Bachelor thesis

Modeling concepts taught by a board game

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Abstract

To reach a goal, a person has to take a certain amount of steps in a specific order. In most cases those steps and their order aren't made explicit. This is because most of the goals are part of people's daily routines. When such goals have to be digitalized though, a software engineer has to spend a lot of time to discover the corresponding steps and their orders. This task of the software engineer could be simplified by enabling domain experts to make such information explicit by themselves, using the same modeling language as the software engineer does. In this research it is shown that a board game can be designed which is able to teach people implicitly how to model dependencies and as a result activities. Besides it is shown that there are reasons to believe that this board game is able to teach people how to make correct and useable models in a relatively short amount of time.

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1. Introductory

1.a. Introduction

More and more processes within organizations are being digitalized, for a correct digitalization can result in a time and cost reduction on the long term. Before a process can be digitalized though, the requirements for such a digitalization have to be made explicit. This is done by a software engineer who, among other things, tries to discover the steps that are taken within the process that has to be digitalized. This task is harder than most people expect, because nearly all processes are part of people's daily routines and, as a result, haven't been made explicit. Therefore it would be helpful for a software engineer if the domain experts, who have the knowledge of the flows within these processes, were able to communicate in the same language of steps and their relations. [1]

Teaching people to communicate with such models isn't straight forward though, because it requires a specific way of thinking, which can only be acquired by training. In other words, the communication with such models requires a certain amount of tacit knowledge. [2] Combined with the short timeframe in which domain experts should be taught to communicate with such models to be significant, this means that a powerful teaching method has to be employed. One such method is the use of games, whose powerful effects upon individuals, groups and organizations can be explained by multiple elements in the theories of change. [3]

A game is a contest with rules for which the result is being determined by skill, strength or chance. Because collaborative learning is proven to enhance critical thinking by giving the opportunity to engage in discussions [4] and such discussions are best experienced in real life, a non-virtual multiplayer game will optimize the teaching results. Board games are such non-virtual multiplayer games for which a persistent interest continues to exist, despite the computer game sales exploding over the years. [5]

1.b. Research question

Even though board games appear to be a powerful method in teaching domain experts how to communicate with models, there currently is no empirical evidence proving this prospect. This research will try to find such evidence by answering the next research question:

Can a board game teach people how to use modeling concepts without giving them any technical education on these concepts?

To answer this question, first a board game will be created which implicitly teaches people how to model dependency diagrams. The concepts that will be used for this board game follow from literature studies on dependency diagrams, UML activity diagrams and board game mechanics. Once the board game is completed, its playability shall be analyzed and improved. Next the board game will be played by non-experts, who are also asked to draw UML activity diagrams on a given case. These diagrams will then be analyzed for a final conclusion to be drawn. A more detailed description on the methods that shall be used can be found in the next subsection.

1.c. Methods

To answer the research question, the research is divided into four sub-questions. Each sub-question is being answered using a unique method. In this subsection each sub-question and its corresponding method is discussed individually.

Which format should a board game, with the purpose of teaching people how to use modeling concepts without giving them any technical education on these concepts, have?

To answer this sub-question, a literature study on dependency diagrams, UML activity diagrams and board game mechanics has to be done. First it has to be determined which modeling concepts should be included in the game. These will be the concepts that are of such importance that they are needed for almost every dependency and activity diagram. When the modeling concepts to be used have been determined, it has to be chosen which board game mechanics will be used, or rather, which board game mechanics can be used for a game based on modeling concepts. During the creation of the board game, the used board game mechanics may change to ensure that all important modeling concepts are sufficiently present.

Is the resulting board game playable by non-experts?

First the board game will be tested by experts to rule out the existence of deadlocks and to increase its playability. During this phase the description of the rules may be subject to change, that is, the rules should be interpreted correctly for the modeling concepts to be understood correctly. Furthermore the playability of the game should be satisfactory. Next the game will be played by non-experts to determine the educational value. During both test phases the enjoyment of the players will be analyzed as well. It, however, is not yet certain to what degree this analysis shall result in changes towards the game.

Are non-experts who played the game able to model an UML activity diagram?

The target of the board game is to teach non-experts implicitly how to use modeling concepts. Therefore they should be able to apply these concepts after playing the game. As UML activity diagrams are used by requirements engineers and can be drawn using basic modeling concepts only, players are asked to individually draw such a diagram of a given case after playing the game. Some of the players are asked to draw a model on the case before playing the game as well. This is done to observe how the game's effectiveness is being affected when people already conceived a picture of the model for a certain case.

What is the quality of the resulting UML activity diagrams?

If it is possible to create a board game based on modeling concepts and the non-experts are indeed able to draw activity diagrams, the resulting drawings should be checked on validity. The validity of the diagrams is determined by grading them conform a set of general criteria like the correct use of ANDs and ORs, the amount of valid steps and the correctness of the connections between these steps. When the grading is completed, an analysis on the results will be done and a definitive answer to the research question will be given.

2. Concepts to integrate

2.a. Modeling concepts

The game to be created is intended for people having no experience in modeling at all. This means that the modeling concepts to be used should be relatively straightforward. If not, people won't be able to understand the rules of the game and also fail to understand the concepts of the modeling language. Therefore the main concepts to be used in the game will be derived from UML activity diagrams. Such diagrams are composed using only a few concepts but are essential for the digitalization of a process.

The concepts to be used from UML activity diagrams are: activities, decisions, splits, joins, initial states and final states. [6] These concepts are expanded with the concepts 'requirements' and 'deliverables'. Those two concepts are required to enforce connections between components in the game and should not necessarily be incorporated in the models drawn by the players. Next a detailed description of each concept follows:

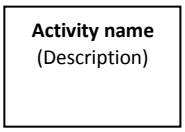
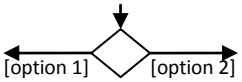
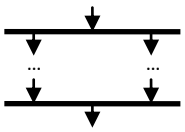
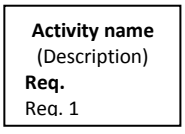
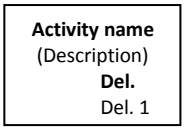
Name	Description	Note	Visualization
Activity / Component	An action which can be taken by both a human being and a computerized machine. A set of activities forms a process.	In UML an activity is visualized by a rounded square. This, however, would raise the costs for the cards unnecessarily.	
Decision	A decision is used when options exist within a process. The path splits into multiple paths, each belonging to a certain situation.	In the game the options are omitted. Instead the word 'or' is written in the diamond.	
Split & join	A split, which should always be combined with a join, is used to define parallel activities. In between a split and a join an entire sub-process may exist.	Because a system is being designed in the game, the split and join are used to define a combined functionality.	
Initial state	The initial state shows where the process starts. In general there is only one initial state.		
Final state	The final state shows where the process ends. The existence of multiple final states isn't rare.		
Requirement	A requirement shows what is needed for a component to be functional. These requirements are used to make connections between components explicit.	The players of the game are not expected to add the requirements to the activities they define in their model.	
Deliverable	A deliverable shows what a certain component brings in. These deliverables are also used to make the connections between components explicit.	The players of the game are not expected to add the deliverables to the activities they define in their model.	

Table 1: The modeling concepts to be incorporated.

2.b. Game concepts

When designing a game, one first has to think about the game concepts to be used. These concepts, often referred to as mechanics, define the gaming pieces to be used as well as the actions the players have to perform in order to play the game. Within the domain of board games a distinction is made between 44 different mechanics. [7] With these mechanics all board games to date can be defined.

As the goal of the game is to teach people how to use modeling concepts, the game should focus on the construction of diagrams. There is no better way to do this than making people construct diagrams by themselves. Therefore the main concept of the board game to be created is the mechanic of 'pattern building'. For pattern building though, one needs resources, which means that the board game also requires a second concept.

This concept is the mechanic of 'card drafting'. As the people who will be playing the board game have no experience with modeling concepts, they should be guided through the modeling process. This guidance can be implemented by limiting and thus predefining the components from which can be chosen. The only way to do this is to make use of cards on which the component, the requirements and the deliverables are defined.

Another important element into take in account during this conceptual phase is the board of the game. Even though the board itself is not a mechanic, the role of the board should be defined before one can start designing the game itself. Following from the previous concepts and the idea that the players should be guided during the modeling process, the modeling concepts should be incorporated in the board of the game. This means that the board shall define the structure of the pattern that has to be built.

3. Designing the board game

3.a. Gaming pieces

Now that both the modeling and the game concepts are clear, the board game can be designed. Essentially a board game exists of two components which are closely related to each other, namely the gaming pieces and the rules. Because of this close relation, the components are being designed at the same time. However, for the intelligibility of the paper these components are being handled separately.

As already has been discussed, the board should define the structure of the pattern that has to be built. This means that the board should incorporate all the modeling concepts of interest. On the other hand, though, there is only a limited space on a board. Therefore the board should include all modeling concepts using the least amount of components. This results in the following board concept:

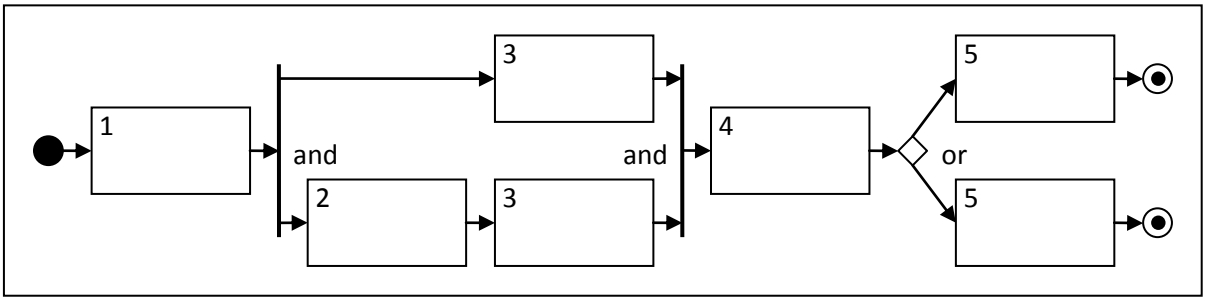


Fig. 1: Board as used in versions 0.5 and 0.5.5 of the game.

On this board you see an initial state which leads to a component. This is a simple start to show the basic flow of a dependency diagram to the player. Next you see a split which leads to two components. One of these components leads to another component before the join. This has to show the player that a sub-process may exist between a split and a join. The join results in another component. Here the size of the board could have been reduced by placing the decision directly after the join. This, however, wasn't done to make a clear distinction between the two concepts. At the end of the board you see a decision leading to two components, which both lead to a different final state. The decision is placed at the end to reduce the complexity at the beginning of the board. Even though the board was subject to change during the tests, the structure of the diagram did not change.

As has been discussed previously, the game will use cards to guide the players through the modeling process. Besides a name and description, these cards should also include the requirement(s) and the deliverable(s) of the component. This is required to make connections between the components. To limit the positions on which the component may be placed on the board, a reference number should be added to the cards. The result is the following card concept:

5 **Component name**
(Description)

Requirements:	**Deliverables:**
Requirement 1	Deliverable 1
Requirement 2	Deliverable 2

Fact:

Fig. 2: Step cards as used in all versions of the game.

After defining the lay-out of the cards, their content should be determined. Here it becomes important whether the game will be cooperative or not. The risk of a cooperative board game in a teaching environment is that one player may take the lead, which decreases the teaching potential of the game. Therefore the game should be competative, which will manifest itself in each player receiving a unique goal at the start of the game. This goal is defined by the diagram to be modelled (fig. 3). On the other hand though, the game should provide ways of interaction as this increases the enjoyment of playing the game. To stimulate the interaction in the game, the components within the diagrams shall partly overlap. This is accomplished by defining the components using a tree structure, starting with only one possible component right behind the initial state as the root.

Furthermore a theme should be decided upon in this phase, as the theme directs the content of the cards. The initial idea was to add activities to the cards, so that UML activity diagrams would be created on the board. It, however, turned out to be very hard to define one starting activity which is required for a broad range of final activities, especially in a diagram with a given structure. Therefore the game describes the required components for a series of products, which can be expressed using the same modeling concepts. Next, the tree structure showing the contents of the cards follows:

<table>
<tr><th>Position 1</th><th>Position 2</th><th>Position 3</th><th>Position 4</th><th>Position 5</th></tr>
<tr><td rowspan="18">Switch:
➢ Signal</td><td rowspan="9">Engine:
➢ Rotating axle</td><td rowspan="6">Wheels:
➢ Driving object

Sensor (2, 3):
➢ Observation</td><td rowspan="3">Controlled driving robot</td><td>Robotic lawn mower</td></tr>
<tr><td>Transport platform</td></tr>
<tr><td>Robotic car</td></tr>
<tr><td rowspan="3">Driving object finder</td><td>Book sorter</td></tr>
<tr><td>Container crane</td></tr>
<tr><td>Measuring robot</td></tr>
<tr><td rowspan="6">Propellor:
➢ Shifting air

Temperature controller (2, 3):
➢ Heat / Cool</td><td rowspan="3">Shifting hot air</td><td>Foehn</td></tr>
<tr><td>Hot air oven</td></tr>
<tr><td>Hot air balloon</td></tr>
<tr><td rowspan="3">Shifting cold air</td><td>Airconditioner</td></tr>
<tr><td>Cold corridor</td></tr>
<tr><td>Cold store</td></tr>
<tr><td rowspan="9">Pump:
➢ Pressure</td><td rowspan="6">Tentacles:
➢ Moving object

Sensor (2, 3):
➢ Observation</td><td rowspan="3">Controlled walking robot</td><td>All-terrain robot</td></tr>
<tr><td>Serving robot</td></tr>
<tr><td>Stair sweeper</td></tr>
<tr><td rowspan="3">Robot with controlled arms</td><td>Surgical robot</td></tr>
<tr><td>Security camera</td></tr>
<tr><td>Painting robot</td></tr>
<tr><td rowspan="6">Fluid tube:
➢ Shifting liquid

Temperature controller (2, 3):
➢ Heat / Cool</td><td rowspan="3">Shifting hot liquid</td><td>Floor heating</td></tr>
<tr><td>Coffee-maker</td></tr>
<tr><td>Massage bathtub</td></tr>
<tr><td rowspan="3">Shifting cold liquid</td><td>Engine cooling</td></tr>
<tr><td>Ice-rink</td></tr>
<tr><td>Snow machine</td></tr>
</table>

Table 2: The contents of the step cards as used in all versions of the game.

In this table you see the components that can be placed on the different positions of the board. The numbers of the positions correspond to the reference numbers on the board. Furthermore this table shows the connections between the components. Components at the right require the components at the direct left of them. The sensor and the temperature controller, however, don't require the engine and the pump. These should therefore be placed on the upper 3 of the board.

The last gaming pieces that have to be discussed are the cards on which the goals are defined. These cards are referred to as concept cards. As already has been said, each player will receive a unique goal at the beginning of the game. The uniquness of the concept cards is guaranteed by a unique combination of the last two components. As each component on position 4 results in three components on position 5, it is possible to form three combinations of two components resulting from each component on position 4. As there are eight components on position 4, there can be made 3 * 8 = 24 unique concept cards. Next an example of such a card follows:

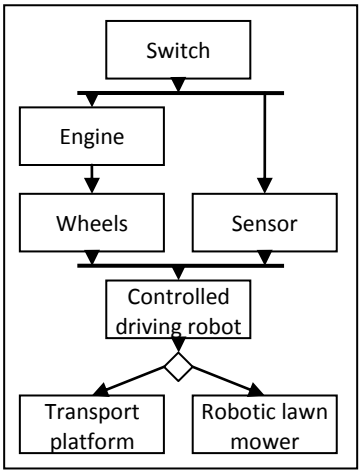


Fig. 3: Sample concept card.

Besides the number of concept cards the number of so-called step cards has to be determined as well. First of all it is important to note that there should be at least duplicate cards for these components that are meant to be placed at one of the first positions, as the chance that the same component at one of the first positions in the diagram is required by multiple players is significantly higher than a component at one of the last positions in the diagram being required by multiple players. Combining this knowledge with the assumption that the number of cards shouldn't be too high, to prevent that the game exists out of card drawing alone, the following distribution has been chosen.

Position	Number of components	Number of cards	Duplicates of each component
1	1	6	6 / 1 = 6
2	2	6	6 / 2 = 3
3	6	12	12 / 6 = 2
4	8	16	16 / 8 = 2
5	24	24	24 / 24 = 1

Table 3: The distribution of the components over 64 step cards.

3.b. Game rules

In this subsection the rules of version 0.5 of the game are being discussed. First you will find the complete rules being displayed in a structured overview which handles every single rule separately. This overview will be referenced to by the other sections of the paper. The rules in their default format can be found in appendix A.1. The overview is followed by an explanation on the reasons why each rule is chosen.

a	**Preparation of the game**
a.1.1	Place the board on the table in such a way that everybody can read the cards which will be placed during the game.
a.2.1	Shuffle the concept cards and give each player one of these faced down. (You can also keep the deck faced down as a fan in front of each player and let them choose one.) Next place the remaining concept cards aside, those aren't needed anymore during the game.
a.3.1	Put the 64 step cards together and shuffle them as well. Give each player 8, 7 or 6 cards for a game with respectively 2, 3 or 4 players.
a.4.1	Place the deck with the remaining step cards face down next to the board and place the top card open next to this stack. The open card forms the beginning of the discard stack.

b	**Concept cards**
b.1.1	Each player now has a unique concept card and as a result a personal goal. On the concept card a design is depicted. This design shows the steps that will lead to ones concept. The goal for each player is to recreate as much of the given design on the board as possible.
b.2.1	During the game the players may view their own concept card as often as needed. One's concept card should not be visible to any of the other players though.
c	**Flow of the game**
c.1.1	Now that everybody knows his / her goal, the game can be started by the youngest player.
c.2.1	The game is played in turns in which a player executes four steps.
c.3.1	First of all the player takes the top card from the open discard stack or the top card from the face down stack.
c.4.1	Next the player may choose to expand or optimize the design (this will be explained later on).
c.5.1	Then the player places one of his / her cards face up on the discard stack.
c.6.1	And at the end of the turn the player restores the amount of cards in his / her hand (8, 7 or 6 cards for a game with respectively 2, 3 or 4 players).
c.7.1	When the face down stack is out of cards at the end of a turn, the top card is taken off of the discard stack and the remaining cards are shuffled to form a new faced down stack. The card which has been taken off of the discard stack is placed next to the new faced down stack as the beginning of the new discard stack.
d	**Expanding the design**
d.1.1	You expand the design by placing cards out of your hand onto empty spaces on the board.
d.2.1	This is done by taking the step numbers into account, which means that step 2 can never be placed when step 1 is not on the board yet.
d.3.1	It is allowed, to place more than one card on the board in a single turn.
d.4.1	The last card, which ends the game, may, however, only be placed alone and thus never in the same turn with other cards.
d.5.1	When expanding the design, a step may be placed onto the board, only when the deliverables of the preceding step(s) are requirements for the step to be placed.
d.6.1	This means that you have to optimize the design if you want to place a step on the board which has other requirements then those that are available as deliverables on the board.
d.7.1	Sometimes a preceding step has more deliverables than those that are required for the subsequent step, this is no problem.
d.8.1	Notice that step 1 doesn't have any requirements and thus can always be placed.
e	**Optimizing the design**
e.1.1	When a step is placed onto the board which doesn't meet your requirements, the game is not lost yet, for the design may be optimized. This is done by replacing cards on the board with cards out of your hand.
e.2.1	You may replace as many steps as you want, as long as the requirements of a step match the deliverables of the preceding step(s). In other words, there has to be a faultless design on the board after the optimization.
e.3.1	Attention: Someone who is optimizing the design, is not able to end the game, because the last card may never be placed onto the board in combination with other cards.
f	**'or' on the board**
f.1.1	The interpretation of the 'or' on the board is not very obvious. That is, both fields of step 5 have to be filled to end the game.
f.2.1	(The last step 5 card may not be placed onto the board in combination with another card.)
f.3.1	The requirements of both step 5 cards that are placed onto the board must follow from the deliverables of the preceding step 4 card.

g	**'and' on the board**
g.1.1	For the front part of the 'and' on the board the same holds as for the 'or'.
g.2.1	Ensure that step 2 is placed before the bottom step 3 is placed onto the board. This means that the top step 3 may be placed onto the board, even before step 2 is placed, since there is no connection between these two steps.
g.3.1	However, before step 4 may be placed, both step 3 cards must be placed onto the board. This is because step 4, the end part of the 'and', has a direct relation with both step 3 cards.
h	**The end of the game**
h.1.1	The game ends when the last card is placed onto the board and thus the design is completed.
h.2.1	When the resulting design is a direct match with the design on the concept card of one of the players, this player wins the game.
h.3.1	If this is not the case, all players compare the resulting design with their own design. A point is given for each matching step. The player with the most points wins. When points have to be counted, the game may result in a tie.
i	**Variant for multiple rounds**
i.1.1	For a game with multiple rounds, points will always be counted.
i.2.1	When the design is a direct match with the design on the concept card of a player, this player gets a bonus of 3 points, resulting in a score of 10 points.
i.3.1	For the other players counting finds place as described in 'The end of the game'.
i.4.1	The game is played for a specific amount of rounds or until one of the players reaches a specific score.

Table 4: The rules of version 0.5 of the game.

The rules begin with the preparation of the game. Rule a.1 is introduced to ensure that everybody is able to read the step cards which are placed onto the board during the game. Especially the component names should be readable as these are depicted on the concept cards as well. Rule a.2 explains what to do with the concept cards at the beginning of the game. The concept cards have to be handed out faced down, so that the goal of each player stays secret. In the rules the secrecy of the concept cards is explained in rule b.2. The reasoning behind the number of step cards each player receives at the beginning of the game, as explained in rule a.3, is related to multiple other rules. First of all there is rule c.3, which states that the player on turn has to draft an extra card. Combining this with rule c.5, which states that the player on turn has to discard one of his / her cards at the end of the turn and the fact that the maximum number of cards that may be placed onto the board in a single turn is equal to six (d.4), makes that each player should receive at least six cards at the beginning of the game. Giving each player more than six cards, would enable players to collect the entire design in hand, which reduces the opportunity to apply optimization (e) for the other players. For a two- and three-player game, however, the players receive more than six cards at the beginning of the game to reduce the amount of card drafting. Rule a.4 introduces the open discard stack. More on this discard stack follows in the rules about the flow of the game (c).

Next the rules discuss the goal of the game. Rule b.1 explains that each player has a unique concept card and thus a personal goal. Furthermore this rule explains that the resulting design on the board doesn't have to be a direct match with the design on a player's concept card. This rule creates the possibility to apply scoring (h.3). Especially for games with multiple rounds (i) this enables for quick scoring opportunities. Rule b.2 defines that the concept card of a player has to stay secret for the other players. The reason for this rule is that players could lock a unique position five card, which they know is required by another player. This blocks the player requiring the card from winning the game.

The rules about the flow of the game mainly consist of the steps the players have to perform during a turn. Rule c.1, however, states that the youngest player starts the game. As in many games, being the first player has the benefit of being able to complete the game with an 'extra' turn. Rule c.2 explains that a turn consists of four steps, which are being defined by the subsequent rules. Rule c.3 (step 1) defines that the top card from the open discard stack or from the faced down stack has to be drawn, resulting in the hand of a player being changed each turn. Players are allowed to draw the top card from the open discard stack to reduce the chance that a player has to wait on a card for the stack to be gone through once again. Rule c.4 (step 2) enables the player to expand (d) or optimize (e) the design on the board. These actions will be explained later on. Rule c.5 (step 3) obliges the player to discard one of the cards in hand to the discard stack. This must be done to keep the discard stack replenished. Rule c.6 (step 4), restoring the number of cards in hand, guarantees that a player never runs out of cards and that a player will always be able to discard one of the cards at the end of the next turns. The last rule about the flow of the game, rule c.7, explains what to do when the faced down stack runs out of cards. A new faced down stack has to be created to keep the game running, otherwise some of the cards required by the players will become inaccessible.

Next the rules explain how to expand the design. Rule d.1 explains the basic action, which consists of placing a card onto an empty position on the board. The subsequent rules explain the preconditions for this basic action. Rule d.2 says that the step numbers must be taken in account. This is required for rule d.5, which enforces that the requirements of the card to be placed must follow from the deliverables of the preceding cards, to be applicable. Rule d.5 is added to stimulate people to think about processes in terms of deliverables and requirements. Furthermore this rule enables players to monitor each other's actions. On the other hand though, it could block people from winning the game. Therefore rule d.6 is added, which refers to optimization (e). Rule d.3 allows for multiple cards to be placed onto the board in a single turn to accelerate the game. Rule d.4, however, says that the last card must be placed alone and thus never in the same turn with other cards. This rule is added to give players the last opportunity to apply optimization (e) and as a result change the course of the game. The rules d.7 and d.8 have an informative purpose only. Rule d.7 explains that it is no problem when a preceding card has more deliverables than those that are required by the card to be placed, whereas rule d.8 notifies the players about the fact that the step one cards may always be placed onto the board, as they don't have any requirements. Both rules can be deduced from the modeling concepts.

As already has been said, the rules about optimization are added to protect a player from losing the game before it has ended. Rule e.1 explains when and how optimization should be applied. Rule e.2 excerpts the rules d.2, d.3 and d.5, as these rules about the deliverables and requirements and the number of cards that may be placed onto the board in a single turn apply to optimization as well. Rule e.3 indicates that a player who is optimizing the design won't be able to end the game. This is because rule d.4 states that the last card may never be placed onto the board in combination with another card.

Next the rules explain how the 'or' should be handled. Rule f.1 explains that both step five cards must be placed onto the board for the game to be ended. As most people tend to interpret an 'or' as an exclusive one, which could result in the final design being incomplete, this rule has to be mentioned explicitly. Rule f.2 once again repeats rule d.4, stating that the last card must be placed alone, because one of the two step five cards will be the card ending the game. Rule f.3 explains that

the requirements of both step 5 cards must follow from the deliverables of the preceding step 4 card. This rule can be deduced from the modeling concepts and is added for those players having difficulties to grasp the meaning of the 'or'.

The rules also explain how the 'and' should be handled. For the front part of the 'and' rule g.1 refers to the rules of the 'or' (f). This reference should be sufficient as the handling of the front part of the 'and' is rather intuitive. Rule g.2 on the other hand defines a less intuitive aspect of the 'and' on the board, namely the fact that the upper step 3 card may be placed onto the board before the step 2 card has been placed. The reason for this is that the upper step 3 card has a direct connection with the step 1 card, which means that placing the upper step 3 card before the step 2 card has been placed onto the board won't result in a faulty design. Rule g.3 explains that both step 3 cards have to be placed onto the board before the step 4 card may be placed. The reason for this is that the requirements of the step 4 card follow from both step 3 cards. As a result the design would be faulty if the step 4 card is placed onto the board before both step 3 cards have been placed.

Rule h.1, the first rule concerning the end of the game, defines that the game is ended when the design has been completed. This happens when a card is placed onto the last open position of the board. As can be derived from rule d.5, the design must be sound to end the game. Rule h.2 explains that a player wins the game if the design on the player's concept card is a direct match with the design on the board. Rule h.3 on the other hand takes the scoring of points into account, since the game doesn't enforce the existence of a direct match. Points are rewarded for each matching component. When points have to be counted, the possibility exists that the game ends in a tie.

The rules end with a variant for multiple rounds. Rule i.1 notes that for a game with multiple rounds, points must be counted at all times. Rule i.2 explains that if the design on a player's concept card is a direct match with the design on the board, the player receives a bonus of 3 points to raise the ranking of that player. As rule i.3 states, the other points are rewarded in the same way as they are rewarded in a single game (h.3). Rule i.4 gives examples of a goal which has to be set at the beginning of a game with multiple rounds, such as a specific number of rounds or a specific score. Such a goal must be set for the players to be able to finish the game.

3.c. First tests (redesign)

After the gaming pieces have been designed and the rules have been written, the game must be tested. In general there are two aspects which have to be considered when testing a game. The first aspect is the existence of deadlocks. When a deadlock exists, the game may enter a state through which it can't be finished anymore. Obviously such a state is undesirable. The second aspect is the playability. This includes the ease by which the game can be played, the replay value and the duration of the game. Because the game to be tested is an educational game, a third aspect has to be taken into account as well. This aspect is the educational value of the game, which, without an experiment, can only be based on intuition.

First the game is tested by experts. These are people having experience in modeling dependency and / or activity diagrams. This experience is required as the first test phase focuses on the existence of deadlocks and the playability of the game. The first few test rounds of this phase are played by two people including the designer of the game. This enables for quick changes in the rules and the possibility to test multiple variants of the game in a short amount of time.

The game as played according to its original rules takes approximately 15 minutes. In the opinion of both the designer and the expert this is too short for the game to be educational. As a result two changes to the game were proposed to prolong its duration. The first change reduced the amount of cards each player receives at the beginning of the game to three. Due to this change it becomes impossible to collect a large part of the design in hand. As a result, players are forced to place their cards on the board more frequently, increasing the possibilities to apply optimization. The second change obliged the play of multiple rounds and allowed for the last step five card to be placed on the board in combination with other cards. This combined placement can now be allowed as there will be sufficient possibilities to apply optimization due to the reduced number of cards each player receives at the beginning of the game. The changes in the rules have been incorporated as follows:

a	**Preparation of the game**
a.3.2	Put the 64 step cards together and shuffle them as well. Give each player 3 cards.
c	**Flow of the game**
c.6.2	And at the end of the turn the player restores the amount of cards in his / her hand to 3.
c.7.2	When the player has placed all cards from his / her hand on the board and as a result isn't able to place a card on the discard stack, the top card of the face down stack is placed open on the discard stack before the player restores the amount of cards in his / her hand.
c.8.2	*Shift of rule c.7.1*
d	**Expanding the design**
d.4.2	*Removed*
e	**Optimizing the design**
e.3.2	*Removed*
f	**'or' on the board**
f.2.2	*Removed*
h	**The end of the game *(Rewritten)***
h.1.2	A round ends when the last card is placed onto the board and thus the design is completed.
h.2.2	When the design is a direct match with the design on the concept card of a player, this player gets a bonus of 3 points, resulting in a score of 10 points.
h.3.2	The other players compare the resulting design with their own design. A point is given for each matching step.
h.4.2	The game is played for a specific amount of rounds or until one of the players reaches a specific score.
i	**Variant for multiple rounds *(Removed)***

Table 5: Changes made to version 0.5 of the game. (Version 0.5.5)

The changes do prolong the duration of the game as expected. More important though, are the increased possibilities to play the game tactically. When a player tries to cross the plans of another player without fully reproducing the design of the concept card, the attack may result in a poor score for the attacking player. As the game must now be played for multiple rounds though, such a poor score can be raised in the rounds to come. These positive results, however, did not have the desired effect on the educational value of the game. The problem is that the players can reproduce the design of the concept card by simply collecting the components being depicted on this card. As a result, people are able to play the game without taking the modeling concepts into account. Still, it are these modeling concepts which should be taught by the game. Therefore, the designer believes that the players should be forced to use the modeling concepts for the game to be educational. To achieve this, the concept cards, which are the source of the problem, must be redesigned.

To maintain both the modeling and the game concepts, the redesign of the concept cards should be as subtle as possible. Furthermore the redesign should not affect the uniqueness of the goal each player receives at the beginning of the game. These requirements result in the concept cards being replaced by eight step 5 cards which require a unique intermediate product. Due to this replacement, a player may only model the diagram which results from his / her step 5 card. This means that the players must be able to verify each other's actions. To support this verification, the received step 5 cards must be placed on the board at the beginning of the game. This means that the board should be expanded with two more step 5 positions, as the game is intended for 2 up to 4 players. The result is the following board:

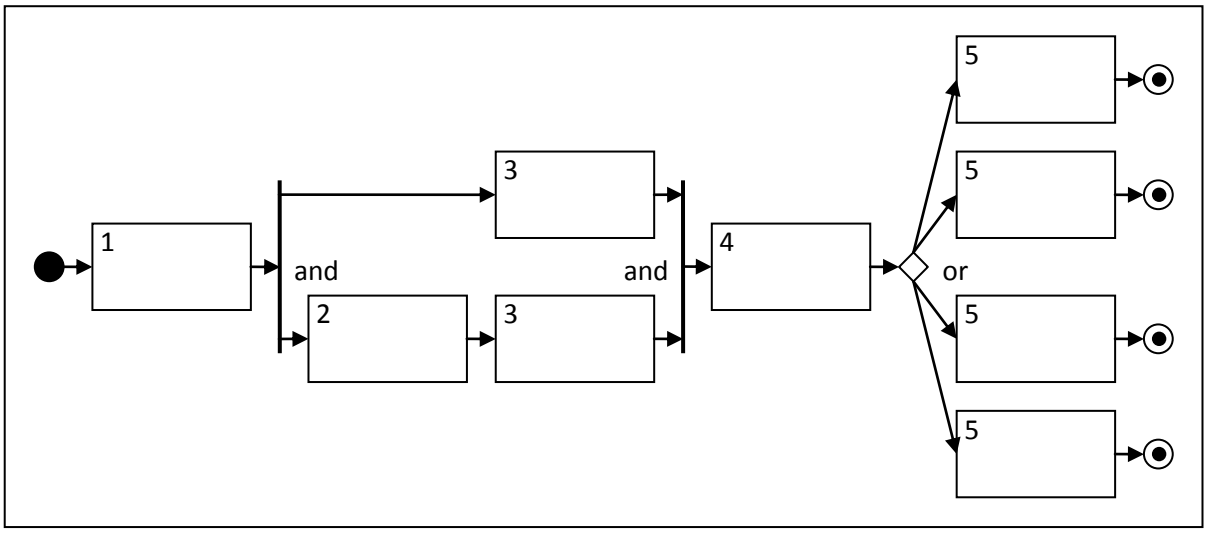


Fig. 4: Board as used in version 0.7 of the game.

The replacement of the concept cards comes along with a few other changes in the game. First of all the replacement leads to a reversion of the direction in which the step cards must be placed on the board. The reason for this change is that a player can only determine the required step 4 card based on his / her step 5 card. To determine the required step 3 cards, a player needs to have the required step 4 card available and so on. This reversion leads to another change in the rules, namely that a player must be able to switch the step 3 cards placed on the board. This is a result of the possibility that a player doesn't know whether a step 3 card follows from a step 1 card or a step 2 card, as these steps don't have to be placed on the board in a single turn. The new changes in the rules have been incorporated as follows: (Keep in mind that the step 5 cards are being referred to as concept cards.)

a	**Preparation of the game**
a.2.3	Shuffle the concept cards and give each player one of these faced down. (You can also keep the deck faced down as a fan in front of each player and let them choose one.) Next each player places his / her concept card on a step 5 position of the board. The remaining concept cards are placed aside, those aren't needed anymore during the game.
a.3.3	Put the 40 step cards together and shuffle them as well. Give each player 3 cards.
b	**Concept cards *(Rewritten)***
b.1.3	Each player now has a unique concept card and as a result a personal goal. On the concept card an end product can be found. This end product requires an intermediate product, which on its turn, requires other intermediate products. The goal for each player is to build the personal end product by placing the correct sequence of cards onto the board.

d	**Expanding the design**
d.2.3	This is done starting with step 4, which has to deliver the requirements for step 5. You continue by placing the cards on the board from back to front, which means that step 3 may never be placed when step 4 is not on the board yet.
d.5.3	When expanding the design, a step may be placed onto the board, only when the requirements of the subsequent step follow from the deliverables of the step to be placed.
d.6.3	This means that you have to optimize the design if you want to place a step on the board which has other deliverables then those that are required on the board.
d.8.3	*Removed*
e	**Optimizing the design**
e.2.3	You may replace as many steps as you want, as long as the deliverables of a step match the requirements of the subsequent step. In other words, there has to be a faultless design on the board after the optimization.
f	**'or' on the board *(Rewritten)***
f.1.3	The interpretation of the 'or' on the board is obvious. Each player tries to build their own end product, leading to only one end product which completes the resulting design.
g	**'and' on the board *(Rewritten)***
g.1.3	At the end of the 'and' there have to be placed two step 3 cards of which the combined deliverables must lead to the requirements of step 4.
g.2.3	When you have only one of the two required step 3 cards in your hand, you're allowed to place this single step 3 card on the board. The step 3 card which will be placed onto the board later on, must than deliver the other requirement of step 4.
g.3.3	For the front part of the 'and' the deliverables of step 1 must be required by both step 2 and the top step 3 on the board. This means that step 1 may only be placed onto the board when all subsequent steps have been placed.
g.4.3	During the game it may turn out that the two step 3 cards have to be switched. You must apply this switch for the resulting design to be faultless.
h	**The end of the game *(Rewritten)***
h.1.3	*Reuse of rule h.1.1*
h.2.3	This last card must be a step 1 card, as a step 1 card may only be placed onto the board when all subsequent steps have been placed.

Table 6: Changes made to version 0.5.5 of the game. (Version 0.7)

The changes in the rules have greatly increased the expected educational value of the game. They, however, lead to some new shortcomings as well. The most important problem is that one of the modeling concepts is used incorrectly. The 'decision' is used in the modeling phase to define the different deliverables which may come forth from a step 4 card. As a result, there is only one correct path originating from the 'decision' in the final diagram. For a methodological 'decision', however, all paths should be realizable as the decision is made when one of the products, as described by the diagram, is being produced. This means that, first of all, the concept cards of the players should not be placed onto the board at the beginning of the game. As the possibilities to validate each other's actions should be maintained though, the concept cards are placed open in front of each player. With this change the 'decision' has been removed from the board completely. Therefore the concept cards are being expanded by a second step 5. As may be obvious, both steps on a concept card must have the same requirements for the 'decision' to be correct.

These changes result in a redesign of the board. There, however, is another shortcoming of which the solution will affect the board. Since the players are obliged to create the design which fits their concept card, the possibility to reward points has disappeared. As a result, the game can't be played

for multiple rounds anymore. Together with the reduced number of step cards, this leads to the duration of the game being decreased back to approximately 15 minutes. As has been discussed previously, the designer believes that this is too short for an educational board game. The solution to this problem is the addition of an extra step, which increases the number of step cards. However, for this solution to be effective there should be more than eight concept cards. The number of concept cards can be increased by making different combinations of components that follow from the same component on position 4, which brings us back to the combinations as depicted on the original concept cards. To keep the goal for each player unique, the step cards which shall lead to these new concept cards must be unique. This problem is solved by the addition of a new kind of step card, namely the 'or' step. Such an 'or' step depicts a combination of components which matches the combination of components as depicted on one of the concept cards. As a result, the number of 'or' step cards equals the number of concept cards.

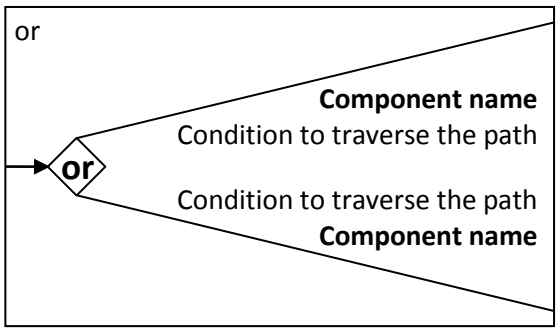


Fig. 5: New variant of the step card, the 'or' step.

The last change that is made for the redesign to be completed, doesn't originate from an error. This change is the replacement of three step 1 cards by the 'Ignition lock'. The 'Ignition lock' has the same deliverables as the 'Switch' to show the players that there can be different components which may be used in the same end product. Now that the changes in the rules have been completed, the board can be redesigned. This redesign is shown next, followed by the incorporation of the changes in the rules.

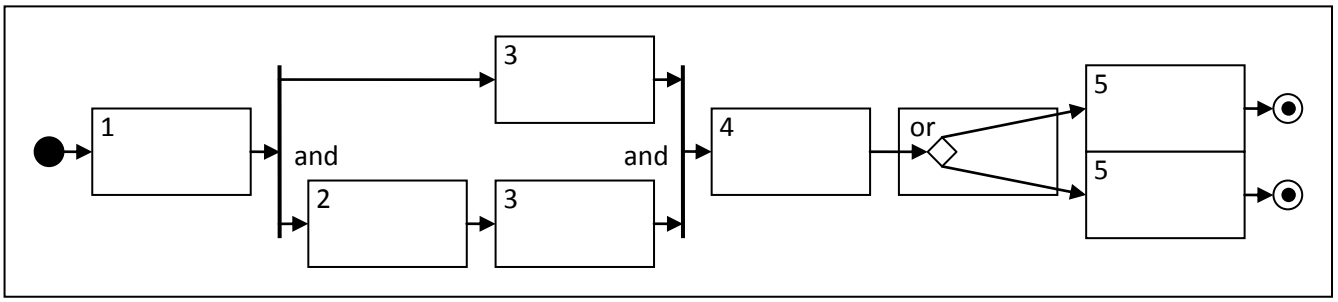


Fig. 6: Board as used in version 0.9 and up.

a	**Preparation of the game**
a.2.4	Shuffle the concept cards and give each player one of these faced down. (You can also keep the deck faced down as a fan in front of each player and let them choose one.) Next each player places his / her concept card open in front of oneself. The remaining concept cards are placed aside, those aren't needed anymore during the game.
a.3.4	*Reuse of rule a.3.2*
b	**Concept cards**
b.1.4	Each player now has a unique concept card and as a result a personal goal. On the concept card two end products can be found. These end products require the same intermediate product, which on its turn, requires other intermediate products. The goal for each player is to build the personal end products by placing the correct sequence of cards onto the board.

e	**Optimizing the design**
e.3.4	Attention: You are not allowed to place a step 4 card onto the board which has other deliverables than those that are required by your concept card.
f	**'or' on the board *(Rewritten)***
f.1.4	The interpretation of the 'or' on the board is not very obvious. After step 4, which delivers the intermediate product as required by your concept card, has been placed onto the board, you're allowed to place the 'or' card that leads to your two end products. These two end products have been bolt printed on both the 'or' card and the concept card.
f.2.4	The 'or' card may be placed onto the board later on in the game as well. Even after step 1 has been placed to complete the intermediate product.
f.3.4	When a player needs the same step 4 card as the one that has been placed onto the board, this player is allowed to replace the 'or' card.
f.4.4	However, when an 'or' card has been placed onto the board and a player replaces the step 4 card, the 'or' card must be removed from the board, but doesn't have to be replaced directly.
h	**The end of the game**
h.2.4	This last card is the concept card of one of the players, which may only be placed onto the board to complete the design.

Table 7: Changes made to version 0.7 of the game. (Version 0.9)

The new changes in the rules prolong the duration of the game with approximately 30 minutes. This means that a game takes up to 45 minutes, which is believed to be more acceptable for a board game that has to be educational. Furthermore, both the designer and the expert expect the modeling concepts to be clear for non-experts, meaning that these non-experts should be able to play the game and from that learn how to use the modeling concepts. However, before the game is played by those people it has to be fine-tuned.

3.d. Fine-tuning

To fine-tune the game, test rounds with different groups of four experts are played. Because the notation of the rules has to be verified as well, the designer of the game does not participate in these test rounds. As a result, the game can be played incorrectly which makes it possible to indicate vague or incomplete rules. Furthermore the possibilities to play the game tactically should be increased and with that the replay value. For this to be accomplished, a lot of test rounds with small changes in the rules have to be played. As it will be rather uninteresting to discuss every single subversion of the game, the rules of the game which are subject to change will be discussed thorough.

The first rule of the game which is subject to change, is the first step a player has to perform during one's turn. This is the step in which a player must take the top card from the open discard stack or the top card from the face down stack. The reason that this rule must be examined, is the uniqueness of the 'or' step card, which increases the chance that a player is not able to collect the required 'or' step card during one iteration through the stack of step cards. This chance can be removed by giving the player on turn the possibility to take two or three cards from the top of the open discard stack. This change, however, turns out be disorganizing, as the players don't remember which card is placed on the top third and second positions of the open discard stack. Another change which completely removes the chance that a player is not able to collect the required 'or' step card in one iteration, is to allow all players to swap one of the cards in their hands with the top card of the open discard stack, each time a new card is placed on top of this stack. This change turns out to function very well and makes the game far more balanced. To support this new rule even better, the card that has to be placed open next to the face down stack at the beginning of the game is being omitted.

This is done to prevent a round of card swapping before the game has started. Another small change which adds to the functionality of the new rule is the addition of a button which indicates the player on turn. Important to note is that these changes make the use of another rule which has been tested incompatible. This rule allowed the player on turn to discard as many cards as desired, increasing the number of swapping rounds and as a result slowing down the progress of the game too much.

Another rule which is subject to change, is the visibility of the concept cards. At the beginning of the game, the players have to place their concept cards open in front of themselves. As a result, the players are able to see which 'or' step cards are required by their opponents. Since these 'or' step cards are unique, a player is able to block another player by keeping the required 'or' step card occupied. When every player is blocked using this tactic, the game enters a state through which it can't be finished anymore. In other words, a deadlock arises. This problem can be solved by keeping the concept cards secret till the end of the game. A rule which makes the game more balanced as well, as none of the players can be blocked deliberately anymore. This change, however, has an effect on a few other rules of the game as well. First of all the players must be allowed to place an arbitrary step 4 card on the board, as the fitness of the step 4 card can only be validated at the end of the game, after the concept card has been placed onto the board. Furthermore the players must be obliged to place the 'or' step card on the board at the end of the game, together with their concept card. The reason for this change is that none of the players are able to verify whether an 'or' step card being placed onto the board does follow from the step 4 card available on the board, except for the player who requires the specific 'or' step card. This could result in the diagram on the board being incorrect during the game, which would negatively affect the educational value.

The last rule being subject to change, is the number of cards each player receives at the beginning of the game. Ever since version 0.5.5 of the game, it has been played with three cards in a hand. This number, however, turns out to be obsolete, as it now slows down the progress of the game too much. The cause of this problem is that the card which has to be placed onto the board first, is not unique anymore, increasing the chance that a player is able to optimize the diagram. This can be solved by increasing the number of cards in a hand. However, to prevent that the players collect the entire diagram in their hand, this number of cards should not be too high neither. Since the number of cards that has to be placed onto the board is equal to six and the player on turn has to take a card from the face down stack at the beginning of his / her turn, the number of cards in a hand can only be raised by one. This means that each player receives four cards at the beginning of the game. Now that the fine-tuning has been completed, the rules can be incorporated:

a	**Preparation of the game**
a.2.5	Shuffle the concept cards and give each player one of these faced down. (You can also keep the deck faced down as a fan in front of each player and let them choose one.) The concept card each player receives must stay secret for the other players till the end of the game.
a.3.5	Put the 64 step cards together and shuffle them as well. Give each player 4 cards.
a.4.5	Place the deck with the remaining step cards face down next to the board. Ensure to leave some blank space alongside this face down stack for the discard stack to be placed.
c	**Flow of the game**
c.1.5	Now that everybody knows his / her goal, the game can be started by the youngest player who receives the 'turn button' which indicates the player on turn.
c.3.5	First of all the player takes the top card from the face down stack.
c.6.5	And at the end of the turn the player restores the amount of cards in his / her hand to 4.

c.9.5	After the player has completed the turn, the other players are allowed to swap one of the cards in their hand with the newly placed card on top of the open discard stack. This is done in turns as well, starting with the player at the left of the player on turn.
c.10.5	When a player decides to swap the card on top of the discard stack, the other players are allowed to swap the newly placed card on top of this stack as well. This goes on until none of the players has interest in the top card of the discard stack anymore.
c.11.5	Now that the turn has ended the 'turn button' is passed to the next player.
d	**Expanding the design**
d.2.5	This is done starting with step 4, working backwards.
e	**Optimizing the design**
e.3.5	*Removed*
f	**'or' on the board *(Rewritten)***
f.1.5	The use of the 'or' on the board is relatively simple. The 'or' card which leads to the two end products of your concept card, may only be placed onto the board at the end of the game, together with the concept card itself. On both the 'or' card and the concept card the two end products have been bolt printed.
g	**'and' on the board**
g.3.5	For the front part of the 'and' the deliverables of step 1 must be required by both step 2 and the top step 3 on the board. This means that step 1 may only be placed onto the board when the two subsequent steps have been placed.

Table 8: Changes made to version 0.9 of the game. (Version 1.0)

The final version of the game is played in approximately 30 to 45 minutes. Furthermore it is free of deadlocks and the playability has strongly increased. The game is not yet completed though, as the rules seem to be unclear at some points. This means that the rules have to be rewritten to increase the understandability of the game, which is greatly important as the game is meant to be educational. The rewritten version of the rules can be found in appendix A.2.

4. Usability tests

4.a. Game with non-experts

Now that the game has been completed, its educational value can be determined. To do so, non-experts will be asked to play the game and to draw a diagram on a given case afterwards. This case must be written in such a way that the knowledge about all modeling concepts which are used in the board game can be examined. Before the case will be considered though, the impressions of the people who played the game are being discussed.

In general, the impressions of the people who play the game are consistent. At first, players think that the game will be very hard, given the model that is drawn on the board. During the game this fear is being substituted by enthusiasm, as the players become aware of how the game is supposed to be played. Due to this enthusiasm, mistakes made during the game are being resolved correctly among the players, which the designer expects to increase the educational value for the group as a whole. For the players these positive impressions result in the feeling that they've learned something from the game. This feeling could be evidence for the board game to be educational.

As has been discussed previously, a case is required to determine the actual educational value of the game. Based on this case, a non-expert should be able to deliver a diagram which includes all modeling concepts that are used in the game. Furthermore the case should be recognizable, so that the non-experts don't have to focus on the meaning of the case itself but instead are able to focus on the model. However, to make a case recognizable for a large group of people, you can't describe the components required for an end product, as this requires at least some technical insight. Therefore the case has to describe a process which most people are confronted with on a regular base. An advantage that comes along with the description of a process, is that the non-experts shall be stimulated to deliver real UML activity diagrams as being drawn by software engineers. Based on these requirements, the following case is written:

> *WebSuper is an online supermarket where people can buy victuals. Up to now, all activities that play a role in the processing of orders are being executed within the department 'Order processing'. Due to a growth in the amount of customers, this clustering has proven to be inefficient. For this reason the company has decided to split up the department in a few different departments. To this end, WebSuper wants to know which activities can be performed in parallel. For this to be visible in one glance, a model of the activities is required, which you are asked to draw. The activities which are being performed within the division 'Order processing' can be found in the annual report:*
>
> *When the division 'Order processing' receives an order, a digital invoice is sent to the customer. At the same time the products are being collected from the warehouse and the package is being composed. After the payment has been received, the package is sealed and being sent to the customer. When the package has to be delivered within 24 hours, the delivery is taken care of by a courier service. However, when the package may be delivered after 24 hours, WebSuper itself takes care of the delivery, which reduces the costs for the customer. After the package has been delivered, the division 'Order processing' confirms the completion of the order.*

To be able to determine whether the knowledge of a person has increased, you need to measure this knowledge at two moments in time. To this end, a group of non-experts is asked to draw a diagram of the case both before and after the game has been played. There, however, may be a chance that the diagram which has been drawn beforehand affects the educational value of the game. The reason for this would be that the person who has drawn the diagram is biased at the beginning of the game. For this expectation to be examined, another group of non-experts is asked to only draw a diagram of the case after the game has been played.

4.b. Resulting diagrams

When the diagrams of the non-experts have been collected, they have to be evaluated. Unfortunately there can be found only very little documentation on objective evaluation methods with regards to diagrams. This is caused by the amount of freedom a modeler has. That is, for a single domain there can be a lot of different correct diagrams. The case as used in this research, however, is unambiguous in such a way that there's only one correct diagram. This diagram can be found in appendix A.3. Together with the fact that the main interest is the correct use of the modeling concepts, the unequivocality of the case makes it possible to evaluate the resulting diagrams in a completely objective way. Yet, this requires the formulation of a new evaluation method.

The newly formulated evaluation method makes use of a score system which takes into account the modeling concepts and the activities. Due to this score system, a decision has to be made on the maximum number of points that can be assigned to a diagram. To this end, the following aspects of a diagram are being treated separately: 'initial and final state', 'decision', 'merge', 'split', 'join', 'number of correct activities' and 'number of incorrect activities'. The initial and final states have been combined since the order in which the activities have to be performed follows from the direction of the arrows as well, which makes these two concepts less important. Now that the aspects which can be evaluated have been identified, the maximum number of points must be determined. For all aspects, the maximum number of points equals the number of correct activities. These are the activities that a person should add to the diagram. In the case used for this research, the number of correct activities equals 9. For the 'decision', 'merge', 'split' and 'join' this maximum number of points should be multiplied by the number of occurrences of each modeling concept. The maximum number of points for the incorrect activities on the other hand should be negative. This negative bound is set to prevent that a diagram is evaluated with a very low score, due to the use of incorrect activities alone. What becomes obvious is that the number of correct activities plays a relatively small role in this evaluation method, the reason for this is that the accent lies on the correct use of the modeling concepts.

Now the evaluation method itself is completed, there has to be decided on the assignment of points. For the number of correct and incorrect activities, this assignment is simple. One positive point is given for each correct activity and one penalty point is given for each incorrect activity. The modeling concepts, however, consist of two aspects, namely the correct use of the concept and the correct notation of the concept. As the accent on the evaluation method lies on the correct use of the modeling concepts, 2/3 of the correct number of activities is assigned as points for the correct use of a single instance of a concept. The remaining 1/3 is assigned as points for the correct notation of a single instance of a concept. Two modeling concepts require a special treatment, as these concepts have been combined. Those are the initial and final states. 1/3 of the maximum number of points is

assigned for the correct use of the initial state, another 1/3 of this maximum is assigned for the correct use of the final state and the last 1/3 is assigned for the correct notation of both concepts. Due to the penalty points given for the incorrect activities, it may happen that the final score is negative. If this is the case, the final score is set to 0. The table resulting from this evaluation method is displayed next, including the evaluation of the diagrams as drawn by the non-experts. A detailed evaluation of each diagram can be found in appendix A.4. Please note that in this table the merge has been ignored as this modeling concept is not present in the game.

Subject	Before the game								After the game							
No.	A	B	C	D	E	F	G	**H**	A	B	C	D	E	F	G	**H**
Max.	9	9	9	9	9	-9	Y	**45**	9	9	9	9	9	-9	Y	**45**
1	0	0	0	6	2	-4	N	**4**	0	6	0	6	4	-2	N	**14**
2	0	0	0	0	0	-4	N	**0**	0	6	6	6	0	-7	N	**11**
3	0	0	0	0	0	-4	N	**0**	0	0	0	0	0	-7	N	**0**
4	0	0	6	0	0	-6	N	**0**	3	0	0	6	1	-1	N	**9**
5									0	6	6	6	6	-2	N	**22**
6									0	9	9	6	6	-3	N	**27**
7									0	9	9	6	3	-5	N	**22**
8									0	6	6	6	6	-3	N	**21**
9									0	9	6	6	2	-4	N	**19**
10									0	9	9	6	3	-5	N	**22**

Table 9: Evaluation of the resulting diagrams.

Legend

A Correct use of the initial and final state
- 3 points for the correct use of the initial state
- 3 points for the correct use of the final state
- 3 points for the correct notation

B Correct use of the split
- 6 points for the correct use
- 3 points for the correct notation

C Correct use of the join
- 6 points for the correct use
- 3 points for the correct notation

D Correct use of the decision
- 6 points for the correct use
- 3 points for the correct notation

E Number of correct activities
- 1 point for each correct activity

F Number of incorrect activities
- 1 penalty point for each incorrect activity

G Use of requirements and deliverables
- Only a determination

H Total number of points

Now that the resulting diagrams have been evaluated, the educational value of the game can be determined. First of all it is important to note that the non-experts truly had no experience in modeling dependency and / or activity diagrams. This is proven by the low number of points scored for the diagrams which have been drawn before the game was played. Most often these diagrams scored 0 out of 45 points. What can be derived next from the results, is that the game does have an educational value, as the lowest number of points scored for the diagrams which have been drawn after the game was played, is equal to 9. (One exception scored 0 points and therefore won't be taken into account anymore.) When difference of the means is computed for those non-experts who drew a diagram both before and after the game, one can determine that they have learned approximately 22% about the use of the modeling concepts.

$100 / 45 * ((14 + 11 + 9) / 3 - (0 + 0 + 4) / 3) \approx 22\%$

When this computation is done for the non-experts who only drew a diagram after the game was played, using the same mean for the points scored before the game was played, one can determine that these non-experts have learned approximately 46% about the use of the modeling concepts.

100 / 45 *((22 + 27 + 22 + 21 + 19 + 22) / 6 - (0 + 0 + 4) / 3) ≈ 46%

With these results the game has proven to have a significant educational value. Furthermore these outcomes verify the expectation that the non-experts who are asked to draw a diagram before the game is played have less benefit from playing the game. This is proven by looking at the difference in terms of percentages between these non-experts and the non-experts who didn't draw a diagram before the game was played, which is approximately 24%.

5. Concluding

5.a. Conclusion

Before the research question can be answered, the sub-questions have to be answered. In this paper the answers to these sub-questions have been discussed extensively. However, for the overview of this conclusion each sub-question will be addressed again shortly.

Which format should a board game, with the purpose of teaching people how to use modeling concepts without giving them any technical education on these concepts, have?

First a literature study on UML activity diagrams has been done, as the modeling concepts used in this language are relatively basic. The concepts being employed from this language are: activities, decisions, splits, joins, initial states and final states. These have been expanded with the concepts 'requirements' and 'deliverables' of dependency diagrams to enforce connections between components in the game. The board game mechanics used for the creation of the game were derived from a list of 44 different mechanics. The two mechanics which have been chosen are 'pattern building' and 'card drafting'. Besides the definition of the board game mechanics, the role of the board itself has been defined in this part of the research as well.

Is the resulting board game playable by non-experts?

The creation of the board game has been discussed extensively, so are the changes that have been made during the test phase. Although the first version of the game (version 0.5) was playable, the designer expected the game to lack in educational value. For this reason, the so-called concept card had to be redesigned, which affected the game as a whole. After the redesign, the game was being fine-tuned to increase the playability, including the replay value. A lot of small changes resulted in a game which is both enjoyable and educational at the same time.

Are non-experts who played the game able to model an UML activity diagram?

To be able to determine whether the non-experts who've played the game are able to model an UML activity diagram, a case had to be written. This case had to result in a diagram which includes all modeling concepts that are being used by the board game. Furthermore this case had to be unambiguous, so that the resulting activity diagrams of the non-experts could be evaluated. These requirements have led to a case which describes the activities of a department that processes the orders of an online supermarket. All non-experts who played the game did an attempt to draw a diagram based on this case and only one of these non-experts failed to score points with the diagram that was drawn after the game was played.

What is the quality of the resulting UML activity diagrams?

After the UML activity diagrams were collected, they had to be evaluated. Unfortunately there can be found only very little documentation on objective evaluation methods with regards to diagrams. As a result, a new evaluation method had to be formulated. This method uses a score system which enables for the correctness of an UML activity diagram to be expressed in percentages. The UML activity diagrams as drawn by the non-experts scored 9 up to 27 out of 45 points, which may be considered a high score for people who have had no technical education on these diagrams.

Now that the sub-questions have been answered, the research question itself can be answered. For this answer to be obtained though, a little more computations using the evaluation method had to be done. Apparently these computations have been discussed extensively in this paper.

Can a board game teach people how to use modeling concepts without giving them any technical education on these concepts?

As the idea to use board games in information science is relatively new, very well everything required for this research had to be developed from scratch. The resulting components are: an educational board game which teaches people implicitly how to use certain modeling concepts; an unambiguous case which results in a diagram that uses the basic modeling concepts; an evaluation method which can be used to evaluate the correct use of modeling concepts in diagrams that follow from unambiguous cases.

The educational value of the board game has been proven by defining the attainments of the non-experts in terms of percentages. The non-experts who were asked to draw a diagram both before and after the game was played, learned approximately 22% about the use of the modeling concepts. The non-experts who were only asked to draw a diagram after the game was played learned even more about this use, namely 46%. These results show, that the board game as designed for this research is a powerful tool to get people started with the design of relatively correct UML activity diagrams in a very short amount of time.

5.b. Future research

As this research has shown that the use of educational board games in information science can be effective, it is interesting to do research on the possibilities to further increase the educational value of these board games. To this end, three recommendations for future research are proposed.

Game mechanics: The game mechanics which are used in the board game for this research, have been chosen based on the reasoning of how they could be effective in combination with the modeling concepts. This, however, doesn't mean that these mechanics are the best choice for a board game which has to teach modeling concepts. Therefore it would be interesting to look deeper into the different mechanics. This can be done in different ways, for example by testing the use of the different mechanics in a series of small games or by doing a literature study on educational board games in other areas of research.

Increased playability: An increased playability increases the educational value of a game. That is, when a player doesn't understand or like the game, there will be too little concentration to learn from it. The problem, however, is that the task to increase the playability comes along with a lot of trial and error. The reason for this is, that there no guidelines which can be used to increase the playability of a game. Therefore it would be interesting to look into the possibilities to compose a set of golden rules which can be used in future game design.

Series of games: The research has proven that the board game as discussed in this paper not only affects the knowledge of a person, but the thinking pattern of a person as well. This means that the game fulfils two functions at once. If, however, these two functions would be split up into two board games, the combined educational value of these two games could be higher. Furthermore a series of games could enable for more complicated modeling languages to be taught step by step.

A. Appendices

A.1. Game rules (version 0.5)

Build a Bot

A game for 2 to 4 players with a minimum age of 8.

Idea: D.J.H Aarts
Duration: 15 minutes

In Build a Bot you'll find yourself in a battle against other designers to create a robot which meets your goal. This goal, in the form of a design, is defined at the beginning of the game. Step by step you'll try to get the design on the board closer to your design by placing the correct cards. Be careful though, as all designers (players) do have a different goal and will try to place the cards on the board that are required for their own design.

Game components

Board
24 concept cards
6 step 1 cards (1 kind, thus there are 6 of each card)
6 step 2 cards (2 kinds, thus there are 3 of each card)
12 step 3 cards (6 kinds, thus there are 2 of each card)
16 step 4 cards (8 kinds, thus there are 2 of each card)
24 step 5 cards (all different kinds)
(a total of 64 step cards)

Preparation of the game

Place the board on the table in such a way that everybody can read the cards which will be placed during the game. Shuffle the concept cards and give each player one of these faced down. (You can also keep the deck faced down as a fan in front of each player and let them choose one.) Next place the remaining concept cards aside, those aren't needed anymore during the game. Put the 64 step cards together and shuffle them as well. Give each player 8, 7 or 6 cards for a game with respectively 2, 3 or 4 players. Place the deck with the remaining step cards face down next to the board and place the top card open next to this stack. The open card forms the beginning of the discard stack.

Concept cards

Each player now has a unique concept card and as a result a personal goal. On the concept card a design is depicted. This design shows the steps that will lead to ones concept. The goal for each player is to recreate as much of the given design on the board as possible. Each player now has a unique concept card and as a result a personal goal. On the concept card a design is depicted. This design shows the steps that will lead to ones concept. The goal for each player is to recreate as much of the given design on the board as possible. During the game the players may view their own concept card as often as needed. One's concept card should not be visible to any of the other players though.

Flow of the game

Now that everybody knows his / her goal, the game can be started by the youngest player. The game is played in turns in which a player executes four steps. First of all the player takes the top card from the open discard stack or the top card from the face down stack. Next the player may choose to expand or optimize the design (this will be explained later on). Then the player places one of his / her cards face up on the discard stack. And at the end of the turn the player restores the amount of cards in his / her hand (8, 7 or 6 cards for a game with respectively 2, 3 or 4 players).

When the face down stack is out of cards at the end of a turn, the top card is taken off of the discard stack and the remaining cards are shuffled to form a new faced down stack. The card which has been taken off of the discard stack is placed next to the new faced down stack as the beginning of the new discard stack.

Expanding the design

You expand the design by placing cards out of your hand onto empty spaces on the board. This is done by taking the step numbers into account, which means that step 2 can never be placed when step 1 is not on the board yet. It is allowed, to place more than one card on the board in a single turn. The last card, which ends the game, may, however, only be placed alone and thus never in the same turn with other cards.

When expanding the design, a step may be placed onto the board, only when the deliverables of the preceding step(s) are requirements for the step to be placed. This means that you have to optimize the design if you want to place a step on the board which has other requirements then those that are available as deliverables on the board. Sometimes a preceding step has more deliverables than those that are required for the subsequent step, this is no problem. Notice that step 1 doesn't have any requirements and thus can always be placed.

Optimizing the design

When a step is placed onto the board which doesn't meet your requirements, the game is not lost yet, for the design may be optimized. This is done by replacing cards on the board with cards out of your hand. You may replace as many steps as you want, as long as the requirements of a step match the deliverables of the preceding step(s). In other words, there has to be a faultless design on the board after the optimization.

Attention: Someone who is optimizing the design, is not able to end the game, because the last card may never be placed onto the board in combination with other cards.

'or' on the board

The interpretation of the 'or' on the board is not very obvious. That is, both fields of step 5 have to be filled to end the game. (The last step 5 card may not be placed onto the board in combination with another card.) The requirements of both step 5 cards that are placed onto the board must follow from the deliverables of the preceding step 4 card.

‘and’ on the board

For the front part of the ’and’ on the board the same holds as for the ‘or’. Ensure that step 2 is placed before the bottom step 3 is placed onto the board. This means that the top step 3 may be placed onto the board, even before step 2 is placed, since there is no connection between these two steps. However, before step 4 may be placed, both step 3 cards must be placed onto the board. This is because step 4, the end part of the ‘and’, has a direct relation with both step 3 cards.

The end of the game

The game ends when the last card is placed onto the board and thus the design is completed. When the resulting design is a direct match with the design on the concept card of one of the players, this player wins the game. If this is not the case, all players compare the resulting design with their own design. A point is given for each matching step. The player with the most points wins. When points have to be counted, the game may result in a tie.

Variant for multiple rounds

For a game with multiple rounds, points will always be counted. When the design is a direct match with the design on the concept card of a player, this player gets a bonus of 3 points, resulting in a score of 10 points. For the other players counting finds place as described in ‘The end of the game’. The game is played for a specific amount of rounds or until one of the players reaches a specific score.

A.2. Game rules (version 1.0)

Conceptualize this!

A game for 2 to 4 players with a minimum age of 12.

Idea: D.J.H Aarts
Duration: 45 minutes

In Conceptualize this! you're being approached by two producers. For the products that they want to bring to the market they require the same intermediate product. It is your task to conceptualize this intermediate product. Be careful though, as all players are approached by different producers and will try to control the design of the final intermediate product.

Game components

Board
24 concept cards
6 step 1 cards (1 kind, thus there are 6 of each card)
6 step 2 cards (2 kinds, thus there are 3 of each card)
12 step 3 cards (6 kinds, thus there are 2 of each card)
16 step 4 cards (8 kinds, thus there are 2 of each card)
24 'or' cards (all different kinds)
(a total of 64 step cards)

Preparation of the game

1. Board placement
Place the board on the table in such a way that everybody can read the step cards which will be placed during the game.

2. Dealing the concept cards
Shuffle the concept cards and give each player one of these cards face down. Next place the remaining concept cards aside, those aren't needed anymore during the game. The concept card each player receives must stay secret for the other players till the end of the game and thus may only be viewed by the player who owns the card.

3. Dealing the step cards
Put the 64 step cards together and shuffle them as well. Give each player 4 of these cards face down. Place the deck with the remaining step cards face down next to the board. Ensure to leave some blank space alongside this face down stack for the discard stack to be placed.

Concept cards

Each player now has a unique concept card and as a result a personal goal. On this concept card two end products can be found. These end products require the same intermediate product, which can be found underneath the heading 'Requirements' on the concept card. The goal for each player is to conceptualize this intermediate product by placing the correct sequence of cards onto the board.

Flow of the game

Now that the goal for each player is clear, the game can be started. The game is played in turns, starting with the youngest player who receives the 'turn button' which indicates the player on turn. A turn consists of the following steps:

1. Draft a card
A turn starts by drafting a card from the face down stack. When this stack has run out of cards, the discard stack is being shuffled and placed face down next to the board, so that a new face down stack is available to draft cards from.

2. Conceptualize
Next the design may be expanded or optimized. A detailed description of this can be found further on in these rules.

3. Return a card and restore to 4
At the of a turn one card from the hand is being placed open on top of the discard stack. When the player has run out of cards, the top card of the face down stack is placed open on the discard stack. Next the number of cards in the hand is restored to 4.

4. Trade with the discard stack
The top card of the discard stack, which has just been placed by the player on turn, may be swapped by the other players with one of the cards from their hand. This is done in turns as well, starting with the player at the left of the player on turn. When a player decides to swap the card on top of the discard stack, the other players are allowed to swap the newly placed card on top of this stack as well. This goes on until none of the players has interest in the top card of the discard stack anymore.

Now that the turn has ended the 'turn button' is passed to the next player.

Expanding the design

You expand the design by placing cards out of your hand onto empty spaces on the board. This is done starting with step 4, working backwards. The concept card (step 5) is placed onto the board at the end of the game to complete the design. If possible, you're allowed to place more than one card on the board in a single turn.

When expanding the design, a step may be placed onto the board, only when the requirements of the subsequent step(s) match the deliverables of the step to be placed. In other words, the design on the board has to be faultless at all times. Sometimes a preceding step has more deliverables than those that are required for the subsequent step, this is no problem.

Optimizing the design

When a step is placed onto the board which doesn't meet your requirements, the game is not lost yet, for the design may be optimized. This is done by replacing cards on the board with cards from your hand. You may replace as many steps as you want, as long as the deliverables of a step match the requirements of the subsequent step(s). In other words, there has to be a faultless design on the board after the optimization.

‘and’ on the board

The use of the ‘and’ on the board is a little complicated. At the end of the ‘and’ there have to be placed two step 3 cards of which the combined deliverables must lead to the requirements of step 4. When you have only one of the two required step 3 cards in your hand, you’re allowed to place this single step 3 card onto the board. However, the step 3 card which will be placed onto the board later on, must than deliver the other requirement of step 4.

For the front part of the ‘and’ the deliverables of step 1 must be required by both the step 2 and the top step 3 on the board. This means that step 1 may only be placed onto the board when these two subsequent steps have been placed. During the game it may turn out that the two step 3 cards have to be switched. You must apply this switch for the resulting design to be faultless.

‘or’ on the board

The use of the ‘or’ on the board is much simpler. The ‘or’ card which leads to the two end products of your concept card, may only be placed onto the board at the end of the game, together with the concept card itself. On both the ‘or’ card and the concept card the two end products have been bolt printed.

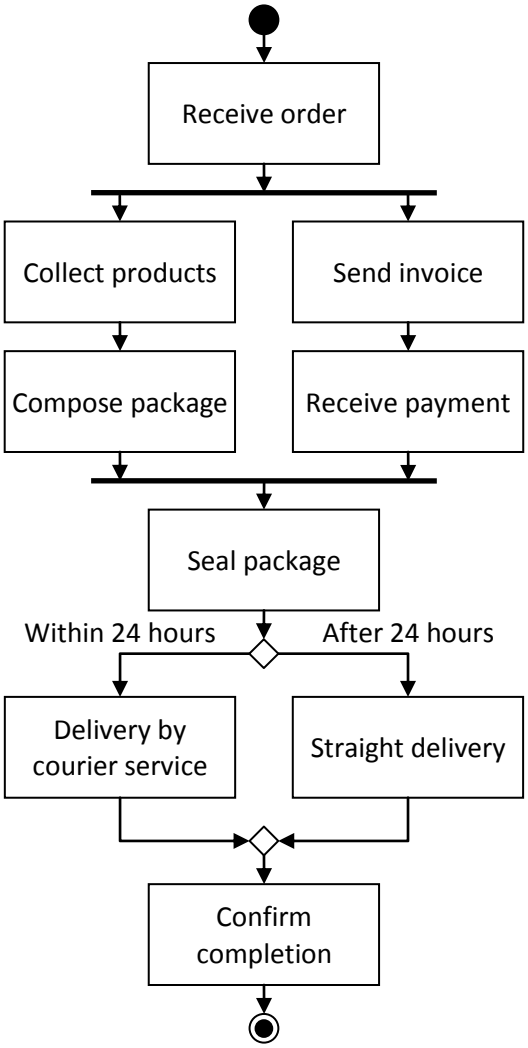
End of the game

The game ends when the last card is placed onto the board and thus the design is completed. This last card is the concept card of one of the players, which may only be placed onto the board to complete the design.

A.3. Case and diagram

WebSuper is an online supermarket where people can buy victuals. Up to now, all activities that play a role in the processing of orders are being executed within the department 'Order processing'. Due to a growth in the amount of customers, this clustering has proven to be inefficient. For this reason the company has decided to split up the department in a few different departments. To this end, WebSuper wants to know which activities can be performed in parallel. For this to be visible in one glance, a model of the activities is required, which you are asked to draw. The activities which are being performed within the division 'Order processing' can be found in the annual report:

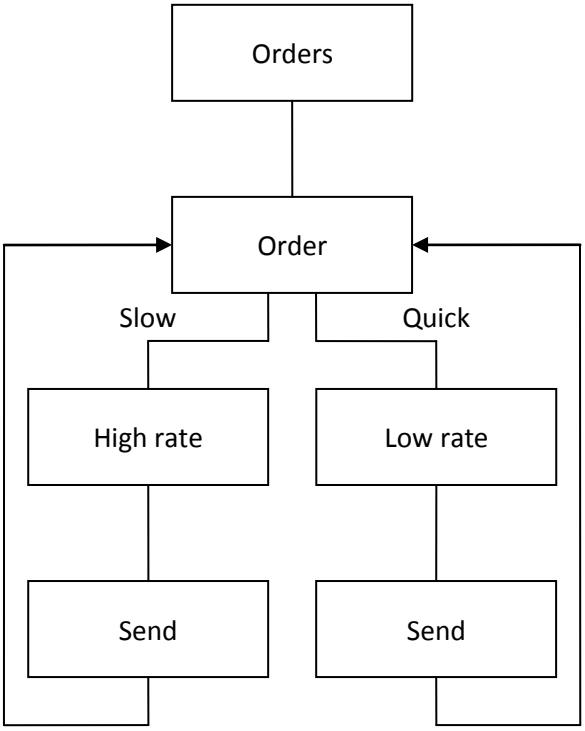
When the division 'Order processing' receives an order, a digital invoice is sent to the customer. At the same time the products are being collected from the warehouse and the package is being composed. After the payment has been received, the package is sealed and being sent to the customer. When the package has to be delivered within 24 hours, the delivery is taken care of by a courier service. However, when the package may be delivered after 24 hours, WebSuper itself takes care of the delivery, which reduces the costs for the customer. After the package has been delivered, the division 'Order processing' confirms the completion of the order.



A.4. Resulting diagrams

Subject number: 1
Moment: Before

Age: 55
Education / profession: VISA-inspector
Modeling skills: Piping and instrumentation diagrams



Not an activity

Not an activity

Decision, incorrect notation

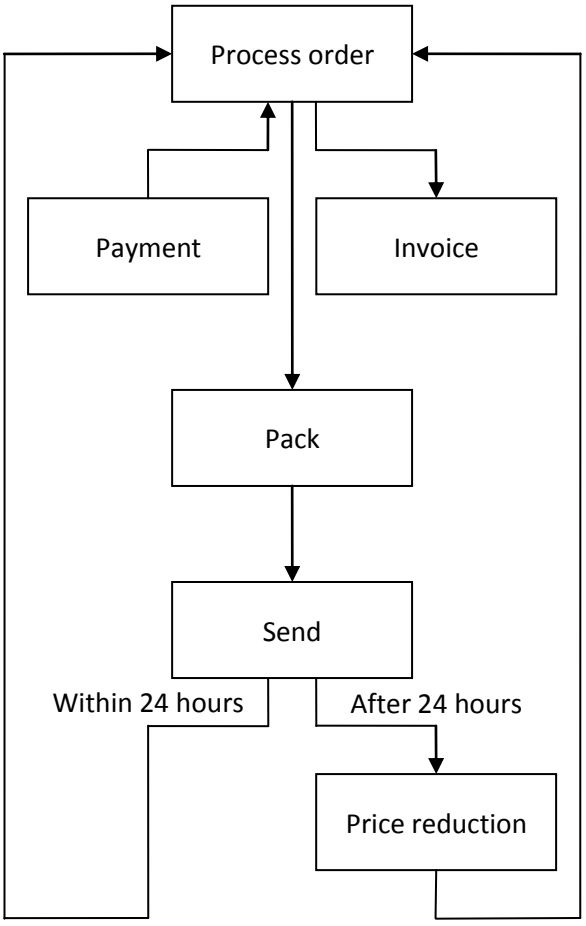
Not an activity (2 times)

Correct activity (2 times)

Endless loop

Subject number: 1
Moment: After

Age: 55
Education / profession: VISA-inspector
Modeling skills: Piping and instrumentation diagrams



Incorrect activity

Split, incorrect notation

Arrows show transmit direction

Correct activity (2 times)

Correct activity

Correct activity

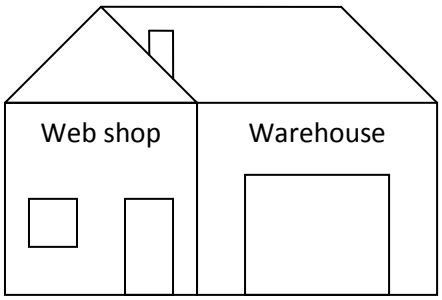
Decision, incorrect notation

Not an activity

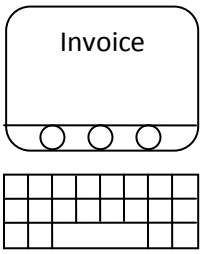
Endless loop

Subject number: 2
Moment: Before

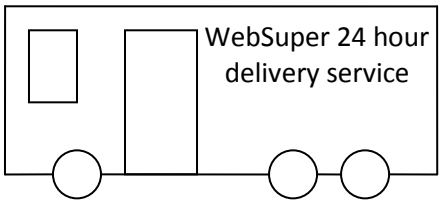
Age: 47
Education / profession: Cleaning lady
Modeling skills: None



Not an activity
(2 times)



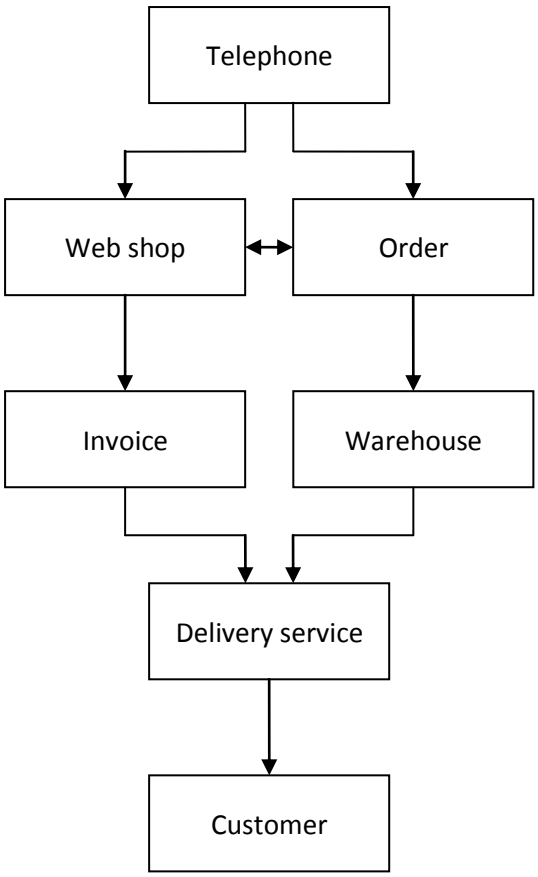
Not an activity



Not an activity

Subject number: 2
Moment: After

Age: 47
Education / profession: Cleaning lady
Modeling skills: None



Not an activity

Decision, incorrect notation

Not an activity (2 times)

Split, incorrect notation

Bidirectional arrow shows total role

Not an activity (2 times)

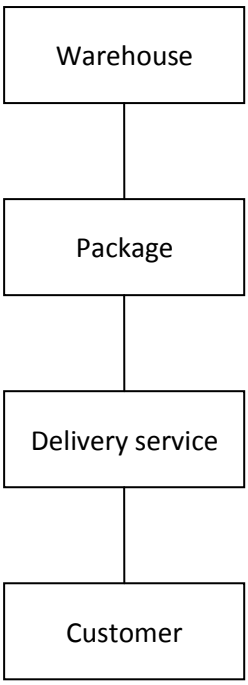
Join, incorrect notation

Not an activity

Not an activity

Subject number: 3
Moment: Before

Age: 38
Education / profession: Warehouse employee
Modeling skills: None



Not an activity

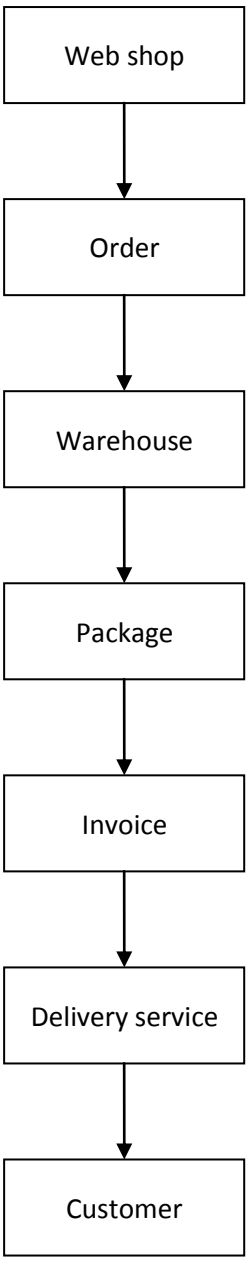
Not an activity

Not an activity

Not an activity

Subject number: 3
Moment: After

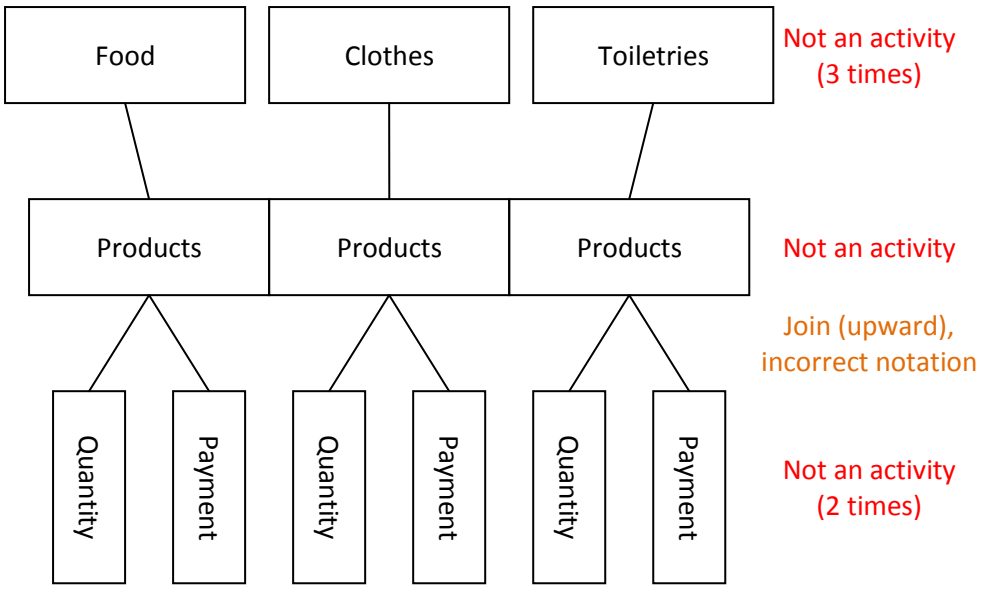
Age: 38
Education / profession: Warehouse employee
Modeling skills: None



Not an activity
Not an activity
Not an activity
Not an activity
Not an activity
Not an activity
Not an activity

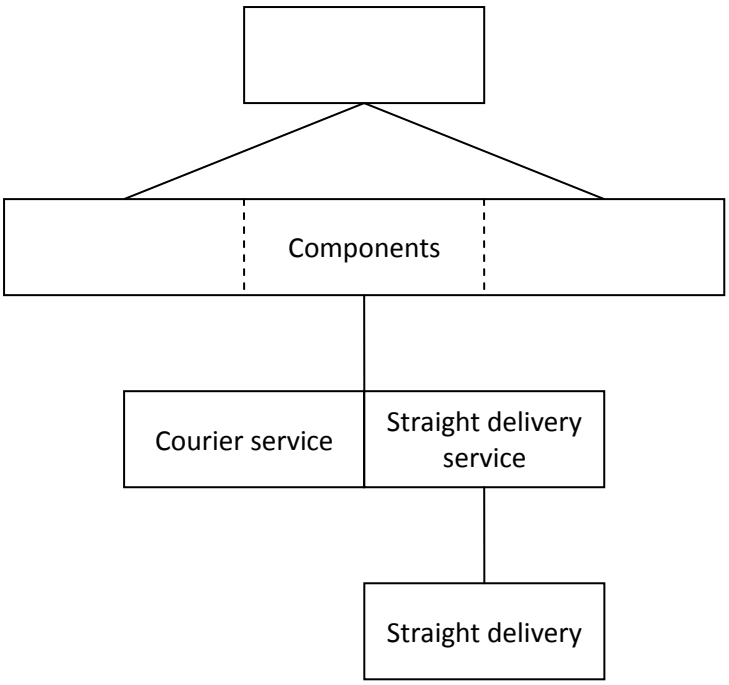
Subject number: 4
Moment: Before

Age: 45
Education / profession: Nursing home caretaker
Modeling skills: None



Subject number: 4
Moment: After

Age: 45
Education / profession: Nursing home caretaker
Modeling skills: None



Initial state, incorrect notation

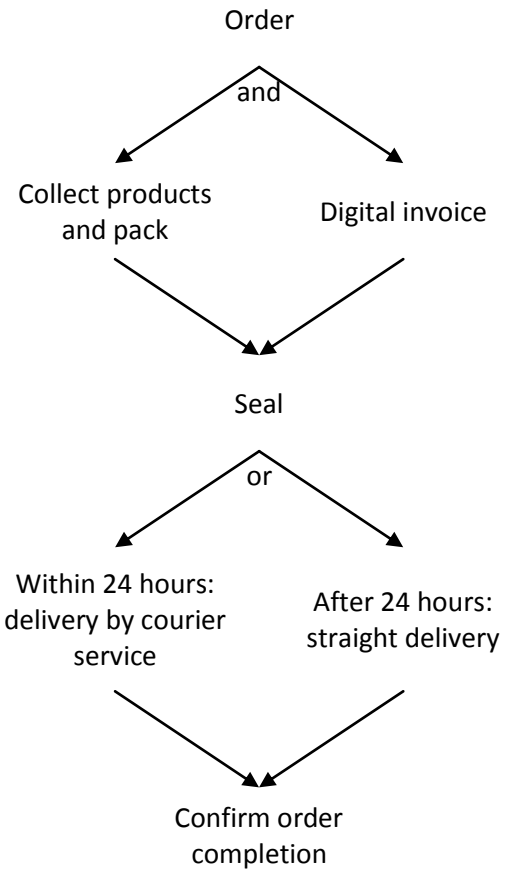
Split, incorrect use and notation

Not an activity

Decision, incorrect notation

Correct activity

Subject number:	5
Moment:	After
Age:	22
Education / profession:	Courier
Modeling skills:	None



Not an activity

Split, incorrect notation

Correct activity (2 times)

Not an activity

Join, incorrect notation

Correct activity

Decision, incorrect notation

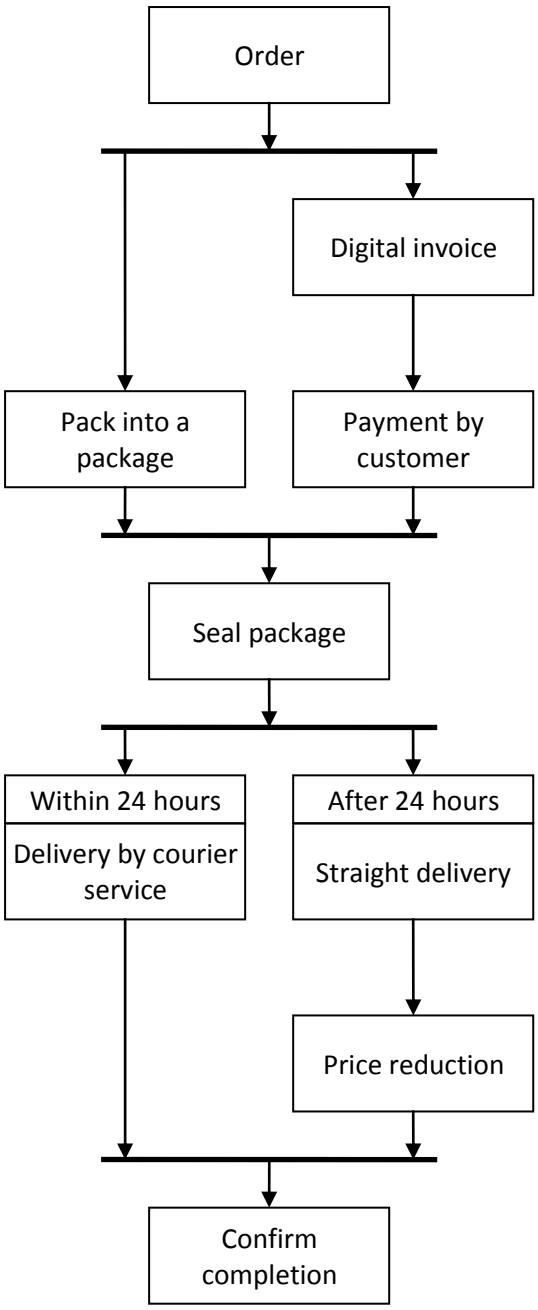
Correct activity (2 times)

Merge, incorrect notation

Correct activity

Subject number: 6
Moment: After

Age: 19
Education / profession: Academy of classical music
Modeling skills: None



Not an activity

Split, correct notation

Not an activity

Correct activity (2 times)

Join, correct notation

Correct activity

Decision, incorrect notation

Correct activity (2 times)

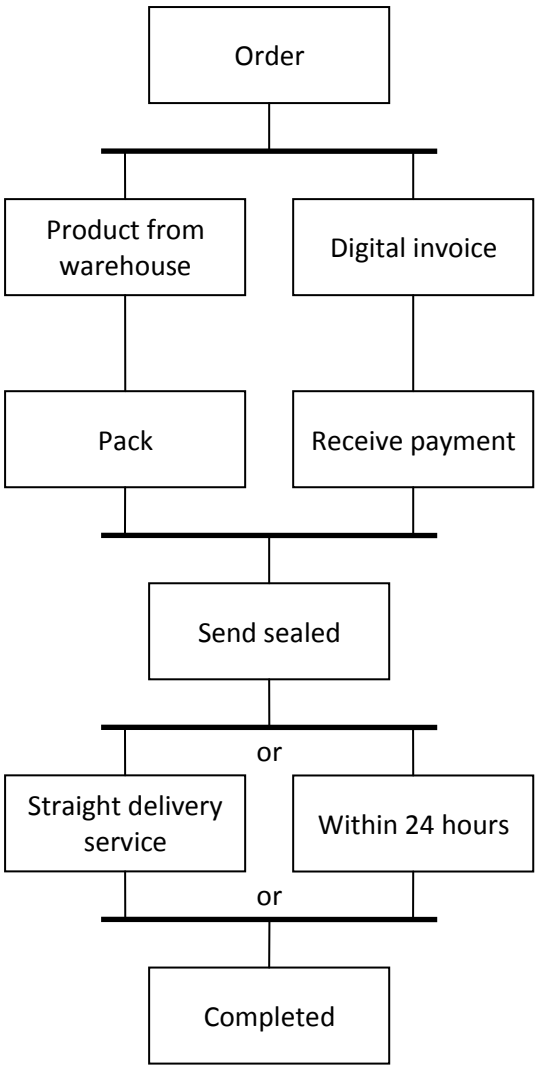
Not an activity

Merge, incorrect notation

Correct activity

Subject number: 7
Moment: After

Age: 53
Education / profession: Singer
Modeling skills: None



Not an activity

Split, correct notation

Not an activity (2 times)

Correct activity (2 times)

Join, correct notation

Correct activity

Decision, incorrect notation

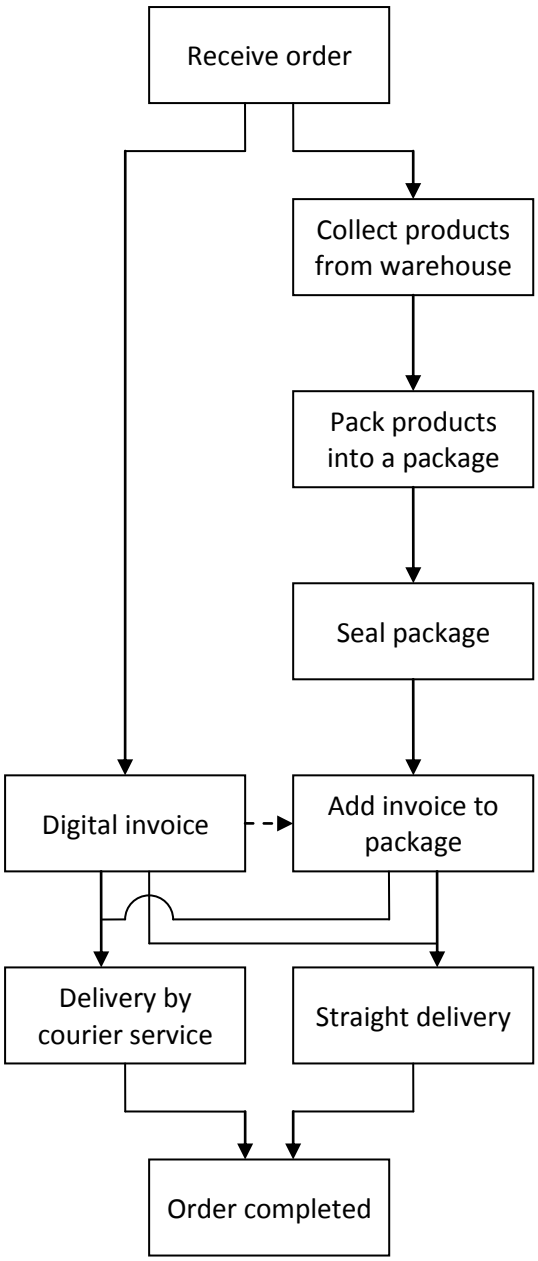
Not an activity
Part of decision

Merge, incorrect notation

Not an activity

Subject number: 8
Moment: After

Age: 44
Education / profession: VWO
Modeling skills: Process flow diagrams



Correct activity

Split, incorrect notation

Correct activity

Correct activity

Correct activity

Not an activity
Incorrect activity
Dotted arrow shows relation

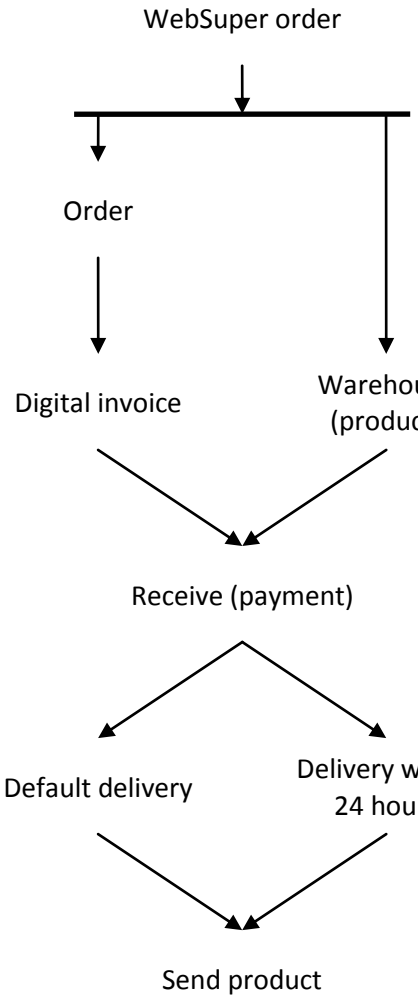
Join and decision, incorrect notation

Correct activity (2 times)

Merge, incorrect notation

Not an activity

Subject number:	9
Moment:	After
Age:	16
Education / profession:	HAVO
Modeling skills:	None



Not an activity

Split, correct notation

Not an activity

Not an activity (2 times)

Join, incorrect notation

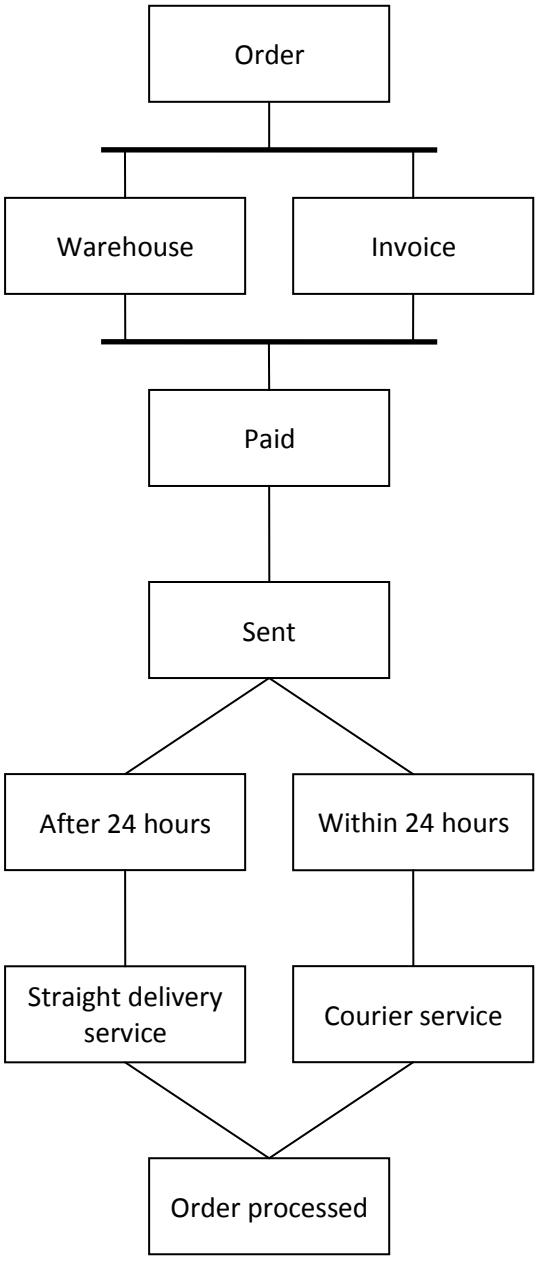
Correct activity

Decision, incorrect notation

Correct activity

Subject number: 10
Moment: After

Age: 20
Education / profession: Informatics
Modeling skills: Recently started school, thus no experience yet



Not an activity

Split, correct notation

Not an activity (2 times)

Join, correct notation

Correct activity

Correct activity

Decision, incorrect notation

Not an activity (2 times)

Merge, incorrect notation

Correct activity

B. Bibliography

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