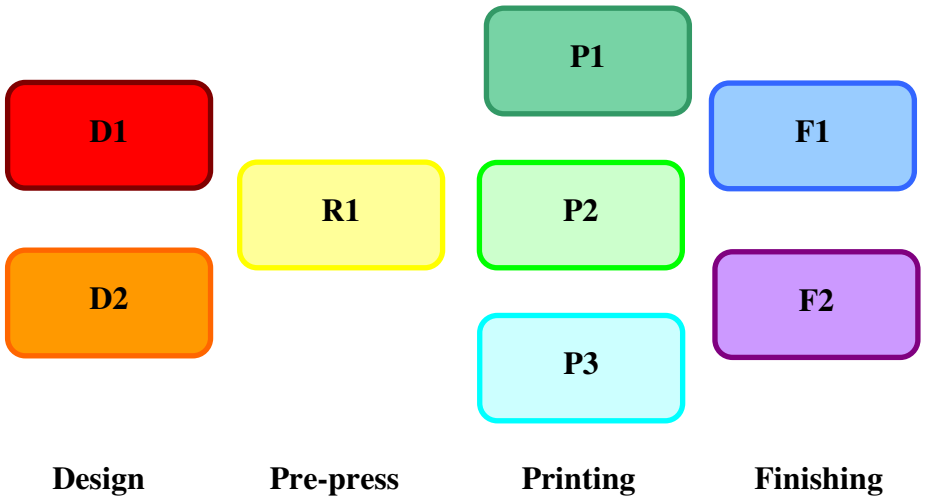


Figure 3.3 Cells at MSD Printing Company

All the cells were given certain abbreviations. From now on, these abbreviations will be used.

3.3.2 POLCA loops

For every possible interaction between a pair of cells, there is a loop. Therefore, when POLCA is implemented, all possible loops have to be identified. For identifying the loops all possible combinations of sequences of routings have to be checked. If you take for example cell R1 (metal plates), than three loops are possible. Namely loop R1/P1, R1/P2 and R1/P3. (P was the abbreviation of the Printing Department). It is not possible to pass a metal plate back to the DTP department, and it is also useless to pass a metal plate directly to the finishing department.

Now it is apparent how the loops are identified, we will make clear how the POLCA loops are used. We give an example. Assume that POLCA is already implemented at MSD Printing Company. One day the MSD Printing Company has to make 65 birth tickets. What should the company do with these orders? The process will be explained below.

When a pregnant woman and her husband come to the MSD Printing Company, they can look into the birth tickets books of the company and then they can choose a birth ticket for their expected baby. These tickets are almost ready; the only thing that has

to be done is to print some data (name, size, weight, visit times, poem et cetera) on the card. But this can only be done when the baby is born. A feature of this type of orders is that the parents always want the tickets to be finished in maximum one day after the baby is born, so speed is very important in this case. Today the father comes to the MSD Printing Company to tell the happy news. He has a baby, a boy, and he called him Thomas. He also gives the other data and wants the birth tickets to be ready as soon as possible. What has to be done now? For this order, the parents already chose the tickets two weeks ago. They received the envelopes last week. What has to be done now is for MDS Printing Company to print the data on the birth ticket in dark purple characters. What POLCA loops are needed now and in what sequence?

First, the layout of the cards has to be made. This is very simple and can be done in cell D1 (simple graphical computers), only the data have to be filled in. Then the people in cell D1 print the layout and give it to cell R1. In this cell the metal plate is made for the printing department. The plate is needed by the printing department to print the text on the cards (see figure 3.6). So now a D1/R1 loop has been created.

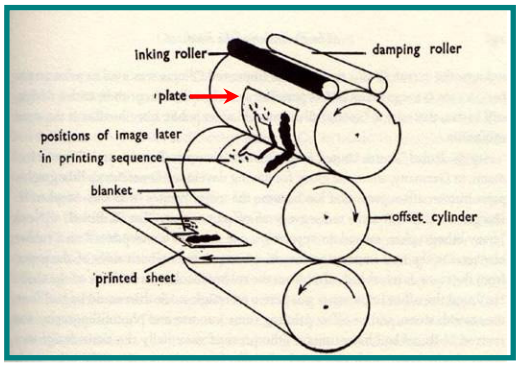


Figure 3.4 Offset printing process

After this, the printing department receives the metal plate from the pre-press department. When the printing cell is authorized by the HL/MRP to start and capacity is available, it starts to mix the right color of ink. Then the text is printed on the cards. Because only one color is needed the P1 cell can do this. The relevant loop is thus R1/P1.

When the ink is dry (technical waiting time), the finishing operations have to be performed. Birth tickets are quite small, so the finishing operations will be done in cell F2. The relevant loop is from P1 to F2, thus P1/F1. Now the cards are cut on the cutting machine and placed in a box in which the final product will be given to the customers.

All the needed loops are thus D1/R1, R1/P1, and P1/F1. These loops are visualized in the picture below:

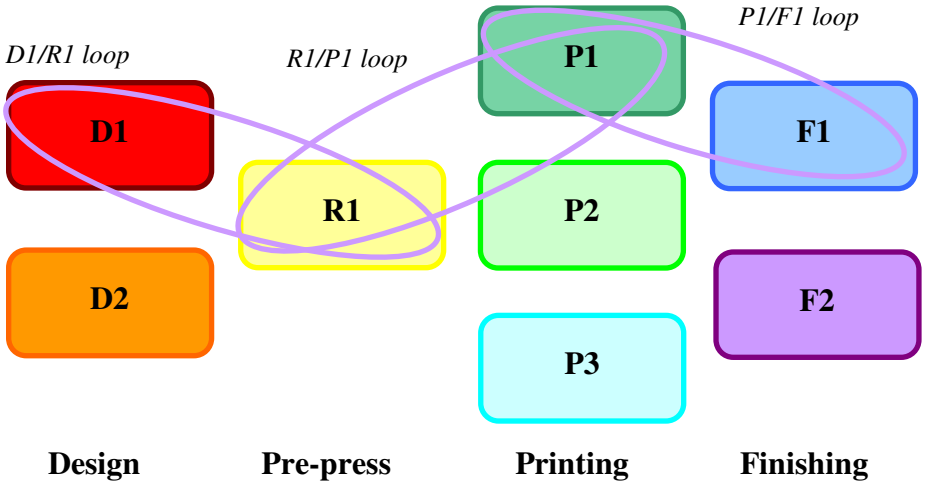


Figure 3.5 Loops made when producing birth tickets

Note that when the birth tickets order is in one cell, there are always two loops overlapping in that cell, as you can see in the picture. Except for the first and the last cell. Why this is will be explained later.

3.3.3 POLCA cards

When cell D1 wants to start to make the layout of the birth ticket there are two requisites we have seen in paragraph 3.2:

- Authorization by the HL/MRP;
- Availability of a POLCA card.

Thus, in the case a cell wants to start producing, it first needs the permission of the HL/MRP to start. When is this permission given, the cell needs capacity to be able to produce. A POLCA card represents this capacity. When a certain POLCA card is not available, a cell cannot start producing because the needed capacity is not there.

A POLCA card is always connected to a loop and not to a single cell. For the loop D1/R1 for example the card D1/R1 has to be available. Like this, not only is checked if capacity is on hand in D1, but also in R1. The POLCA card joins the order from the beginning of D1 until the end of R1. At the end of the operations of cell R1, the card is returned to cell D1 to indicate that capacity is available in the loop D1/R1. Consequently, at the beginning of cell R1, the R1/P1 card joins the order, et cetera.

The following takes place:

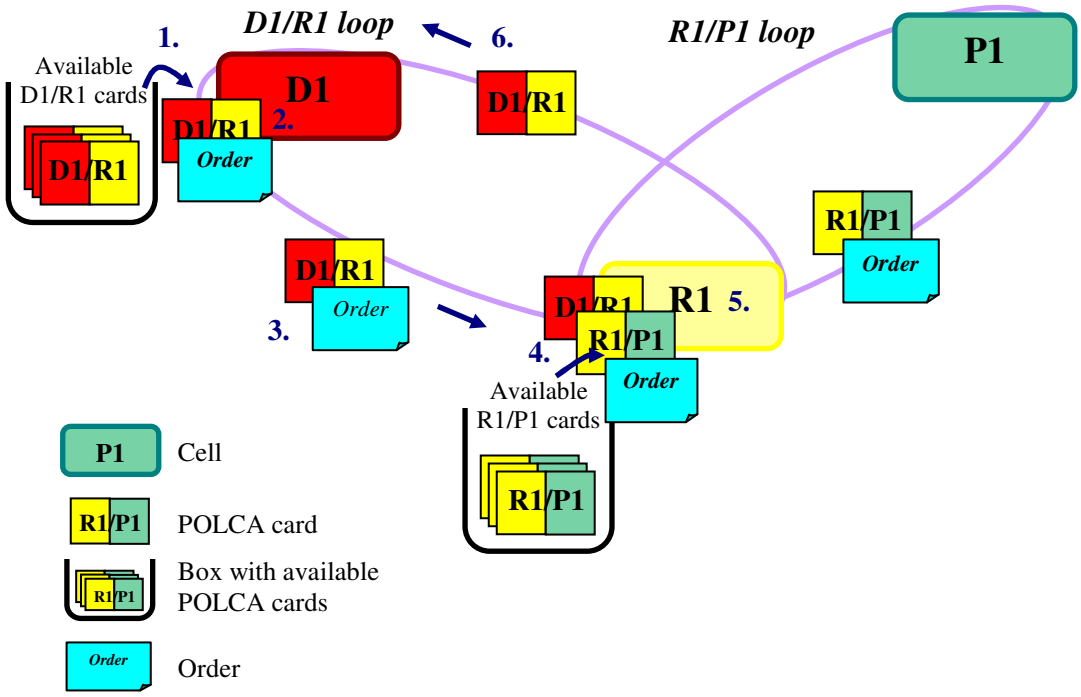


Figure 3.6 Loop that a POLCA card makes

The figure is quite complex and will be explained. To be able to start producing the birth tickets, first a D1/R1 loop has to be a made. For this loop, the following happens.

1. To start the D1/R1 loop there are two requisites, namely:
- Authorization to start the D1/R1 loop by the HL/MRP;
- Availability of a D1/R1 card.

The available POLCA card is linked to the order, in this case the birth tickets.

2. The operations in cell D1 are performed while the D1/R1card accompanies the order.

3. The next cell is R1. The order now goes from cell D1 to cell R1. The D1/R1 card is still coupled to the order.

4. To be allowed to start the operations in this cell, cell R1, the requisites are:
- Authorization to start the R1/P1 loop by the HL/MRP;
- Availability of a R1/P1 card.

The available R1/P1 card is coupled to the order. At this moment two cards are linked to the birth tickets, namely the D1/R1 card en de R1/P1 card.

5. The operations in cell R1 are done while the D1/R1 card and the R1/P1 card accompany the order.

6. When both D1 and R1 are finished, the D1/R1 card can be placed back in the box of available D1/R1 cards because capacity is available in the D1/R1 loop.

The R1/P1 card and the order go to the P1 cell. In this cell the P1/F1 card is coupled to the order. When the P1 cell is ready, the R1/P1 card is returned to the box of available R1/P1 cards. Et cetera.

Always two POLCA cards are coupled to an order when an order is in a cell (except for the first and the last cell because no loop has been made yet respectively no loop will be made anymore). The reason for this is that only when there is capacity in both the current cell and the next cell (or will be in the near future), the first cell is allowed to start. Because, why should you start if you will have to wait for the next cell? We have seen that it is better to put your efforts on something more useful. So for example only if there is capacity in both cell D1 (DTP) and cell R1 (Pre-press) cell D1 is allowed to start making the layout of a birth ticket.

Because a POLCA card represents both the current cell and the next cell, the cards are overlapping. This can be seen in the routing from the birth tickets: D1/R1, R1/P1, P1/F1. Only the first and the last cell are not overlapping because there respectively exist no previous or next cells in that case.

Now we know what the use of POLCA cards is (reveal whether there is capacity), we need to know how the cards are made. One important aspect is the appropriate 'quantum' of capacity that should be represented by a POLCA card. It is essential that the quantum is not too large and not too small. If the quantum were too large, then it would imply too few POLCA cards in the loop between two cells resulting in infrequent and possible 'lumpy' signals of available capacity to the upstream cell. On the other hand, if the quantum were too small, it would result in excessive POLCA cards in the loop, making it time-consuming to manage and keep track of them. These two tradeoffs need to be considered while determining the quantum.[25]

Another aspect is the number of POLCA cards in each loop. The number of cards can be computed by the following simple formula:

$$N_{A/B} = (LT_A + LT_B) \times (NUM_{A,B} / D)$$

Where:

$N_{A/B}$	=	Number of the POLCA cards in the POLCA loop going from cell A to cell B
LT_A	=	Estimated average lead time for cell A
LT_B	=	Estimated average lead time for cell B
$NUM_{A,B}$	=	Total number of jobs (in terms of the quanta) that go from cell A to cell B during the planning period
D	=	Length of the planning period[26]

This formula is based on Little's Law, which states that for any given production system the work-in-process is equal to the lead time multiplied by the throughput.

[25] Suri, 2003: 8
[26] Suri, 1998: 256

According to Vandaele[27] and others, the formula is too simple to be effectively applied. For example, it is quite superficial to determine the lead time as a fixed amount of time. A lot of variables can influence the lead time. Orders of course can differ in the lead time, depending on the size of the order and on the specific operations that are needed. Therefore, an amount of safety lead time should be added, which can be operation dependent. And, what if an order has to wait some time for some reason? The POLCA card then is attached to the order, but the order does not use capacity in the cell. Therefore, also some safety cards should be added. In addition, the way to calculate the several parts in the formula is missing. The formula of Suri is a basis formula that can be refined and that has to be refined when a more precise estimate of the number of POLCA cards is needed.

Then finally, the design of the POLCA cards is important. A POLCA card always has the same basic layout.[28] An example:

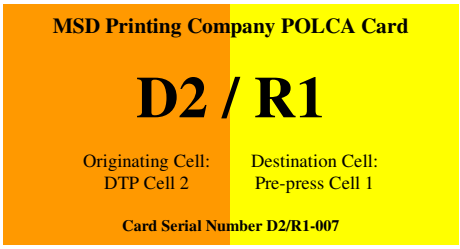


Figure 3.7 POLCA card

The main information on the card consists of the acronyms for the paired cells for which the card is used. These are written in large characters. The card is split into two colors. Each color is associated with a cell. Cell D2 is orange and cell R1 is yellow. And the card contains some more detailed information: the abbreviations are explained and the serial number of the card is projected.

3.3.4 HL-MRP

We saw that at MSD Printing Company cells where formed and that these cells where connected through POLCA loops and POLCA cards. As a result, all cells are attuned to their former and their next cell. But, how does a POLCA organization plan the total, complete process of *all* the needed cells by orders?

This planning is performed by a HL/MRP (High Level Material Requirements Planning) system. The final element in implementing POLCA is making sure that there is a HL/MRP in the organization. HL/MRP is a covering system that oversees the whole organization. This system plans the timing of the production and makes sure that every thing needed is at the right cell. According to Suri, it has the following functions:

- Prediction of the need for, and ordering materials from external suppliers;
- Coordination of material delivery across internal cells.[29]

[27] Vandaele, 8
[28] The layout of this POLCA card is slightly different from the layout proposed by Suri. The text of the originating and destination cell are placed at the half where their abbreviation is also placed.
[29] Suri, 1998: 212

A POLCA organization uses a system for high-level planning and coordination of materials. Rather than looking at the details of replenishing materials and routing steps within each cell, the HL/MRP sees each cell as one step in the MRP logic. In this way, only a few steps have to be scheduled. According to Suri, this results in a simpler system than regular applications of MRP.[30]

However, do we need a simpler planning; do we not have powerful computers that can easily handle complex routings? There are three reasons why a company can benefit from a simpler planning:

- There are fewer steps to schedule and control. The ripple effects from 16 steps can quickly become unmanageable, while for three steps there is a good chance you can keep them under control;
- With the simpler planning, the cells can be given realistic and well-organized, clear targets as opposed to unreasonable ones, ones that would be soon be ignored;
- In the organization with HL/MRP the cells are more likely to keep their end of the bargain and deliver products on time.[31]

In a figure, the interaction of the HL/MRP and the cell planning systems looks for MSD Printing Company as follows:

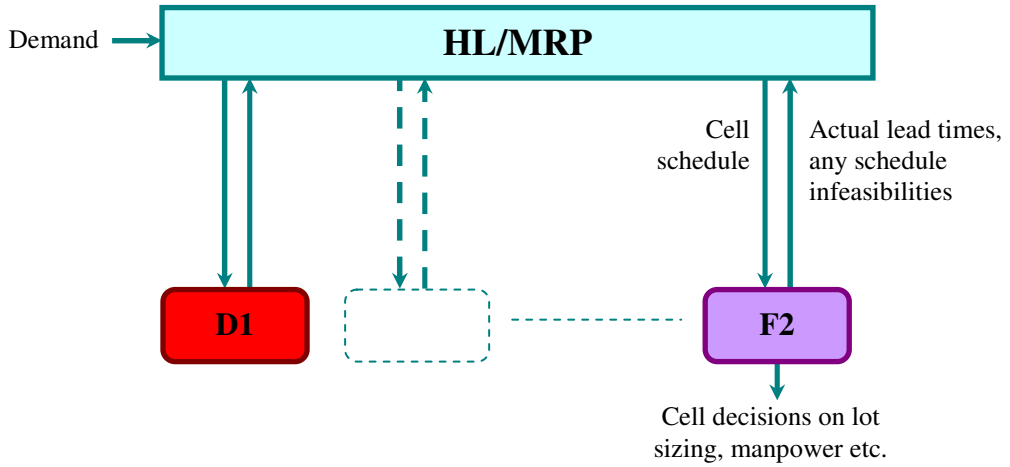


Figure 3.8 HL/MRP

The HL/MRP is driven by specified demand. This might be customer orders, sales forecasts (if possible), or a combination of both. Based on this demand, and using the cell lead times, the HL/MRP system develops delivery schedules for each cell. These schedules are given to each cell. In accordance to the schedules, each cell develops its own rough-cut lot sizing and work force policies to achieve the desired schedules. If the cell detects periods when it cannot meet the production targets, or when its lead times differ significantly from the ones being used by the HL/MRP system, it gives this feedback to the HL/MRP system. Based on such feedback, the HL/MRP system develops a modified schedule.

[30] Regular MRP is, according to Suri, a very detailed system that assists the micro management of every work center. This detailed application of MRP can cause excessive inventories. With introducing the term High Level MRP, he demonstrates an application of MRP that takes cells as a black box.
[31] Suri, 1998: 217

3.4 Summary and conclusions on POLCA

POLCA is a hybrid material control strategy and is mainly meant for companies that struggle with high WIP and long lead times because of high variety in product mix and high variety in demand. POLCA is needed because no suitable material control system exists for organizations in a high variety environment.

The central objective of POLCA is lead time reduction. This lead time reduction will lead to better quality, lower costs and reduction of waste. Lead time reduction can also improve customer satisfaction and attract new customers.

The implementation of POLCA can be divided into the following elements:

- Cells;
- POLCA loops;
- POLCA cards;
- HL/MRP.

Underlying the POLCA system is a *cellular organization*. Employees and machines that produce certain semi-finished products are placed in one independent cell. POLCA coordinates the flow of materials between the cells. A cell is responsible for perfectly finishing the operations in the cell.

Each cell is connected to its previous and its next cell (except for the first and last cell) by a *POLCA card*. This card represents capacity that is available and stays with an order during the operations in two cells. Then the card is returned to this first cell. This move of the POLCA cards is called a *POLCA loop*. At every cell, the loops are overlapping (also except for the first and the last cell).

An *HL/MRP* oversees the whole system and decides when a cell is allowed to start working on an order. The HL/MRP sees each cell as one step in the MRP logic and is driven by specified demand. Like this, unneeded inventory build-up is prevented.

4. Learning

~ Standing still is going back ~

Economic pressures such as growth and profit force organizations to be increasingly competitive. How can organizations keep up with this? Pautzke stated that 'Careful cultivation of the capacity to learn in the broadest sense, i.e. the capacity both to acquire knowledge and to develop practical abilities, seems to offer a realistic way of tackling the pressing problems of our time'[32] In other words, *organizations need to learn*.

One way to keep up with the mentioned pressures is to implement concepts like POLCA, we saw in the last chapter. So, in this specific case organizations (and students that will work in organizations), are going to learn about POLCA.

The aim of this chapter is to find out in what way POLCA can be best taught to organizations and to students and what requisites for the POLCA simulation game can be extracted from this. The subject learning will be elaborated in two paragraphs: the first about the theory on individual learning and the second about a learning strategy for teaching POLCA. The chapter will be closed with a conclusion.

4.1 Introduction to learning

In this paragraph a look will be taken at how individuals learn. To do this, the experiential learning theory of Kolb will be explained. After this, the effectiveness of learning tools are discussed. And finally, barriers for and facilitators to learning will be considered.

4.1.1 The experiential learning theory

The experiential learning theory is 'an integrative perspective on learning that combines experience, perception, cognition and behavior.'[33] Kolb introduced a cycle through which individual learning progresses. This model is relevant to the use of simulation games in education and training since they are a type of 'controlled experience' from which learning can happen if the whole experience is used effectively and the learner goes through all four stages.

The cycle that can be seen in figure 4.1 consists of four stages. At stage one of the learning cycle a person starts off with an experience; the '*concrete experience*'. To learn from this experience, people must engage in a second step of consciously reflecting on what has occurred. Stage two of the cycle thus is the reflection on the experience and is called the '*reflective observation*'. Reflection is selective and, as could be derived from the definition of individual learning, is influenced by our expectation and our existing meaning. Stage three is to develop certain principles and

[32] Probst, 1997: 5, referring to Pautzke, 1989: 2
[33] Riis, 1995: p. 15

concepts from the reflection. Kolb called this step '*abstract conceptualization*'. It is the sense making of what is experienced. Stage four finally is to test these principles and concepts either by replicating the initial experience or by trying out the principles in new circumstances; the '*active experimentation*'. At this step people test out the meaning that was constructed by taking action – which leads to new experiences etc.[34,35] Thus, for an individual to learn, all the four stages have to be passed at least once.

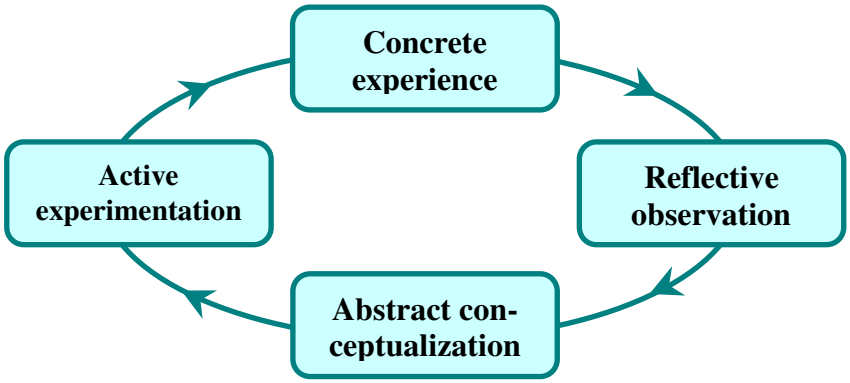


Figure 4.1 The experiential learning cycle

4.1.2 Learning tools

Although it is part of the assignment underlying this research to develop a simulation game, it has to be made sure if this choice was right. The choice for simulation games as a learning tool will be discussed.

To now how people learn best, we have to now how our brains react on different ways of teaching. Scientist Sousa compared a number of forms of teaching on their performance. He examined the percentage of information that people still remember 24 hours after the information was given to them. The research resulted in the conclusion that the more active someone is when he gets information, the better he will remember that information. If someone only hears information, only 5% of this information is known after 24 hours. People learn most when they have to explain the information or when it is applied.[36] Consequently, simulation games can be assumed to be a good and effective tool to learn people something because a type of action is involved. The results of the research can be seen in the pyramid.

[34] Sloman, 1994: 33
[35] Dixon, 1994: 32, 33
[36] www.wiskundeles.nl

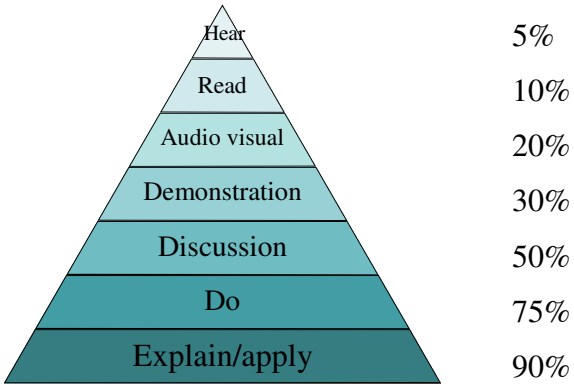


Figure 4.2 Learning pyramid of Sousa

The conclusion of Sousa aligns with the beliefs of Probst. Also according to this author, people learn best from experiences.[37] He writes that 'games in micro-worlds give managers an opportunity to experience in and learn from a real situation. The special features of this kind of learning,' he says, 'are that space and time are compressed, so experimentation, i.e. seeing the consequences of one's actions and learning from them, can take place within a short period.' Simulation games have in addition been suggested for their 'visibility, reproducibility, safety and economy. Simulation games are used when there are no possibilities for people to get experience of systems or situations in the real life; simulation games allow learners to explore systems where reality is too expensive, complex, dangerous, fast or slow.'[38]

In chapter 5, the subject simulation games will be elaborated more extensively. For now, it is enough to know that simulation games are a right tool for teaching POLCA to people.

4.1.3 Barriers and facilitators

In this sub paragraph, some factors that can influence a smooth learning process will be discussed. These factors are mainly relevant to people from organizations and some are also relevant to students. Learning namely does not always go easy and automatically, especially in organizations where people are stuck to routines and believes and are not, unlike students, in the rhythm of studying.[39] This can lead to disinterested, unwilling participants.

Barriers

POLCA, and thus the POLCA simulation game, might change the current known and save situation. Effective change and thus effective learning needs the support of the people involved. Therefore, support for change needs to be gained and the resistance to change needs to be decreased or eliminated. It is significant for the game that it shows that POLCA will be a step to a better, improved organization. One first

[37] Probst, 1997: 89
[38] Riis, 1995: 14
[39] An assumption is that students in general are more willing to actively participate in games than people from organizations. This was for example obviously the case at the POLCA game with Post-Its in America.

important barrier namely is that people have a *resistance to change*. They often fear the unknown and may prefer an imperfect present to an unknown and uncertain future. Other reasons for the resistance might be a lack of conviction that the change is needed, objections to the imposed change, fear of disturbed practices, habits and relations, and fear of inadequacy and failure.[40]

One way to decrease the resistance to change is to draw attention to the need for change. People have to be convinced that change is needed. In the POLCA simulation game this can be done by creating a challenging situation, the participants have to feel that something has to be done to save a fictitious organization. When they play the game, they might see a link with their own situation which can make them realize that change in the organization is needed. If the results of the game without POLCA game are worse than the results with POLCA, the participants will see that POLCA can have a positive effect on the results of their own organization.
An additional way to decrease the resistance to change is to make the participants of the game feel comfortable with POLCA. They should experience that POLCA is quite simple to use and that they will not fail when the concept is implemented.

Another important barrier for effectively learning, mainly for organizations, is *unlearning*. This is 'the process by which knowledge is erased from the memory.'[41] When learning something new, old structures and ways of thinking must be removed in order to make room for new ones. Unlearning makes it possible for new knowledge to be accepted, and for old structures to be changed or removed. However, people often lack the means and the opportunity to free themselves from their current beliefs and routines. The process of unlearning can also be stimulated by a need for change. When individuals feel such need for change, they are more willing to learn something new.

Facilitators
Argyris gives recommendations to support an effective learning process[42]. These general recommendations will be applied to games. First, guarantee that the leaders/teachers understand the things to be learned. If they do not understand completely and thoroughly the content of the POLCA concept, they will never be able to explain it clearly. The theory should be given to them in an understandable and readable form to make the underlying basics and assumptions of the concept explicit and clear. Secondly, the game has to be error free in order to get the best and most realistic results. For this purpose, the game has to be tested and adjusted until the game is error free. Thirdly, the models and data used in the game must be simplified as much as possible to make them work so that costs are reduced and usability are increased. Fourthly, the game has to take into account the cognitive structures of the participants. The information presented by the POLCA simulation game has to be connected to what the participants already know. The teacher can play an important role in this.[43] There should not be too much old information, but there also should not be only new and difficult information. Participants should be able to give the learned things a place in the view of reality they already have. Finally, the game should be

[40] Kubr, 2002: 90
[41] Probst, 1997: 64
[42] Argyris, 1992: 125
[43] Kolb, 2005: 195

should be seen as part of a total development program. It is not something that stands on his own. For students this means that it is part of the total matter that is taught to them. For organizations, this means that people will hear more often about POLCA than only during the game. The game is just an introduction to the implementation of POLCA in the company.

4.2 A learning strategy for teaching POLCA

In the previous paragraph, many requirements for learning where formulated. These requirements will be important when developing the POLCA simulation game. Before this can be done, a learning strategy has to be developed. In the learning strategy a total, covering statement about how the POLCA project will be build up. Many opinions exist about how learning strategies have to be designed. According to Sloman, the most important, and pervasive, model for the role of training in the organization is the Systematic Training Model.[44] This model will be described and filled in within this paragraph.

Systematic training is training developed on a planned basis as a result of applying a logical series of steps. In practice, the number and description of these steps tends to vary, but in general terms they would cover such aspects as development of training policy, identification of needs, development of training objectives and plans, implementation of planned training, and validation, evaluation and review of training.[45] In a figure, this looks as follows:

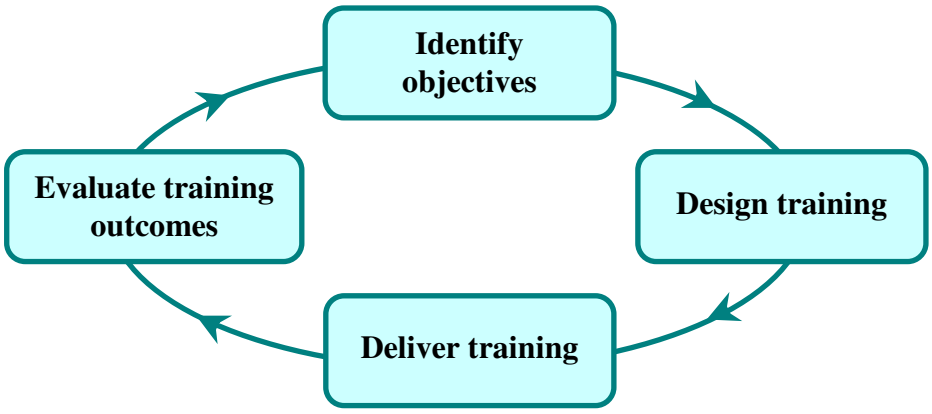


Figure 4.3 Systematic Training Model

The Systematic Training Model is a circular model because is introduces a link from evaluation to the further identification of needs. The process becomes then continuous. The paragraph now will go on with describing the various phases with respect to the POLCA simulation game.

4.2.1 Identification of objectives

When developing a learning tool, first the learning objectives have to be identified. Thus the relevant question here is: what should the participants learn by playing the POLCA simulation game?

[44] Sloman, 1994: 21
[45] Sloman, 1994: 21

The answer on this question is threefold. First, the participants need to know something about the context and the application of POLCA. To make this clear, they will look at POLCA in the context of other material control systems. This has to lead to an insight in why there is a need for POLCA. Attention should be also given to when POLCA is applicable, thus in what production situations POLCA can be useful, and to the main advantages and disadvantages of POLCA compared to other systems. This part is very theoretical and needs to be discussed shortly.

Secondly, the participants have to understand the main topics of POLCA. As could be seen in the previous chapter, the chapter about POLCA, the main topics are:

- Cells (cellular organization)
- The POLCA loops (to connect the cells)
- The POLCA cards (to visualize and control the flow of orders)
- HL/MRP (planning total order)

This is an important part for the participants of the POLCA simulation game and has to be discussed extensively.

Thirdly, the participants need to learn to work with POLCA. As told earlier, it is not the aim of the research that participants can implement POLCA. When POLCA is implemented, participants should be able to recognize the system and its characteristics and they should be able to work with it. By playing the POLCA simulation game, the participants have to make decisions about the number of orders to accept and about the allocation of these orders in the process. When doing this, they apply the things learned about POLCA. Like this, they will experience the way POLCA can affect an organization.

4.2.2 Design of the training

Now the learning objectives are clear, a training strategy has to be developed. To do this, an extended version of the experiential learning theory of Kolb will be used.

Simulation games can be viewed as a three-phase process involving:

1. Introduction or briefing before the game;
2. Actual game activity;
3. Debriefing or post-experience analytic process.[46]

The phases of simulation games and the experiential learning cycle are closely linked. Because of the repeated actions that are taken in a simulation game, participants go through the four phases of the learning cycle. Riis has extended the model of Kolb with a summary follow-up (part of stage 3). In this follow-up, the participants of the game have an extra opportunity to reflect and conceptualize the experiences. And, to be able to play a game about POLCA, participants need to know something about the subject. For the purpose of this research, the model will be in addition extended with starting information (stage 1). Figure 4.4 shows the extended learning cycle.

[46] Riis, 1995: 16

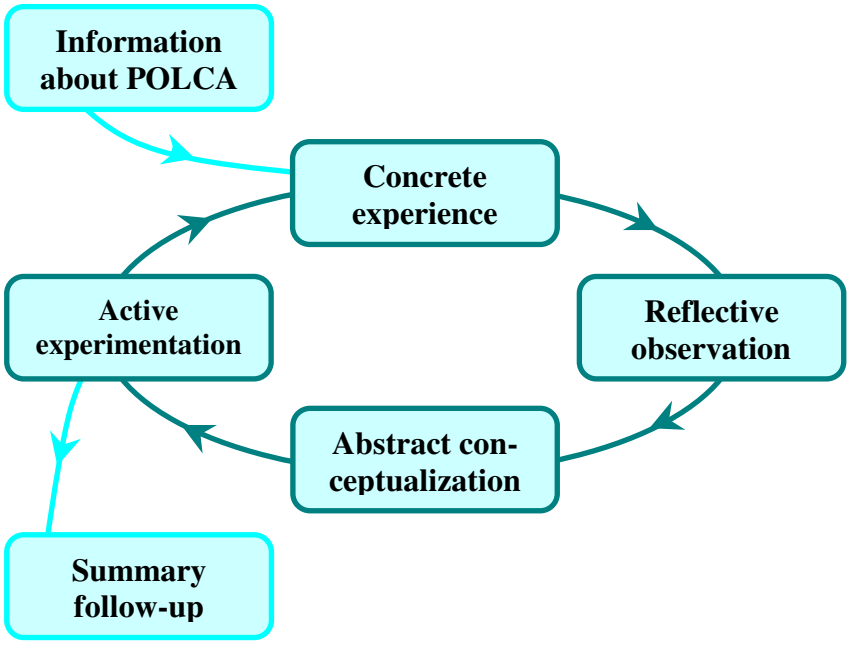


Figure 4.4 The extended experiential learning cycle

Based on the learning goals of paragraph 4.2.1 and based on the experiential learning cycle a training strategy will be developed now. The total POLCA 'project' will be divided into three parts. These parts are chosen such that they overlap with the phases of gaming.

First, the participants have to read an introduction on POLCA to learn them the basics of the concept. This part is a theoretical preparation to the main part. The first and second goal mentioned in paragraph 4.2.1 (give insight to both the context of POLCA and to the main topics of POLCA) will be covered by this introduction. In the second part the theory will be applied in 'practice'. By playing a simulation game, participants will experience how the different parameters that play a role in the production process influence each other. And finally, to give the new insights a remaining place in their cognitive structure, participants have to play a Internet version of the POLCA simulation game and write a little paper about POLCA and the findings during the games. The goal of this last part is that the participants spend some time on thinking about POLCA. By writing a report, they can list all the things learned and make it a clear whole in their minds. By playing the computer simulation game, they can experiment with the parameters without disruption of other, external, factors. Like this, arisen questions during the game can be answered.

Thus, in short:

1. Introduction to POLCA
    a. Context of POLCA (need for POLCA, application)
    b. Main topics of POLCA
2. Game (learn to work with POLCA)
3. Reflection (Internet simulation and report)

The general line in this structure will be, as can be seen, from theoretical to practical.

For part 1a it is sufficient to treat quite general. There will be no in-depth analysis of the existing material control systems. Just the core of the need for POLCA in certain situations will be elaborated. It is only to introduce the concept of POLCA and the reason why it is developed. And, to explain what kind of production situations should kept in mind when reading the text about POLCA.

Part 1b will be a more in-depth text about the elements of POLCA. First, the organizational structure, planning system, POLCA loops, and POLCA cards will be discussed in a theoretical manner. Then this will be commented by an example of a company that is implementing POLCA. Like this, the subjects will be discussed twice, first short and theoretical and secondly more extensive and practical. There will also be a link with the subjects dealt with in the Field Course O&SC. By making a link with the real world (example and Field Course) students can imagine better what POLCA means to an organization. All learning namely is *re*learning. According to Kolb, learning is best facilitated by a process that draws out the students' beliefs and ideas about a topic so that they can be integrated with new, more refined ideas.[47]

Part 1 will take place individually by reading an interactive text (website) that encourage a thorough understanding of POLCA. This text will be placed on the Internet (Nestor).

Part 2 is a group activity. In a classroom, the POLCA simulation game will be played by groups that compete with each other. Each person is responsible for the performance of one production cell. By selling orders, planning, and producing, the group will experience the several factors that play a role in the ultimate performance of the company.

The game will consist of two rounds. In round I, the groups are free to take orders and to determine the planning of the orders. The goal of this round is to show what happens when no obvious planning rules are used. This round probably will lead to long lead times, high work in process, and/or low number of finished orders. With this, the notion arises that something has to be done. All groups then implement POLCA and round II starts. In this round, expectantly the above-mentioned factors will be more optimistically. Possibly, in round III and further the participants can experiment with certain variables to see what happens. Examples are the number of POLCA cards and improvements proposed by the participants

Part 3 finally, is only mentioned for students and will be performed individually. To conclude the POLCA project, the students will play an Internet version of the POLCA simulation game individually and they will have to write a report. The computer simulation game will be offered by means of Nestor. In this game, players can experiment with the same variables as in the game, but now the computer calculates the results and the players can make additional decisions about for example priority rules.

For the set up of the POLCA project, the pyramid of Sousa is applied. First, during part 1, participants *read* a text. This is not enough to learn very well about POLCA. To make that the participants have a thorough understanding of POLCA, teaching

[47] Kolb, 2005: 195

methods at the bottom of the pyramid have to be applied. During part 2, participants *do,* they work with POLCA and they *apply* the concept to their situation. And finally, during part 3, participants have to *explain* POLCA and the results of the game in a paper. According to Sousa, the basics of POLCA should now remain in the brains of the participants.

4.2.3 Delivery of the training and evaluation of the training outcomes

As described in the research design, the POLCA simulation game will be tested and the results of the test game(s) will be evaluated in chapter 6. Therefore, the last two parts of the Systematic Training model will be described in chapter 6.

4.3 Summary and conclusions on learning

The world is changing faster and faster. To keep up with these changes learning is required. In the paragraph on individual learning, a number of requirements for effective learning were formulated. For the POLCA simulation game, it is required that the participants feel motivated to put effort in learning about POLCA. They have to feel a need to learn about POLCA and they have to be made interested in the subject in order that they want to learn about POLCA. In addition, the material to be taught has to be at the right level of difficulty and has to be presented in a clear format. It has to be kept in mind that the game has to connect to the current knowledge and skills of the participants.

Important for learning is that room for learning has to be created; the participants have to get the opportunity to move through all the four phases of the learning curve. Therefore, actions in the game have to be repeated and participants should be able to reflect the experiences. Simulation games are a right tool for learning because it makes participants apply POLCA to a certain situation.

Barriers to learning that have to be considered when developing a simulation game are resistance to change and unlearning. Both can be decreased by a need for change.

To develop a learning strategy for teaching POLCA, the Systematic Training Model is applied. The first step in this model is to identify the training needs. The goals of the POLCA simulation game are:

- To give insight in the need for POLCA and when POLCA can be applied;
- To teach the main topics of POLCA (cells, POLCA loops, POLCA cards, and HL/MRP);
- To teach participants to work with POLCA.

The second step of the Systematic Training Model is to design the training. For designing the training, the experiential learning theory of Kolb was used. Based on this model for individual learning and based on the three-phase process of simulation games the ‘POLCA project’ is designed. The POLCA project consists of three parts. First, the participants have to read an introduction on POLCA to them the basics of the concept. The second part will be playing the game and the POLCA project will be closed by individually playing an Internet version of the game and writing a report in which students reflect on what they learned.

The third and fourth step of the model are delivery of the training and evaluation of the training outcomes. This will be described in paragraph 6.5.

5. Simulation Games

I hear and I forget
I see and remember
I do and I understand

This old Chinese proverb reflects an important conclusion of the last chapter. We saw there that simulation games are a valid way of teaching a complex concept as POLCA. Simulation games namely make participants *do* something; it lets participants experience the concept. In this chapter, a further description of simulation games as a teaching tool will be given. This will be done in three paragraphs. In the first paragraph, a definition will given to make clear what simulation games exactly are. In the second paragraph will be described what can be accomplished by simulation games. And in the third paragraph, the characteristics of simulation games will be elaborated to know what should be considered when developing the POLCA simulation game. The chapter again will be closed with a summary and conclusions.

5.1 Introduction to simulation games

The term simulation game is composed of two elements, namely simulation and game. Authors explaining what a simulation game is, often make this distinction because a simulation game is a combination of the features of simulations and the features of games. Although the terms are often used synonymously, simulations do not have to be games and visa versa. A definition of *simulation* is:

A simulation is an operating model of central features or elements of a real or proposed system, process, or environment. This model may be abstracted, simplified or accelerated. It purports to have a relevant behavioural similarity to the original system.[48,49]

The definition stresses the critical dimensions of a simulation:[50]

- A simulation is a form of a *model*. A model is a representation of relevant (given a certain aim) elements of a reality.[51] There has to be a similarity to the original system;
- It is *dynamic*, as opposed to static;
- Only *selected elements*, central features, of the referent system are included.

Thus, central features of a situation are identified, represented, and constructed into a model that operates in a manner similar to the real world. An example of a simulation that is not a game is the famous wind tunnel model.

[48] Greenblat, 1988: 14
[49] Riis, 1995: 13
[50] Greenblat, 1988: 14
[51] De Leeuw, 2000: 125

Riis defines *games* in the following way:

'A game is played when one or more players compete or cooperate for payoffs according to a set of rules. A game means a setting in which participants make choices in an effort to achieve given objectives. Gaming employs persons in some role, actual or simulated, in its operation in an environment, which is either actual or simulated.'[52]

The definition stresses the critical dimensions of a game:
- One or more players with certain *roles* participate;
- Participants *compete* and/or *cooperate* when trying to reach *objectives*;
- *Rules* structure the game;
- Games take place in a certain gaming *environment*.

Greenblat adds to these dimensions that 'the term game is applied to those simulations that work wholly or partly on the basis of players' decisions.'[53]

Examples of games that are not simulations are board games like the Dutch game 'Ganzenbord' or card games.

A *simulation game* finally, as already told above, combines the features of a game with those of a simulation. In a simulation game, the *game* roles, goals, activities, rules, environment, and the linkages between them are related to real life, or, in the term used above, they *simulate* these elements of the real-world systems.[54]

5.2 Application and purposes of simulation games

Simulation games are designed and utilized for a variety of different objectives. Greenblat, Riis, and Garris mention several objectives of simulation games. These objectives can be segregated into six categories.

First, simulation games increase motivation and interest in the subject of the game. People in general like playing a game more than reading a text about a certain subject. When playing a game, you 'learn by playing', which is attractive. As we saw in the last chapter, simulation games are an active learning form, so the things learned will be remembered better. In stead of individually reading a text, playing a game is a pleasant and enjoyable activity that people often do voluntary in their spare time.

Secondly, games can be used in a teaching context by handing over information or by reinforcing information already given in another format. Educational games often handle about subjects that are quite familiar to the participants or about subjects (partly) treated in the lessons before the game. The Shop Floor Scheduling Game[55] is for example about planning and scheduling procedures. All participants knew already what planning is and they already have ideas about how to plan. Still a lot could be learned by practicing with planning in 'real'. By playing a game, participants can get a broadened awareness of options, policies, and issues. In addition, they can learn

[52] Riis, 1995: 13
[53] Greenblat, 1988: 14
[54] Riis, 1995: 14
[55] See Appendix 1

about the probable consequences of particular policies or events. Of course, a game can also be used to present new information to the participants. The POLCA simulation game will be an example of a game that builds on the information participants already have (material control systems, process dynamics)[56], but it will also contain new information: the information about the concept POLCA.

Thirdly, games can be applied for skill development, for training skills that are needed later. Examples of skills that can be learned by playing simulation games are critical thinking and analysis, decision-making, preparedness for specific future tasks and interactive, writing, or communication skills. For the POLCA simulation game, decision-making is important. The core of the game is to make smart decisions about the allocation of workload to the different parts of an organization. One important advantage of games is that activities in the game have no impact on the outside world, and when involved in the game, nothing outside the game is relevant. Participants can experiment and practice skills without causing problems in the real world.

Fourthly, games can facilitate a needed change in attitude. Playing the POLCA simulation game can be, as discussed before, an eye-opener to the participants. They can learn that there is a need for change and that POLCA can facilitate the way to an improved organization.

Fifthly, games can help by self-evaluation or by evaluating others. 'By playing a game, a participant can become aware of the consequences of their decisions or of their behavior.'[57]

Finally, games can be effective tools for understanding a complex subject. They are used to 'present complex abstract models of reality in experientially rich and complete forms.'[58] Instead of reading or listening, playing a simulation game is a multi-dimensional learning activity. An organization for example can be viewed from different points of view simultaneously. Participants should be able to describe, analyze and evaluate the multi-dimensional realities to which the games refer.

5.3 Elements of simulation games

To describe the elements of simulation games, the Input-Process-Outcome model of Garris[59] will be used. This model aligns very well with the learning theory of chapter 4. The three parts of the POLCA concept (introduction, game, reflection) are represented in the model. Like Riis, also Garris recognizes that in order to gain learning objectives and to attain the greatest impact, simulation games should be part of a wider training program. Figure 5.1 shows the Input-Process-Outcome Game Model. The components of this model will be discussed in the upcoming three sub paragraphs.

[56] Students learned about material control systems in the Field Course Operations & Supply Chains and people from organizations have insight in process dynamics.
[57] Greenblat, 1988: 16
[58] Cordova, 1996: 726
[59] Garris, 2002: 445

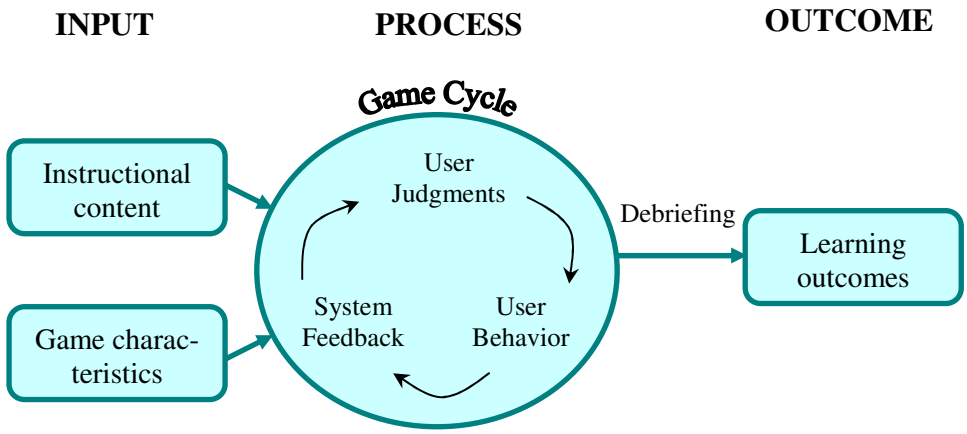


Figure 5.1 Input-Process-Outcome Game Model[60]

5.3.1 Input

According to the model, a simulation game needs two inputs: instructional input and game characteristics. These two inputs will be discussed now.

The first element that is important is the instructional content. What do the participants need to know before they start playing the game? The answer to this question is twofold. First, they have to know enough about POLCA to be able to play the game and to reach the objectives of the game, and secondly, they have to know the rules of the game. As told in paragraph 4.2.2, a Nestor introduction will be made to the POLCA simulation game with information about the need for and context of POLCA and about the main topics of POLCA. In addition, a manual will be developed with the rules of the game. In this manual first, the case will be described. As mentioned in chapter 4, this case has to be challenging and concrete. Then the goal of the game, the several components of the game, and the rules will be explained.

The second input are the game characteristics. Opinions differ in what the main characteristics are, but according to Garris the six most important are fantasy, rules/goal, sensory stimuli, challenge, mystery, and control.[61]

Research indicates that when the instructional content (the information about POLCA) is embedded in *fantasy* contexts, participants will show more interest and increased learning can be achieved.[62] It is thus, as already concluded before, important to have a good and imaginable case. The case has to make sense to the participants and has to give the participants the feeling that it is needed to put effort in the game. Fantasy can in addition offer analogies with the real-world processes. It can help people to make the link to the processes of the organization they work for. To give the participants a fantasy context in which they can imagine themselves to really work for, a company will be made up. Thus, the POLCA simulation game will take place in an organization that is fictitious. This company has to perform activities that are imaginable to the participants; it has to deal about processes everybody knows. A big advantage of a fantasy world is that it can be adjusted to the goals of the simulation

[60] Garris, 2002: 445
[61] Garris, 2002: 447
[62] Cordova, 1996: 725

game. The structure of the organization will allow that POLCA can be implemented in such way that it clearly shows what the features of POLCA are and how it works. Each participant will have a certain role with its special characteristics. In addition, some extras will be implemented like a bottleneck and a cell with set up time to show how POLCA deals with these kinds of situations.

Although the game activity takes place apart from the real world, it occurs in a fixed space and time with precise *rules* that structure the game. The rules and constraints of real life are temporarily suspended and replaced by a set of rules that are operative within the fixed space and time of the game. The rules of a game describe the *goal* structure of the game. A finding in the literature is that clear, specific, and difficult goals lead to enhanced performance. 'Clear, specific goals let participants perceive goal-feedback discrepancies, which are a trigger to greater attention and motivation. When feedback indicates that current performance does not meet established goals, individuals attempt to reduce this discrepancy. Under conditions of high goal commitment, this discrepancy leads to an increase in effort and performance.'[63] At the POLCA simulation game participants work for a company with decreasing profits. They have to, first without POLCA and later with POLCA, try to improve the profits of the organization. Another, very motivating, goal is to perform better than other participants do.

Attention has to be paid to the appearance of the game. Factors influencing this are called *sensory stimuli*.[64] When designing the POLCA simulation game, it is important that the layout is attractive and clear. It should be obvious what the elements of the game mean, even without further instructions (where possible). The layout should be simple enough for participants to remember every element of the game and its meaning without rereading the manual. The colors and shapes can play a role in this and should be nice-looking and eye-catching. Other requisites for the layout are that the elements of the game have to be decent and solid and the game has to be easy in use; things should not be too small or too large.

Participants of a game want an optimal level of *challenge*. Challenging means that achieving the goal should be neither too easy nor too difficult. The goals must be meaningful to the participants. Moreover, there have to be several ways in which an optimal level of challenge can be obtained.[65] In the POLCA simulation game some options to think about when improving the focus company should be incorporated. A bottleneck and set up times were already mentioned. The participants can also vary in the number of orders they accept. In addition, the possibility of obtaining the goal should be uncertain. Performance feedback and score keeping allows the participants to track progress towards desired goals.

Curiosity is one of the primary factors that drive learning, we saw in chapter 4. Garris refers to this as *mystery*. Mystery is according to him enhanced by complexity, novelty, surprise, inability to predict the future, and information that is incomplete or inconsistent.[66] By dividing the game in two rounds, one without POLCA and one with

[63] Garris, 2002: 449, referring to Locke, 1990
[64] Garris, 2002: 449
[65] Garris, 2002: 450, referring to Malone, 1987: 223-253
[66] Garris, 2002: 450, referring to Berlyne, 1960

POLCA, two scenarios or situations are generated. The information in the two rounds will be incomplete and therefore participants cannot predict the future. Machine breakdowns or compulsory orders can also be added to the game. The fact that POLCA is a quite unknown concept to the participants can trigger the desire for knowledge. Participants might ask themselves how POLCA works and how it can improve performance.

Control finally, refers to 'the exercise of authority or ability to regulate, direct, or command something.'[67] For some games, all rules are fixed; the rules control all elements of the game. This is called program control. Some games, on the other hand, exist where participants have control over a great deal of the rules. This is called learner control. Research found that the best thing to do lies in between those two extremes, which is providing participants with control over instructionally irrelevant parts of the learning activity. By doing this during the POLCA simulation game, the risk is avoided of participants making pedagogically poor choices while the learner control leads to increased motivation and greater learning.[68]

5.3.2 Process

The process, or the game cycle, refers to the actual playing of the game. This cycle overlaps in a certain way the experiential learning cycle of Kolb. Both cycles consider the psychological processes of the participants during the game. However, the game cycle is more focused on the motivational aspect of simulation games. In Garris' opinion namely motivation is needed to create an effective learning environment. He states that 'to draw out desirable behavior from learners, participants first need to experience desirable emotional or cognitive reactions, which result from interaction with and feedback generated from game play.' Thus, reactions → behaviour → feedback → reactions → et cetera. Or, in other words, user judgments lead to user behavior, user behavior leads to feedback, feedback leads to user judgements, et cetera. The game cycle focuses attention to this chain of dependencies. In the following, the three components of the game cycle will be elaborated.

As participants play the game, they make subjective *user judgments* on how they experience the game. User judgments are important for the *user behavior* of the participants. When they like the game, involvement will increase, which leads to improved motivation and improved learning. Thus, the POLCA simulation game has to be interesting right from the start. The participants should want to continue the game. User judgment can be positively influenced by factors like:

- *'Control factors*: the extend to which actions taken to control or manipulate the environment are immediate and natural;
- *Sensory factors*: quality, richness, and variety of information presented to the senses;
- *Distraction factors*: the extend to which the user is isolated from the external physical environment,
- *Realism factors*: scene detail, texture and realism.'[69]

[67] Garris, 2002: 451
[68] Cordova, 1996: 726
[69] Garris, 2002: 453, referring to Witmer, 1994

An additional factor is the duration of the game. When most of the participants are likely to understand what is meant by the game (thus when the learning goals are achieved), the game has to be stopped.[70]

Feedback finally, is critical to support performance and motivation. User judgments and behavior are influenced by comparisons of performance with goals. Feedback drives participants to expend more effort and to focus more attention on the task.

5.3.3 Outcome

In figure 5.1, a link was shown between the game cycle and the achievement of the learning outcomes. This link is the debriefing process, which is 'the review and analysis of events that occurred in the game.'[71] As explained in paragraph 4.2.2, the experiences of the game will be followed up with debriefing in the form of individually playing an Internet game and writing a report. This will allow the participants to draw parallels between the game events and real-world events. Thus, learning by doing must be coupled with the opportunity to reflect relevant information for effective learning to occur and for learners to link knowledge gained to the real world. This is harmony with the extended experiential learning curve of Riis.

Participants that are not students will not have to play the Internet game and write a report because this probably will not fit into their daily schedules. For them, the learning outcomes have to be shown during the implementation of POLCA, which of course on the longer term will also be the case for the students that are going to work in an organization that implements POLCA. The required learning outcomes described in paragraph 4.2.1 are, shortly, knowing what POLCA is, being able to place POLCA in context to other material control system and knowing how to work with POLCA. These are both cognitive learning outcomes and skill-based learning outcomes. For people from organizations, there also might be some affective learning outcomes like a feeling of need for change and the willingness to change.

5.4 Summary and conclusions on simulation games

Simulation games simulate roles, goals, activities, rules and environments that are related to the real world. They are used to increase motivation and interest in the subject of the game, to hand over new information or reinforce information already given in another format, to develop skills, to facilitate a needed change in attitude, to evaluate people and their behavior, and to understand a complex subject.

Simulation games are a teaching tool, therefore requirement for an effective simulation game overlap with requirements for effective learning. Simulation games can, according to the Input-Process-Outcome Game Model, be divided into three main parts: the input, the process, and the outcome. These parts are similar to the three parts of the 'POLCA project', but they are more focused to motivation because motivation is an important requisite for learning.

[70] When playing the Just-In-Time game, the game mentioned in the research design, participants at the start liked the game, but then got the feeling that it continued too long. After a while, they understood the message of the game and at that time, they preferred to stop.
[71] Garris, 2002: 454

Input to simulation games are the instructional content and the game characteristics. Instructions to the POLCA simulation game will be given by means of a Nestor introduction that explains the basics of POLCA and by means of a manual that explains the rules. Game characteristics are fantasy, rules/goal, sensory stimuli, challenge, mystery, and control. Fantasy has a positive effect on interest and learning, therefore, the POLCA simulation game will take place in a fictitious organization in which participant have the feeling they know how this organization looks. Sensory stimuli, the looks of the game, play a role in the acceptance of the fantasy world. Rules structure the game. Challenge is added to the game by setting difficult but reachable goals. The goals of the POLCA simulation game are improving the performance of the fictitious company and being better than other participants.

During the game, user judgments will influence user behavior, user behavior influences the feedback, and feedback influences user behavior, et cetera. This chain of dependencies is important to the motivational process and thus to the learning process of the participants.

To generate favorable outcomes, debriefing is important. To reflect experiences, participants will have to play an Internet version of the POLCA simulation game and they have to write a report about the main findings during the game.

6. POLCA simulation game

~ Let's POLCA! ~

Rajan Suri

Now we know what POLCA is, how the learning process progresses, and what elements effective simulation games consist of, the POLCA simulation game can be developed. This will be a creative and challenging process. However, despite the creative aspect, frameworks can be used to structure the development process and to prevent getting lost in all the complex elements of it. Riis proposes a design process in four steps: 'initializing, design, engineering, and operation of the game.'[72] He furthermore presents a set of rules, hints and methods for the design and engineering of simulation games. In addition, Greenblat proposes a design process in five steps: setting objectives and parameters, model development, decisions about representation, construction and modification of the gaming simulation, and preparation for use by others.[73] For developing the POLCA simulation game, a combination of both proposed design processes will be used. In this chapter, the first paragraph will explain the design process for developing the POLCA simulation game. Then each step of this model will be elaborated. In the final paragraph, a summary and conclusions will be given.

6.1 Introduction to the development of the POLCA simulation game

First, the design process of Riis will be explained. The first phase of this process is *initializing*, defining the objectives and the scope of the simulation games. Efforts should be spent on the identification of the need for the game. In the second phase, *design*, a concept of the simulation game has to be developed. This concept is quite rough and includes basic ideas about the game process, game setting, game symbols and components. Creativity and brainstorming play an important role in this phase. The third phase, *engineering*, comprises detailed engineering and manufacturing of the simulation game according to the requirements and ideas described in the simulation game concept. The fourth phase finally, *operation of the game*, is essential to make sure that for participants the game is a constructive element in the learning process which the game should support.[74]

The design process of Greenblat overlaps with the suggested process of Riis, but gives some useful supplements. It starts with the *setting of objectives and parameters*. In this stage, the specific needs for the simulation game have to be defined. The second step, *developing the model*, entails developing a conceptual model of the system to be simulated and deciding which elements are to be included in the gaming-simulation. In stage three, *decisions about the representation* have to be taken like decisions concerning the level of abstraction, the time frame, and the interactive structure. Stage

[72] Riis, 1995: 198, referring to Greenblat, 1981
[73] Greenblat, 1988: 27
[74] Riis, 1995: 198 – 200

four contains the *construction and modification* of the simulation game and stage five finally considers the *preparation for use by others*.[75]
The suggested process of Greenblat is more concrete within the steps. The process of Riis gives a clear outline of the development of a simulation game.

In figure 6.1, an overview of the development process that will be used to develop the POLCA simulation game is showed. As can be seen in the figure, the steps of Riis are taken as a starting point. Substantively, the steps will be completed by considerations of Greenblat and by common sense.

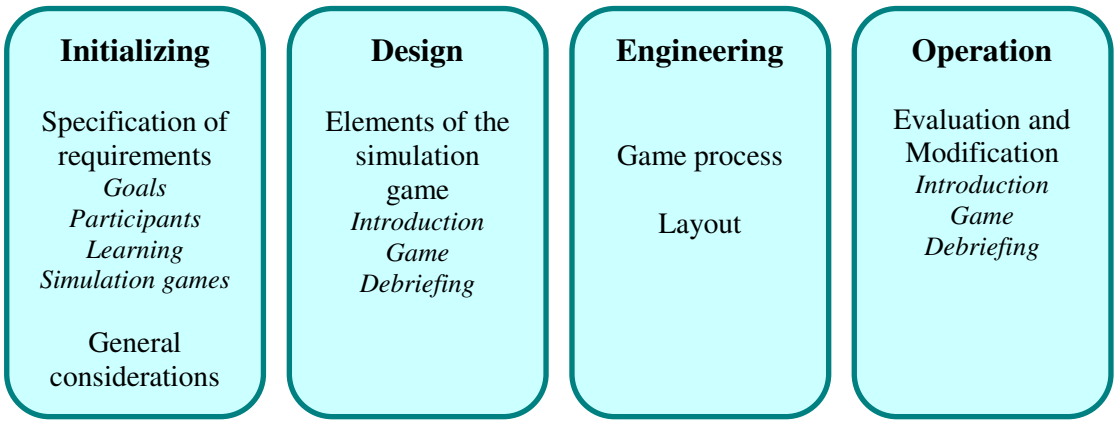


Figure 6.1 Development process

6.2 Initializing

The initializing step is divided into two sub steps. First, requirements for the game have to be specified. Then some 'checkpoints' which are very general have to be considered. These points have to be thought about before starting the development process of the game.

6.2.1 Specification of requirements

In the last four chapters, some requirements for the POLCA simulation game were stated.

The first important issue is the determination of the goal of the POLCA simulation game. Why has the game to be developed? 'The focus of the game has to be clear'[76] to be able to work through a targeted development process. In chapter 2, the following goal was stated:

'The goal of this research is to develop a POLCA simulation game for the faculty of Management and Organization of the Rijksuniversiteit Groningen. The learning objective of this game is that participants master the material control system POLCA after playing the game.'

In paragraph 4.2.1, this goal was refined. The three objectives of the POLCA simulation game are that participants need to learn about the context and the

[75] Greenblat, 1988: 27 – 29
[76] Riis, 1995: 202

application of POLCA, that participants need to learn about the main topics of POLCA, and that participants need to learn to work with POLCA.

When the goals are clear, the developer should ask himself 'is there an existing gaming-simulation that could be used?'[77] In America, Suri developed a POLCA game. This game does not cover the goals of the Dutch POLCA simulation game. The main comment on this game is that the keyword of POLCA and QRM, lead time reduction, is not mentioned in the game.[78] Therefore, a new POLCA simulation has to be developed.

Secondly, the participants have to be defined. The research design stated that the participants of the POLCA simulation game can be divided into two groups, namely students and people from companies. Because different groups with possibly very different backgrounds will use the game, problems can raise.

The first group consists of students. All members of this group are fourth year students following their last course, the Field Course, before they start working on their master thesis. This course lies in their field of interest; it is the main course in the master they choose. An assumption can be made that the students are willing to play the game seriously and that they want to learn about POLCA. However, this is not always the case. Another assumption that can be made is that the students have some background knowledge about several material control schemes and their characteristics. It will be quite easy for them to imagine what POLCA is and how it works.

The other group consists of people from organizations. The members of this group can vary on their level of education. However, in general the assumption can be made that they are much more practical orientated than the students. For them it will be difficult to think in the 'academic' way of material control schemes. They often do not have insight in the positive consequences these schemes can have and how these consequences can be achieved. An problem might be that they in some cases *have* to participate in the game. The motivation to take part actively can therefore be quite low.

The POLCA simulation game has to be able to teach both groups about POLCA.

Thirdly, requirements for effective learning are important. To clarify the concept to students or companies, only a theoretical explanation might not be enough to show how POLCA really works, we saw in chapter 4. It is more effective to combine the theory with 'practice' to get in-depth and useful insights in the concept. Another conclusion of chapter 4 is that a challenging case is essential. The case has to show a need for change. In addition, the material taught has to be at the right level of difficulty and has to be presented in a clear format. It should be kept in mind that the new information has to connect to the current knowledge and skills of the participants.

[77] Greenblat, 1989: 20. According to Greenblat, this question should be asked before determining the goal. In my opinion, it is more logical to first determine goals and then look for an existing simulation game. Otherwise, you do not know what you are looking for.
[78] See Appendix 4A for the description of and other comments on the American POLCA game.

The final point about learning is that the opportunity for learning should be given; all the phases of the experiential learning curve should be passed repeatedly.

Fourthly, requirements for an effective simulation game should be considered. To let the game run smoothly, two inputs are needed. First, the instructional content is important. Participants have to know the basics of POLCA and participants have to know the rules of the POLCA simulation game. Secondly, the game elements are important. As explained in chapter 5, attention should be given to fantasy, rules/goal, sensory stimuli, challenge, mystery, and control. The case should be challenging and imaginable and the game should look attractive and clear. Participants need to have some control over the game process. In addition, the game should be decent and easy to store and move. During the game, user judgments, user behavior, and feedback are important and influence each other. Debriefing finally is important to generate favorable learning outcomes.

6.2.2 General considerations

Riis mentions several checkpoints that have to be considered before starting to develop a simulation game.[79]

A first consideration is about the need for the POLCA simulation game. Is it relevant to develop a POLCA simulation game? The POLCA concept has been developed quite recently and is unknown to the public, especially in Europe. In America POLCA is a little better known and already leads to impressive results. The technique can be interesting for European organizations too and some universities show interest in the concept. This is a main reason to spend effort on developing a teaching tool for POLCA.

A second consideration is about the damage a poor game might cause. In case the game fails to show the realistic consequences of applying POLCA, two effects can occur for companies: it is possible that the game will be applied when not appropriate for the regarding company or that the game will not be (right) applied when application could be very useful to the company. To prevent this, attention will be given to the intentional application of POLCA. For students a poor game can result in a misunderstanding of POLCA. On the longer term, when students have finished University and start working, it can result in the same practical problems as companies can face.

Another consideration is about the role and behavior of the game leader. A game leader can have great influence on the game process; his behavior can lead to success or failure.[80] The main role of the game leader in the POLCA game is to let the process run smoothly and to analyze the game and its results. To do this he will first give a short introduction presentation on the game and its rules and afterwards he will give the results of the game and discusses them. The game leader will be as much as possible in the background. The game has to be simple enough to play without much explanation from the leader.

[79] Riis, 1995: 200 – 201
[80] Riis, 1995: 200

This leads to the following point. One important goal of the development process namely is to model a game that reflects the complexity of the real world. As we saw in chapter 4, games are a manner to give a multidimensional view on a subject. However, the game itself should be easy to play. A comprehensive game manual with many instructions and rules might confuse the participants and reduce the learning effects. Riis says about this complexity: 'It should be emphasized that games must be kept simple. There is a temptation to include too many subjects in combination to reflect the complex reality. It means that the game will be too confusing to engineer and its effect might be reduced. Managing more subjects and problems should be done through more games or versions of the game.'[81]

The next consideration is about the effect of the different roles in the game. It is not accurate to assume that all the participants will get the same experiences when having different roles. 'Different roles will give different experiences from the process, and even with a good game résumé, where experiences and opinions are exchanged, the results will hardly be the same for all participants.'[82] A goal of this POLCA game is to keep it as well organized and clear as possible so all participants can see how the flow of material, cards and information is. The tasks have to be simple enough to pay attention to more important things.

In the previous chapter, several ways were shown to improve motivation and involvement. However, still some participants might not be interested or motivated to play the game. Reasons for this can be that they are 'forced' to play it by their company or they are 'forced' to play it for receiving EC's for the course they follow. There can be a lack of interest and motivation, negative attitude to simulation gaming, or insufficient individual preparation. 'These participants might refuse to play their role, but more likely they will be passive and they could easily spoil the game for the other participants.'[83] If they have to participate, they should be allocated to roles that they accept or to roles which cannot disturb the game, for example observer.

6.3 Design

In chapter 4, the decision was made that POLCA will be taught by means of a 'POLCA project' that consists of three parts, namely introduction, simulation game and reflection. The design of these three parts will be elaborated in this paragraph.

6.3.1 Part 1: Introduction

The introduction to the POLCA simulation game will consist of two parts, as discussed in chapter 5. First, the participants have to read an introduction about POLCA and secondly they have to read a manual. In the introduction on POLCA, they will learn about the context of and the need for POLCA and about the main characteristics of POLCA. Instead of a flat text, an Internet site has been designed that will be available by means of Nestor, the student site of the RUG. The theory on POLCA will be explained by an interactive text that systematically elaborates on the different aspects of POLCA. In this text, quiz questions will test whether the participants understand the content of the text. The participants will read the Nestor Introduction some time before the POLCA simulation game takes place. Like this,

[81] Riis, 1995: 200
[82] Riis, 1995: 201
[83] Riis, 1995: 201

they have a blank mind when playing round 1 of the game and it is easy to refresh the things learned about POLCA for round 2. Appendix 1 contains a paper version of the Nestor Introduction.
The second text participants have to read is the manual of the POLCA simulation game. The manual has to be read at the day of the game. In the manual, the case will be described, the rules of the game, and the needed materials. The manual will be supported by a short presentation that summarizes the main points of the manual. The manual and an associated presentation can be found in the Appendices 2A and 2B.

6.3.2 Part 2: Simulation game

In chapter 5, six game characteristics were described. Five of these characteristics will be applied to the POLCA simulation game in this sub paragraph, namely fantasy, rules/goal, challenge, mystery, and control. Sensory stimuli, the sixth element, will be discussed in paragraph 6.4. To describe the elements, on the advice of Riis[84], literature and existing games are consulted. Appendix 3 contains a description of some inspiring simulation games. Hereafter, attention will be paid to the game cycle of Garris.

When a game takes place in *fantasy* context, participants will be better motivated then when there is no case and when the game is very abstract. The POLCA simulation game will take place in a fictitious factory that produces pieces of furniture. The process in the factory consists of operations that all participants know, like sawing, boring, and painting. The case is very conceivable because all participants can imagine how for example a table has to be made. Like this, the case makes sense to the participants and analogies can be seen with real-world processes.

The participants of the POLCA simulation game will be divided into two or more teams of preferably six persons. Each team represents a factory; the factories are the same, only the name is different. Within the teams, each participant will have his role in the production process. The features of each role can be seen in the following table.

Role	*Task*
Sales & planning	Accept orders, determine routing, transport orders to cell A, maintain planning board, note date of acceptation
Operator cell A	Set up of the machine, perform operations, transportation to the next cell
Operator cell B	Perform operations, transportation to the next cell
Operator cell C	Perform operations, transportation to the next cell
Operator cell D	Perform operations, transportation to the cell E
Operator cell E	Perform operations, transportation to the cell F
Operator cell F	Note date of delivery

One person will perform the tasks of Sales & Planning and cell F. When seven persons participate in one team, the tasks of Sales & Planning and cell F can be split. In case of eight persons, the eighth person can be an observer or a client.

The fictitious company is in a number of ways adjusted to the characteristics of a company that is suitable for implementing POLCA. First, the company is a high-variety company. The demand of the products differs very much and the product mix

[84] Riis, 1995: 204

is very broad (infinite). Secondly, the company faces typical 'POLCA problems': the company faces ever more competition on the lead times. Thirdly, the production can be characterized as job shop, which makes several different routings possible. Finally, 'extras' are added to the game like a bottleneck and set up time.

The *goals* of the POLCA simulation game are to learn to work with POLCA and to perform better than the other participants. This first goal is the learning goal. It is the reason why the participants play the game. The second goal added is to increase the motivation of the participants. To reach both goals, some *rules* have to be taken into account. The number of rules however, is kept to a minimum. The first rule deals with the acceptation of orders. The team can accept as many orders as they want, but once accepted the order has to be made.

The second rule considers the routings. All the orders have to visit some cells, at least four and maximal six. All cells cannot be visited more than one time. Figure 6.2 shows the possible routings.

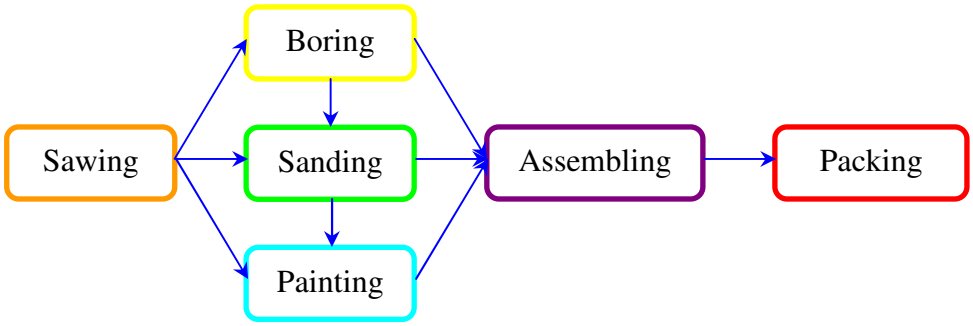


Figure 6.2 Possible routings (seven)

The third rule takes care of time aspects. A cell is allowed to work eight hours per day. This means that a cell can only work on a few orders each day. The participants have a limited amount of time to spend their eight hours, which will decrease during the game.

The fourth rule considers the revenues, costs, and profits used in the game. Possible parameters that can determine the revenues and the costs are:

Revenues
- Number of finished products;
- Number of products finished on time;
- Ability to deliver;
- Working time;
- Production quality.

Costs
- Personnel costs;
- Stock costs;
- Control costs;
- Covering costs
- Number of products not delivered;
- Number of quality defects found;
- Average lead time.[85]

For the simplicity of the game, which is important we saw in paragraph 6.2.2, only one parameter for the revenues and one parameter for the costs will be selected. The

[85] Appendix 4B. Log time – Logistic Processes Just-In-Time.

revenues will be calculated by the 'working time', which will be translated into the number of cells an order visits. The costs will depend on the lead time, which is the keyword of QRM and POLCA. Customers of the factory find this very important. When the factory takes a long time to produce, customers will become impatient and will not order by the factory the next time. In addition, it takes time and space to store the products in the process. The money invested in material et cetera (tied-up capital) can be used for other aims. Therefore, the costs start when a product enters the company and the costs end when this product is delivered. Profits of course can be calculated by distracting costs from revenues.

The last rule is that participants have to apply POLCA and the belonging activities, like making POLCA loops with POLCA cards, in the second round of the game.

Related to the goal of the POLCA simulation game is the level of *challenge*. Two factors influence the level of challenge we saw in chapter 5: the existence of several ways to reach the goal, and the uncertainty about whether the goal can be reached. Participants can experiment with the bottleneck, the set ups, and the number of orders the factory accepts. Uncertainty will be added by incomplete information. Although participants can decide on the number of orders to accept, they cannot decide what the routing of these orders is. In addition, some 'disturbances' can be added to the game. Like in the real world, sometimes things go wrong. Examples are:

- Rush orders;
- Bad quality;
- Absence of workers;
- Breakdowns;
- Inaccurate data;
- Strikes.[86]

Uncertainty also relates to the game element *mystery*. Another concept related to mystery is the amount of novelty in the game. In the POLCA simulation game, novelty is created by dividing it into two scenarios: one without POLCA and one with POLCA. Novelty is also created by the fact that POLCA is a quite unknown concept.

During the game, the participants will have a certain amount of *control* over the actions taken during the game. As we saw in chapter 5, the best thing to do is to provide participants with control over instructionally irrelevant parts of the learning activity. For the POLCA simulation game, this means that the teams are allowed to vary in number of orders they accept et cetera, but the implementation of POLCA has to go in a prescribed way.

6.3.3 Part 3: Reflection

To conclude the POLCA project, the students will play an Internet version of the POLCA simulation game individually and they will have to write a report on the findings about POLCA and about both games. The computer simulation game will be offered by means of Nestor. In this game, players can experiment with the same variables as in the game, but now the computer calculates the results. Appendix D shows the layout of the Internet version and contains an explanation of the game.

[86] Appendix 4C. The Ruler Game – Physical Simulation of Production Activities

The report will contain the following subjects:

- A summary about POLCA and the main effects of POLCA — 1 ½ pages
- An explanation of what happened during the game (per function). A description of the effects of POLCA on the production process. A description of the problems and what was done to solve these problems. — 4 pages
- A description of the same subjects for the computer simulation on Nestor — 2 ½ pages

The report will include about eight pages and will be valued on what the participant learned about POLCA.

6.4 Engineering

In the previous paragraph, an outline of the game was given. 'The next step is a *detailed* engineering of the elements of the game.'[87] The focus will be on the second part of the POLCA simulation game because the other two parts are already discussed in sufficient detail.

6.4.1 Game process

The POLCA simulation game is part of the Field Course Operations & Supply Chains, therefore it should preferably take no more than two hours. Based on Ebbens, who states that a period with one teaching tool should not take longer than twenty minutes, unless it is fascinating to the participants,[88] the following scheme is developed:

'Academic quarter'	15 minutes
Explanation of the game	15 minutes
Round I (without POLCA)	20 minutes
Results first round	10 minutes
Break	15 minutes
Explanation second round	15 minutes
Round II (with POLCA)	20 minutes
Results second round	10 minutes
Total duration:	120 minutes

First, the game will be introduced and explained, and then round I will be played and discussed. After a break, round II will be explained, played and discussed.

6.4.2 Game layout

The POLCA simulation game takes place in a factory that produces pieces of furniture. The layout of the game will reflect that in several ways. As told before, the factory consists of six cells. Each of these cells will show a picture that represents a part of the production. In addition, the elements of the game will be made of wood wherever possible. Figure 6.3 illustrates the layout of the game.

[87] Riis, 1995: 204
[88] Ebbens, 1995: 40

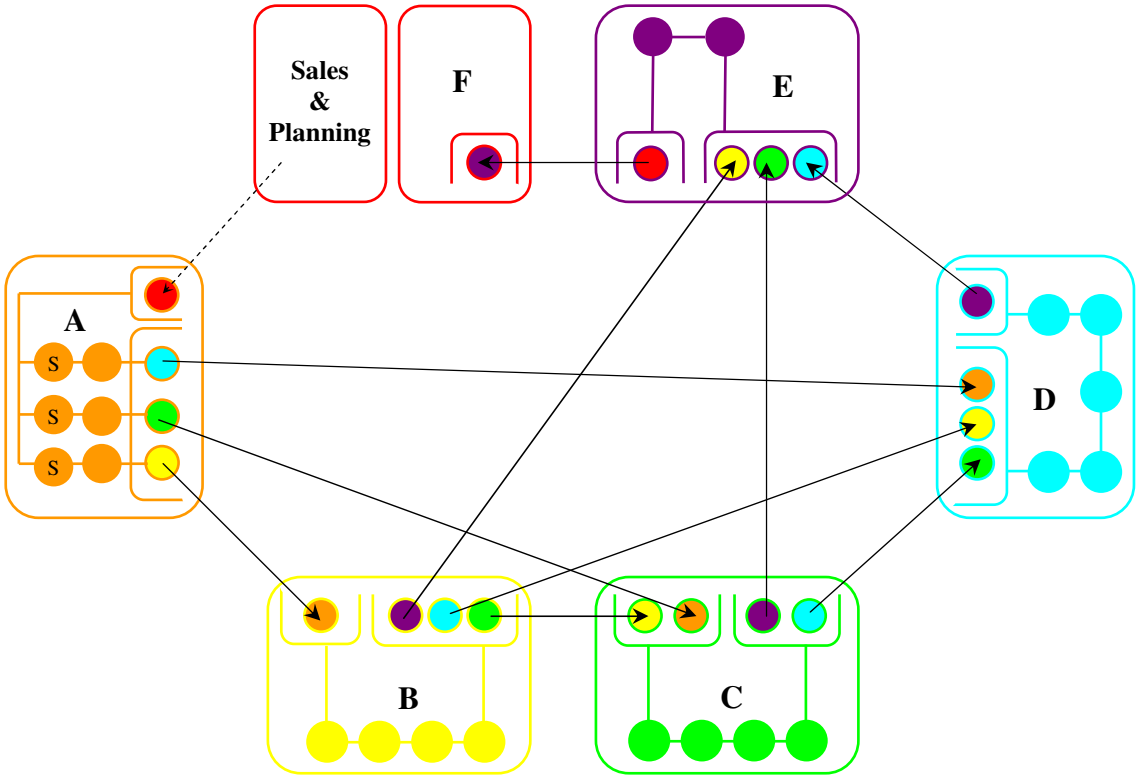


Figure 6.3 Overview of the cells

In this picture, the arrows show the routings of the orders. Each one-colored circle represents one step in production and a two-colored circle represents inventory.

The cells of the factory are placed in a 'circle' because like this, the POLCA loops can be visualized. Each arrow is one loop. In addition, the participants can follow the process of the factory well. They can see the flow of orders and POLCA cards and they can debate on what measures or actions should be taken.

According to the rules described in paragraph 6.3.2, the number of possible routings is seven:

One cell out of A,B,C:	A ***B*** E F	A ***C*** E F	A ***D*** E F
Two cells out of A,B,C:	A ***B C*** E F	A ***B D*** E F	A ***C D*** E F
Three cells out of A,B,C:	A ***B C D*** E F		

To create one bottleneck, the number of operations within each cell will be divided in a way in that the pressure on each cell (occupancy) is lower than the pressure on the bottleneck.

	Possibility[89]	Number of steps within cell	Total occupancy (in proportion)
Cell A	1	2	2
Cell B	2/3	4	2 2/3
Cell C	2/3	4	2 2/3
Cell D	2/3	5	3 1/3
Cell E	1	2	2
Cell F	1	0	0

With this distribution, the most pressure is on cell D, the bottleneck. The cells A, E, and F are not overloaded and more pressure lies on the 'job shop cells' B, C, and E. The reason cell A is not overloaded relates to the set up time of this cell. In the real world, often a lot of attention is paid to reducing set up times. This is not always needed. In the POLCA simulation game a situation will be created where focusing on set up times negatively influences the total process (sub optimization). By adding set up time, the effect of POLCA on the profits might increase because POLCA does not focus on set up times, but on a most favorable allocation of the orders.

The tasks of cell F will be combined with the tasks of Sales & Planning. Therefore, this cell will have no operation steps. Like this, the cell does not have to work with the beads (which will stand for operations as we will see later), and only a little with the POLCA cards.

Cells
Each cell in the game will be represented by a wooden board. As we saw in chapter 3, colors are important when implementing POLCA. Each cell will have its own color. The cells, colors, and functions are:

A: Sawing
B: Boring/milling
C: Sanding
D: Painting/enameling
E: Assembling
F: Packing/sending

An example of a cell can be seen in figure 6.4. Appendix 5A shows the layout of all cells.

[89] For cell A, E, and F, the possibility of being part of the routing of an order is 1 because all orders pass these cells. This possibility is for the cells B, C, and D:

- Possibility of one, two, or three cells: 1/3
- Possibility of joining when
  - One cell out of A, B, C: 1/3
  - Two cells out of A, B, C: 2/3
  - Three cells out of A, B, C: 1

This leads to the total possibility of (1/3 * 1/3) + (1/3 * 2/3) + (1/3 * 1) = 2/3

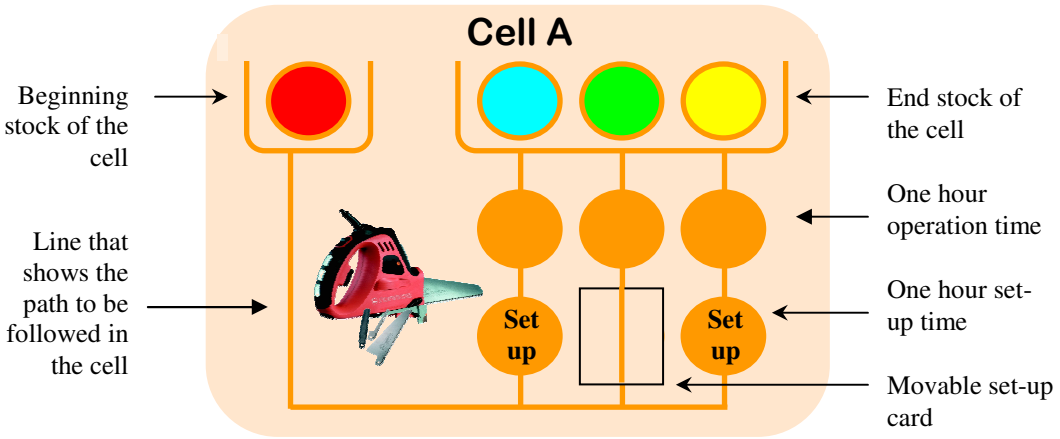


Figure 6.4 Elements cell

The board displays the number of hours it takes to do the operations for that cell. A one-color circle represents one hour production time. Set up times are also reflected by means of a circle. On these circles is written 'set up'. Also these circles represent one hour of time.

The routing within a cell is reflected by means of a line. This line starts at the beginning stock of the cell and goes via operation circles and possibly set up circles to the end stock. The orders run along this line. The stocks are also reflected by means of circles. The beginning stock (the stock of orders that must be still treated by the concerning cell) stands always at the left-hand side of the board (in figure 6.4 the red circle). The end stock always stands at the right-hand side of the board (in figure 6.4 the blue, green, and yellow circles). The color, with which the stock circles are colored, is the color of the originating cell, or the color of the destination cell.

The time an order spends at one workstation can be divided into the following elements:

- Waiting before working;
- Set up;
- Working;
- Waiting before transport;
- Transport.[90]

The board represents four of these elements. Waiting before working takes place in the beginning stock of the cell, set ups is represented by the set up circles, working is represented by the one-colored working circles, waiting before transport takes place in the end stock of the cell, and transport is not represented. Transport takes place by transporting an order to the next cell.

POLCA cards and order cards

The POLCA cards used in the game are simple versions of the cards proposed by Suri. Order cards are also simple cards. They only show the number of the order.

[90] Appendix 4D. Simulation-based Training System for Job Shop Control (TRAIN-F). The sequence of the time elements is adjusted to the tasks of the cells. The cells namely are responsible for the transport to the next operation

Examples of a POLCA card and an order card can be seen in figure 6.5. All POLCA cards and order cards can be found in the Appendices 5B and 5C.

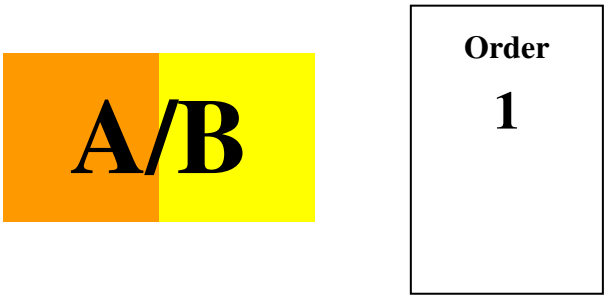


Figure 6.5 POLCA card and order card

Orders
Orders are reflected by means of wooden platforms with a rod. The beads that are on the rod show how far the order is progressed. Each bead stands for one hour of work. Therefore, each cell has eight beads per day. At each step, thus each 'hour', one bead is added to the order. An order which is ready for sending can look like this:

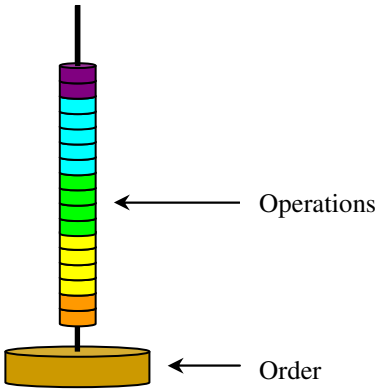


Figure 6.6 Meanings order

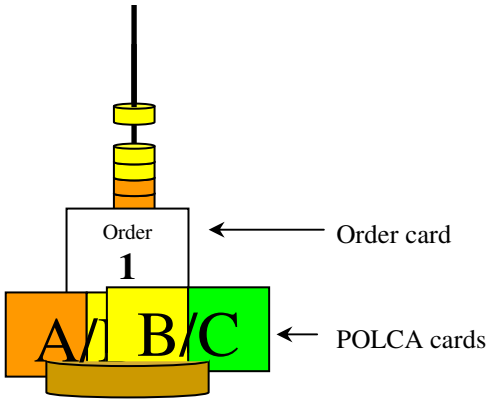


Figure 6.7 Meanings cards

The platform has a slot. The planner places a card with the number of the order in the slot.

During the second round of the game POLCA has been implemented. Then POLCA cards are added to the orders. With cards, the order looks for example as follows:

Order generation
As we saw in paragraph 6.3.2, Sales and Planning accepts the orders. Accepting orders goes by throwing two dices. With the first dice (see figure 6.8) is determined how many cells of the cells B, C and D will be visited. This can be one, two or three cells. With the second dice, it is determined which of the cells B, C and D will be visited. The colors on the dices correspond with the colors of the cells. Once thrown, means that the order must be accepted.

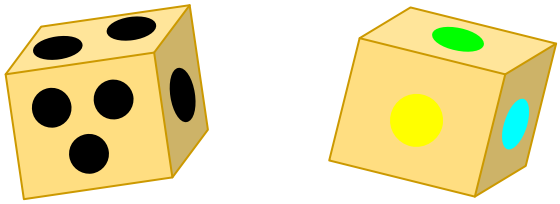


Figure 6.8 Dices

Disturbances
During the game, some disturbing situations can take place like a machine breakdown, absence of workers, et cetera. In appendix 5E, the disturbances can be found.

Revenues, costs, profit
To determine which team played best, the factory can make revenues, costs, and profits (or losses). The number of cells an order visits determines the revenues. The more operations needed, the higher the price of the product. Each visited cell means a revenue of €100,-. The lead time determines the costs, was decided in paragraph 6.3.2 Each day an order is in the company will cost the organization €100,-. Profit, of course, can be calculated by deducting costs from revenues.

Sales & Planning has to fill in the form Order Administration, which can be found in Appendix 5D. When the form is filled in properly, revenues, costs and profits can be calculated easily.

6.5 Operation

Now the game is developed, it is important to know if the game 'works'. On July 14 2005, the POLCA simulation game was tested. To know how different participants react on the game, heterogeneous teams where arranged. Both target groups mentioned in the research design are represented. The team members can be divided into the following categories:

1. Management and Organization students;
2. Other students (Technical / Econometrics / Law);
3. Experts from the faculty of Management and Organization;
4. Business people.

Furthermore, two people observed the game.

Figure 6.9 Test game

The objective of the heterogeneous groups is to see whether the game and its goals are clear to both participants who know something about material control systems (categories 1 and 3) and to participants who do not know (much) about material control systems (categories 2 and 4).

The participants were split into two groups, each representing one factory ('L'Intérieur and 'Möby'). All material described in paragraph 6.4 was made and placed in the proposed layout.

6.5.1 Part 1: Introduction

The participants had to prepare the game by reading the Nestor Introduction. All participants found the introduction clear and complete. One remark was about the colors of the Introduction. Black and red are quite 'hard' colors. Therefore, the Introduction will be adjusted: the black background will be replaced by light blue.

The explanation of the game took place in two ways, the manual was read and a presentation was given. The manual was understandable and comprehensible, but on the presentation, the feelings were mixed. Some participants found it too extensive, others found it too short. Improvements for the presentation are:

- The explanation of the layout of the boards and the set up should be illustrated by a sheet. This because the group could not see it very well;
- The team decisions and the explanation of the periods have to be explained more explicitly.

6.5.2 Part 2: Simulation game

In this sub paragraph, the six elements of simulation games (fantasy, rules/goal, sensory stimuli, challenge, mystery and control) will be discussed again.

The *fantasy* context did his work, the participants were motivated and they liked the case. All participants understood their roles and the belonging tasks; they had no difficulty in performing them.

The rules of the game were followed by the participants. The first rule, considering the acceptation of orders, was understood well by the participants. However, it took them quite a long time to decide on the number of orders. An important disadvantage of this was that the participants, mainly the 'university experts', began to calculate how much orders they should accept. When the participants of the game were students of the Field Course Operations & Supply Chains of people from organizations, then these calculations probable might have not been made. It would be better to restrict this time to, for example, five minutes.

The second rule, considering the routings of the orders, did not cause any difficulties.

The third rule, considering time aspects, caused more problems. Because periods were one day and not one hour, it was possible to work on a product for more than eight hours per day. This of course does not correspond with reality. To prevent this, no more than eight beads should be added to the product in one day. This will be done by adding a pink bead to all products in the end of each day.

In addition, the duration and the end of a playing day should be clearer. In the test game, the teams took quite a long time to perform the actions of one day. While doing this, they thought very long on how to distribute the orders along the factory. This is not realistic; in the real world people have to work more than they discuss the planning, and not the other way around. A limit should be drawn to the time of one

day. This time should be decreased during the game. And, the playing time for each round should be extended because even with limited playing time for each day, 20 minutes for 20 days is short. An average of two minutes for each day should be feasible. Including the time to accept orders, this will lead to 60 minutes per round.[91] For participants, this will not be too long because they were exited and concentrated when playing the game and far from bored. When the academic quarter is skipped and the explanation of the second round is set at ten minutes, the total time the game takes, will be exactly three hours:

Explanation of the game	15 minutes
Round I (without POLCA)	60 minutes
Results first round	10 minutes
Break	15 minutes
Explanation second round	10 minutes
Round II (with POLCA)	60 minutes
Results second round	10 minutes
Total duration:	180 minutes

A third problem that relates to time was that the teams made a planning in which the accepted orders were all finished in the end of the week. In reaction to this, all cells where empty in the end of the week. Especially cell A had a low occupancy; it had only work for the Mondays and Tuesdays. This was because of a simple calculation the participants had made. The revenues an order can generate, lie between €400,- and €600,- because each possible routing exists of four to six cells and each cell generates €100,-. The costs were €100,- per day, so all orders should be finished within four to six days.

Minimum number of cells in the routing			4
Maximum number of cells in the routing			6
Revenues per cell:	€100,-	Minimal revenues per order	€400,-
		Maximal revenues per order	€600,-
Costs per day:	€100,-		
Thus: maximal allowed lead time per order			4 to 6 days

In order to make profit, all orders should be finished within one week because the weekends were included in the lead time. This is not a realistic situation. It is better when the cells can work during the complete week.

[91] Playing time =
- 20 days (Mondays – Fridays) * 2 minutes = 40 minutes
- 4 days (Saturdays) * 5 minutes = 20 minutes

Three options can solve this problem. First, the revenues can be set higher. This will take the fear away of not having orders finished in the end of the week. An additional advantage of this is that the prices will be closer to real-world prices. When doubling the revenues, the allowed lead time is also doubled.

Secondly, the costs can be set lower. This can be done by eliminating the weekends as part of the lead time.

Thirdly, the lead times can be made longer in order to stimulate or force the cells to work also on Thursdays and Fridays. By letting a bead represent two hours instead of one hour, the lead times will be doubled. In reaction to this, the revenues should doubled again because the effect of the first doubling is eliminated by the doubling of the lead time.

A combination of the three options leads to the following proposal:

Revenues: €500,- per visited cell
Costs: €100,- per day, weekends will not be counted anymore

A bead will not stand for one hour of work, but for two hours of work. Therefore, each cell can spend four beads per day.

Minimum number of cells in the routing			4
Maximum number of cells in the routing			6
Revenues per cell:	€300,-	Minimal revenues per order Maximal revenues per order	€1200,- €1800,-
Costs per day:	€100,-		
Thus: maximal allowed lead time per order			12 to 18 days

Like this, the participants do not have the possibility to work only at Mondays and Tuesdays.

The *goals* of the game were clear to all participants, but not all fully reached. People did learn to work with POLCA; however, they did not see a clear difference between working without and working with POLCA. In figure 6.10, the results of both teams are shown:

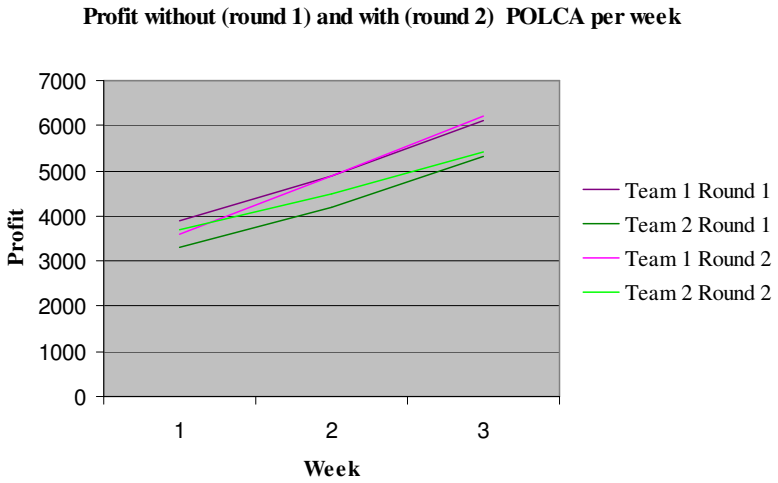


Figure 6.10 Results of the test game (time)

In the figure can be seen that during the second round the best results were gained. However, this 'improvement' is quite small: €100,-, which is only about 2%. This little improvement might be attributed to a learning effect.

In addition, the figure shows that in both rounds team 1 performed better. However, the only reason they performed so well was that they accepted more orders then team 2, as can be seen in figure 6.11. This again has not much to do with POLCA.

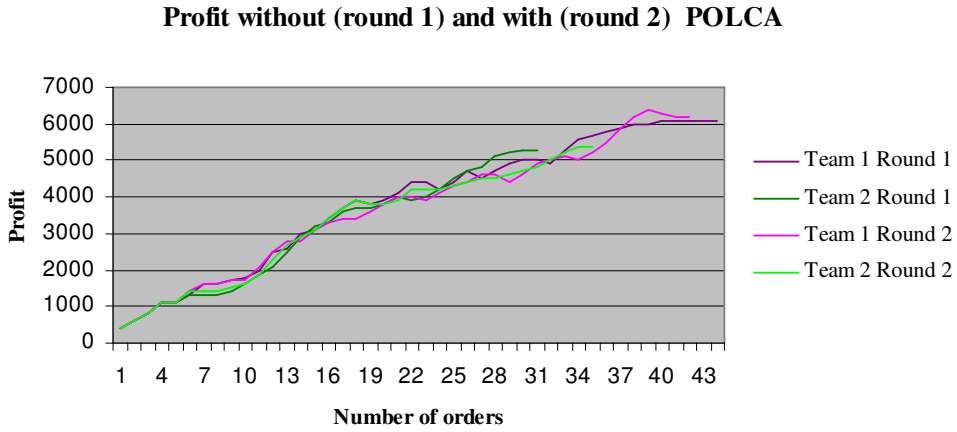


Figure 6.11 Results of the test game (orders)

A main reason for the similar results with and without POLCA are the conversations and discussions that took place during the game. Because of the communication 'POLCA-like' allocation of orders was applied. These discussions can be reduced by decreasing the time of the game periods, as was proposed before. Another solution can be a change in layout of the game. In a 'classroom layout' for example (see figure 6.12) it is less easy to discuss things.

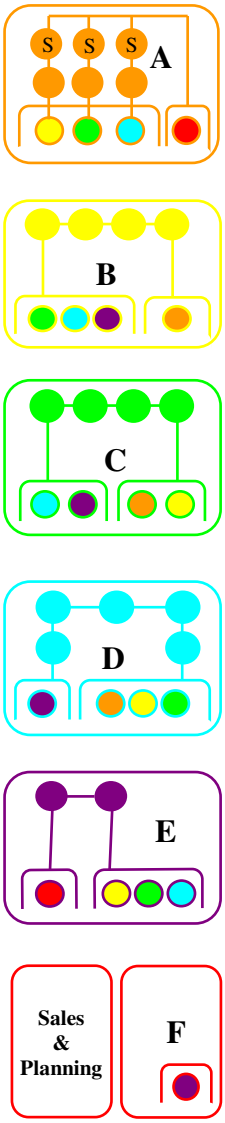


Figure 6.12 Classroom

Disadvantages of this layout are that the participants cannot see the POLCA loops and the flow of orders. In addition, the group might feel less a team, which can lead to less motivation.

In order to have the advantages of both a 'circle layout' and a 'classroom layout', a circle layout with less conversation is proposed. In order to accomplish this, the 'shop' and the 'factory' will be separated. Sales & Planning has to go to a special table where the orders can be accepted without consulting the other team members.

The combination of a time limit with a separate shop will lead to less conversation and will lead to a more realistic situation.

The participants assessed the *sensory stimuli*, thus the layout of the cells and the orders, positively. Two practical improvements will be made. First, the material that it needed by cell F has to be placed closed to this cell. Secondly, a system is needed to distribute the beads quickly. The beads will be put into transparent boxes which looks as follows:

Figure 6.13 Bead boxes

In addition, the participants sensed a right level of *challenge*. On the *control* finally, were no complaints.

6.5.3 Part 3: Reflection

Part three cannot be evaluated yet because during the test game the participants did not have to play the Internet version of the POLCA simulation game and they did not have to write the reflection.

6.6 Summary and conclusion on the POLCA simulation game

To develop the POLCA simulation game, a combination of the proposed development processes of Riis and Greenblat was used.

First, the requirements for the game were specified. The goal, participants, their features, learning requirements and simulation games requirements were determined. These requirements were extracted from foundings of previous chapters.

Based on the requirements, the three parts of the POLCA project, Introduction, Simulation game, and Reflection, were designed.

To be able to play the game and to reach the learning objectives, the participants have to read the Nestor Introduction. The Nestor Introduction is an interactive web text that elaborated on the aspects of POLCA. In addition, to make the rules and elements of the game clear, a manual is made and a presentation is prepared.

The POLCA simulation game will take place in fictitious factories that are imaginable and that are struggling with lead time problems. A team of six persons will represent on factory. In order to see the effects of POLCA, some rules have to be followed. Teams can accepts as many orders as they want, cells can be visited once, cells can work at most eight hours per day, and teams can make revenues, costs and profits (or losses). To increase the level of challenge, some ‘disturbances’ are added to the game.

The layout of the POLCA simulation game is chosen such that the effects of POLCA are shown optimally. With the ‘circle layout’, the POLCA loops and the product routings can be seen. When Sales & Planning goes to the store to accepts orders, too much discussion and thinking by the participants is prevented. An additional way to prevent too much communication is to restrict the amount of time to perform activities.

The POLCA project will be concluded with playing an Internet version of the POLCA simulation game and with writing a paper on POLCA. The layout of the Internet game is connected to the layout of the POLCA simulation game. Subjects in the paper are a description of POLCA, the effects of POLCA during the game and the results of the Internet version of the POLCA simulation game.

Conclusion

~ All truths are easy to understand once they are discovered;
the point is to discover them. ~

Galileo Galilei

Galileo Galilei was very right when he said this almost five centuries ago. Even when developing a simulation game, many factors that influence the effects of this game have to be considered and many puzzle pieces have to be placed on the right position. Additionally, existing theories and common sense have to be combined with creativity.

To develop a POLCA simulation game, the two main subjects that should be considered as a starting point are of course POLCA and simulation games. Furthermore, the learning process should be involved to get insight in the way participants of the game learn. Elaboration of these three, partly overlapping, subjects together led to requirements for the game.

First, POLCA was elaborated, which helped by answering the first research question. This question dealt with the concept POLCA and what features of it important are for the participants of the game. In short, POLCA is a material control strategy with lead time reduction as its main goal. It is developed for manufacturing companies in a high-variety environment and requires a cellular organized production process in which each cell is responsible for a certain phase of production. POLCA cards represent available capacity in two succeeding cells. The move of the cards through these two cells and back is called a POLCA loop. An HL/MRP (High Level Material Requirements Planning) oversees all cells in the production process. This system decides when a cell is allowed to start working on an order. The POLCA simulation game will focus on the context of and need for POLCA, on the cells, the POLCA loops, the POLCA cards, and on the HL/MRP system. The HL/MRP will be explained to participants however, it will be not part of the POLCA simulation game because the game is well observable and clear and therefore it will not add value to the game.

Secondly, because POLCA has to be taught to participants of the game, the learning process is considered. The second research question, about how the learning process takes place and how POLCA can be taught optimally to participant of the game, will be answered by that. Conclusions are that room should be created to let the phases of the learning process pass several times, that people learn best when the learning tool requires an active attitude, that participants of the POLCA simulation game need to understand why they have to learn about POLCA, that the material has to be at the right level of difficulty, and that it has to connect to the current knowledge and skills of participants. The explanation of POLCA in the relation to other material control systems and types is needed to give the concept a place in the cognitive structures of participants. The story about push and pull systems is treated in the Field Course O&SC, so students can place POLCA in a context. The concepts MRP and Kanban

are also familiar. For people from organizations, this can be more difficult, because they have a practical point of view. For them it is important that there is a recognizable case.

Thirdly, in order to answer the third research question, attention is paid to simulation games. The question aims at finding out the elements and aspects that should be considered when construction a simulation game. We saw that simulation games are effective when participants get the opportunity to reflect the things learned. Therefore, a reflection in the form of an individual Internet version of the simulation game is made and a paper has to be written by the participants. In addition, an introduction is made that explains POLCA and the rules of the game. Other conclusions on effective simulation games are that the case should make sense to the participants and that the case and the game should be challenging, that the goals and rules should be clear, and that the participants should enjoy playing the game.

When all these (relating) requirements were clear, the POLCA simulation game could be developed. By doing this, research question four, the question about the development of the simulation game, will be answered. The game reflects the real life and context of a company by an easy to imagine production situation as the starting point of the game. The company has lead time problems and wants to solve it with POLCA. The level of abstraction is kept as low as possible. Symbols are be unambiguous and have a clear message. The link between the theory in the introduction text and the game are obvious. Driving forces in the game are the competition and learning something new and useful. several teams competing in a marketplace. The team with the highest profit wins and profit is related to lead time.

Finally, to answer research question five and to see the effects of the game, the game was tested and improved. The main result of the test game was that the improvements by applying POLCA were small. This was mainly caused by the fact that participants took a long time to think about how many orders should be accepted and how to allocate these orders. Time limits were set and the person accepting orders had to do this by his own.

The products of this research are:

- A Nestor Introduction about POLCA;
- A manual and a presentation to explain the game;
- A POLCA simulation game[92]
    - Boards that represent production cells;
    - POLCA cards;
    - Orders and order cards;
    - Dices;
    - Planning boards.
- An Internet version of the POLCA simulation game[93].

[92] Material for two teams is available: 'L' Intérieur' en 'Möby'.
[93] The Internet version is not completely finished, the appendices contain a proposal for finishing the Internet version.

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