Design, Implementation and Evaluation of a Virtual World for Subject-Oriented Business Process Modelling

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submitted by

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Design, Implementierung und Evaluierung einer virtuellen Welt für Subjekt-Orientierte Geschäftsprozess-Modellierung

Masterarbeit

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von

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Abstract

Business processes and employees are the heart and soul of an organisation. Efficient and effective business processes are critical and a fast adaption to changes is vital. Business process modelling captures the way an organisation executes business processes and provides a framework to improve these business processes. As business processes span across diverse departments or organisations, modelling requires communication and collaboration of distributed individuals. Subject-oriented business process modelling (S-BPM) is based on a simple notation that enables individuals to capture models of business processes without support of a business analyst. Virtual worlds offer new opportunities to communicate and collaborate together and find application in various areas like e-commerce, social, business or education. Successful practice of business process modelling in virtual worlds provides a basis to build the first virtual world to collaborative learn S-BPM. The objective of this thesis is the design, implementation and evaluation of a virtual world, which supports learning of how to structure communication to perform S-BPM. A literature review and interview with experts captures insights of virtual worlds designed for applying and learning business process modelling. A concrete adaption and transition of S-BPM notation for applying in a virtual world is performed. A business process and various concepts, like animations, are designed to support the learning process of users in the virtual world. An evaluation with students from FH Joanneum shows that the virtual world is a platform where geographically dispersed people can learn S-BPM any time. Although usability and immersion were rated poorly and some concepts that should support the learning process were not accepted as expected. At the end of this thesis, therefore, recommendations for improvements are presented.

Keywords: virtual world, subject-oriented business process modelling, collaborative learning

Kurzfassung

Geschäftsprozesse (GP) und Mitarbeiter sind das Herzstück einer Organisation. Effiziente und effektive GP, sowie eine rasche Anpassung bei Änderungen sind entscheidend, um am Markt präsent zu bleiben. Um GP zu verbessern, werden Modelle erstellt, welche ein gesamtheitliches Bild eines GP ermöglichen und als Kommunikationsbasis dienen. GP sind in der Regel abteilungsübergreifend und benötigen für die Erstellung eines Modells die Kommunikation und Zusammenarbeit mehrerer Mitarbeiter. Subjekt-orientierte Geschäftsprozessmodellierung (S-BPM) ermöglicht mit einer simplen Notation Modelle von GP zu erstellen. Virtuelle Welten erlauben die Kommunikation und Kollaboration von geografisch verteilten Personen und finden in verschiedenen Bereichen, wie zum Beispiel Ausbildung und Handel, Anwendung. Selbst für das Erstellen und Lernen von GPM wurden bereits virtuelle Welten erstellt. Das Ziel dieser Masterarbeit war ein Design, Implementierung und Evaluierung einer virtuellen Welt für kooperatives Lernen von S-BPM. Eine umfassende Literaturrecherche und Interviews von Experten erfasste den aktuellen Stand von virtuellen Welten zum Lernen von GPM. Aus den Ergebnissen wurde ein Design einer virtuellen Welt erstellt und Konzepte, welche das Lernen von S-BPM unterstützen sollen, entwickelt. Eine Evaluierung der virtuellen Welt wurde mit Studenten der FH Joanneum durchgeführt. Das Ergebnis zeigt, dass eine virtuelle Welt das kooperative Lernen von S-BPM für verteilte Personen unterstützt. Die Studenten bemängeln jedoch die Benutzerfreundlichkeit und die Immersion. Des Weiteren wurden nicht alle Konzepte zur Unterstützung des Lernens so bewertet wie erwartet. Es werden mögliche Verbesserungen, die zu einer besseren Benutzerfreundlichkeit und Immersion führen vorgestellt.

Schlagwörter: Virtuelle Welt, Subjekt-orientierte Geschäftsprozessmodellierung, Kooperatives Lernen

Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

Graz, 18.05.2015

Date   Signature

Eidesstattliche Erklärung[1]

Ich erkläre an Eides statt, dass ich die vorliegende Arbeit selbstständig verfasst, andere als die angegebenen Quellen/Hilfsmittel nicht benutzt, und die den benutzten Quellen wörtlich und inhaltlich entnommenen Stellen als solche kenntlich gemacht habe.

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Datum   Unterschrift

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Acknowledgements

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Nomenclature

BPM Business Process Modelling

$BPMN$ Business Process Model and Notation

$S - BPM$ Subject-oriented Business Process Modelling

SBD Subject Behaviour Diagram

SID Subject Interaction Diagram

1 Introduction

Business processes and employees are the heart and soul of an organisation. Efficient and effective business processes are critical and a fast adaption to changes is vital. Business process modelling captures current execution of business processes and provides a framework to improve business processes. As business processes span across diverse departments or organisations, modelling requires communication and collaboration of distributed individuals, also called domain experts.

In general, Hoppenbrouwers, Proper, and Weide (2005) define the modelling process as a collaborative activity of participants, where each participant has an internal model of the process. A dialogue between participants lead to a common and agreed model. A model is an abstract representation of the real world. A business process model graphically capture what work an organisation perform to create business value (Luebbe, 2011).

Common modelling languages like BPMN or UML, are difficult to understand by individuals without modelling background. Therefore the common and agreed model of participants has to be translated with respect to grammar of a chosen modelling language. Modelling experts, also called business analysts, support the process of modelling business processes. In order to acquire the process knowledge, modelling experts use different elicitation techniques, like interviews or workshops. Interviews require the same terminology and background of interviewee (domain expert) and interviewer (modelling expert). Otherwise misunderstanding will lead to wrong models. Workshops are conducted with multiple domain experts and at least one modelling experts. The domain experts interact with each other and the modelling experts, moderates the workshop and produces a model based on the workshop result. A workshop can be designed to use a software tool, to map out information. Limited screen resolution of standard projectors

makes it difficult to display the whole model for participants. Further software tools are usually used by domain experts, rather than domain expert, causing a slow down of the creative process (Luebbe, 2011).

Virtual worlds offer new opportunities to communicate and collaborate together and provide solution for business process modelling drawbacks. The application of virtual worlds range from e-commerce, social, business to education. The first reported attempt of business process modelling in a virtual word was performed by Brown, Recker, and West (2011). A novel and innovative 3D BPMN modelling environment was built in Second Life. The virtual environment increased user empowerment and added significantly to the collaboration and consensual development of modelling a business process. From then on, several attempts on application of business process modelling in virtual worlds followed.

In this thesis, a virtual world was designed and evaluated which supports learning of how to structure communication to perform subject-oriented business process modelling (S-BPM). S-BPM grammar is simple and easy to learn. This gives domain experts the opportunity to model without support of modelling experts.

A proverb says "Tell me and I will forget, show me and I may not remember, involve me and I will understand". This work provides a virtual world, where people will be actively involved in collaborative learning of S-BPM.

1.1 Goals and Objectives

This thesis was written as part of a Double Degree Programme between Graz University of Technology and Cranfield University. The main objectives of the thesis submitted to Cranfield University were the literature review and the design of the virtual world. The chapter 1, 2, 3 and parts of 7 and 8 were originally written in Angerer (2014). This thesis covers the implementation and the evaluation of the virtual world. The goal of this thesis was to understand how a virtual world can support learning and collaboration to learn S-BPM. Subject-oriented business process modelling (S-BPM) focuses on domain experts, rather than the flow of activities or events. Key point

of S-BPM is to identify how to structure the communication of all domain experts involved in the business process.

1.2 Methodology

The following research methodology was implemented:

- Conduct literature review to understand currently used framework to learn business process modelling
- Iterative development of a virtual world based on suggestion of previous studies and collection of information from stakeholders
- Evaluation of virtual world by experiments
- Recommendations and suggestion for improvement of virtual world environment
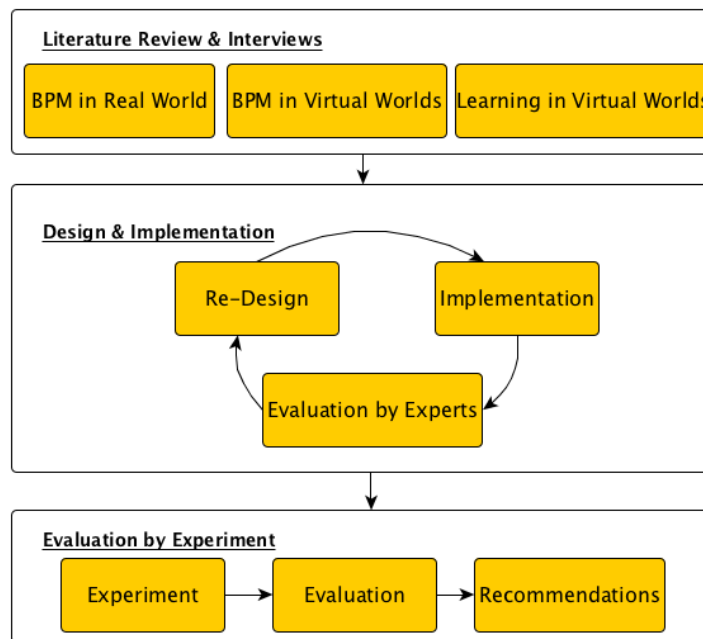
Figure 1.1: Methodology

2 Background and Related Work

The first section introduces business process modelling (BPM) and virtual world technology. Related work is then presented detailing current methods to learn subject-oriented business process modelling (S-BPM) and application of BPM in virtual worlds. This chapter was originally written in Angerer (2014).

2.1 Business Process Modelling

In order to facilitate understanding of business process modelling, Business Process and Business Process Management is presented.

Business Process

Magal and Word (2012) and Weske (2007) define a business process as a coordinated execution of activities that produce a desired business goal. Every process is triggered by some event, e.g., low inventory level or hiring a new employee and lead to a business goal, e.g., desired inventory level or new employee. The structure of organisations are usually divided into departments, like warehouse, purchasing or human resource. A business process span across diverse departments in an organisation to achieve the desired outcome. A business process is not limited to a single organisation, it can also span across various departments of different organisations.

Business Process Management

Weske (2007) define Business Process Management as concepts, methods, and techniques to support management of business processes. Fleischmann, Rass, and Singer (2013) define the following activities as management of business processes:

- Analyse a process (Identify the scope)
- **Model a process** (Capture the process in a model)
- Validate a process (Does the model represent the process?)
- Optimise a process (Identify and solve bottlenecks)
- Embed a process in into the organisational structure
- Embed existing IT-solutions into a process
- Run and monitor instances of a process

The activities do not have to be executed in the given order. Several activities can be iterated until the desired result is reached.

Business process modelling (BPM) is a subtask of Business Process Management. BPM captures and presents knowledge of business processes into models by usage of a specific notation. Different notations are available to describe a business process, for example S-BPM, BPMN, UML, IDEF to name a few. The administration and development of business process models require a close cooperation of different stakeholders. Important stakeholders of the business process modelling process are (Weske, 2007):

- Business engineer: Also called business domain experts, are defining strategic goals of business processes.
- Process participant: Also called domain experts, are performing activities of business process
- Knowledge worker: Are process participants who use software systems to perform activities of a business process.
- Process designer: Also called modelling method experts, are modelling the business process. Experts in modelling and communication.

It is common to use only the word domain expert to refer to business engineer, process participant and knowledge worker. In order to gain knowledge of a business process and capture it in a model, process designers are interviewing domain experts individually or in workshops. Process designer are

experts in modelling and use a specific modelling notation for modelling. Two modelling notations, i.e., S-BPM and BPMN are presented in the next section.

2.1.1 Subject-Oriented Business Process Modelling

Subject-oriented business process modelling (S-BPM) is defined and well described in Fleischmann, Schmidt, et al. (2012) and Fleischmann, Rass, and Singer (2013). S-BPM is based on natural language sentence structure: subject, predicate, and object. While common BPM techniques see modelling of business processes as flow of activities; S-BPM is moving the subject (domain expert) to the focus of attention. As business process activities are performed by subjects. A natural language sentence describes all relevant information of an activity. The subject who is enacting the activity. The predicate defines the action of the subject on the object. The object which is affected by the action performed by a subject. An object can be tangible, e.g., goods, printed document or intangible, e.g., web form or software program. In the case, the sentence contains an indirect object, the predicate is either send or receive, and the indirect object defines the receiving or sending subject, respectively. Figure 2.1 illustrates a language-based representation of an employee (subject), who is applying for a business trip.

The business trip application example in Figure 2.1 illustrates that a sentence is either about an interaction of two subjects (i.e., send or receive) or a specific activity (e.g., fills out) of a subject. Considering the business process description of the involved manager, his description includes amongst other sentences, *"The manager receives the request form for business trips from his employee"*. All interactions of subjects involved in a business process are captured in a Subject Interaction Diagram (SID). All activities performed of a subject are captured in a Subject Behaviour Diagram (SBD). Each subject has an exclusive SBD, which model internal behaviour of the subject.

The *employee* fills out the **request form for business trips**. After that, the *employee* sends the **request** form to his/her **manager**. After that, if the *employee* receives the **approval** from his/her **manager,** then he/she does the **business trip**; After that, he/she does **nothing** any more

if the *employee* receives the **rejection** from his/her **manager,** then he/she does **nothing**

Figure 2.1: Natural language description of a business trip application from an employees view. The subject are employee and manager. Predicates are yellow-marked and describe the action e.g fill out, send or receive. Objects are underlined and a distinction is drawn between direct and indirect object. Direct object is either tangible or intangible, whereas indirect object always represents a subject. Specifically, a receiver in a send action and a sender in a receive action (Fleischmann, Schmidt, et al., 2012).

S-BPM uses two types of diagrams to describe a business process:

1. Subject Interaction Diagram: Modelling communication between subjects
2. Subject Behaviour Diagram: Modelling internal behaviour of a subject

Subject Interaction Diagram

The subject interaction diagram (SID) shows all participating subjects and communication between them. When modelling this diagram, the question is *what kind of messages subjects exchange and what are the contents*. This diagram gives an overview of participating subjects and flow of messages between them. Figure 2.2 illustrates SID of the business trip example.

Subject Behavioural Diagram

After modelling SID, the internal behaviour of subjects are modelled with Subject Behaviour Diagrams. Each subject defines the internal behaviour
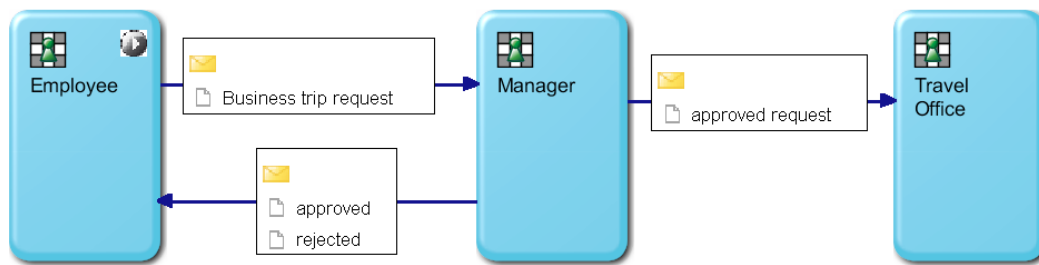
Figure 2.2: Subject Interaction Diagram of business trip application. Participating subjects are employee, manager and travel office. In total 3 messages are sent. The message sent from manager to employee depends on the internal behaviour of the manager and is either approved or rejected

with an exclusive SBD. The internal behaviour is described by three states shown in Table 2.1. The receive and send states are used for interaction with other subjects. The function state corresponds to an action, e.g., fill out, create and analyse, of respective subject.

Function state	... corresponds to an action of respective subject
Receive state	... corresponds to receiving a message from another subject
Send state	... corresponds to sending a message to another subject

Table 2.1: Three states for modelling internal behaviour of a subject

Figure 2.3 shows the SBD of subject employee in the business trip application.

Summary

The S-BPM methodology, transfer of business process description to S-BPM diagrams, is illustrated in Figure 2.4. In order to create the SID, participation
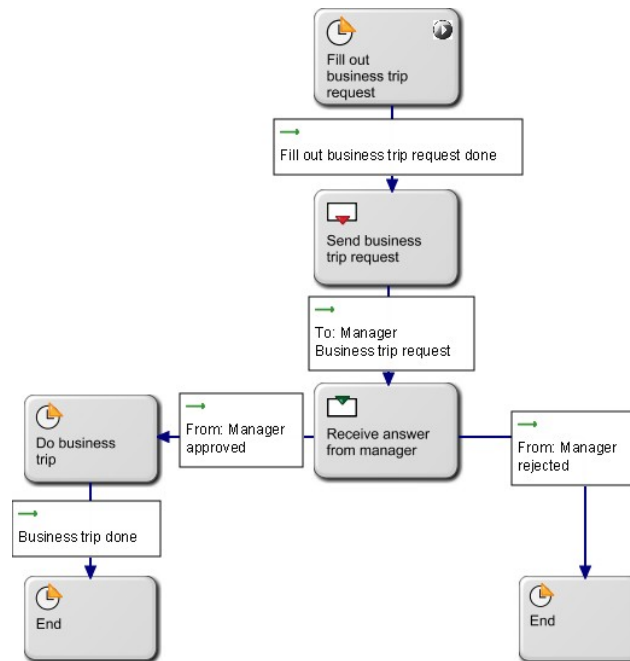
Figure 2.3: This Figure illustrates the internal behaviour of an employee applying for a business trip. Play button on the first state indicates the start state. The transitions from the receive state "Receive answer from manager" depends on what the manager sends. If the manager sends an approval, then the outgoing transition is to the state "Do business trip". Otherwise, if the manager sends a rejection, then the outgoing transition is to an end state. End states indicate the end of the business process of a subject. Please note, that a state can also have more than one incoming transition.

of all subjects is necessary. While the creation of SBD for a subject can be done by the respective subject alone. The internal behaviour of other subjects can be seen as a black box, knowledge of the internal behaviour of other subjects is not necessary.

Since 2011, S-BPM is categorised as technology trigger in Gartner Hype Cycle for Business Process Management, as shown in Figure 2.5. Gartner Hype Cycle is a graphical representation of maturity of emerging technologies and applications. The hype cycle is divided into five key phases which represent time it takes for new technology to mature. The x-axis represents
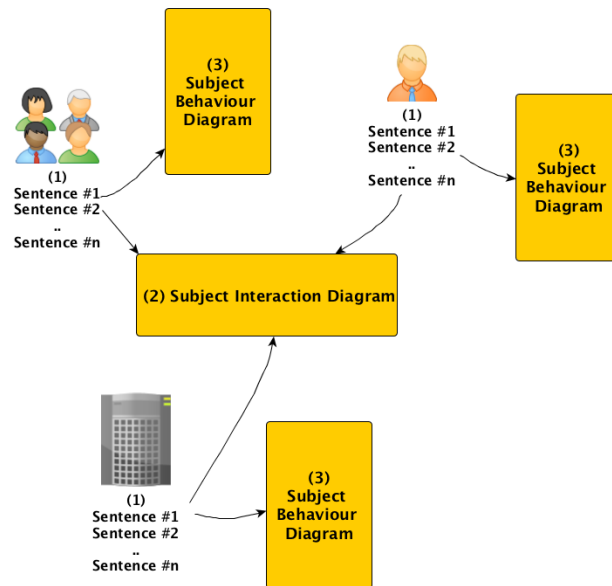
Figure 2.4: Overview of S-BPM methodology: This Figure shows three subjects. A subject can be a single person, a team, a department or a machine. The subjects have sentences which describe the activities in the business process. The creation of the SID requires participation of all subjects. While each subject can model their respective SBD on their own.

maturity and y-axis visibility of technology on market. The first phase is technology trigger, potential technology gets high publicity. The second phase is peak of inflated expectations and is characterised by number of success stories - often accompanied by scores of failures. The next phase is through of disillusionment and interest on technology is decreased because implementation fail to deliver. Providers need to improve their products to the satisfaction of early adopters. In the forth phase slope of enlightenment the technology is more understood and enterprise benefit from technology, plateau of productivity technology is mature and mainstream adoption takes place as technology is paying off (Gartner, 2014a).

Benefits of S-BPM The main advantage of S-BPM is that it is easy to learn. As soon as people are familiar with the simple notation, they can model their business processes on their own. No more business analysts are required.
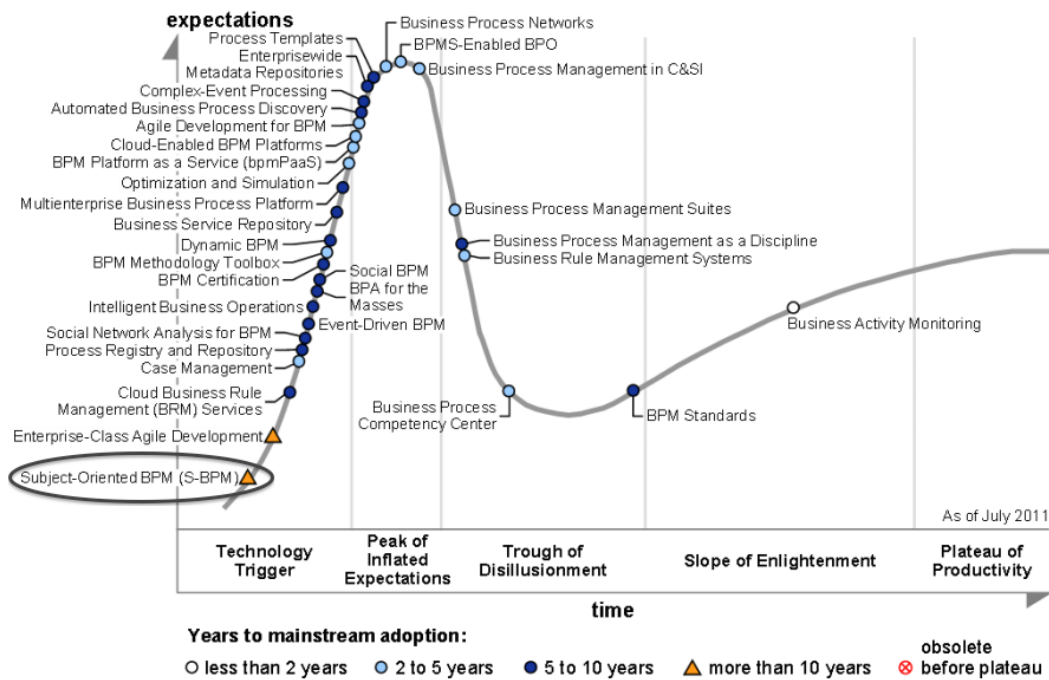
Figure 2.5: Hype Cycle for Business Process Management, 2011 (Dixon and Jones, 2011)).

Saving costs and preventing wrong or not complete business process models from business analysts who misunderstood domain experts.

Drawbacks of S-BPM The creation of the SBD of a subject do not require additional help of other subjects. This can lead to a silo effect of subjects, focusing on their tasks and do not see the overall process (big picture). Further, business analyst have consolidated knowledge of best-practise business process. As business analyst are not required, the missing knowledge can lead that business process management of domain experts are not developing in an efficient and effective way.

2.1.2 Business Process Modelling Notation

As most virtual worlds for business process modelling are designed for Business Process Modelling Notation (BPMN), this industry standard modelling notation is presented.

BPMN was developed by the Business Process Management Initiative (BPMI) with the goal to provide a notation that is readily understandable by all business users and handle the complexity of business processes as well. The graphical representation of a business process is called Business Process Diagram (BPD) and is based on flowcharting technique to capture all activities and relevant information the business process (White, 2004).

A BPD is made up of graphical elements that are distinguishable from each other and familiar to most business analysts. Figure 2.6 shows an overview of BPMN elements, which are classified in four categories.
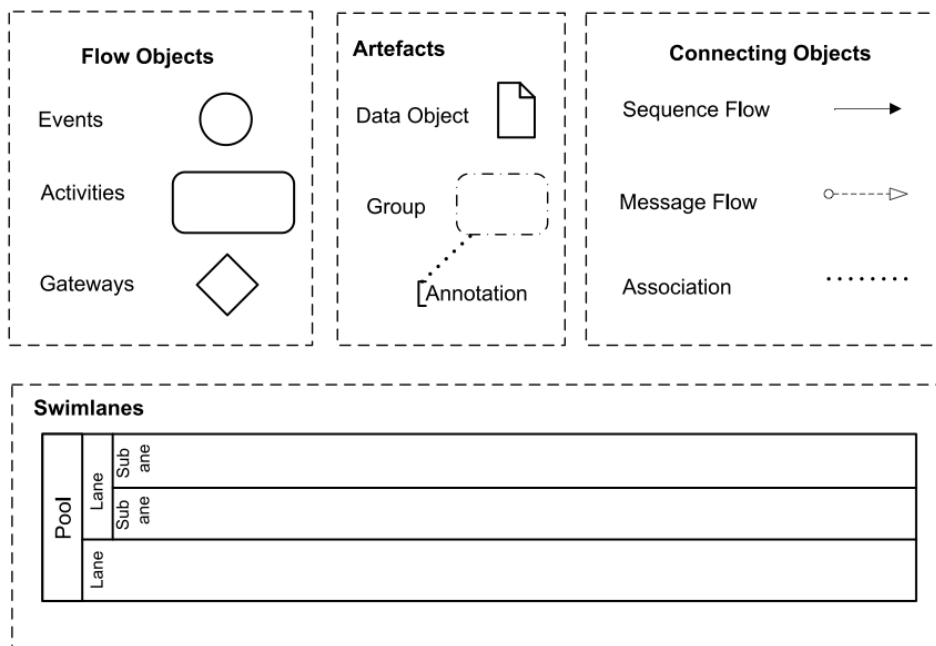
Figure 2.6: Overview of BPMN elements (White, 2004)

The BPMN notation consists of more than 60 elements. More than 70 software tools that support BPMN are listed on OMG (2014). Figure 2.7 shows the business process example business trip application, introduced in S-BPM section, modelled with BPMN.
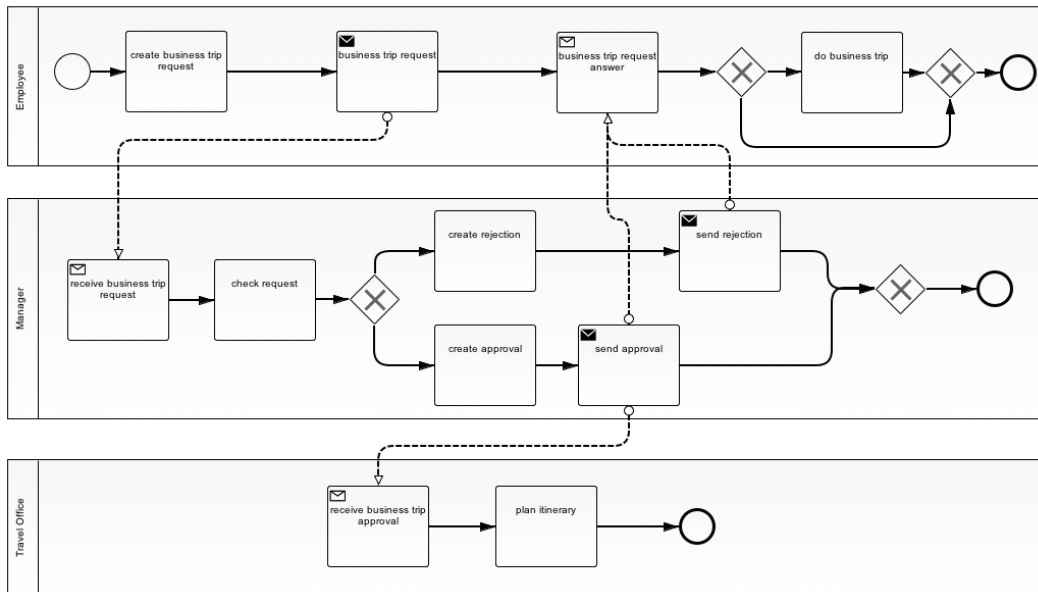
Figure 2.7: Business process example business trip application modelled with BPMN

This section introduced the concept of S-BPM and BPMN. In the next section four methods to learn and apply S-BPM are presented. Two of the four methods use a virtual world for learning. Readers who are not familiar with virtual worlds are advised to read the section 2.4 first.

2.2 Methods to Learn and Apply S-BPM

In this thesis the focus is on learning S-BPM. Therefore four methods to learn and apply S-BPM are presented. The methods are discussed and compared. Two of the four methods are using a virtual world. Therefore the main benefits of virtual worlds can be deduced. In section 2.3 the reasons why a virtual world is the right platform for collaborative learning of S-BPM is presented.

2.2.1 S-BPM Illustrated

One way to learn S-BPM is with the book "S-BPM illustrated". A story of communication issues between production department and logistics department guides the reader through step-by-step activities. All activities can be modeled with S-BPM software from metasonic called metasonic suite. The final result of the hands-on book is a workflow that executes the business process in metasonic suite.

2.2.2 Metasonic Touch

Metasonic[1] has designed a modelling table with a tangible tabletop interface called metasonic touch (GMBH, 2014). Tangible articulation support systems facilitate the explication and negotiation of knowledge (Oppl and Stary, 2014). The metasonic touch provide a shared elicitation environment for employees to model S-BPM together. Figure 2.8 shows schematic bird's-eye view on metasonic touch. Coloured building blocks (states) are automatically recognised by an integrated camera and displayed on the interactive multi-touch display. Models created with the metasonic touch can be imported into metasonic suite and executed as a web application.

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[1]www.metasonic.de
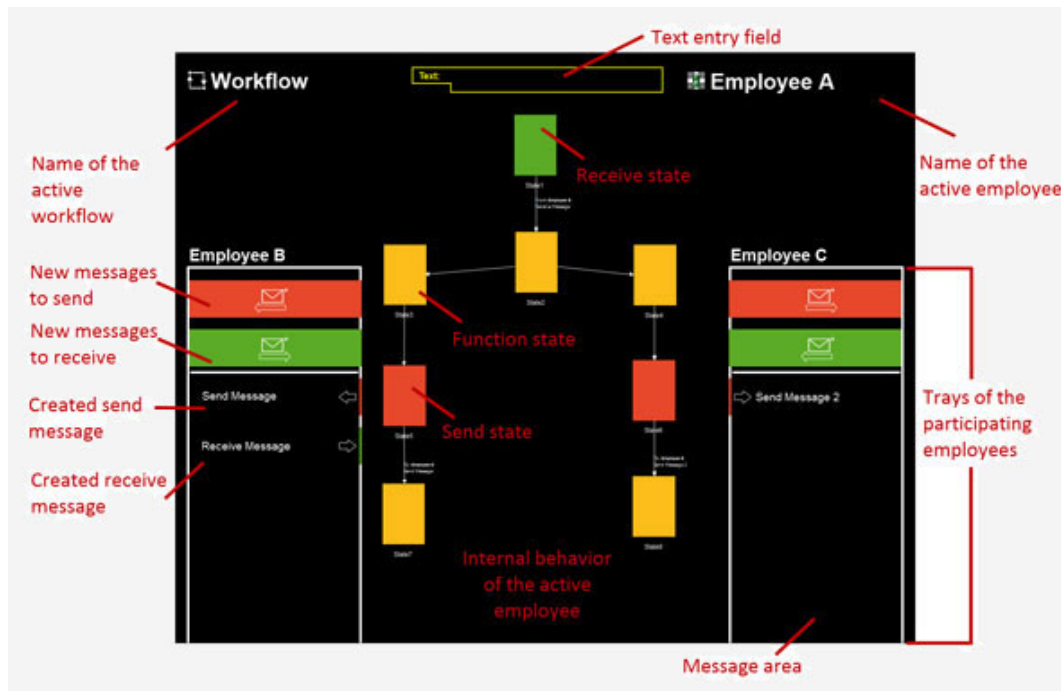
Figure 2.8: Schematic bird's-eye view on tangible tabletop interface metasonic touch (GMBH, 2014). The center is reserved for modelling of internal behaviour of a subject. Left and right of the modelling interface (trays) shows message communication of subject.

2.2.3 3D Progressive Education Environment for S-BPM

Weichhart et al. (2014) applied the Dalton Plan within a 3D virtual world, enabling and facilitating self-organised learning of S-BPM. This is first attempt of S-BPM in a virtual world. The educational Virtual S-BPM World is designed as an interactive, creative place, where students work and learn collaboratively or individually. The initial prototype is separated in three different areas, i.e., Motivation Area, Work Area and Feedback Space. The motivation area provides motivational information for modelling with S-BPM, e.g., videos. The work area (one for each task) is a shared working space for task supported by collaboration tools such as whiteboards, sticky notes, or image uploaders. The last area is the Feedback Space, providing

an interactive representation using 3D-objects for students and teacher to assess learning progress.

2.2.4 Virtual World S-BPM Elicitator

Joel Harman from Queensland University of Technology built in collaboration with metasonic a virtual environment to model a process with S-BPM. A video is provided in the blog post (Brown, 2014). The virtual environment is called "Virtual World S-BPM Elicitator" and is designed to provide a virtual office in which user can model process by interacting with subject and objects in the world. User can walk in the office and click on co-workers, computer or photocopier to select an action. For example the user can click on the photocopier to send a fax (action state), or printer to print documents as well on a person to give (send state) or take (receive state) item or informations. In order to select a person for receive or sending, a bird view is opened. The user can also add conditions to model branches. The final process can be viewed spatially - overlaying the internal behaviour model with virtual word (bird view) shown in Figure 2.9.

Figure 2.9: Bird's-eye view of a Subject Behavioural Diagram in the virtual world S-BPM Elicitator (Harman et al., 2015).

2.2.5 Comparison

The book "S-BPM illustrated" features a step-by-step task of modelling an industry standard business process based on a story. It is suited for individual self-organised learning but lacks in collaborative learning setting. On the other side, the metasonic touch, provides a shared modelling space for collaboration of many users. The tangible tabletop interface focuses on users with S-BPM experience. Nevertheless, the modelling table can be used to support learning of S-BPM in a group of experienced user. But a major drawback is the mobility of modelling table. The table is too heavy for quick transportation. Geographically dispersed people need to meet up at the same place. While the 3D Progressive Education Environment for S-BPM allows people easily to learn together. The focus is more on S-BPM theory and not on modelling of business processes. The Virtual World S-BPM Elicitator allows modelling of business processes but only alone and not with others also represented as avatars.

The proposed virtual world in this thesis allows geographically dispersed people, from two up to four people, to learn S-BPM in a collaborative way. Only a computer with microphone and internet connection is required. The virtual world will be designed in an authentic way, separated in several areas and animations which will support the learning process.

2.3 Why a Virtual World to Learn Business Process Modelling?

Co-located business process modelling is often conducted in a shared visual space like a table with process model in form of a print-out or projection. This setting facilitates communication between participants by spatial juxtaposition of modelling artefact and collaborators performing the work. Active collaborators are able to intuitively perceive who is present, who is working on which part of the model and who is working with whom together. The perception of collaborators facilitate engagement in modelling via discussion or non-verbal cues (gestures, facial expression). Although information technology support geographically dispersed business process

modelling, common tools as Microsoft Visio or IBM Blueworks do not fully support spatial references and visual cues (Poppe et al., 2013) (Brown, Recker, and West, 2011). Virtual worlds overcome lack of spatial references with collaborators representation as avatars and artefacts as 3D objects in a shared 3D space.

Dillenbourg (1999) defines collaborative learning as *"is a situation in which **two or more people** learn or attempt to **learn something together"***. This definition is very broad and each of the underlined element can be interpreted in different ways:

- two or more may be interpreted as small group of 5 people or a community with thousands of people
- learn something may be interpreted as follow a course or learning activities as brainstorming, decision making or problem solving
- together may be interpreted as face-to-face or computer-mediated, synchronous or not. The interaction type is not defined

We learn by performing some activities (reading, building, predicting, ...) which trigger some learning mechanisms (induction, deduction, compilation, ...) Additionally, when we learn with a partner or a group together, we perform activities (explanation, disagreement, mutual regulation, ...) which trigger extra cognitive mechanisms (knowledge elicitation, internalisation, reduced cognitive load ...).

How virtual 3D worlds can support and foster collaborative learning:

- Users with a human like full-body avatar feel more comfortable than in a chat or audio-communication (Koubek et al., 2001)
- Avatar create a psychological feeling of proximity and social presence. This results in a suspension of disbelief and an increase in motivation and productivity (Bouras and Tsiatsos, 2006) (Koubek et al., 2001)
- Awareness of spatial proximity and orientation of avatars has a strong influence on dynamic of group communication (Bouras and Tsiatsos, 2006)
- Geographically dispersed people can meet more spontaneously (Gütl, 2011)
- Motivation and attention of users by experience unseen (real world) phenomena by 3D simulations (Pirker, 2013)

- 3D artefacts or other content in a virtual world facilitates collaboration (Livingstone and Kemp, 2006)

2.4 Virtual Worlds

This section introduces the field of virtual worlds. An overview and comparison of virtual world platforms is presented, and technology to build virtual world for learning S-BPM is introduced.

2.4.1 Definition

There is a lack of a formal definition for virtual world. The term is used in different ways at different times in literature. Bell (2008) defines a virtual world as *"A synchronous, persistent network of people, represented as avatars, facilitated by networked computers"*.

The main characteristics of a virtual worlds are described as follows:

- Synchronous: A virtual world gives a sense of common time, geography and terrain. Users are aware of space, distance and co-existence of other participants.
- Persistent: A virtual world keeps running and continues to exist even if a user left the virtual world
- Network of people: The virtual world is an ecosystem, where people communicate and interact. All actions of people affect virtual worlds ecosystem.
- Represented as avatars: Humans interact with the virtual world by controlling an avatar. An avatar is any digital representation that perform actions of humans in real time.
- Facilitated by networked computers: Network computers facilitate data management of virtual environment and allow entering of virtual word beyond geographical boundaries.

Each of these characteristics makes a specific, unique contribution to the definition of a virtual world. All characteristics must apply in order to be a virtual world.

The Gartner 2012 Hype Cycle for Emerging Technologies categorise virtual world in the phase through of disillusionment (Gartner, 2014b). Virtual world has moved from peak of inflated expectations in Gartner 2007 Hype Cycle to last third of through of disillusionment in Gartner 2012 Hype Cycle. Gartner states that virtual world and other listed technology in the Hype Cycle will make interaction of people with technology more naturally (Gartner, 2014b). Gütl (2011) is convinced that in future users can navigate in a 'web' of interlinked virtual worlds.
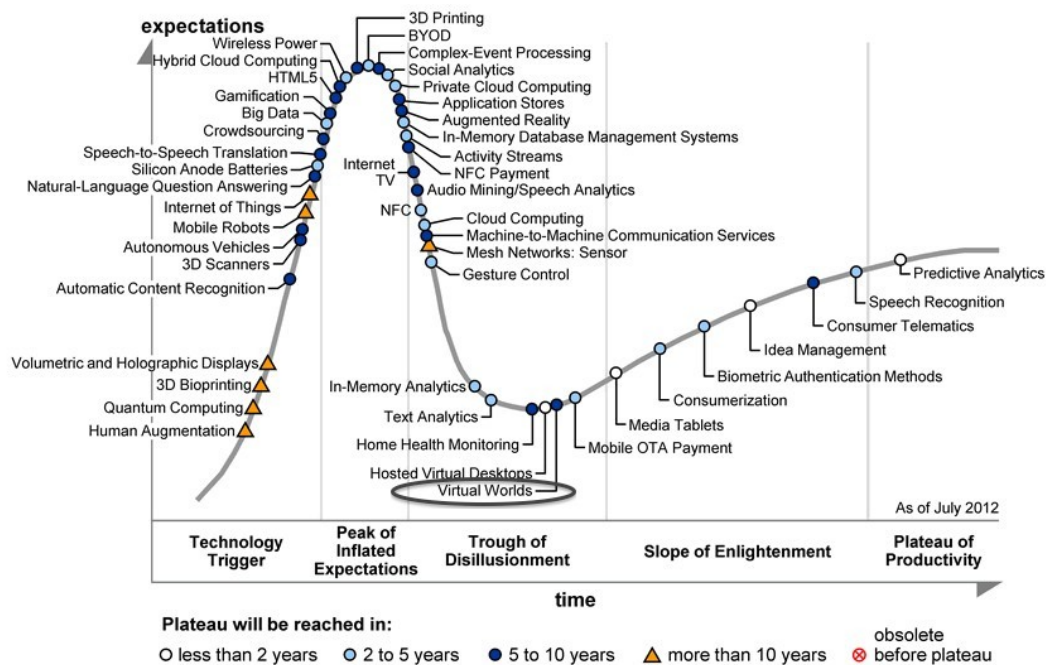

Figure 2.10: Gartner 2012 Hype Cycle for Emerging Technologies (Gartner, 2014b)

2.4.2 Evaluation of Virtual Worlds

Virtual and Mobile Work Research Unit (vmWork) from Aalto University conducted Professional Collaboration and Productivity in Virtual Worlds (ProViWo) project that observed more than 120 virtual environments, technological platforms, and solution providers.

The research consider the following 4 use cases:

1. Small collaborative meetings
2. Large Events
3. Learning and Training
4. Product Development and Process Simulation.

Figure 2.11 shows the considered virtual environments of the benchmark of vmWork. We will focus on virtual words with focus on Enterprise and Open Source framed by a rectangle.
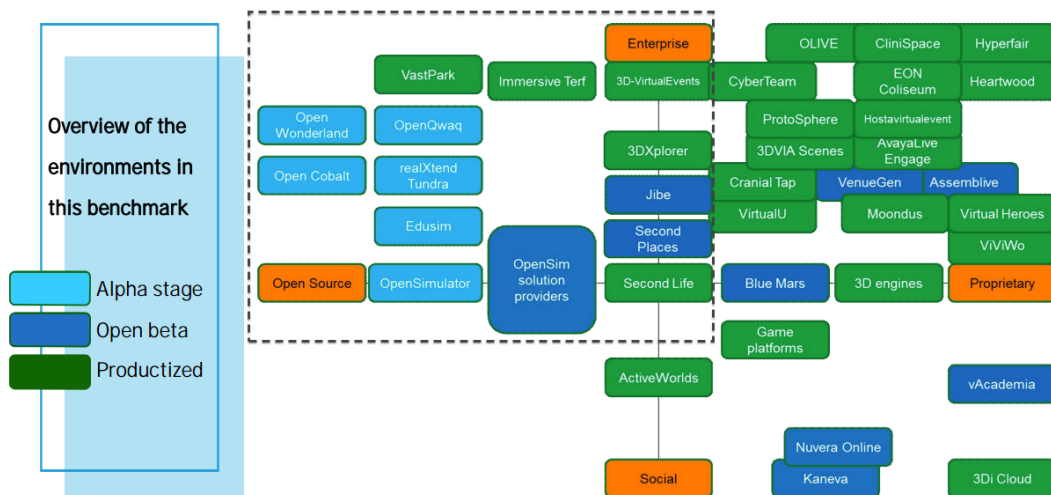

Figure 2.11: 3D virtual environments of benchmark. Categorised in Social, Enterprise, Open Source and Proprietary (Surakka, 2012)

3DXplorer is *"a web 3D platform for live cloud-based collaboration, learning, teaching, marketing, selling and more"* (Corp., 2011). 3DXplorer virtual worlds

Name	Client / Browser	Server platform	Scripting	Share media	Development
3DXplorer	Browser	-	Javascript, PHP, HTML	yes	active
Edusim	Client	Peer to peer architecture	Smalltalk/Squeak	yes	active
Immersive Terf	Client (Windows & Mac) or Browser	Windows & Mac	Python	yes	active
Jibe	Client or browser plug-in	hosted by ReactionGrid or installed on own server	C♯, Javascript, Boo	yes	active
Open Cobalt	Client	Peer to peer architecture	Smalltalk/Squeak	yes	active
Open Simulator	Client	Win, Linux, OS X	C♯	Limited and difficult	Last change 2014-06-17
Open Wonderland	Java Web Start	Win, Linux, OS X	Java	yes	last stable release January 2012
OpenQwaq	Client	Linux	Python	yes	Last SVN commit Feb 2012
RealXtend	Client	Win, Linux, OS X	realXtend Tundra SDK	yes	active
SecondLife	Client	NA	Linden Scripting Language	web-based media	active

Table 2.2: Comparison of business-focused virtual worlds

are accessible in a browser, without having to download software or install plugins. The Open-API allows to add or extend features to 3DXplorer. It is available as SaaS or as Enterprise edition to install on a private server. Both version are proprietary.

3D-VirtualEvents *offers an instantly ready self-service platform, allowing anyone with an internet connection to create virtual conferences and trade shows capable of handling hundreds of attendees in a full 3D Immersive space* (Corp., 2014). 3DXplorer and 3D-VirtualEvents are both provided by Altadyn Corporation.

Edusim *"is a 3D multi-user virtual world platform and authoring toolkit intended for your classroom interactive whiteboard (but equally powerful on the students laptop or desktop computers)"* (**RefWorks**). Edusim is a slimmed

down version of Open Cobalt and is based on peer to peer architecture.

Immersive Terf is a 3D immersive environment with focus on easy collaboration. Immersive Terf platform from 3D ICC was created and is supported by collaboration and gaming experts (ICC, 2014). 3D ICC purchased OpenQwaq and immersive terf is built on top of OpenQwaq (OpenQwaq, 2014). Immersive Terf is the commercial version.

Jibe is described as *"a Developer Kit for creating and deploying Multiuser Immersive 3D Environments on the Web."* (ReactionGrid, 2014). Developed by ReactionGrid, Jibe platform uses as backend system SmartFox and frontend Unity3D. VW created with Jibe are accessible via standalone client, web browser or smartphones. Jibe Project Kit license depends on amount of developers starting with $750 USD (http://reactiongrid.myshopify.com/products/jibe-project-kits). ReactionGrid clients are IBM, Microsoft, Siemens, and Boston College to name a few.

Open Cobalt is an open source platform for building and sharing virtual workspaces for research and education. In analogy of web browser and web page open cobalt is designed "as a tool for accessing and interacting with virtual workspaces that can exist anywhere on the Internet (rather than a virtual world in itself)" (OpenCobalt, 2014). Open Cobalt is still an experimental and early stage platform technology but EduSim based on Open Cobalt is a good example of using Open Cobalt.

Open Simulator aka OpenSim, is described as *"an open source multi-platform, multi-user 3D application server. It can be used to create a virtual environment (or world) which can be accessed through a variety of clients, on multiple protocols* (OpenSimulator, 2014). It is difficult to share media, e.g., powerpoint slides (http://planet.opensim.us/)

Open Wonderland is an open source toolkit for building 3D virtual worlds and is primarily designed for developers familiar with the Java programming language (OpenWonderland, 2014). Open Wonderland, formerly developed under the name Project Wonderland by Sun Microsystem, is now a completely community driven project. While the focus of Sun Microsystem was mainly on business collaboration, e.g., complex 12 , the mission of Open

Wonderland is now to provide a toolkit for education, training, simulation and visualisation.

OpenQwaq is a highly-secure, enterprise-class virtual collaboration platform that provide features like drag and drop content, edit content together and webcam video-conferencing. All what people need to be more productive (OpenQwaq, 2014). Installation of OpenQwaq is tricky and difficult (Suslov, 2012).

RealXtend association focuses on an open-source development of the global standardized 3D internet of virtual worlds. realXtend provide a scriptable 3d multiuser application development kit, called Tundra SDK, to run standalone applications or networked worlds. realXtend does currently not provide a complete virtual world solution, with authentication, avatar editing, simple world creating tools, inventories, virtual currency, social groups etc.

Second Life is the *largest-ever 3D virtual world created entirely by its users* (Linden Research, 2014). Second Life is perhaps the most popular virtual world platform with main focus on Social but also various application of education, business or commercial. For example, Open University offers teaching in Second Life and also a virtual student residences (Open Life Village) to foster social interactions (Linden Research, 2009).

Conclusion

As installation of several virtual world environment are difficult and time consuming or development is frozen, the decision was made to use Unity to built a virtual world. In the next section Unity is introduced. In chapter 4 implementation details of Unity are presented.

2.4.3 Unity

Unity Technologies states Unity as a game development ecosystem, consisting of a rendering engine with an integrated development environment (IDE) to create interactive 2D and 3D content that is easy to publish on web sites, desktop platforms, consoles and smartphones. Including an Asset Store for ready-made assets and a knowledge-sharing community (Technologies, 2014b).

Unity is not a virtual world platform, but can be used to built one. Unity Technologies offers two version of Unity software. Unity Free means the free version of the Unity software, which includes reduced feature versions. Unity Pro is the full featured version of the Unity software and costs $ 1,500 per year or $ 75 monthly. For Unity Free some entity size restrictions (annual gross revenues) and legal entities rules apply. The Unity Pro version includes features like Level-of-detail support, IK Rigs for character animations or GPU profiling. All features of the Pro version have strong focus on optimisation of resources. Nevertheless, the free version of Unity is sufficient for design, implementation and evaluation of a virtual world to learn S-BPM.

Why Unity?

Worldwide, Unity takes a 45% market share of the full feature game engine market. Unity customers are Cartoon Network Coca-Cola, Disney, LEGO to name a few. Unity is most popular game development software amongst developers and registered Unity developers is growing (Technologies, 2014a).

There are several game engines on the market. The benefits of Unity compared to other game engines are manifold (Craighead, Burke, and Murphy, 2008):

- Documentation - a complete documentation with examples
- Developer Community - active online developer communitiy
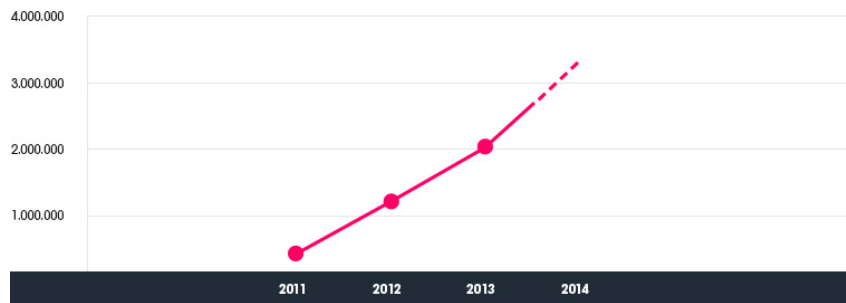- Unity editor - user-friendly interface in a drag-n-drop manner

Figure 2.12: Registered Unity developers (Technologies, 2014a)

- Multiplatform distribution - Deploy for Desktop, Web Browser, Consoles, and Smartphones
- Support of assets from major 3D applications like 3ds Max, Maya, Blender

The last benefit "Support of assets" is also a major drawback, as Unity offers only a few primitive shapes, so everything will need to be created in a 3D application or downloaded/purchased from the Unity Asset Store.

Unity and Virtual Worlds

Several virtual worlds are implemented using Unity. Jibe from ReactionGrid and Vastpark, presented in the previous section, are Unity-based virtual worlds. Vastpark projects[2] are for example an interactive virtual world to train hospital staff or a mental health platform enabling people people to talk to therapist online directly via either web page or mobile app. ReactionGrid offer virtual worlds for Government, Enterprise and Universities. ReactionGrid's Client are NASA, IBM, Microsoft, Xerox, Boston College to name a few.

Another virtual world that is based on Unity is Army OneSource Virtual World, an interactive environment where soldiers can connect with family and friends from anywhere around the world (MarketWire, 2011).

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[2]www.vastpark.com/projects.html

Adam Frisby, one of the OpenSim founder, now CEO of Sine Wave Entertainment, is developing large-scale virtual worlds based on Unity. His main reason for Unity is scaling, as with OpenSim putting more than sixty avatars into a single region is critical, whereas Unity has the capability. Further he emphasises that Unity provides full-time support and better graphics. Also multiplatform publishing is one of the reasons for using Unity (Gladstone, 2012).

2.5 Virtual Worlds for Business Process Modelling Notation

The Progressive Education Environment and Virtual World S-BPM Elicitator are the only virtual environments to learn and apply S-BPM so far. But many virtual worlds are designed for BMPN. The first reported attempt of business process modelling in a virtual word was performed by Brown, Recker, and West (2011). A novel and innovative 3D BPMN modelling environment was built in Second Life. The modelling environment consists of PowerPoint Wall, a Process Modeler, Mind Mapper and Information Holodeck.

Process Modeler: Collaborative modelling is performed on a regular grid with interactive squares at ground level. Avatars can walk on the model and have an extensive view range. Users can choose between 65 BPMN icons. For better usability the BPMN icons were sub-divided into categories. The Process Modeler is shown in Figure 2.13.

Mind Mapper: The Mind Mapper support redesign activities to enable process innovation or reengineering. The open-source 3D spatial mind mapping system allows concurrent participation of avatars to support choices and arguments.

Information Holodeck: The open source Holodeck from Linden Research Inc. are a virtual world construct used to store Second Life scenes. The Holodeck concept is used to display information regarding the description of business processes.
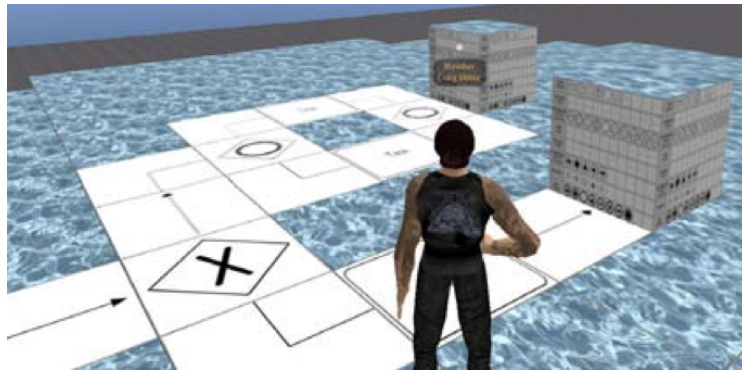
Figure 2.13: Process Modeler with dialog menu options displaying 65 BPMN icons (Brown, Recker, and West, 2011)

A case study designing and developing a process model of a credit card application process was performed by five people. The team consisted of one facilitator and four students enrolled in a business process modelling unit. The four students had little to no experience of 3D virtual worlds. The case study concludes that the virtual environment increased user empowerment and added significantly to the collaboration and consensual development of modelling a business process.

In a successive work, Poppe et al. (2013), further findings and difficulties of the virtual world were presented. The usage of SecondLife required specific chat commands to interact with Process Modeler. Furthermore, the fixed grid layout of Process Modeler required moving other model elements out of the way first before adding new icons. Another difficulty was that SecondLife uses predefined animations and individual animations requires complex workaround. They present a virtual world that overcome these difficulties and further examine visual cues in collaborative process modelling. They present a process model which is a 2D plane, as users can interact the way they are used with present 2D tools. Furthermore, 3D objects can cause occlusion by viewing from a particular point of view. The 2D plane ensures fewer issues with occlusions. Also floating labels that turn towards the user minimises occlusions.

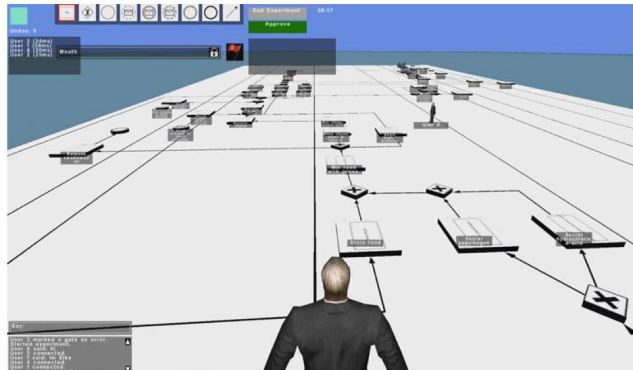Visual cues are supported as users can choose specific predefined anima-

Figure 2.14: Collaborative process modelling tool prototype. Drag & Drop user interface on the top. (Poppe et al., 2013).

tions such as a head nod or an waving arm. User keyboard inputs are automatically played on avatar. User can click on model elements and avatar point at the selected element. An "awareness" display shows all actions of users, e.g., User X is typing. A process model can be locked for validation. It is locked until all user agree and mark model element as error. When all users marked the element as error, then they then can suggest changes which are gathered in a change log. Before changes can be applied, all users have to agree on changes. This mechanism facilitates to reach a consensus on process model. The prototype has not been evaluated, as the 3D virtual world was not mature and well-tested.

3 Design and Conceptual Model of the Virtual World

The literature review shows various application of business process modelling, e.g., BPMN, S-BPM, in virtual worlds. Although virtual worlds were designed for learning S-BPM, no virtual world covers learning of modelling a Subject Interaction Diagram (SID). Furthermore, no virtual world supports a multi-player mode for modelling S-BPM. This thesis presents a virtual world that allows collaborative learning of both diagram types (SID and SBD) of S-BPM. In order to design the virtual world for effective learning of S-BPM, a deep understanding of the procedure of business process modelling is vital. The first section describes the procedure of business process modelling, including the common business process modelling and specifically the S-BPM approach. The insights are then used for the design of the virtual world environment. In the second section, the design of the virtual world will be presented. This chapter was originally written in Angerer (2014).

3.1 Procedure of Process Modelling

Poppe (2012) states that business process modelling requires modelling method experts, who understand the modelling notation and which conduct interviews with domain expert, who are actually doing the processes/tasks. Modelling method expert and domain expert are experts in their own field. Hoppenbrouwers, Proper, and Weide (2005) define the modelling process as a collaborative activity of participants, where each participant has an internal model of the process. A dialogue between participants lead to a common and agreed model. Figure 3.1 shows the process with a set $A_1, ...A_n$

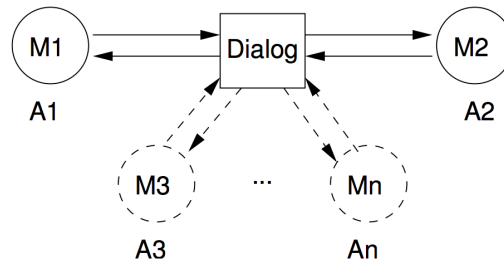of participants with each participant having an own internal model M. The

Figure 3.1: Modelling as a dialogue of participants. Each person has his own view of the model. The dialogue leads to a common and agreed model (Hoppenbrouwers, Proper, and Weide, 2005).

modelling dialogue is a symmetric exchange of knowledge of domain experts with modelling method experts. The exchange of knowledge, as each is expert in his area, contributes to a common model.

Notice: The virtual world should support communication to find a common model.

On the other side, S-BPM is an easy-to-understand graphical notation based on natural language (subject, predicate, object) allowing domain experts to model their processes by themselves (Fleischmann, Rass, and Singer, 2013). As soon as domain experts have familiarised with the S-BPM notation, no modelling method experts are required for modelling. S-BPM does not require exchange of knowledge between domain experts and modelling method experts. Modelling requires exchange of knowledge between the subjects, i.e., domain experts of the business process.

Notice: Communication is only between domain experts.

3.2 Design of the Virtual Word

The virtual world will be designed for people who have little to no knowledge of S-BPM. Although knowledge of other modelling notations is beneficial. No instructor or facilitator is required, as text-based instructions guide users through the tasks.

3.2.1 Idea

Users will learn S-BPM notation by modelling a business process. The designed business process is a procurement process and involves four subjects in total (warehouse, purchasing department, accounting and vendor). The SID in Figure 3.10 shows the procurement process, acquiring needed materials externally from a vendor. A low level of inventory triggers the warehouse to create purchase requisition. The purchasing department sends requests for proposal to the vendor. If the bid of the vendor is acceptable the purchasing department requests delivery of goods to the warehouse. The invoice from the vendor is sent to the accounting department. The warehouse checks the delivered goods and sends delivery details to the accounting. The accounting cross checks delivery details with the invoice. The payment is sent to the vendor.

Based on real world settings, domain experts have knowledge of performing tasks of the business processes. This knowledge is in their head and sometimes written down on a paper, called business process descriptions. Business process descriptions are mostly vague and not documented in a S-BPM way with a clear Subject-Predicate-Object structure. For example, instead of clearly mentioning the subject of a task, the pronoun *one* is used instead. The idea is to provide a business process description in a clear S-P-O structure (see Figure 3.9) and let participants model SID and SBD based on the given business process descriptions. Users choose subject(s) of the procurement process which they would like to model. The business process description of a subject is only visible to the user who has chosen the subject. This **facilitates communication** of users, as the SID can only be completed with collaboration.

3.2.2 Layout

Schmeil and Hasler (2012) conducted an empirical study of collaboration tasks in a virtual world, investigating different designs of environment and activities. The collaboration tasks consisted of information creation, information sharing and decision making. The empirical study outcome shows that spatially separating collaboration tasks improves the memorability of information shared and created when the information has a relation to the collaboration environment in which the collaboration takes place. The authors suggest to separate tasks spatially which creates knowledge and information. As the completed SID can be seen as information for the SBDs, the modelling of SID is spatially separated of modelling the SBDs. The separation is performed with the representation of a subject as a room. Figure 3.2 shows a bird's-eye view of the virtual world. The modelling of the SID and SBDs are spatially separated.
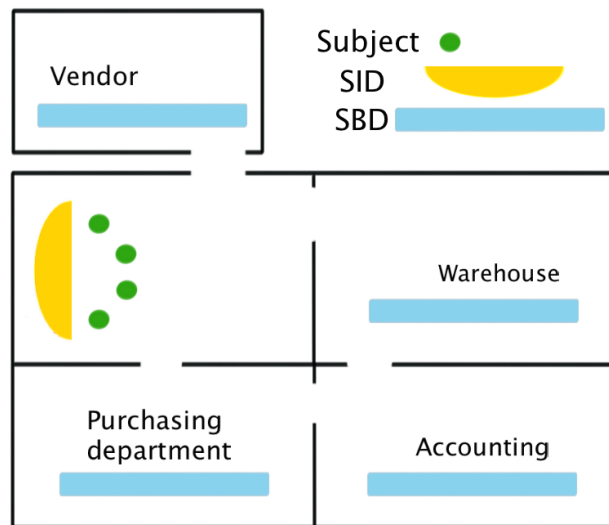

Figure 3.2: Bird's-eye view of virtual world. One room to create collaboratively the SID. A room for each subject (warehouse, purchasing department, vendor and accounting)

The interactions of the SID define receive and send states of the subjects.

After the SID is successfully modelled by the users, an animation is showing the correlation of send and receive states in the SID and the SBD. All receive and send states, represented as 3D cubes, are floating to the corresponding subject room. After the animation, users can start modelling the internal behaviour of their chosen subject(s). Figure 3.3 shows the room where users choose the subject they would like to model and the Subject Interaction Diagram is modelled.
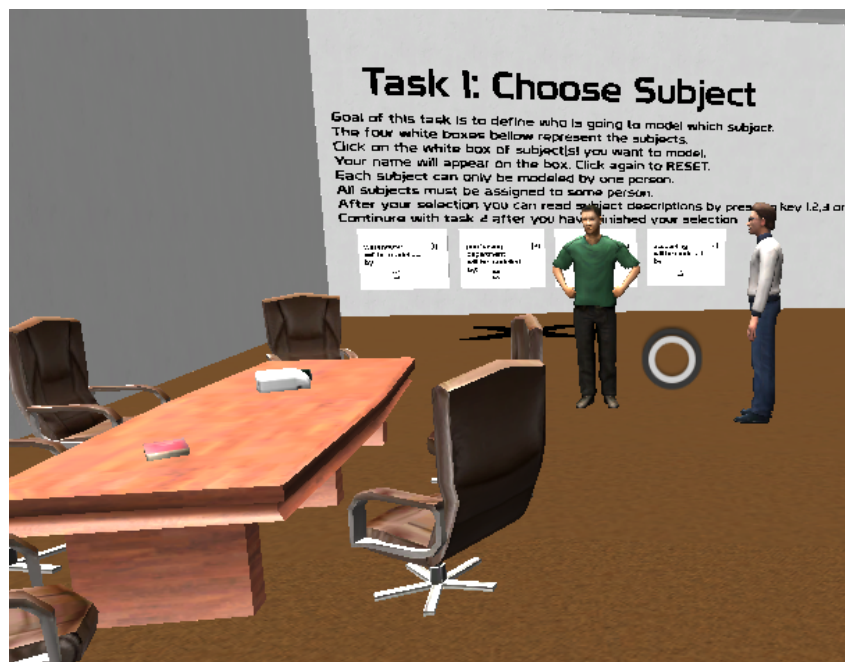

Figure 3.3: The room where users choose the subjects they would like to model and the Subject Interaction Diagram is modelled collaboratively.

Each room has a specific interior that represents the subject's environment. For example, the warehouse room contains boxes and a forklift truck, whereas the purchasing department room contains desks and computers. The design is based on epistemic games, *where the player learns to think like professionals by playing a simulated game of such professions as management, engineering, journalism or urban planning* (Levasseur, 2014). The interior facilitates that the players of the virtual world identifies as an employee of the business

process. Figure 3.3 shows the vendor building, which is a single building and separated from the building that contains the three other subjects.

Figure 3.4: The single building that represents the vendor.

The vendor is a supplier and does not belong to the company with the departments (subjects) warehouse, purchasing department and accounting. The separation of the vendor building reflects this circumstance.

3.2.3 Task Design

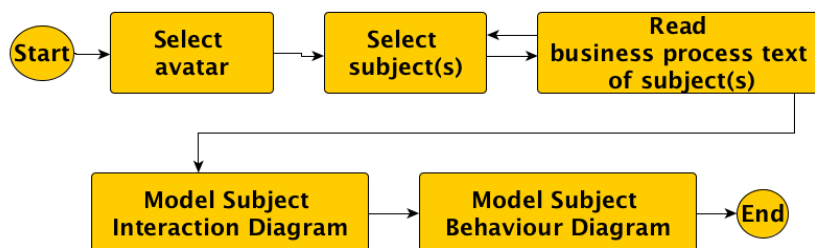Figure 3.5 shows the flow of tasks users have to perform to learn S-BPM.

Figure 3.5: Flow of tasks to learn S-BPM.

The tasks are now described in chronological order of completion.

Avatar selection

After completion of the pre-questionnaire, users specify their username and select an avatar, as shown in Figure 3.6.
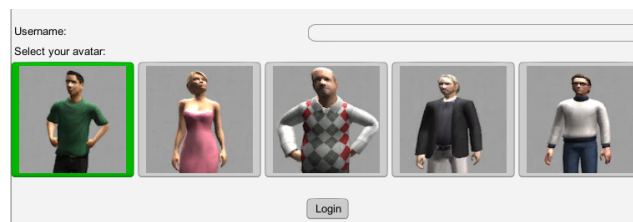

Figure 3.6: Selection of avatar.

As soon as users enter the virtual world, an info box with instructions appears. Figure 3.7 shows the introduction dialogue box. The introduction dialogue box can be displayed again at any time by pressing button h.
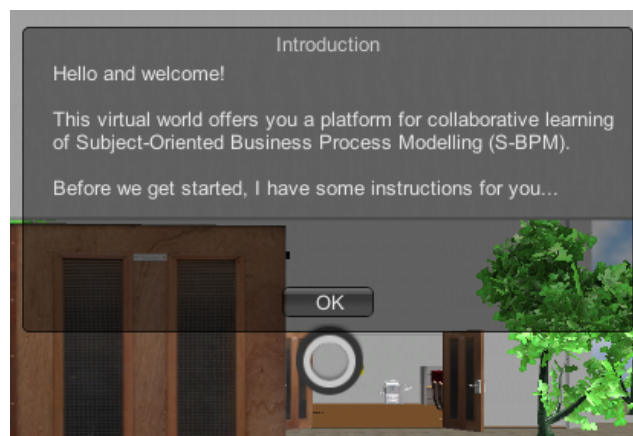

Figure 3.7: Introduction in the virtual world: Instructions on how to move the avatar, enable audio chat and what tasks have to be completed

Subject selection

The virtual world is designed for up to four players, as the business process contains the subjects warehouse, purchasing department, accounting and vendor. As S-BPM is based on communication of subjects, at least two people are required to conduct the experiment. Users are choosing at least one or more subjects by clicking on subject boxes shown in Figure 3.8.
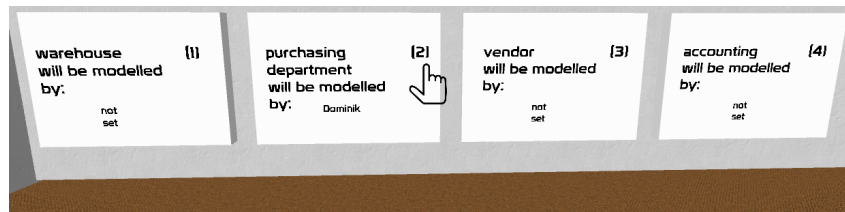

Figure 3.8: Selection of subjects a user would like to model. In this case, purchasing department is selected by Dominik. The other subjects are not assigned to a user yet.

The business process text of a subject is only visible to the user, who chose the subject. This prevents that one user can model everything alone without collaborating with the others. In order to model the SID users have to communicate and exchange information.

Read business process description

Users can display the business process text of the selected subject(s) and familiarise with the tasks of the subject(s). Figure 3.9 shows the business process description of subject the purchasing department.

Purchasing department   (Press 2 again to hide Subject Business Process Text)
===

(01) Purchasing department receives purchase order request from warehouse. After that,
(02) Purchasing department calculates price range. After that,
(03) Purchasing department looks for vendor. After that,
(04) Purchasing department sends request for proposal to vendor. After that,
(05) If Purchasing department receives decline from vendor then
(06)   Purchasing department does step 3 again
(07) If Purchasing department receives bid from vendor then
(08)   Purchasing department evaluates bid from vendor.
(09) If bid is not acceptable then
(10)   Purchasing department sends decline to vendor. After that,
(11)   Purchasing department does step 3 again
(12) If bid is acceptable then
(13)   Purchasing department sends request for delivery to vendor. After that,
(14)   End
(14) End

Hint: Keywords send and receive indicate a connection.
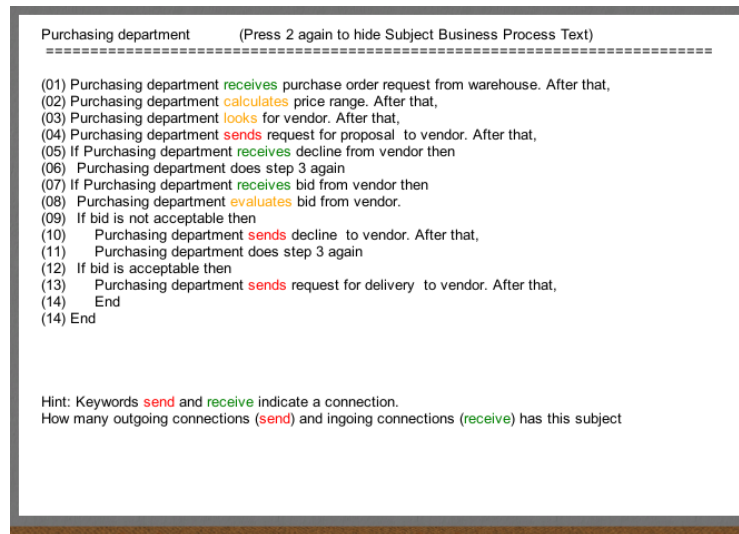How many outgoing connections (send) and ingoing connections (receive) has this subject

Figure 3.9: Business process description of subject purchasing department

Users can also reset assignment of subjects by clicking on subject boxes shown in Figure 3.8.

Modelling of Subject Interaction Diagram

Standard Subject Interaction Diagram

The first diagram, which has to be modelled is the subject interaction diagram (SID). This diagram shows all interactions between subjects of a business process. The SID of the designed procurement process is shown in Figure 3.10 and was built with metasonic suite. This diagram design has some drawbacks. The more subjects and interactions the diagram has the higher the possibility is that interaction lines are overlapping. This means that either the user or an algorithm must align interaction lines to get a view without occlusion. The alignment of interaction lines by a user can take a long time and lead to frustration. It can be concluded that this design has a bad influence on the learning effect. Another drawback is

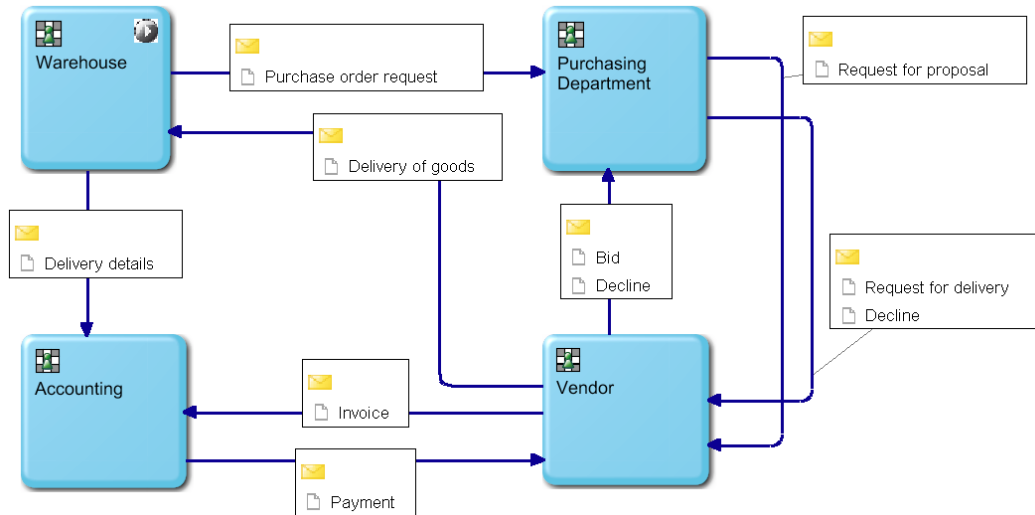that no chronological order of interactions is given. The diagram shows all interactions without any numeration.

Figure 3.10: Standard Subject Interaction Diagram with 4 subjects (Warehouse, Purchasing Department, Vendor and Accounting)

Proposed Subject Interaction Diagram

This proposed diagram design overcomes the two drawbacks. The diagram design is based on UML sequence diagram and BPMN swimlanes. The UML sequence diagram is used to describe interactions between objects. A object can be an instance of a class or business objects An interaction is a method call or any message between business objects.

Organisational aspects are modelled in BPMN by pools and swimlanes. A pool is a rectangular box and represents a participant in a business process. This may be a concrete organisation or a role like supplier or customer. Lanes within a pool represent organisational entities of participant such as departments in organisations (Weske, 2007).
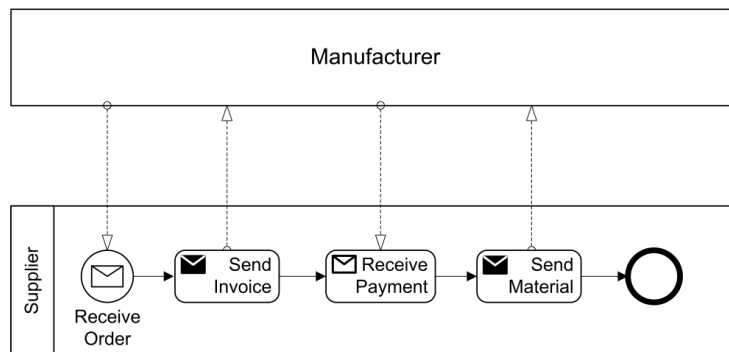
Figure 3.11: A business process involving multiple organisational entities. Communication between organisational entities is exclusively handled through messages. Like subjects communicate exclusively with interactions (Weske, 2007)

Inspired by UML Sequence Diagram and BPMN pools, the interactions between subjects will be modelled with vertical boxes representing subjects and horizontal lines as interactions. This design has no more occlusion by overlapping interaction lines and displays interactions in a chronological order. Figure 3.12 shows the proposed design with the procurement process. This design is more suing for a virtual world than the standard SID.
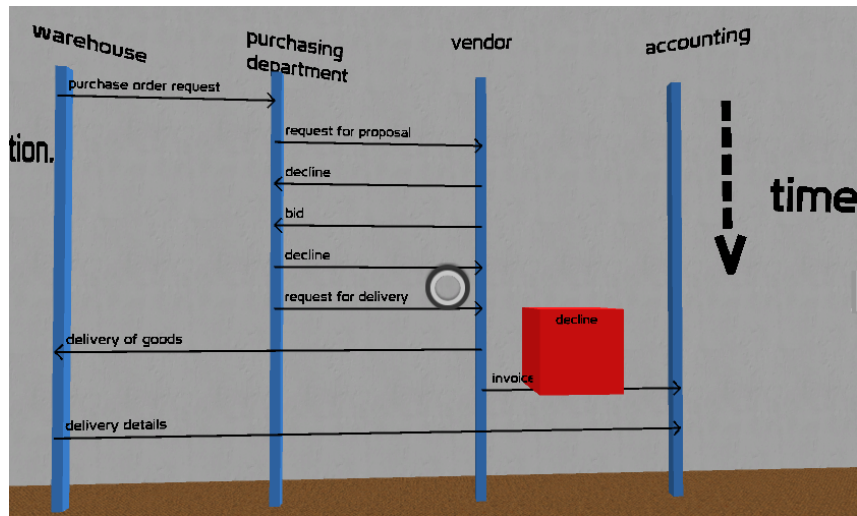
Figure 3.12: Proposed Subject-Interaction Diagram based on UML sequence diagram and BPMN pools. Also displaying floating send state "decline" from subject purchasing department which is moving to room of purchasing department.

Users add interactions by pressing button "i" on the keyboard. A dialogue box is displayed allowing to select via a dropdown menu the source and target subject as well as the interaction type, e.g., purchase order request, decline or invoice. In order to prevent that users model false interactions, only correct interactions are added to the SID. Users get informed about wrong interactions. This should help to succeed in completion of this task, as users can only start with task 3, when the SID is correct. This restriction is applied because the interactions of the SID correlate with the SBD of the subjects. After the completion of the SID a congratulations message is displayed. The animation of the floating 3D receive and send states, which are moving to corresponding subject room, starts. This animation takes about 2 minutes and 30 seconds and will show users the correlation of interactions (= receive and send states) of the SID and receive and send states in the SBDs.

Modelling of Subject Behaviour Diagram

After the animation of the moving receive and send state cubes, the SBD of subjects contain loose send and receive state cubes. Users have to add the action state cubes and connect all state cubes based on the given business process text of the chosen subject(s). Figure 3.13 shows a snippet of a SBD after transcription of SID interactions. The states of a subject are represented as 3D cubes. Users can move state cubes via drag and drop. State cubes are connected by clicking on the arrow of the origin state cube and then clicking on the target state cube. Figure 3.14 shows the SBD of the subject purchasing department, modelled with metasonic suite. In the virtual world, all states are represented as 3D cubes, allowing users to walk around the model and collaborate together.

Figure 3.13: The send state cube "delivery details" connected with the action state "store delivery". Each subject room is equipped with furniture that represents the subject. Users connect state cubes based on the given subject business process description of the subject.
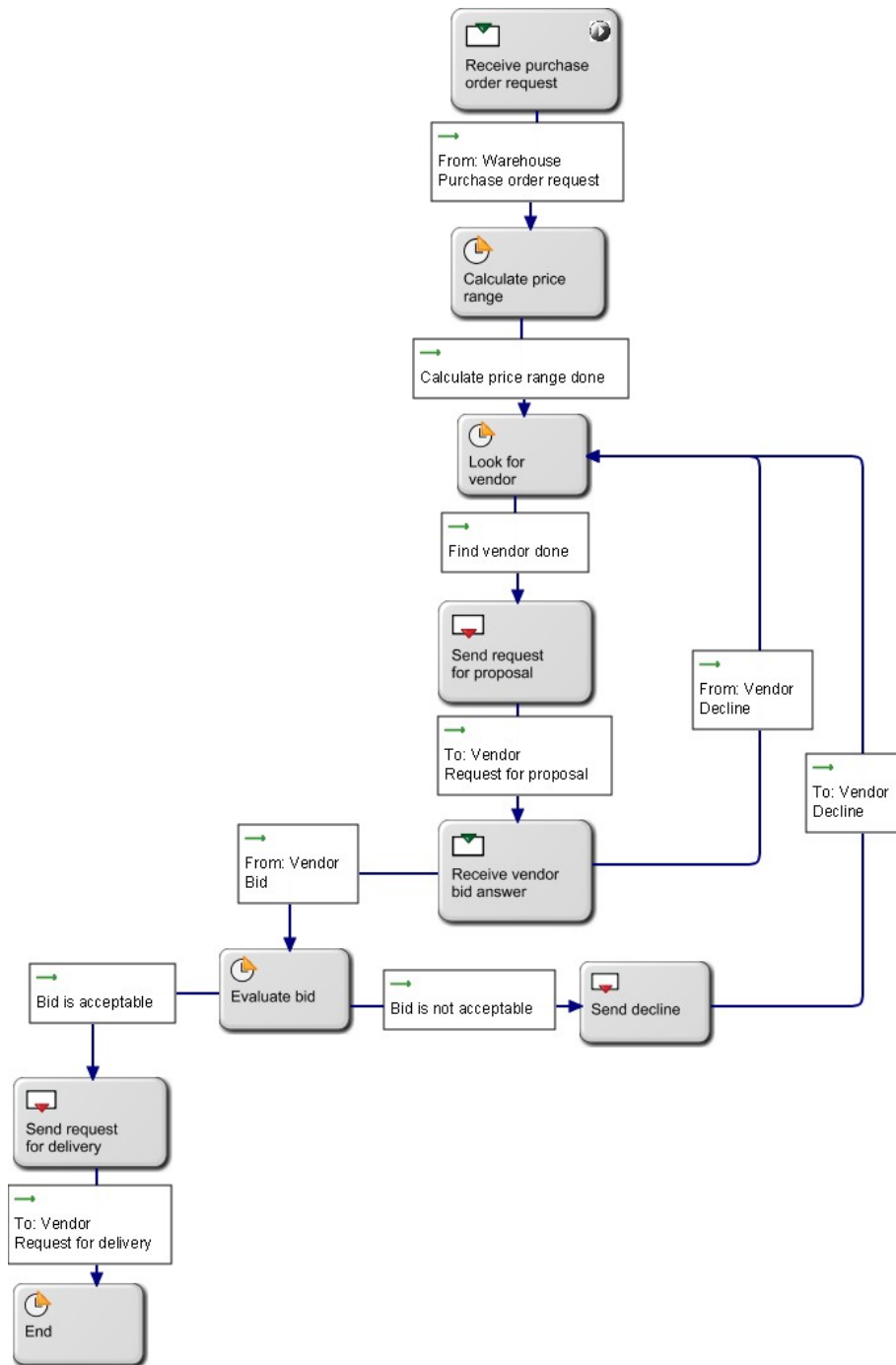
Figure 3.14: Subject Behaviour Diagram of subject purchasing department modelled with metasonic suite. This is one of the four subject of the designed business process to learn S-BPM

3.2.4 User Interface Design

For an intuitve interaction of users in the virtual world, some features are presented in this section.

Cursor types: In order to help users interaction in the virtual world, several cursor types give hints on possible interaction. The cursor type changes depending on the user mouse movement, providing an intuitive way to interact with objects in the virtual world.

Figure 3.15: The three different cursor types: Standard cursor, Click cursor and Drag cursor

Floating Labels: Even though the subject interaction diagram is two-dimensional, it is placed in a three dimensional virtual environment and the user can look at it from different angles. Some of these viewing angles make it difficult to read text. The same applies to the connection text of state cubes in the Subject Behaviour Diagram. Therefore floating labels that turn towards the camera are introduced.

Colour codes: Several colour visualisation are used to support users immersion in the virtual world. Figure 3.9 and Figure 3.16 illustrate the use of colours.
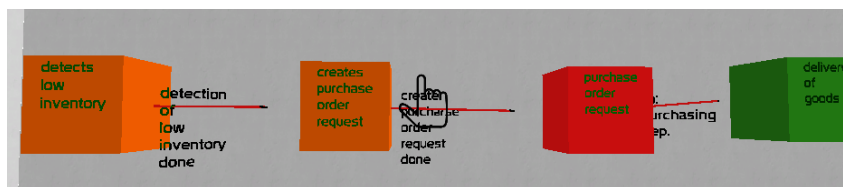

Figure 3.16: The Subject Behaviour Diagram from subject warehouse. The red state cube represents a send state. The orange state cube visualises an action state. The green state cube represents a receive state.

4 Implementation Details

This section contains details of how the virtual world was implemented. Before showing the details of the implementation, the technologies used to build the virtual world will be presented.

4.1 Technologies

An evaluation of platforms to build a virtual world was conducted and the winner was the game engine Unity. In this section the concept of GameObject, Components and Prefab of Unity will be explained. Furthermore, the SmartFoxServer SDK will be introduced.

4.1.1 Unity - GameObject, Components and Prefab

The GameObject is similar to the concept of a class in object-oriented programming. In Unity the GameObject is a container for components. This container allows a composition of components, which represent objects in the virtual world, e.g., an avatar, a desk or an action state. An example of a component is the Transform component, which defines the position, rotation and scale of a GameObject in the game. By adding the components Cube and Mesh Render to the Transform component, a 3D cube representing an action, receive or send state of a SBD can be created. By adding a script to a GameObject, we enable the GameObject to react to the world and users. Unity supports scripting with C# and UnityScript, which is a language specifically designed for Unity (Technologies, 2015).

A Prefab is a GameObject with predefined components, e.g., Script or Box Collider, which can be easily instantiated during runtime using only one line of code. An equivalent GameObject would take more lines of code.

4.1.2 SmartFoxServer

SmartFoxServer is a multi-platform client/server SDK for developing multi-player games and applications. Since 2004, the Italian company gotoAnd-Play() has been continuously refining SmartFoxServer. Many companies like DreamWorks Animation SKG, EA, IBM, to name a few trust in the high-performance and scalable architecture of SmartFoxServer supporting online web and mobile technologies, i.e., Adobe Flash, Unity, iOS, Android, Windows Phone 8, HTML5 and Windows 8. The SDK is available in three different editions. The SmartFoxServer 2X community edition, which is limited to 100 concurrent users, was used for the virtual world implementation. (gotoAndPlay(), 2015b).

Server side

The server runs on Windows, Linux and other Unix-based variants. Server-side extensions allow you to add custom game logic. Figure 4.1 shows the SmartFoxServer 2X platform stack. The network engine, called BitSwarm, is at the bottom of the stack, providing TCP/UDP connectivity, monitoring and network security tools. The Core Services and Managers provide a number of services such as user management, HTTP service and configuration services, which can be accessed by the Server API. The topmost element is the public Server API consisting of two controllers:

- System Controller: deals with system calls, e.g., Login, Join and Create Game
- Extension Controller: dispatch calls to corresponding custom extension

An installation guide for installing SmartFoxServer on a Linux machine is described in the Appendix.
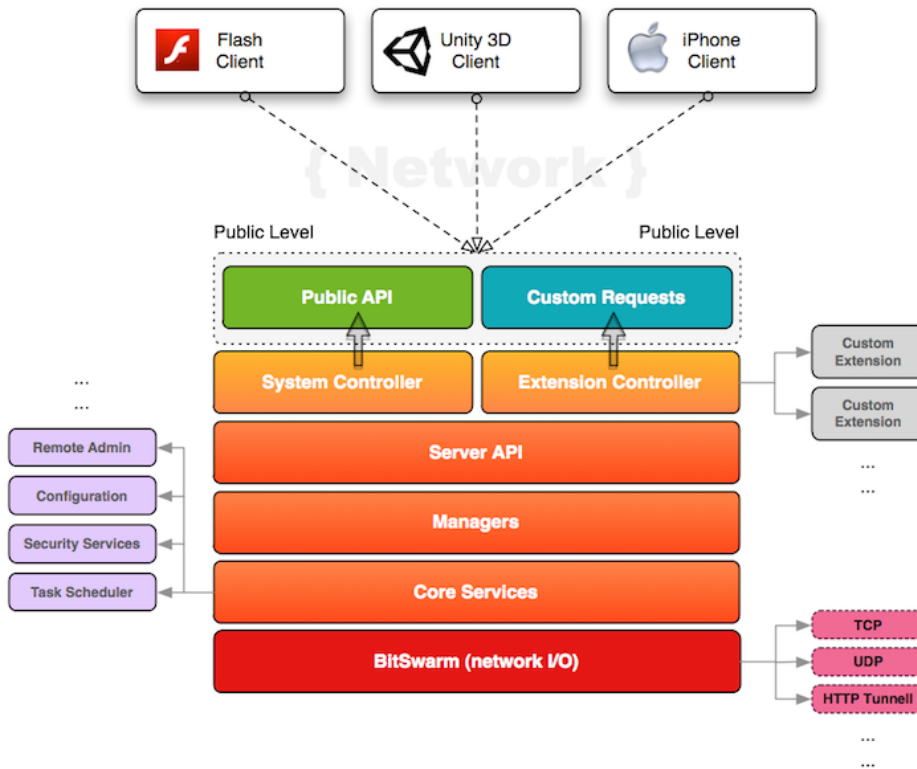
Figure 4.1: SmartFoxServer 2X platform stack (gotoAndPlay(), 2015c)

Client side

Any client using the SFS2X protocol can communicate with the server. SmartFoxServer supports platforms like Unity (standalone, web-player, iOS/Android/Windows 8), HTML5, iOS, Android and many more. The C# client API is required for developing games with Unity using the Smart-FoxServer platform. The API is distributed in the form of a DLL library and must be stored in the /Assets/Plugin folder of the Unity project.

Communication between the Server and the Clients

Clients are connected to a server via a persistent connection using the Transmission Control Protocol (TCP). The server maintains game state updates from the clients and forwards game state updates to clients in order to synchronise all clients.

Two classes called *SFSObject* and *SFSArray* are used for the transmission of data between the clients and the server. For the transmission, *SFSObject* offers a list of values with different types, like a Dictionary/Map, whereas *SFSArray* is used for a list of values of the same type, like an Array (gotoAndPlay(), 2015a). Listing 4.1 shows an example of using the *SFSObject* class to store information for transmission from the server to the clients.

```java
public class State extends GameObject {
  .
  .
  @Override
  public void toSFSObject(ISFSObject data) {
    ISFSObject itemData = new SFSObject();

    itemData.putInt("id", id);
    itemData.putUtfString("type", tag.toString());
    this.transform.toSFSObject(itemData);
    itemData.putUtfString("description", description);
    data.putSFSObject("item", itemData);
  }
}
```

Listing 4.1: Using SFSObject to transmit data between the server and the clients

SmartFoxServer also supports the User Data Protocol (UDP) for the transmission of data. UDP is an unreliable protocol. This means that it makes no provisions for whether a data package arrives at the receiving point or is intact. Therefore it should be used for fast streaming of data like position updates or Voice over IP. UDP is used when the loss of data packages or incorrect packages have little impact. The constant flow of information is more important. For the virtual world, UDP was used for Voice over IP and position updates of the player and items.

Demo

Several examples showing the capabilities of SmartFoxServer are available for download from the SmartFoxServer website. A "3rd Person Shooter" demo for Unity3D was adapted for this virtual world. The demo contains a login window, a chat room and the shooting game. The login window and chat room were reused, whereas the shooting game was redesigned.

4.2 Implementation

Figure 4.2 shows how virtual worlds of all clients are synchronised. Whenever a user performs an action within the virtual world, a request is sent to the server. The server keeps all information of objects of the virtual world. When the server receives a request from a client, the request is processed, e.g., instantiate object or update position. After the processed request, the server updates the clients via sending the respond. The *SFSObject* and *SFSArray* classes are used for the transmission of data.
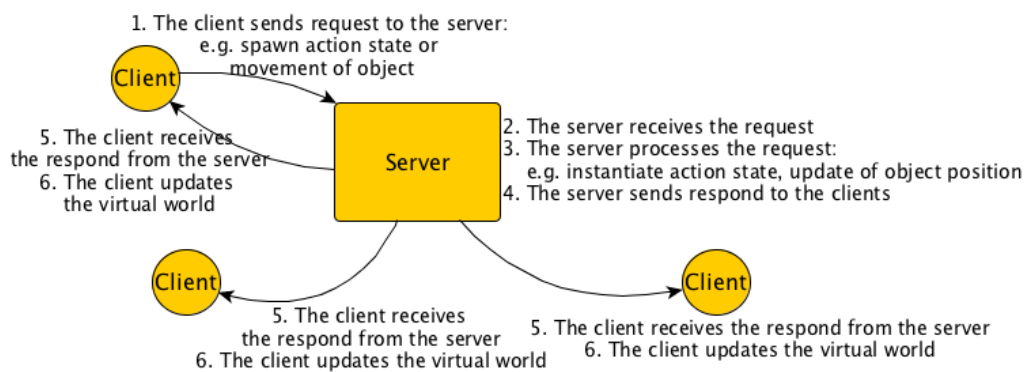

Figure 4.2: Synchronisation of virtual worlds from clients via the server

Note: If the client moves in the virtual world or drags states, then this movement is already performed in the virtual world. The client sends this

movement information to the server which notifies all remaining clients of this position update. The client who sent the request for position update does not need a respond from the server. Listing 4.6 shows the process of transform updates from the server.

The classes including attributes and functions of the server and the clients, will be presented in the next subsection. For reasons of clarity and comprehensibility, not all classes, attributes and functions are included. Several code snippets serve to illustrate the use of these classes.

4.2.1 Server

The UML class diagram in Figure 4.3 gives an overview of the classes and their interrelationships. In addition to the UML class diagram, a short description of the classes is provided.

SFSExtension class is an abstract class from the SmartFoxServer library. It provides an invocation mechanism for requests and events from Smart-FoxServer clients. Custom classes, in which requests and events are processed, can be registered with the *addRequestHandler* function. Requests are then forwarded to the registered class.

GameObject class is an abstract class that provides common attributes, e.g., transform, tag or description of objects within the virtual world. Each subclass of *GameObject* inherits these attributes and the functions *toSFSObject* and *moveTransform*. Each subclass defines what data is stored in a *SFSObject* generated by the function *toSFSObject*. The *moveTransform* function updates the movement of the object within the virtual world.
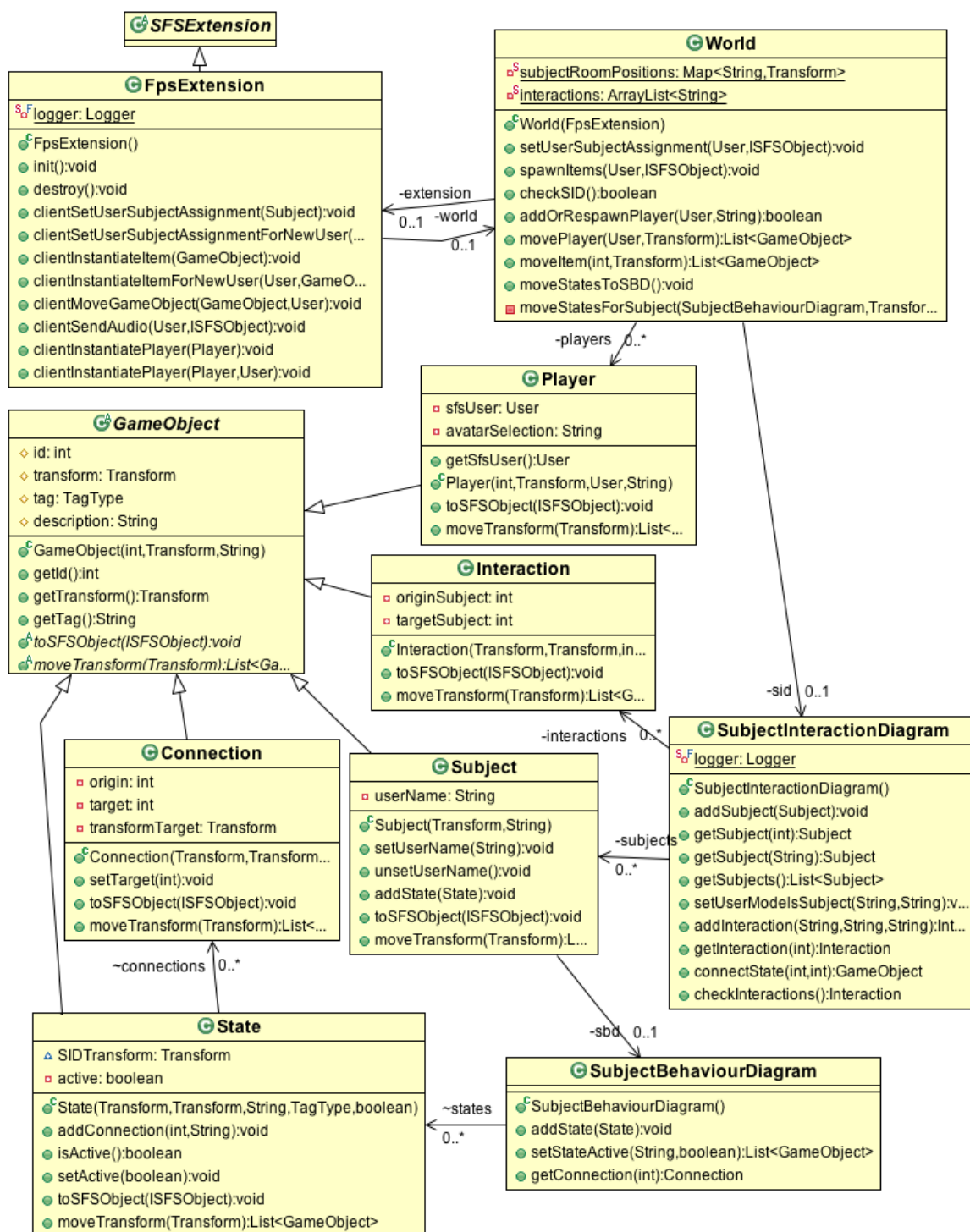
Figure 4.3: UML class diagram showing the structure of the server

FPSExtension class is derived from the *SFSExtension* class. It processes requests and events from the clients. The following requests from the Smart-FoxServer clients are processed:

- *"userSubjectAssignment"* request belongs to task 1, in which users can choose the subjects they would like to model. This request sends the selected subject to the server. The server stores the assignment in *Subject* class in the *userName* attribute and sends all clients to update their virtual world.
- *"spawnMe"* request is sent from a client who wants to spawn a player or items, e.g., action state, interaction in SID or connection in SBD. The type of element to spawn is saved in the *type* attribute shown in Listing 4.4.
- *"sendTransform"*: information about the movement of the player and objects is sent to the server in order to store and forward it to other clients.
- *"sendAnim"* request is sent from a client to the server to forward information about the avatar's movement, e.g., idle or walking.
- *"audio"* request contains the audio byte stream of a client.

For each request from the clients, a custom class which extends the *BaseClientRequestHandler* class is processing the request on the server side. The following Listing 4.2 shows the custom handler *UserSubjectAssignmentHandler* class which processes the request *"userSubjectAssignment"*.

```
public class UserSubjectAssignmentHandler extends
    BaseClientRequestHandler {

  @Override
  public void handleClientRequest(User u, ISFSObject data) {
    World world = RoomHelper.getWorld(this);
    world.setUserSubjectAssignment(u, data);
  }
}
```

Listing 4.2: Custom request handler for processing the request *"userSubjectAssignment"*.

Listing 4.2 shows the server sending the respond for the request*"userSubjectAssignment"*. The *Subject* class contains the *userName* attribute, which saves the assigned user. The *toSFSObject* function of *Subject* class creates a *SFSObject* object,

which is sent to the clients. The clients update their world based on the received *SFSObject* object.

```
public void clientSetUserSubjectAssignment(Subject subject) {
  ISFSObject data = new SFSObject();

  subject.toSFSObject(data);
  Room currentRoom = RoomHelper.getCurrentRoom(this);
  List<User> userList = UserHelper.getRecipientsList(currentRoom);

  this.send("userSubjectAssignment", data, userList);
}
```

Listing 4.3: The server responds to request *userSubjectAssignment*

In addition to requests, the *FPSExtension* class handles the events USER_DISCONNECT, USER_LEAVE_ROOM and USER_LOGOUT. All three events lead to the removal of the player in the *players* attribute in *World* class by *userLeft* function.

World class saves all information about players and items in the virtual world. In the constructor all subject and states with connections are initialised. The functions *addOrRespawnPlayer* and *spawnItems* add the player and items (interaction, connection and action state) to the *World* class.

Subject class represents a subject, i.e., warehouse, purchasing department, accounting or vendor. It saves the SBD of the subject as an *sbd* attribute.

SubjectInteractionDiagram class saves all interaction added by the users to the SID. It also holds the position of blue lines of SID representing subjects. The *checkSID* function verifies the correctness of an interaction a user wants to add to SID. An pseudo-interaction with the description "*SUCCESSALL*" is sent to the clients when SID is completed correctly.

Interaction class represents an interaction in the SID. It saves the source and target subject and the transform information.

SubjectBehaviourDiagram class saves all states and connections of a SBD. During the movement of states form the SID to the rooms, none of the states' connections are shown (see Figure 3.12). After the states have arrived in the subject room, the *setStateActive* function is called. This function adds the connections to all states.

State class represents a state in the SBD. A state can be one of the following three types: action, receive or send. It saves the connections of a state in the *connections* attribute.

Connection class represents a connection between states in the SBD. When a user connects a state with another, the *target* attribute saves the target state.

4.2.2 Client

This section includes an excerpt of prefabs designed for learning subject-oriented business process modelling in the virtual world.

Player prefab is instantiated in order to represent the user. It consists of a Cube Mesh component and the following scripts:

- *Mouse Look.cs* script shows different mouse cursors (hand, forefinger) based on the focused object. The script shows the normal cursor when the Escape button is pressed.
- *NetworkTransformSender.cs* script sends the position of the player to the server.
- *WalkController.cs* script moves the avatar based on the user's keyboard input.
- *AnimationSynchronizer.cs* script sets the animation based on the *WalkContoller.cs* script. The animation state is sent to the server in order to inform the clients of the moving avatar.
- *SIDGUI.cs* script provides a user interface, which allows the to add interactions to the SID and add action states to the SBD.
- *Introduction.cs* script contains instructions, which are shown when the user enters the virtual world. These instructions contain information on how to move an avatar, talk to other users and more.
- *GameHUD.cs* script shows the business process description of a subject based on the user's keyboard input (1,2,3 or 4).

Note: An avatar is only instantiated for other users in the virtual world. As the virtual world does not contain any mirror, an avatar instantiation is not

necessary. All avatars were used from the character pack 02[1] package from the Unity asset store.

Game prefab handles the communication with the server. It sends requests to the server and processes responds from the server:

- *NetworkManager.cs* script sends requests to the server and processes the repsonds from the server. Listing 4.4 shows how a spawn request is sent to the server. Responses from the server are delegated to corresponding scripts. For example, the spawn request of a player is forwarded to *PlayerManager.cs* script and the audio respond is forwarded to *MyLocalVoiceController.cs*.
- *PlayerManager.cs* script is responsible for the spawning of players and other objects like states or interactions.
- *MyLocalVoiceController.cs* script sends microphone input to the server and receives audio from other clients from the server. This class is from the DFVoice[2] package from the Unity asset store.

```
public class NetworkManager : MonoBehaviour
{
  .
  .
  .
  public void SendSpawnRequest(String type, String description) {
    Room room = smartFox.LastJoinedRoom;
    ISFSObject data = new SFSObject();
    data.PutUtfString("type", type);
    data.PutUtfString("description", description);
    ExtensionRequest request = new ExtensionRequest("spawnMe",
        data, room);
    smartFox.Send(request);
  }
}
```

Listing 4.4: Code snippet from the client. Sending a spawn request from a client to the server. The parameter type of the function defines the type of object the client wants to spawn.

Action State, *Send State* and *Receive State* prefab contain a Cube (Mesh Filter), a Mesh Renderer and the following scripts:

---

[1] www.animationarts.de
[2] www.daikonforge.com

- *Drag.cs* script for dragging a state cube.
- *NetworkTransformSender.cs* script sends the altered position of a state cube to the server, so that other clients can synchronise the position.
- *NetworkTransformReceiver.cs* script receives the position from the server and updates the position of the state cube.
- *MakeConnection.cs* script enables connections between states. When a user clicks on a connection and then clicks on the target state cube, this script sends a request to the server to connect the start state cube with target state cube.
- *Text.cs* script displays text on state cubes.

ConnectionLine prefab visualises a connection between two state cubes in a SBD:

- *Text.cs* visualises the description of the connection.
- *ConnectionScript.cs:* this script draws the connecting line between state cubes and holds the user interface logic.
- *LineRenderer* component is used to draw the connecting line.

InteractionLine prefab visualises an interaction between two subjects in the SID:

- *Text.cs* visualises the description of the interaction.
- *InteractionScript.cs:* draws the interaction line.
- *LineRenderer.cs* component is used to draw the interaction line.

4.3 Logic

This section will present the flow of logic within the system. The UML sequence diagrams visualise the internal behaviour of the system on various requests. For better clarity and comprehensibility, not all messages are shown in the UML sequence diagrams.

4.3.1 New Player

The following three UML sequence diagrams visualise the process of a new user joining the game. Figure 4.4 shows that the client uses a *SFSObject* class with *type* and *description* attributes to send a request to the server. *Type* is set to *"player"* and *description* stores the avatar selection of the user.
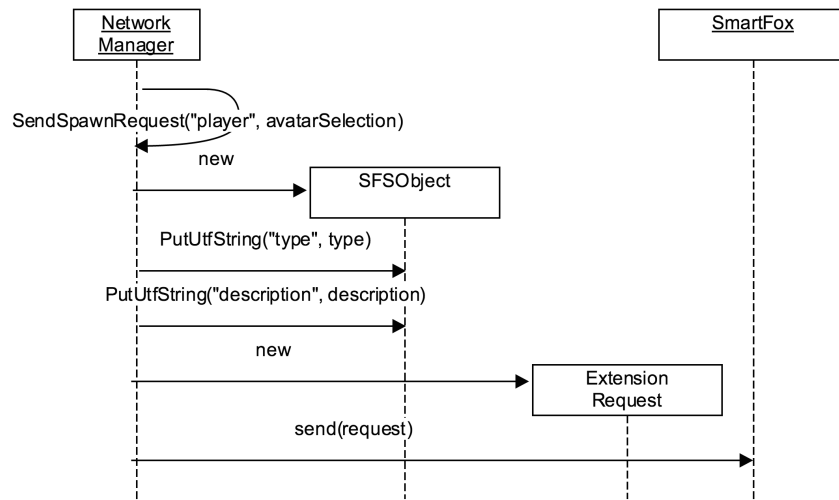

Figure 4.4: Client sends the spawn request of a player to the server.

The server processes the request *"spawn"* from the client. Figure 4.5 visualises the flow of logic on the server side. The request is forwarded to the *SpawnMeHandler* class, which then adds the player to the *World* class. After successfully adding the player on the server, the request to add the player on the client side is sent. All clients receive a response from the server. The client who requested the player spawn adds the *Player* prefab. All the other clients add an avatar to their world.
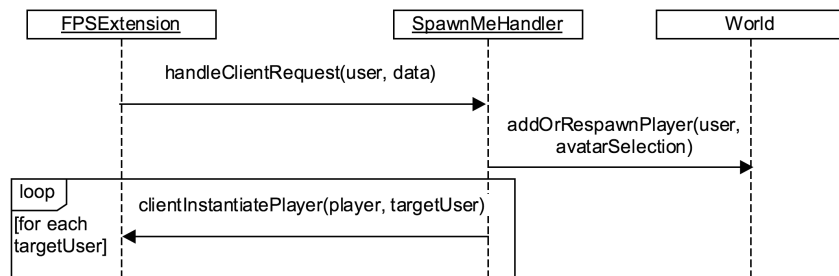
Figure 4.5: UML sequence diagram visualises the logic of a player spawn request on the server side

Figure 4.6 shows how the response of a spawn player request is processed on the client side.
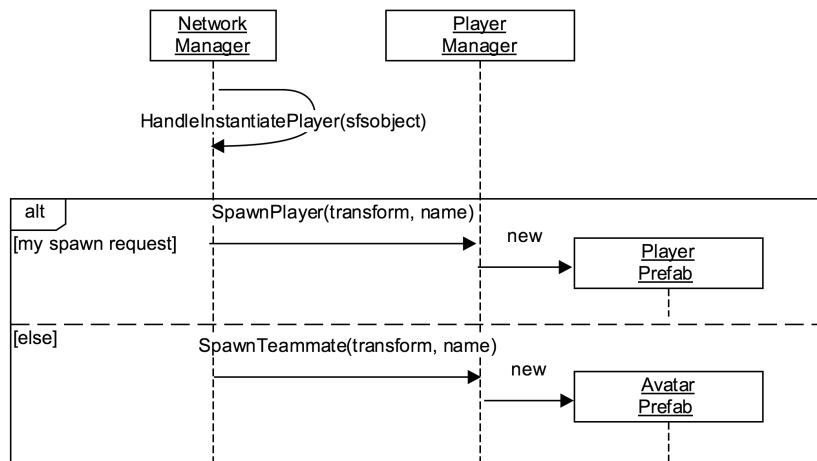

Figure 4.6: Client receiving the response of spawn player from the server

4.3.2 Adding an Interaction to the Subject Interaction Diagram

The logic of adding an interaction to the SID is split between the client and the server. When a user adds an interaction, the client checks the syntax. Only interactions with a correct syntax, i.e., different source and target subject, are sent to the client. Figure 4.7 shows how the client sends a spawn request for an interaction to the server. The request contains the source and target subject of the interaction.
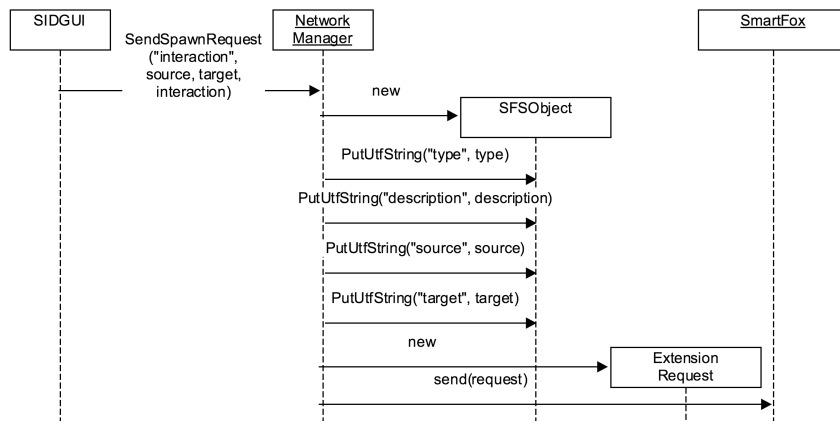

Figure 4.7: Client sending a spawn request for an interaction to the server.

Figure 4.8 visualises how the server processes the spawn request of an interaction. The request is forwarded to the *SpawnMeHandler* class, which forwards the spawn request to the *World* class. The interaction is added to the *interactions* attribute of the *SubjectInteractionDiagram* class. The interactions added by the clients are checked for correctness. Function *checkSID* cross-checks *interactions* with a list of correct *interaction* sequence. If the cross-checking of interactions is correct, then the server sends a response of "spawn interaction" to all clients. If the cross-checking of interactions is not correct, then the latest interaction is deleted and a pseudo interaction spawn response with the description "*FALSE*" is sent to the clients. Furthermore, when the SID is successfully completed, a pseudo-interaction is sent to the

server with the description *"SUCCESS"* and the *moveStatesToSBD* function is executed. This function is described in detail in section 4.3.3.
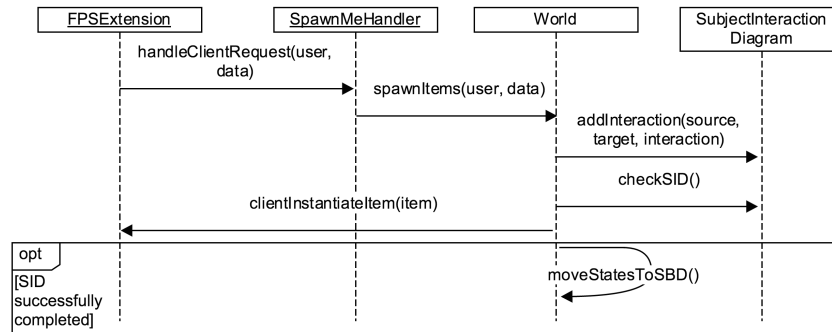

Figure 4.8: Flow of logic on the server of a spawn request for an interaction from a client.

The client executes different actions based on the server respond. The *HandleInstantiateItem* function is called for the instantiation of items like states, connections and interactions. First the *type* attribute from the received *SFSObject* is read. When *type* is equal to *"interaction"*, the interaction logic block is executed. If the description of the received *SFSObject* is *"FALSE"*, then the user is informed that the interaction they wanted to add is wrong. If the description is equal to *"SUCCESS"*, then the user is told that the SID was successfully completed. If no pseudo-interaction with the description *"FALSE"* or *"SUCCESS"* is received, then the client adds an interaction by adding an *InteractionLine* prefab to the virtual world.
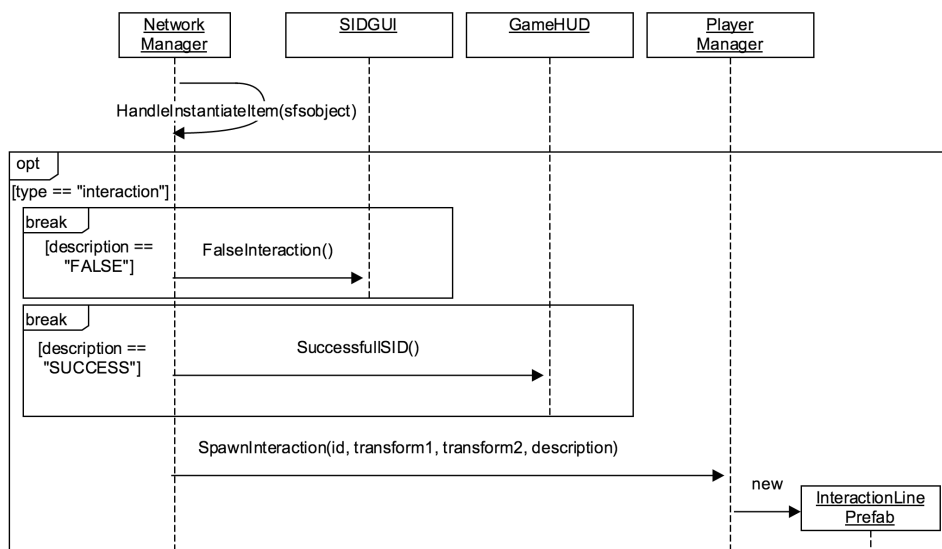
Figure 4.9: UML sequence diagram of the client processing the respond from the server to add an interaction.

4.3.3 Animation of Moving States from Subject Interaction Diagram to Subject Rooms

Successful completion of adding the correct interactions to the SID starts the animation of moving state cubes from the SID to the subject rooms. The function *checkSID* in the *World* class checks the interactions of the SID. When all interactions are correct, the *moveStatesToSBD* function is called. This function calls the *moveStatesForSubject* function (shown in Listing 4.5) for each subject. The *moveStatesForSubject* function spawns the state cubes in the virtual world and moves them from the SID to the corresponding subject room. Every state cube has saved the final position of SBD. A direct line from the SID to the final position in the subject room would move the state cubes through walls. To avoid this, the state cubes are moved through the open doors. Therefore, each route for a set of state cubes from a SBD has two help positions. These positions are given to the *moveStatesForSubject* via the *firstPosition* and *secondPosition* parameters.

Every six seconds a state cube is spawned in the virtual world and moves
to the corresponding SBD. The state cube moves one unit along the X- or
Z-axis every 100 milliseconds.

```java
private void moveStatesForSubject(SubjectBehaviourDiagram sbd,
    Transform subjectPosition, Transform firstPosition, Transform
    secondPosition) {

  class MoveState implements Runnable {
    .
    .
    @Override
    public void run() {
      state.setActive(true);
      extension.clientInstantiateItem(state);
      .
      .
      moveToPosition(firstPosition);
      moveToPosition(secondPosition);
      moveToPosition(finalPosition);
      .
      .
    }
  }
  .
  .
  ExecutorService executor = Executors.newCachedThreadPool();

  for (State state : sbd.states.values()) {
    if (state.tag.equals(TagType.ActionState)) {
      continue;
    }
    Transform startTransform = new Transform(subjectPosition);
    executor.submit(new MoveState(extension, startTransform,
        firstPosition, secondPosition, state));
    try {
      Thread.sleep(6000);
    } catch (InterruptedException e) {
      e.printStackTrace();
    }
  }
}
```

Listing 4.5: Code excerpt of the animation of moving states from SID to the corresponding
subject room

The function *moveToPosition* updates the transform position according to the given parameter. The *State* class provides the *moveTransform* function, which updates position and calls the *clientMoveGameObject* function from the *FPSExtension* class. Listing 4.6 shows the *clientMoveGameObject*, which notifies the clients of a movement of all subclasses of the *GameObject* class.

```java
public void clientMoveGameObject(GameObject go, User fromUser) {
  ISFSObject data = new SFSObject();

  if (fromUser == null) {
    data.putInt("userid", -1);
  } else {
    data.putInt("userid", fromUser.getId());
  }
  go.toSFSObject(data);

  Room currentRoom = RoomHelper.getCurrentRoom(this);
  List<User> userList = UserHelper.getRecipientsList(currentRoom);
  if (fromUser != null) {
    userList.remove(fromUser);
  }

  this.send("transform"+go.getTag(), data, userList, true);
}
```

Listing 4.6: FPSExtension sends movement of GameObject to clients to update position of GameObject in their virtual world

Listing 4.7 shows how the clients process the position update of a GameObject. The client who sent the request to update positions does not need to update the position in the virtual world, as it is already up to date.

```
private void HandleItemTransform(ISFSObject dt) {
  int userId = dt.GetInt("userid");
  ISFSObject itemData = dt.GetSFSObject("item");

  if (userId == smartFox.MySelf.Id) {
    return;
  }

  int itemID = itemData.GetInt("id");
  NetworkTransform ntransform = NetworkTransform.FromSFSObject(
      itemData);
  NetworkTransformReceiver recipient = PlayerManager.Instance.
      GetItemRecipient(itemID);
  if (recipient != null) {
    recipient.ReceiveTransform(ntransform, userId);
  }
}
```

Listing 4.7: Client processing a position update of a GameObject.

In the next section the evaluation settings and result will be presented.

5 Evaluation of the Virtual World

This section contains the result of the evaluation of the virtual world with students from FH Joanneum. Before discussing the evaluation result, the research methodology and evaluation settings will be presented.

5.1 Research Methodology

The following three research questions were defined for the evaluation of the virtual world:

- **Usability and immersion**: How users feel when interacting within the virtual world?
- **Learning process**: Has the virtual world design and concepts supported learning S-BPM?
- **Learning result**: Have users actually learned S-BPM?

The assessment of the research questions was performed with a pre- and post-questionnaire. Users had to answer the pre-questionnaire before entering the virtual world and the post-questionnaire after leaving the virtual world. Several questions were defined to answer the research questions from different perspectives. The following question types were used: open-ended question, Likert-scale (1 strongly disagree, 5 strongly agree) and single choice questions. Both questionnaires are listed in the Appendix section. The open source online survey tool LimeSurvey[1] was used. The survey was carried out in the anonymous mode.

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[1]www.limesurvey.org

5.2 Settings

The evaluation was performed at FH Joanneum[2], supervised by Professor Robert Singer. All students are studying Information Management (Bachelor). The evaluation was done as a homework assignment in the course Business Process Management. In this course, students learn the basics of business process management, e.g., BPMN and S-BPM. Robert Singer supported this new approach to learn S-BPM. The students were perfect candidates for an evaluation as they are familiar with the concepts of business process management but new to S-BPM. The server for the virtual world was provided by FH Joanneum.

5.3 Result

All 31 students from the Business Process Management course were asked to evaluate the virtual world. 29 of the 31 students answered the entire pre-questionnaire and 25 students answered the entire post-questionnaire. The students were asked to divide in to several groups spanning from two up to four students. The following constraint of the group size was given:

	number of groups
group of 2 users	6
group of 3 users	1
group of 4 users	4

Table 5.1: Proposed group size distribution

As stated in the research methodology, a Likert-scale with 1 for strongly disagree and 5 for strongly agree was used.

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[2]www.fh-joanneum.at

66

5.3.1 Pre-Questionnaire

This questionnaire contained questions about age, gender, experience with modelling notations and gaming, collaboration in virtual worlds as well as the attitude towards virtual worlds.

Participants

The age of the users ranged from 20 to 29 (M=22.38; SD=2.19). Eight users were female and 21 male.

Modelling experience

Figure 5.1 shows the users' experience with various modelling notations. An absolute beginner is defined as a user who has no theoretical knowledge of a modelling notation.
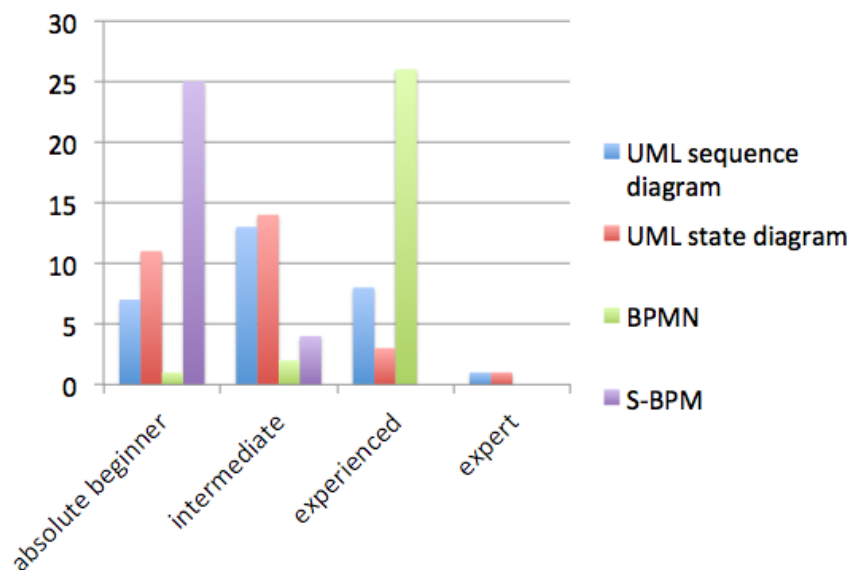
Figure 5.1: Distribution of modelling experience

25 users declared themselves absolute beginners on S-BPM. On the other side, intermediate users already have theoretical knowledge but no practical experience with a modelling notation. Most users stated to be intermediate users in regard to UML sequence diagrams and UML state diagrams. 26 users stated to be experienced in BPMN. Experienced users already have some practical experience with a modelling notation. An expert is someone who has a lot of practical experience with a modelling notation. Only one, not necessarily the same person, stated to be an expert on UML sequence diagrams and UML state diagrams. The distribution shows that the majority were absolute beginners regarding S-BPM, but were intermediate regarding UML diagrams or/and experienced with BPMN. A perfect basis for learning S-BPM, as concepts of UML and BPMN are similar to S-BPM.

Gaming Experience

Figure 5.2 shows the distribution of users playing video games and Massively Multiplayer Online Games (MMOG).
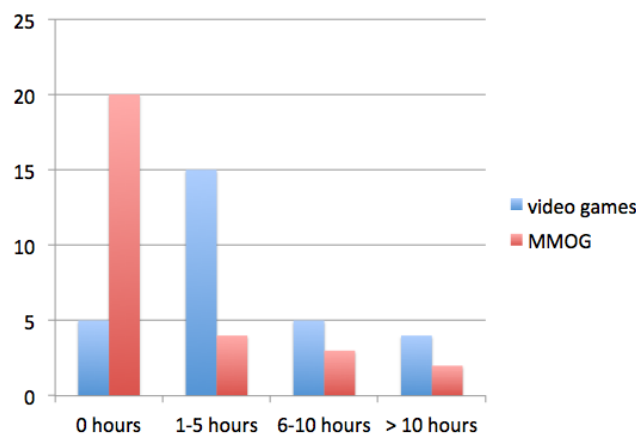

Figure 5.2: Distribution of video games and MMOG

The majority of the participants, 15 users, play video games about 1 to 5 hours per week. The rest of the users playing video games are evenly

divided in the remaining three categories. Looking at users playing MMOGs, the majority of 20 users stated not to play such games.

Collaboration

Users rated collaboration and interactivity in learning as well as a graphically rich learning environment to be important, with (M=3.31; SD=1.11), (M=3.34; SD=1.04), (M=3.34; SD=1.14) respectively. Only 4 of the 29 users stated to have ever worked collaboratively in a virtual world.

Attitude on Virtual Worlds

Users were asked if they see an advantage in using virtual worlds for learning. This is an excerpt of answers from the users:

- *"Yes, because for gamer it is interesting for example to play and learn simultaneously."*
- *"You can learn practical applications of theoretical stuff, if the virtual world is well programmed."*
- *"Learning by doing could be a good way to learn, there is also a positive learning effect when someone can interact with things virtually"*
- *"Experienced users can help you"*
- *"Learning while playing"*

Furthermore, the users were asked whether they see any disadvantages using virtual world environments for learning. The users answered:

- *"Social aspect is reduced"*
- *"Not using these tools regular, maybe they are not intuitive or too complicated"*
- *"Maybe the effect of learning is not that good like learning in a traditional way."*
- *"Too easily distracted"*
- *"The personal contact is missing"*

The statements show that the users had mixed feelings about virtual worlds.

5.3.2 Post-Questionnaire

The first question of the post-questionnaire that users had to answer was how they liked the virtual world. No one of the users stated to be impressed by the virtual world. 14 users (56 percent) said that the virtual world is OK. 8 users (32 percent) did not like the virtual world. 3 users (12 percent) had some issues with the virtual world. This question was used to capture the mood of the users after leaving the virtual world. The remaining questions will help to understand why so many users stated that the virtual world was OK, that they did not really like the virtual world or had issues.

Usability

The usability was assessed with the standardised System Usability Scale (SUS) and various custom questions. The SUS was created by John Brooke in 1986 and has become an industry standard tool for measuring subjective usability (Brooke, 1996). It consists of 10 questions using a 5 Likert scale providing subjective feedback from the users. The SUS value lies between 0 and 100. An interpretation of the scale is provided by Miller (2009), shown in Figure 5.3.
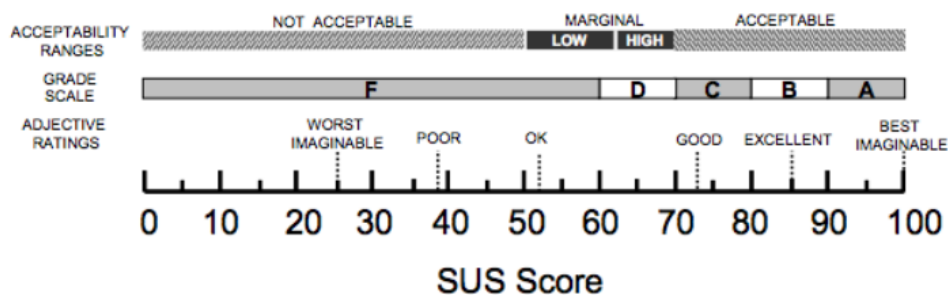

Figure 5.3: A comparison of the adjective ratings, acceptability scores, and school grading scales, in relation to the average SUS score (Miller, 2009)

The mean value of the SUS is 48.5 and the standard deviation is 17.50. Compared to the virtual world from Pirker et al. (2013) with a mean SUS

value of 73.89 but also a high standard deviation of 22.81, the virtual world is ranked at an average low level. The two questions *"I think that I would need the support of a technical person to be able to use this system"* and *"I needed to learn a lot of things before I could get going with this system"* were rated strongly disagree with 56% and 52% respectively. As shown in Figure 5.3 the low SUS value states that the usability is not acceptable and the users' adjective rating is between poor and OK. The SUS value does not state why the usability is rated so poorly. Two open-ended questions about the usability were added to the post-questionnaire asking about issues users encountered and what they did not like in the virtual world. The result is that users had issues with the controls, font, error messages and task descriptions.

Controls: The majority of the users complained about the sensitivity of the mouse cursor. They stated that the mouse was moving too fast. One user said that the controls were counterintuitive.

Font: Many students had problems reading the task description on the walls and suggested to use a more readable font.

Error Messages: Three users complained that the error messages pop up if any user tries to add a wrong interaction to the SID. The pop-up window displaying the error message was initiated to make (wrong) actions of other users visible to all. These notifications were intended to facilitate discussions. The three users stated that the pop-ups were disturbing the game play.

Task Descriptions & Instructions: Some users stated that the explanation of tasks could be improved and that the purpose of tasks had not been so clear. Three questions about the clarity of instructions on the three tasks were rated insufficient. Task 1 with a mean value of 3.16 (SD=1.31), task 2 with a mean value of 2.56 (SD=0.96) and task 3 with a mean value of 2.48 (SD=1).

The post-questionnaire also contains questions about the level of immersion. The bad SUS result is reflected in the immersion of users. The low mean value of 2.8 (scale 0 to 10) shows that users did not feel immersed at all. Users did not feel like in the real world whilst playing (M=1.6; SD=0.96), although the interior of the virtual world (e.g., desk, forklift truck, container) supported the user immersion a little bit (M=2.8; SD=0.96).

Learning process

One purpose of the virtual world is to support the process of learning S-BPM. Several questions assessed whether the concepts designed to support learning S-BPM are actually working.

The concept of **subject representation** in the form of rooms was rated with a mean value of 2.96 (SD=1.06).

The **limitation** of displaying business process description text based on the subject assignment of the user forces users to communicate with each other to solve SID. This concept was rated with a mean value of 2.84 (SD=1.11).

The questions about **colour highlighting** of receive and send states in the business process text to supports learning was rated with a mean value of 3.2 (SD=1.26) for task 2 and a mean value of 3.28 (SD=1.14) for task 3.

Moving states from SID to SBD to support learning of S-BPM was rated with a mean value of 2.8 (SD=1).

The statement "I like the idea of **3D modelling** by moving states via drag and drop in a virtual world" was rated with a mean value of 3.04 and a standard deviation of 1.34.

Collaboration on task 3: Users were asked if they helped someone with task 3 and if so, whether they think that they supported their colleagues. All users rated this question. The mean value is 2.48 with a standard deviation of 1.08. A second question asks users to answer if someone supported them with task 3 and whether they think it helped them. Nine users answered this question, with a mean value of 2.44 and standard deviation of 0.73. Two more general questions were asked about whether the environment supports collaboration and if learning together with other students supports learning. The two questions were rated with a mean value of 3.04 (SD=1.17) and a mean value of 3.16 (SD=1.14) respectively.

Group Size: Users were asked how many users were in the virtual world and what their impression of the group size was.

As not all users completed the post-questionnaire, the distribution of group size is different from the proposed one. Anyway, the majority was happy

	number of users	smaller	ok	larger
group of 2 users	11	-	8	3
group of 3 users	5	0	3	2
group of 4 users	9	3	6	-

Table 5.2: Actual group size distribution and feedback to group size

with their group size. An assumption about the perfect group size cannot be made with the given data.

Learning result

At the end of the post-questionnaire, a short test assessed whether the users had actually learned the concepts of S-BPM. Provided with a business process text of a subject, the users had to answer five questions. The following Table 5.3 shows the questions and the distribution of the right answers.

ID	Question	% with correct answer
1	How many Subjects does the Subject Interaction Diagram have based on the business process text of Employee?	52%
2	How many ingoing interactions does Subject Employee have in the Subject Interaction Diagram?	72%
3	How many outgoing interactions does Subject Employee have in the Subject Interaction Diagram?	84%
4	The interaction "Employee sends holiday request to Manager" becomes what in Employee's and Manager's Subject Behaviour Diagram?	68%
5	How many action states does Subject Employee have in the Subject Behaviour Diagram?	68%

Table 5.3: Five questions to proof acquired knowledge of users on S-BPM

Although the usability of the virtual world was rated poor and users were complaining about insufficient task description, the results of testing the acquired knowledge on S-BPM, are worth mentioning. Each question was answered correctly by more than 50 percent of the users. The first three questions of Table 5.3 are about SID. The remaining two questions are about SBD. Question 2 and 3 stand out with 72% and 84% correct answers respectiv「ely. This shows that the task 2 with modelling interactions has helped users to learn how to model SID. Before the test, users were asked if they think that they had learned S-BPM. The mean value is 2.2 with a standard deviation of 1.04.

Miscellaneous: Although mainly all users encountered some difficulties in the virtual world, some users saw some potential in using a virtual world. The positive answers of users to *What did you like within the virtual world?* are:

- *"The idea behind the "game" is very good, for international projects, this could be a good solution for planning, maybe in the future people use virtual devices, like body suits, glasses with displays in combination with this software to work together in a virtual world"*
- *"It is pretty realistic and therefore a good way to learn the practical work"*
- *"The idea to try a different way"*
- *"That you have to solve a task together"*
- *"I liked gaining knowledge by playing games, and in a visual way"*

5.3.3 Discussion

Many impediments led to a poor **usability**, but the encountered problems can be easily solved. For example, using a different font that supports readability, avoiding pop-up windows and providing users with an option to adjust mouse sensitivity. A workshop with the users might result in further improvements. Users can describe what exactly was not clear about the task descriptions and how they could be improved.

Almost all designed concepts that should support the **learning process** were rated average. The following two concepts were rated highest: Colour coding of business process text with a mean value of 3.2 (SD=1.26) for

task 2 and a mean value of 3.28 (SD=1.14) for task 3 and *learning together with other students supports learning* with a mean value of 3.16 (SD=1.14). Why the concepts of moving states from SID to SBD and the limitation of business process text visible to users based on chosen subjects were rated average cannot be answered with the questionnaire. Again, a workshop might answer why some concepts were not rated to support learning. Furthermore, it is important to facilitate concepts that supported learning. An example could be to also use colour coding in business process text for subjects and objects and not only for predicates.

The research question about the **learning result** of users in the virtual world is remarkable. More than 50 percent of the users correctly answered all five questions testing the acquired knowledge on S-BPM. 72 percent and 84 percent of the users correctly answered the question about ingoing and outgoing interactions. Most users answered the question about how many subjects are in the Subject Interaction Diagram wrong. Colour coding of subjects in the business process text, as already suggested above, could help users to identify the number of subjects in a business process.

The evaluation was done with a very homogenous group of people. All users had business process modelling background. An evaluation with a more heterogenous group of people with different backgrounds in regard to business process modelling is suggested. Also, an experiment could be carried out, in which a group of users had a person who is an expert on S-BPM. This expert could help users who have trouble with a task or do not understand the concept of S-BPM. The expert would gather all the difficulties that user encounter. All these difficulties could be tackled in a successive version of the virtual world.

6 Lessons Learned

This section covers some of my lessons I learned during my thesis. To put it straight: "Keep it short and simple as well as try to fail fast".

6.1 Thesis Methodology

The thesis methodology proposed in chapter 1 consists of three phases. The first phase encompasses a literature review & interviews. The knowledge extracted from the first phase is then used for the second phase: design & implementation. The last phase is the evaluation by experiment. The design & implementation phase consists of a loop of implementation, evaluation by experts and redesign. The evaluation showed that many users did not like the text font, task descriptions and mouse sensitivity. Including users in the development process would have helped to improve the virtual world. Figure 6.1 shows the proposed methodology with a feedback loop from the evaluation phase to the development phase. Therefore, an evaluation of the virtual world should not be done only once at the end. An iterative and incremental development with early feedback in the forms of user evaluations should be considered. Not only feedback from experts but also user feedback should be used for the redesign of the virtual world.

Figure 6.1: Proposed Methodology with a loop from design & implementation phase to evaluation by experiment phase

6.2 KISS

Keep it short and simple. First proof that the simplest version of a concept works and then iteratively add more functionality to it. Many functionalities were overloaded and too complex. For example, the first design for SID to manipulate interactions. Users could add wrong interactions to the SID and manipulate interactions with the options delete or moving an interaction. Figure 6.2 shows the functionality that allows users to manipulate interactions in the SID.
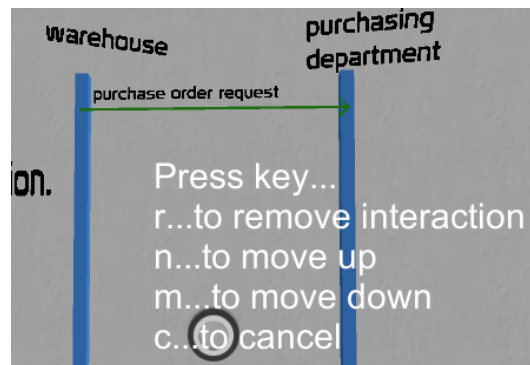
Figure 6.2: First User-Interface Design for Subject Interaction Diagram

A discussion with an expert suggested that this functionality might be too difficult for users. A simpler design with early feedback of correctness would lead to a happier user.

6.3 Technology

The idea was that a public online server hosts the virtual world, making it possible to enter the virtual world from anywhere around the globe. Unfortunately, the UDP connections used for audio and the synchronisation of avatar positions were not sufficient for fluent gaming.

As the system grows with each functionality, refactoring is indispensable. Refactoring is time consuming as not only code is re-structured but the system also needs to be tested again. Testing a virtual word as a single user is quite cumbersome.

Furthermore, tackle functionalities with high value and high risk first. It is better to fail fast with an implementation of high value rather than doing the implementation at the end.

7 Suggestions for Future Work

This section contains suggestions for future work. The suggestions are for the virtual world, including insights from the evaluation, and S-BPM concepts, as the virtual world does not cover all S-BPM concepts.

7.1 Virtual World

Insights from the evaluation: Improve the usability by providing the user with a way to adjust the mouse sensitivity, using a better readable font, an an alternative to pop-up windows. Furthermore, a different way of presenting the task description and aim of tasks is suggested. The learning result questions in the evaluation show that the users answered the interaction questions on task 1 better than the question about how many subjects the SID has. Therefore, a colour highlighting of subjects could help users. In addition, just as users were able to add interactions, the same should be possible for subjects. Subjects should not already be present in the virtual world as vertical lines. Users should have to add them to the virtual world.

New User Interface: Poppe et al. (2013) present a prototype, which uses a Microsoft Kinect as an immersive interface to control an avatar. The body posture, motion and facial expression of a user are automatically captured and displayed in real-time on the avatar. The video "Using Natural User Interfaces for Collaborative Process Modelling in Virtual Environments" available on YouTube[1] shows the prototype with the additional use of a virtual reality headset, see Figure 7.1 (Poppe, 2013). This provides the user with a better sense of immersion than when controlling the avatar with mouse, keyboard and monitor.
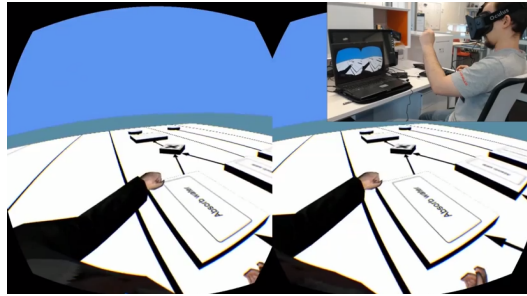
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[1]https://www.youtube.com/watch?v=nvfoBfWpxKU

Figure 7.1: Natural user interfaces for virtual world BPMN process modelling tool (Poppe, 2013). Using Microsoft Kinect and virtual reality headset Oculus Rift

Using a Microsoft Kinect and virtual reality headset in future work would allow users to experience a better immersion.

7.2 S-BPM

The virtual world is designed for people with little to no knowledge of subject-oriented business process modelling. In order do not overburden users, some S-BPM aspects have not been considered.

External subject: If the internal behaviour of a subject is unknown, then this subject is modelled as an external subject (black box). A typical example for an external subject is a customer whose internal behaviour is unknown. In a future work, the concept of external subjects could be included.

Multiple subjects: An example for multiple subjects are external suppliers. As most external supplies will behave the same way, the internal behaviour of one external supplier is modelled, which then represents multiple subjects. The S-BPM book *"S-BPM illustrated"* introduces S-BPM notation to readers, but does not cover multiple subjects. The virtual world S-BPM Elicitator from Joel Harman also does not cover the external subject and multiple subject concept.

End-States: S-BPM allows the marking of states in the SBD as an end state. This is necessary if a subject has to respond in a given time frame. If the

subject has not responded in the given time frame, the process must be terminated no matter what state it is in (Fleischmann, Rass, and Singer, 2013).

Business processes: The concept of business processes was designed for the learning of S-BPM in the virtual world. Various business processes ranging from simple to complex would support the learning process. Users can start with simple business processes to learn the state notation. Then more and more complex business processes could be modelled with several branches and loops. The user would grow with each new business process, applying already learnt knowledge to strengthen their knowledge and challenge it with new input.

Individuality: Rather then providing the business process texts of subjects, the users themselves should have the opportunity to define interactions and action states. For example using a textbox to define an action of a subject. This concept would require a lot of creativity from the user and that users are familiar with S-BPM.

8 Conclusion

The goal of this thesis was to build a virtual world for the collaborative learning of subject-oriented business process modelling (S-BPM). A comprehensive literature review and talks with many **business process experts** were the foundation for the design of the virtual world. A strong emphasis was placed on how the virtual world can support the learning process. Some of the concepts are the representation of subjects as rooms, moving 3D states from Subject Interaction Diagram to Subject Behaviour Diagram, colour coding of business process text, limitation of business process text based on subject assignment of the user, just to name a few.

An **evaluation of platforms** to build a virtual world was conducted. The winner was Unity, which was used to build the virtual world. The virtual world provides an **authentic environment** with interior furnishing. A **business process** was **especially designed** for the virtual world. This business process is a procurement process of goods containing four subjects, i.e., warehouse, purchasing department, vendor and accounting. Users of the virtual world can modell the interaction between the subjects (Subject Interaction Diagram) as well as the internal behaviour of a subject (Subject Behaviour Diagram). This is the **first virtual world** in which users can model the Subject Interaction Diagram (SID).

An evaluation was made with students from the FH Joanneum. All 25 students were participants of the Business Process Management course. **Three research questions** on usability, the learning process and the learning result were evaluated. The **usability** of the virtual world was rated low. Users did not like the mouse sensitivity, the font used for task description, the pop-up windows and that the task descriptions were not clear enough. The problems that caused the bad usability can be solved easily. There was no fundamental problem that caused bad usability results. Almost all

designed concepts that should support the **learning process** were rated average. The following two concepts were rated highest: Colour coding of business process and learning together with other students supports learning. Why the concepts of moving states from SID to SBD and the limitation of business process text visible to users based on chosen subjects were rated average cannot be answered with the questionnaire. A workshop might answer why some of the designed concepts were rated average. The research question about the **learning result** of users in the virtual world is remarkable. More than 50 percent of the users correctly answered all five questions testing the acquired knowledge on S-BPM. 72 percent and 84 percent of the users correctly answered two questions on interactions in the SID.

The evaluation result provides a feedback that can be used to improve the current virtual world. Little adjustments would increase the usability and immersion, which could lead to better learn results. As learning is a never-ending process, so is the development of a learning environment.

The following two statements of participants **after the evaluation** show the impression on virtual worlds:

- *"The idea behind the "game" is very good, for international projects, this could be a good solution for planning, maybe in the future people use virtual devices, like body suits, glasses with displays in combination with this software to work together in a virtual world"*
- *"It is pretty realistic and therefore a good way to learn the practical work"*
- *"I liked gaining knowledge by playing games, and in a visual way"*

Table 8.1 gives a summary of the methods to learn S-BPM. The last row presents the virtual world developed in this thesis. All drawbacks of the other methods are overcome with the virtual world.

Method	Pro	Cons
S-BPM illustrated	This book provides step-by-step instructions to model a real-life business process in metasonic suite; self-organised learning	The book does not support collaborative learning.
Metasonic touch	The modelling table is a shared working environment. Modelling is visual and intuitively	The table is not suitable for geographically dispersed people; heavy to transport; Focus on modelling SBD, but not on SID; Requires a users who is already familiar with S-BPM.
Progressive Education Environment	The virtual world support self-organised learning and collaborative learning of S-BPM	The virtual world does not support modelling of SID and SBD.
VW S-BPM Elicitator	The virtual world provides an authentic environment to model SBD by interaction with various 3D objects, e.g., printer, computer	The virtual world does not support collaboration (single-player mode). Focus only on modelling SBD and not SID.
VW presented in this thesis	The virtual world provides an authentic environment to model SID and SBD; Simulations to support learning;	Usability needs to be improved. Not full coverage of S-BPM notation.

Table 8.1: Overview of methods to learn S-BPM

Virtual world - a right place to learn: We live in a rapidly changing technological and social environment. Learning does not stop after school, Day to day work requires self-organised knowledge acquisition (Laal and Salamati, 2012). The virtual world presented in this thesis offers a learning environment for the digital age. Learning is not restricted to a specific time or place.

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Appendix

Pre-Questionnaire VW S-BPM

Usability Study

Dominik Angerer
Institute for Information Systems and Computer Media
Graz University of Technology

There are 18 questions in this survey

Personal information

[]Age *

Please write your answer here:

[]Gender *

Please choose **only one** of the following:

- ◯ Female
- ◯ Male

Business Process Modelling background knowledge

[]This question is about UML sequence diagrams (Unified Modelling Language). Please choose appropriate answer: *

Please choose **only one** of the following:

⚪ I do not know what a UML sequence diagram is

⚪ I know the theory on UML sequence diagram but I do not have any practical experience

⚪ I know the theory on UML sequence diagram and I have some practical experience

⚪ I am an expert on modelling UML sequence diagrams

[]
This question is about UML state diagrams (Unified Modelling Language). Please tick appropriate answer:
*****

Please choose **only one** of the following:

⚪ I do not know what a UML state diagram is

⚪ I know the theory on UML state diagram but I do not have any practical experience

⚪ I know the theory on UML state diagram and I have some practical experience

⚪ I am an expert on modelling UML state diagrams

[]
This question is about BPMN (Business Process Modelling Notation). Please tick appropriate answer:

*****

Please choose **only one** of the following:

⚪ I do not know what BPMN is

⚪ I know the theory on BPMN but I do not have any practical experience

⚪ I know the theory on BPMN and I have some practical experience

⚪ I am an expert on modelling diagrams with BPMN

[]This question is about S-BPM (Subject-Oriented Business Process Modelling). Please tick appropriate answer: *

Please choose **only one** of the following:

- ◯ I do not know what S-BPM is
- ◯ I know the theory on S-BPM but I do not have any practical experience
- ◯ I know the theory on S-BPM and I have some practical experience
- ◯ I am an expert on modelling diagrams with S-BPM

Experience with the computer and virtual worlds

1 = strongly DISAGREE .... **5 = strongly agree**

[]How many hours per week do you play video games? *

Please choose **only one** of the following:

○ I don't play video games

○ 1-5 hours

○ 6-10 hours

○ More than 10 hours

[]How many hours per week do you play massively multiplayer online role-playing games? *

Please choose **only one** of the following:

○ I don't play MMO games

○ 1-5 hours

○ 6-10 hours

○ More than 10 hours

[]I am expert in usage of virtual world environments. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]If you play video games where do you play these games?

Please choose **all** that apply:

☐ Smartphone/Tablet

☐ Laptop

☐ Computer

☐ Console

[]If you already have experience with virtual world environments what did you use it for?

Please choose the appropriate response for each item:

	1	2	3	4	5
Gaming	○	○	○	○	○
Socializing	○	○	○	○	○
Learning	○	○	○	○	○
Working together on a project	○	○	○	○	○
Communication/Meetings	○	○	○	○	○
Advertising	○	○	○	○	○
Commercial (sales)	○	○	○	○	○
Entertainment	○	○	○	○	○
Simulated experiences	○	○	○	○	○
Training	○	○	○	○	○
Tourism	○	○	○	○	○

[]If you already have experience with virtual world environments did you ever work collaboratively in such environments?

Please choose **only one** of the following:

○ Yes

○ No

[]Do you see advantages of virtual worlds used for learning? Where do you see those? *

Please write your answer here:

[]Do you see disadvantages of virtual worlds used for learning? Where do you see those? *

Please write your answer here:

[]What learning objectives and activities would you like to use in a virtual world? *

Please write your answer here:

[]Is collaboration in learning important to you? *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]Is interactivity in learning important to you? *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]Is a graphically rich learning environment important to you? *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

Post-Questionnaire VW S-BPM

Usability Study

Dominik Angerer
Institute for Information Systems and Computer Media
Graz University of Technology

There are 46 questions in this survey

Impression of the virtual world

[]**What's your first impression of the virtual world? ***

Please choose **only one** of the following:

○ I'm impressed

○ The virtual world is OK

○ I didn't like the virtual world

○ I had some issues with the virtual world

[]**If you had issues with the virtual world then please specify them bellow**

Please write your answer here:

[]What did you like within the virtual world?

Please write your answer here:

[]What did you NOT like?

Please write your answer here:

[]Please write down your suggestions for improvement.

Please write your answer here:

[]

Would you use such a virtual world for learning other subjects? If yes, what subjects, otherwise please describe why not.

Please write your answer here:

Assessment of concepts to support learning I

1 = strongly DISAGREE   ....   5 = strongly agree

[]The representation of subjects (warehouse, vendor, ..) as single rooms supports learning the concept of subject-oriented business process modelling. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]The instructions of task 1 (choosing subjects) were clearly defined and I knew what to do *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]

This question is about the limitation of only allowing to read business process text of chosen subject(s) based on task 1. With this restriction you were forced to communicate as you couldn't see the other subject business process text.

I agree that this concept supported my learning progress. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]The instructions of task 2 (modelling interactions) were clearly defined and I knew what to do. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]Colour highlightning of receive and send states in the business process text supported me to complete task 2. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]The movement of receive and send states of the Subject Interaction Diagram to the corresponding subject rooms supported to learn the concept of subject-oriented business process modelling. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]The instructions of task 3 (modelling internal behaviour of subject) were clearly defined and I knew what to do. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I like the idea of 3D modelling by moving states via drag and drop in a virtual world *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]Colour highlightning of receive, send and action states in the business process text supported me with the completion of task 3 *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]

If you helped others with task 3 then please answer this question.

I think I helped my colleagues to learn modelling of internal behaviour of a subject. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]

If someone helped you with task 3 then please answer this question.

Together with my colleague(s) I learned how to model the internal behaviour of my subject.

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

Assessment of concepts to support learning II

1 = strongly DISAGREE .... **5 = strongly agree**

[]The environment is very interactive. *

Please choose **only one** of the following:

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

[]The environment supports collaboration. *

Please choose **only one** of the following:

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

[]The environment is very stimulating. *

Please choose **only one** of the following:

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

[]I had fun going through the different tasks. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I would consider using this virtual 3d world for learning. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]How many students were in the virtual world (including yourself)? *

Please choose **only one** of the following:

○ 2

○ 3

○ 4

[]Learning as a group/together with other students supported learning of subject-oriented business process modelling. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]

I enjoyed collaborating in the virtual world. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I learned subject-oriented business process modelling. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]Was the group size appropriate, or would you prefer smaller/bigger groups? *

Please write your answer here:

[   ]

Usability of the virtual world

1 = strongly DISAGREE   ....   5 = strongly agree

[]I think that I would like to use this system frequently. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I found the system unnecessarily complex. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I thought the system was easy to use. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I think that I would need the support of a technical person to be able to use this system. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I found the various functions in this system were well integrated. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I thought there was too much inconsistency in this system. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I would imagine that most people would learn to use this system very quickly. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I found the system very cumbersome to use. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I felt very confident using the system. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I needed to learn a lot of things before I could get going with this system. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

Immersion

1 = strongly DISAGREE   ....   5 = strongly agree

[]

How immersed did you feel? (0 = not at all immersed; 10 = very immersed;) *

Please choose **only one** of the following:

○ 0

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ 7

○ 8

○ 9

○ 10

[]

I felt as if I was in the real world whilst playing. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]

It was as if I could interact with the other users in virtual world as if I was in the real world. *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

[]I think that the inventory (desk, forklift truck, ...) supports immersion and learning of S-BPM *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

○ 5

Learning result

Business process text of Employee

=============================

(1) Employee sends holiday request to **Manager**

(2) Employee receives holiday decision from **Manager**

(3) Employee checks decision from **Manager**

(4) If holiday decision is ok then

    (5) Employee sends holiday dates to **Colleague**

    (6) Employee plans holiday activities

(7) If holiday decision is rejected then

    (8) Employee looks for new holiday dates

    (8) Employee does step 1 again

[]How many Subject has the Subject Interaction Diagram based on the business process text of Employee? *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

[]How many ingoing interactions does Subject Employee have in the Subject Interaction Diagram? *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

[]

How many outgoing interactions does Subject Employee have in the Subject Interaction Diagram? *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4

[]The interaction "Employee sends holiday request to Manager" becomes in Employee's and Manager's Subject Behaviour Diagram? *

Please choose **only one** of the following:

○ A receive state in Managers Subject Behaviour Diagram and a send state in Employees Subject Behaviour Diagram

○ A receive state in Managers Subject Behaviour Diagram and a receive state in Employees Subject Behaviour Diagram

○ A send state in Managers Subject Behaviour Diagram and a send state in Employees Subject Behaviour Diagram

○ A send state in Managers Subject Behaviour Diagram and a receive state in Employees Subject Behaviour Diagram

[]How many action states does Subject Employee have in Subject Behaviour Diagram? *

Please choose **only one** of the following:

○ 1

○ 2

○ 3

○ 4