AN EMPRICAL EXAMINATION FOR COLLABORATIVE NATURE OF BUSINESS PROCESS MODELING

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ABSTRACT

AN EMPRICAL EXAMINATION FOR COLLABORATIVE NATURE OF BUSINESS PROCESS MODELING

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In this study, factors that contribute to interaction quality of collaborative group members in a computer-supported collaborative business process modeling context were investigated with qualitative and quantitative methods. Initially, interaction quality factors were identified based on a review of related theoretical frameworks and qualitative analysis of log files from a dual eye-tracking experiment. A rating scheme was then developed to assess the quality of group interactions. A research model, that reveals and validates the relationships between the identified quality factors and the theoretical dimensions, was proposed. In addition to this, a cross-recurrence analysis was conducted on the dual-eye tracking data to identify the degree of gaze coordination among process modelers as an indicator of joint attention. We then evaluated the effect of joint attention over theoretical dimensions and quality factors. According to the results, the degree of joint attention significantly affects awareness and motivation. Moreover, joint attention has a positive relationship with quality factors such as sustaining mutual understanding, structuring the modeling process and knowledge exchange. Finally, the quality of collaboratively produced business process models were evaluated as a success measure of collaborative group members. Results showed that there are significant relationships between the quality of process models and interaction quality factors. Furthermore, our main findings suggest that joint attention significantly contributes to the overall quality of the final group product.

Keywords: Computer Supported Collaborative Business Process Modeling, Collaboration Quality, Joint Attention, Dual Eye Tracking, and Business Process Model Quality.

ÖZ

İŞ SÜRECİ MODELLEMENİN İŞBİRLİKÇİ DOĞASI ÜZERİNE BİR AMPİRİK İNCELEME

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Bu çalışmada nitel ve nicel araştırma yöntemleri kullanılarak, bilgisayar destekli işbirlikli iş süreci modelleme bağlamında iş birliğiyle çalışan grup üyelerinin etkileşim kalitesine etki eden faktörler incelenmiştir. İlk olarak, teorik altyapılar ve ikili göz izleme deneyi sonucunda elde edilen log dosyalarının nitel analizi göz önünde bulundurularak etkileşim kalitesine etki eden faktörler belirlenmiştir. Bunun üzerine, bir değerlendirme şeması oluşturularak grupların etkileşim kalitesi değerlendirilmiştir. Belirlenen kalite faktörleri ve teorik boyutlar arasındaki ilişkileri ortaya koyan bir araştırma modeli sunulmuştur. Ayrıca, ikili göz izleme verisi ile cross-reccurence analizi gerçekleştirilerek ortak dikkatin göstergesi olarak süreç modelleyicilerin göz izi koordinasyonları incelenmiştir. Daha sonra, ortak dikkatin teorik boyutlar ve kalite faktörleri üzerindeki etkisi incelenmiştir. Bu sonuçlara göre, ortak dikkatin farkındalık ve motivasyonu önemli derecede etkilediği gözlenmiştir. Ayrıca ortak dikkatin, karşılıklı anlayışın sürdürülmesi, modelleme sürecinin yapılanması ve bilgi değişimi kalite faktörleriyle pozitif bir ilişkisi vardır. Son olarak, işbirliğiyle üretilen işsüreci modellerinin kalitesi işbirliğiyle çalışan grubun başarı ölçütü olarak değerlendirilmiştir. Sonuçlar, süreç modellerinin kalitesi ile etkileşim kalite faktörleri arasında önemli ilişkilerin olduğunu göstermiştir. Buna ek olarak, ana bulgularımız, ortak dikkatin grup ürün kalitesine önemli derecede katkı sağladığını göstermiştir.

Anahtar Kelimeler: Bilgisayar Destekli İşbirlikli İş Süreci Modelleme, İşbirliği Kalitesi, Ortak Dikkat, İkili Göz İzleme, İş Süreci Modeli Kalitesi

This thesis is dedicated to the memory of my beloved brother, Muhammed Fındık. I miss him so much!

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LIST OF ABBREVIATIONS

ANKDS	Askerlik Nedeniyle Kayıt Dondurma Süreci
AW	Awareness
BP Modeling	Business Process Modeling
cBPM	Collaborative Business Process Modeling
CC	Cross Connectivity
CF	Communication Flow
CFC	Control Flow Complexity
Com	Communication
Coord	Coordination
CO	Cooperative Orientation
CSCBPM	Computer Supported Collaborative Business Process Modeling
CSCL	Computer Supported Collaborative Learning
CSCW	Computer Supported Cooperative Work
DE	Domain Expert
DK	Domain Knowledge
DSS	Ders Saydırma Süreci
eEPC	Extended Event-Driven Process Chain
GDM	Group Decision Making
GM	Group Motivation
HCI	Human Computer Interaction
II	Informatics Institute
IS	Information Systems
JA	Joint Attention
KE	Knowledge Exchange
LOC	Lines of Code
M	Motivation
MC	Modeling Competency
METU	Middle East Technical University
PA	Process Analyst
RC	Reaching Concensus
S	Support
SMP	Structuring Modeling Process
SMU	Sustain Mutual Understanding
TS	Technical Support
UML	Unified Modeling Language
V&V	Validation & Verification

CHAPTER 1

INTRODUCTION

The first chapter provides the background of the study, introduces the purpose and the research questions, summarizes the contributions, and overviews the structure of the study.

1.1 Background of the Study

Nowadays organizations describe their core procedures in terms of business processes and invest considerable effort to define these processes in terms of operational models (Roser & Bauer, 2005). Business process (BP) modeling is a collaborative activity that involves a number of stakeholders who possess the fundamental knowledge of the processes or goals of an organization (Rittgen, 2010). By definition, process modeling is performed in a distributed context (e.g., cross-organizational, cross-geographical) and the stakeholders (e.g., analysts, project managers and domain experts) are often geographically dispersed and need to engage in the process modeling effort from remote locations (Adamides & Karacapilidis, 2006; Brown, Recker, & West, 2011; Mendling, Recker, & Wolf, 2012).

Process modeling is usually performed either in an asynchronous or synchronous manner with the help of computer-mediated communication tools (Riemer, Holler, & Indulska, 2011). Asynchronous modeling is the most commonly used modeling approach in BP modeling domain, where the process is initiated by one user and other users contribute to the evolving model at a different time and most probably at a different location. Email, collaborative writing and content management systems are often used to enable asynchronous collaboration among stakeholders. In contrast, the synchronous modeling approach enables stakeholders to engage with modeling at the same time without having to be in the same location. In this case, communication is usually mediated by teleconferencing or video chat applications. In addition to synchronous and asynchronous communication means, quasi-synchronous communication channels such as instant messengers, chat and shared drawing tools are also available, which are based on the exchange of texts and diagrams among multiple users (Zemel, 2005). The reason why these tools are classified as a quasi-synchronous mean of communication is because they do not necessarily make all of the message production process visible to the interlocutors in contrast to video and voice enabled communication (Garcia & Baker Jacobs, 1999).

Although there are several computer-mediated communication options to facilitate BP modeling practices, with the exception of the ARISalign BP modeling tool, Riemer et al. (2011) states that commercial BP modeling tools predominantly support asynchronous modeling. Even though some video chat applications enable screen sharing options, no product allows model builders to edit and work synchronously on the same model together. Therefore, modeling and managing collaborative business processes involves new challenges, mainly regarding the ability to cope with change, decentralization, and the required support for interoperability (Roser & Bauer, 2005). In order to overcome these challenges BP modeling activities can potentially benefit from computer-supported cooperative work (CSCW) practices. CSCW systems are based on computer-mediated communication tools which provide additional awareness and coordination features tailored to the needs of group members who need to work together to accomplish a particular goal at a specific work setting (Bannon & Schmidt, 1989; Dourish & Bellotti, 1992). CSCW as a research field focuses on understanding the nature and the characteristics of cooperative work mediated by information and communication technologies, and reflecting those insights to inform the design of interfaces and coordination mechanisms that aim to help groups of people engage in successful collaboration (Bannon & Schmidt, 1989). As an inherently cooperative process, the success of process modeling activities heavily depends on the quality and the effectiveness of collaboration among stakeholders, and hence such processes may also be supported by CSCW environments. Identifying what kind of drivers affect the quality of collaboration in the business modeling context requires a detailed examination of the collaboration process.

The recent state of technology has made it practical to track the eye gaze of multiple subjects simultaneously while they are collaborating on a shared task (Jermann & Nüssli, 2012). Such task scenarios are particularly useful for the interpretation of eye fixations in relation to the sequential organization of interaction. The degree of gaze coordination or cross-recurrence among the fixation sequences of interlocutors provide researchers useful information regarding to what extent the participants can mutually orient to each other and to the objects in the shared scene (Richardson, Dale, & Tomlinson, 2009; Richardson & Dale, 2005). Analysis of multiple gaze information in this way has opened up new possibilities to develop meaningful process measures for analyzing collaborative interactions mediated by CSCW systems.

1.2 Purpose and Research Questions of the Study

Bannon & Schmidt (1989, p.3-5) defines CSCW as "…an endeavor to understand the nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies". This definition of CSCW combines an understanding of how people work in groups and how computer networking technologies can be designed to support their activities. CSCW systems are collaborative environments that support geographically dispersed working groups so as to improve the quality and the productivity of their joint work (Eseryel, Ganesan, & Edmonds, 2002). In recent years, the

collaborative nature of process modeling has attracted researchers' attention (Riemer et al., 2011). In this thesis study, a prototype collaborative environment was set up to support quasi-synchronous collaborative business process modeling (CSCBPM) practices, where more than one stakeholder worked as part of a geographically distributed project team. The study focuses on the process of collaboration among the stakeholders to reveal the factors affecting the quality of collaboration through which BP models are co-constructed. In CSCW, the success of collaboration mainly depends on the quality of collaboration. Measuring collaboration is a challenging task due to the complex interplay among relevant measures that unfold during the process of collaboration among the stakeholders. There is no single metric that can measure the emergent nature of collaboration on its own, so, it's necessary to explore multiple dimensions underlying group work. In the scope of this study, the process of collaboration among the stakeholders is analyzed by employing quantitative and qualitative methods, in an effort to reveal the factors that affect (a) the quality of interaction through which BP models are co-constructed, (b) the joint attention of process modelers, and (c) the quality of the final product of that collaboration. In particular, the study focuses on the relationships between these aspects to understand how they interact with each other to lead to a successful collaboration. More specifically, the following research questions are pursued in a synchronous CSCBPM context;

1. Which factors affect the interaction quality of collaborative work groups in a synchronous CSCBPM context?
2. What are the relationships between the factors that affect interaction quality?
3. What are the relationships between the degree of joint attention and the factors that affect interaction quality?
4. How do interaction quality factors affect the quality of the collaboratively produced business process models?
5. How does the degree of joint attention affect the quality of collaboratively produced business process models?

In addition, the constraints and affordances of interaction designs are identified conducting experiments on systems with different CSCW interaction methodologies. Based on the observations, system design recommendations are made to enhance collaboration in collaborative modeling. The results of the research can serve as a guideline for system designers in designing a synchronous collaborative BPM tool, and for customers in choosing a tool for their synchronous modeling practices.

1.3 Contributions of the Study

The present study is expected to contribute to the literature in several ways. Firstly, identification of the factors affecting interaction quality is important to understand how individuals can construct meaning at the group level and which aspects of collaborative process are important for successful interaction. Investigation of the teams' interaction quality throughout the CSCBPM process is a relatively untouched area in the state of the art. Secondly, to date there have not been any reported dual eye-tracking studies in the

literature that investigate collaborative aspects of BP modeling where two or more participants work together. The dual eye tracking paradigm better captures the collaborative aspects of CSCW systems that are designed to support BP modeling processes. Existing eye tracking studies focus on a single user's activity and generally focus on the usability issues involved with the interface through which BP modeling diagrams are constructed. In order to fill this gap in the literature to some extent, we aim to examine the CSCBPM process in detail by employing a dual-eye tracking experimental approach. Moreover, examination of the relation between joint attention and interaction quality enables us to observe how eye movement patterns affect the aspects of interaction quality and the quality of collaboratively produced product. Thirdly, quality of the outcome obtained through a collaborative activity is often considered as another indicator for the evaluation of the quality of collaboration. BP models are collaborative products created through computer supported collaborative interaction and it is expected that product quality will be an indicator for the overall quality of interaction. The relationship between BP model quality and interaction quality as well as joint attention are not elucidated in the current state of the art.

1.4 Structure of the Study

The rest of the thesis is divided into four chapters. Chapter 2 presents the theoretical background and provides an overview of the related work. Chapter 3 discusses the research methodology and data analysis, which is followed by Chapter 4 including the results section. The thesis concludes with Chapter 5 that discusses our main findings and presents limitations of the study, and pointers for future work. Overall research design of the thesis study is shown in Figure 1.

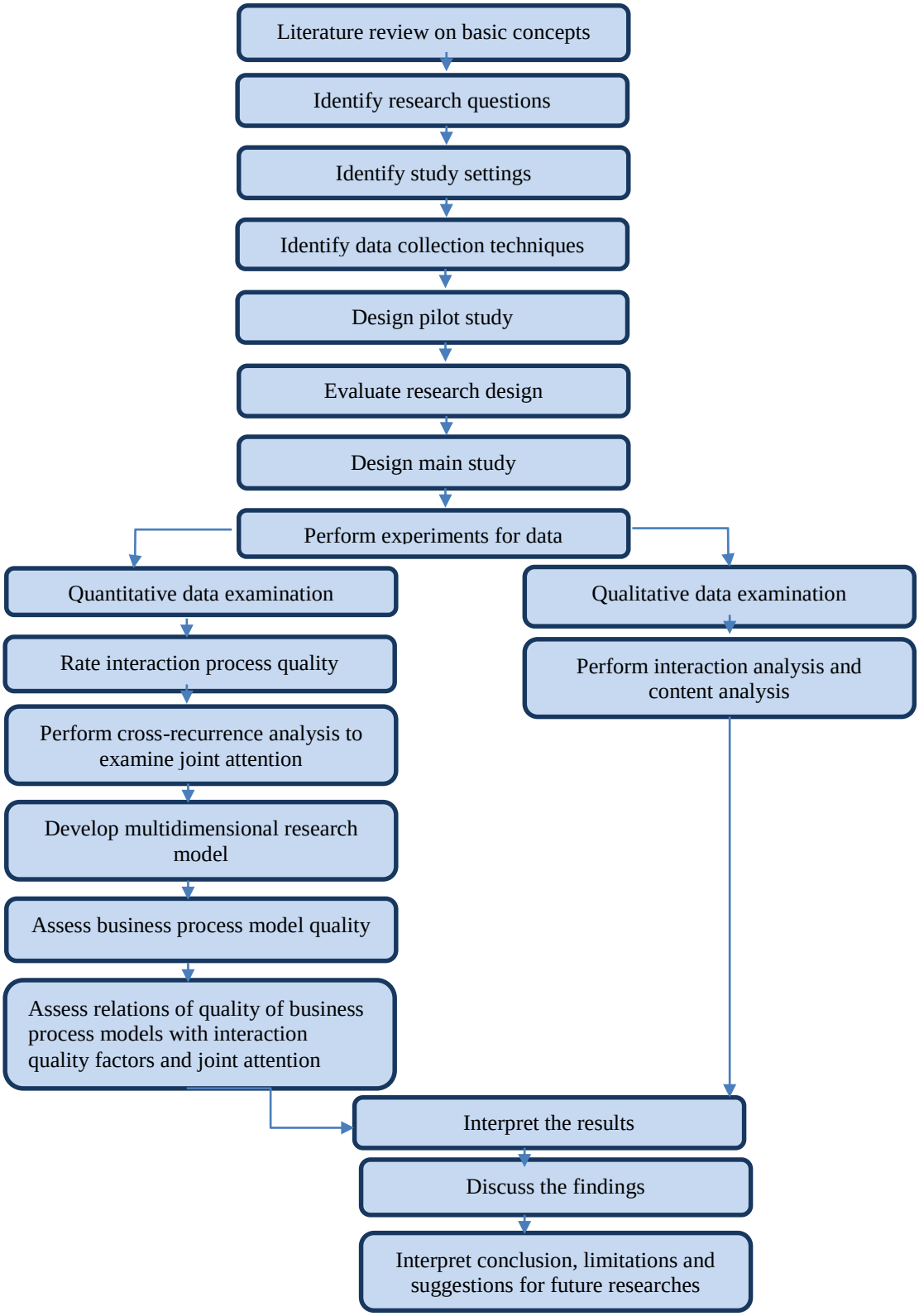

Figure 1 Overall research design

CHAPTER 2

LITERATURE REVIEW

This chapter includes four main sections. The first section gives information about CSCW and collaborative interaction, then presents the related studies of collaborative interaction. The second section introduces BP modeling and collaborative business process modeling (cBPM) contexts, then presents the related studies in CSCBPM. The third section explains joint visual attention, eye tracking and dual-eye tracking methodologies and then introduces the related studies of dual-eye tracking and joint visual attention. Lastly, the chapter is concluded with the discussion of the literature to motivate this study.

2.1 Computer Supported Cooperative Work

CSCW is mainly concerned with the use of computer-based technologies to support collaboration among individuals. Greif (1988, p.11) defines CSCW as "… computer-assisted coordinated activity such as communication and problem solving carried out by a group of collaborating individuals". In CSCW settings, cooperative-work tools perform functions such as helping people collaborate on writing the same document, managing projects, keeping track of tasks, and finding, sorting, and prioritizing electronic messages (Malone & Crowston, 1994).

People who work with these systems are generally organized into teams. Teams are social entities that are often organized hierarchically and sometimes dispersed geographically. Therefore, such teams must integrate, synthesize, and share information; and they need to coordinate and cooperate as task demands shift throughout the course of their joint activity to accomplish their mission (Salas, Cooke, & Rosen, 2008). CSCW tools aim to enable group interactions at a distance by providing software support for communication, awareness, coordination, decision making and team building (Malone & Crowston, 1994; Salas et al., 2008).

2.1.1 Collaborative Interaction

In collaborative interaction, two or more group members work together to perform a joint task in a particular domain to reach a joint goal (Cohen, 1994). Interaction style of the participants, who work together to solve a problem, is classified as collaborative and cooperative interaction (Dillenbourg, 1999; Roschelle & Teasley, 1995; Spada, Meier, Rummel, & Hauser, 2005). Collaborative interaction involves mutual engagement, which

means participants do work and try to solve the problems together (Forman & Cazden, 1994; Kneser & Ploetzner, 2001; Rummel & Spada, 2005). However, cooperative interaction depends on division of labor of participants who have complementary roles to contribute to the joint solution (Forman & Cazden, 1994). In our research design, interaction style of the group members could not be strictly classified as either collaborative or cooperative. In some cases, the participants worked together to overcome the challenges and in some cases they contribute the modeling activities individually or according to the division of labor rule assigned during the interaction. Therefore, in this research, interaction style of the participants is defined with the definition of Roschelle and Teasley (1995, p.70) as "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem".

2.1.2 Related Studies of Collaborative Interaction

Collaboration of group members in a computer supported environment is a socio-technical process, where interaction between participants and technical aspects are highly interwoven (Carell, Herrmann, Kienle, & Menold, 2005; Herrmann, 2003). There is no clear definition of good or bad collaboration, there are many factors affecting the collaboration process (Nüssli, Jermann, Sangin, & Dillenbourg, 2009).Therefore the researchers investigated the process of collaborative interaction to identify the problems and aspects that affect the quality of interaction. Poor knowledge sharing, ineffective system and system use and inefficient organization of the participants for collaborative activities while using the system are some of the issues encountered during collaborative interaction (Carell et al., 2005; Guzdial & Turns, 2000; Lipponen, Rahikainen, Hakkarainen, & Palonen, 2003). Besides, some of the other aspects that can affect the group process and the achievement of a joint solution throughout collaborative interaction are mutuality of exchanges, achievement of joint attention, alignment of group members' goals for the problem solving process (Barron, 2000), providing critiques (Bos, 1937) and engaging in productive argumentation (Amigues, 1988; Phelps & Damon, 1989). Meanwhile, mutual activation, sharing of knowledge and skills, grounding a common frame of reference and negotiation for agreement are the main processes of coordination in the collaborative learning domain (Coleman, 1998; Erkens, Jaspers, Prangsma, & Kanselaar, 2005; Hatano & Inagaki, 1991). Moreover, Spada et al. (2005) examined aspects that are based on theoretical background and interaction of participants to evaluate the quality of collaborative process in the context of a desktop videoconferencing setting. They proposed evaluation criteria for assessing the quality of collaborative interaction, based on effective communication via sustaining mutual understanding and coordinating communication (Clark & Brennan, 1991; Spada et al., 2005), information processing via information pooling and reaching consensus (Hinsz, Tindale, & Vollrath, 1997; Spada et al., 2005), effective coordination via task division, time management and technical coordination (Barron, 2000; Malone & Crowston, 1994; Spada et al., 2005) and motivational aspects via shared task alignment and sustaining commitment (Spada et al., 2005).

2.3 Business Process Modeling

Business process management has attracted the attention of both business administration and computer science communities (Weske, 2012). Weske (2012) proposes a business process management lifecycle that includes Design & Analysis, Configuration, Enactment and Evaluation phases to support the design, administration, configuration, enactment, and analysis of business processes. The life cycle starts with the design and analysis phase. Business process design phase has a central role for the identification, reviewing, and representation of business processes. Business process is

> "… a set of activities that are performed in coordination in an organizational and technical environment. These activities jointly realize a business goal. Each business process is enacted by a single organization, but it may interact with business processes performed by other organizations" (Weske, 2012, p.5).

The process design phase ensures that business processes are optimized and effective, meet customer requirements, support and sustain organizational development and growth (Cousins & Stewart, 2002). The design phase tries to find answers for the following questions; "Who does what, in what sequence, what services or products are produced and what software systems and data are used to support the process?" (Davis & Brabander, 2007). BP modeling and identification is performed to represent the business processes of an enterprise, so that the current process can be analyzed and improved. BP modeling is typically performed by system analysts and process owners who are seeking to improve process efficiency and quality. The communication dialogue perspective by Hoppenbrouwers, Proper, & van der Weide (2005) describes the process of modeling as a goal-driven dialogue between a number of participants who communicate with each other and remember as well as build their discussion on what has been discussed before. The participants' roles can be domain experts who generate and validate statements about the domain, or system analysts who create and verify formal models (Hoppenbrouwers et al., 2005).

Mauser, Bergenthum, Desel, & Klett (2009) state that early phases of business process design is critical for ensuring the validity of the outcome of the business processes. They provide a comprehensive framework to model business processes. In particular, the process of BP modeling includes three important phases - Elicitation, Formalization, Validation and Verification - for the early design of the business processes (Frederiks & Van der Weide, 2006). Mendling et al. (2012) state that, this approach is originally intended for information/data modeling processes. However, this general principle can be used for other modeling contexts such as BP modeling. Figure 2 shows the process of BP modeling approach.

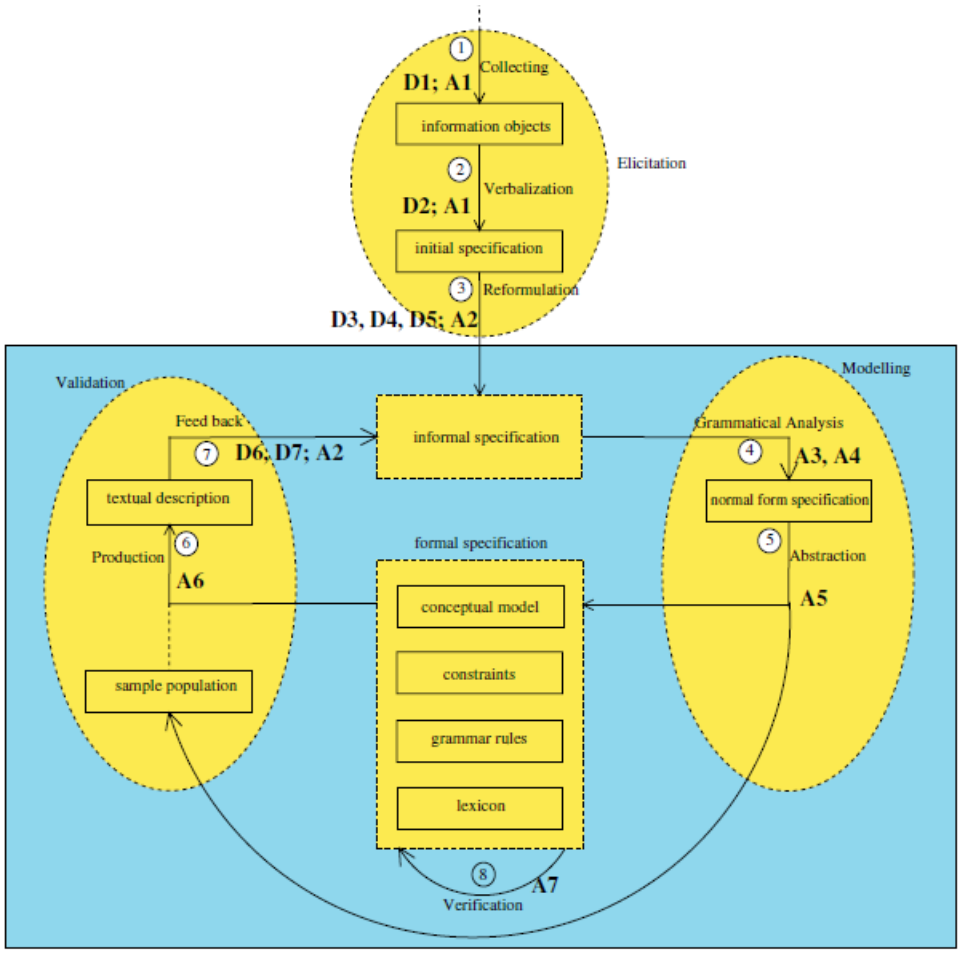

Figure 2 The process of modeling (Frederiks & Van der Weide, 2006)

In the *elicitation phase*, it is expected to define the scope and aim of the project and collect information from different stakeholders. An elicitation plan should be created and the collected information should be filtered and documented. In the *formalization phase*, the structured pieces of information gathered in the elicitation phase can be translated in an appropriate formal representation. This formalization can be made with graphical modeling languages like Event-driven Process Chain (EPC). In the *validation and verification phase*, conflicts, inconsistencies and any lack of clarity in the business process models are concerned. During this phase the correctness of the business process models are ensured. In addition to this, the completeness issue is considered in this phase, which is aimed to gather missing information. Interaction with the information provider enables the validation of the correctness and the completeness of the final business process models.

2.3.2 Collaborative Business Process Modeling

According to Mendling et al. (2012), in the traditional approach, business process modeling is performed as a single person activity. An expert visits the company, conducts interviews, creates a model and finally verifies the model. The main problem with this approach is that most of the stakeholders are considered only as passive readers of the models (Mendling et al., 2012). Since process modeling is typically a multi-stakeholder activity in which elicitation, formalization, validation and verification activities are performed in a collaborative manner, the single person view often does not reflect the corporate reality. For instance, Riemer et al. (2011) characterize cBPM as a collective activity where the team members jointly discuss, design and document business processes. Communication, coordination, awareness and team building play important roles in such joint modeling efforts (Riemer et al., 2011). In particular, team members need to communicate with each other to explain the changes, coordinate the modeling activities and negotiate on common terms and definitions. Throughout the process, stakeholders should be aware of when and what kind of changes have been made by each particular team member. Team members tend to assume different roles; some members will be in charge of the modeling, while others deliver information or review the model. Each team member contributes to the joint modeling effort according to their respective roles.

2.3.3 Related Studies of Computer Supported Collaborative Business Process Modeling

The definition of BP modeling emphasizes the collaborative nature of this field, which motivated investigations of cBPM in various professional contexts. For instance, Chang, Zhang, & Chang (2006) examined the current IT-based collaboration techniques that are capable of supporting business processes. Chang et al. surveyed the scope of CSCW along the 12 most important research topics that are application style, control, environment, perspective, community, coordination, social conduct, human proxy, policy, storage schemas, information presentation and formalization. The researchers analyzed each topic in terms of their past approaches, current status and future trends.

Baghaei, Mitrovic, & Irwin (2007) evaluated the effectiveness of COLLECT-UML tool, which enables students to learn object-oriented analysis and design using Unified Modelling Language (UML). The system provides feedback on collaboration, while learning how to design UML class diagrams. The study showed that using the collaborative system enhanced students' performance, problem-solving skills and domain knowledge.

Türetken and Demirörs (2008, 2011) proposed a method called Plural for organizations to conduct process modeling in a decentralized and concurrent way. In this method, the process owner who actually performs the processes is given the central role to understand, model and improve the processes. The plural method includes three phases, which are context definition phase, description and conflict resolution phase and integration and

change phase, to define and enhance an organization's processes and to sustain its process-base. The researchers validated their method with case studies by using the ARIS Collaborative Suite tool. They showed that the proposed method is suitable for decentralized modeling, and has value to improve an organization's strengths and to gain expected benefits. The plural method enabled process owners to model their own processes concurrently. In this way, the modeling effort is shared among process owners and modeling is completed more efficiently.

Rittgen (2008)introduced the COMA cBPM tool, which was developed around the functions that are Propose, Support, Challenge and Accept. The proposal function is concerned with the revision of current version of the model. The support function is related with the positive assessment on the proposal made by other team members and Challenge is related with the negative assessment on the proposal. The last function is the Acceptance, which includes two rules that are rules of majority and rules of seniority. This tool supports UML notation and provides asynchronous means for communication for collaborative modeling. In this interaction method, a modeler proposes his model, and then the other team members whether support or challenge the model. The proposals can be seen by all participants to enable the comparison and selection of the most suitable model by the group.

Basheri (2010) examined the Computer Supported Collaborative Learning (CSCL) environments for collaborative modeling. The study reviewed COLER, COLLECT-UML, CoLeMo and AUTO-COLLEAGUE systems. COLER is a web-based collaborative learning environment and supports Entity Relationship (ER) to enhance students' performance in database design. The system was criticized by the researcher in terms of its deficiencies to support interactive learning. For example, the system does not evaluate chat window's information in analyzing students' interaction and it compares student's solutions to the group's solution, instead of an ideal solution. COLLECT-UML enables a student to solve a problem individually, then the student can join in a small group to work on a group solution. CoLeMo is developed for students to collaborate on building UML models. It enables students to interact with others to learn from each other. AUTO-COLLEAGUE is a CSCL system for UML learning. This system is based on users' personality and performance; which are evaluated to give advice for learners and teachers. COLER, COLLECT-UML, and CoLeMo have a common inference mechanism and they examine the type and frequency of the contribution of the students in the chat system. However, AUTO-COLLEAGUE is based on user models that trace and evaluate the students' individual characteristics and actions. AUTO-COLLEAGUE does not support collaborative drawing for UML diagrams, as provided in COLLECT-UML, COLER and CoLeMo and just has a chat system as its main collaboration tool.

Hahn, Recker, & Mendling (2011) studied the process of cBPM with the Gravity collaborative modeling editor which is based on Google Wave. The system supported chat communication and real time modeling with BPMN in its version 1.0. The researchers examined IT-enabled process of process modeling and measured the effectiveness of the

modeling process through breakdowns (Guindon, Krasner, & Curtis, 1987) that are classified as semantic, syntactic and pragmatic.

Riemer et al. (2011) examined the existing commercial tools in terms of their collaborative nature. The evaluated tools are CA ERwin Process Modeler, ARIS Design Platform 7, Enterprise Architect 8, iGrafx Process Modeler 2011, Microsoft Visio 2010, Business Modeler Advanced 7, Signavio Process Editor, BONAPART Collaborative, Adonis, Savvion Process Manager, Innovator for Business Analysts. Three criteria were considered for the evaluation of the tools used for process development. The first criterion was the Process Modeling Criteria. According to this criterion, the tools have to support one or more of the process modeling notations that are Event-Driven Process Chains (EPC), Business Process Modeling and Notation (BPMN), Unified Modeling Language (UML) or Integrated Definition (IDEF). Also, this criteria considered the systems' modeling approaches that are synchronous, asynchronous and concurrent modeling. The second criterion was Collaboration Criteria, which included commenting and annotation, user and role management, and repository and conflict management factors. The third criterion was the Technical Criteria, which examined the model according to their client/server architecture, desktop or web-based design aspects and export/import features. As a result of the evaluation, the researchers concluded that;

> "… tool designers perceive modeling as predominantly asynchronous; no product allows modeling synchronously on the same object. Moreover, the tool descriptions above show that no product provides comprehensive, integrated support for collaborative business process modeling. However, each of the seven tools exhibits some features that are relevant and useful in the context of joint process modeling initiatives. Taken together, these features allow us to work towards architecture for supporting collaborative process modeling. To this end, we group the features into three dimensions, modeling roles & workflow, awareness creation, and communicative support." (Riemer et al., 2011)

Dollmann, Houy, Fettke, & Loos (2011) introduced the CoMoMod collaborative BP modeling tool, which supports EPC and Petri Nets. In this system, two modelers can model a process with these modeling notations separately, then the system enable the modelers to convert their modeling notations to the other formalism. After that, the modelers can communicate through an integrated chat tool and work collaboratively on the process.

Brown et al. (2011) suggested a prototype 3D BPMN environment for cBPM, which uses the Virtual World technology in Second Life. The researchers evaluated the proposed environment with a case study and concluded that the suggested cBPM approach increases user empowerment and enhances the collaboration and consensual development of process models, even if the stakeholders are geographically dispersed.

Mendling et al. (2012) examined the collaboration features available in current BPM tools. The researchers proposed a framework to evaluate the systems' collaboration features. The framework was based on the Frederiks & Van der Weide (2006) process modeling approach and Malone and Crowston's (1994) social interaction approach. The proposed framework is shown in Figure 3.

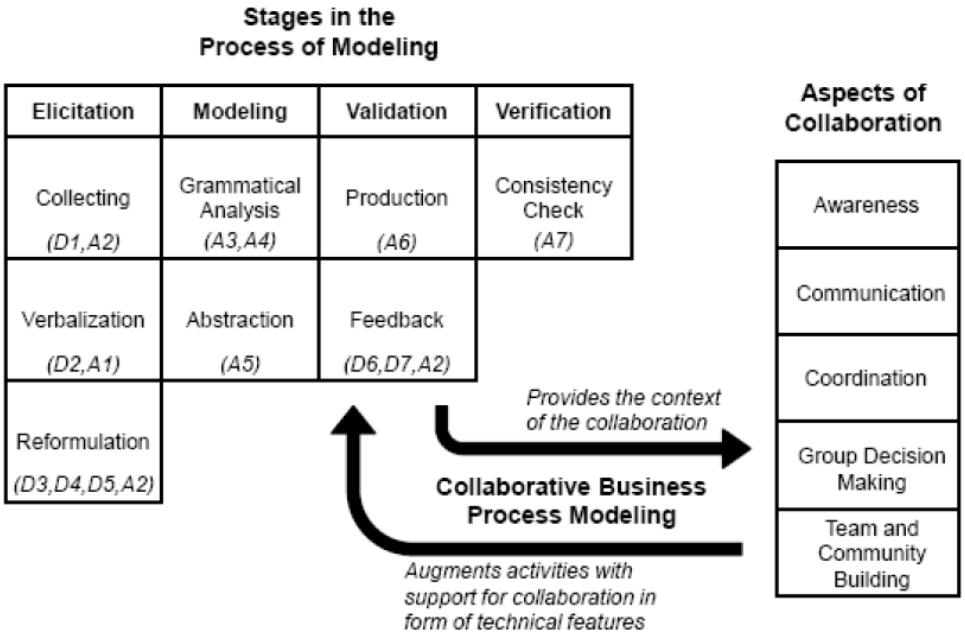

Figure 3 Collaborative Process Modeling Framework (Mendling et al., 2012)

According to Mendling et al.'s framework, process modeling includes three main stages that are, Elicitation, Modeling, and Validation/Verification. The collaboration aspects of the framework considers the level of support for social interaction in geographically distributed settings and states that the technology should support reasonable levels of interaction like awareness, communication, coordination, group decision making and team-building (Malone & Crowston, 1994). Mendling et al. (2012) applied the framework to three applications - Collaborative Modeling Architecture (COMA), Signavio Process Editor, Software AG ARISalign & ARIS Community - that purport to support collaborative process modeling. The study identified some deficiencies that make it difficult to conclude that these systems can fully support collaborative business process modeling. In particular, the following deficiencies stand out. Although the COMA tool supports five UML diagrams that are Class Diagram, Activity diagrams, Use Case Diagrams, Sequence Diagrams, and State Diagrams, the system does not provide any awareness features that allow collaborators to monitor who is doing what on the shared diagram. The participants have to be co-located in the same place to communicate with each other. All communication relies on face-to-face conversations; therefore, the system does not support communication aspects of collaboration. Signavio Process Editor is a

web-based collaborative process modeling solution that allows users to model business processes with the modeling standards BPMN or EPC by using a web browser. However, the system does not support synchronous editing of process model according to the system evaluation study of Riemer et al.(2011). Lastly, ARISalign and ARIS Community support multiple dedicated social features of collaboration that are awareness and communication. While ARISalign does not explicitly support the aspect of coordination, ARIS Community offers a broader range of social features for coordination. The main deficiency experienced about the systems is that only the BPMN notation is supported with the system.

Forster, Pinggera, & Weber (2012) introduced the Cheetah Experimental Platform (CEP), which is a single modeler environment. The researchers aimed to support the system with awareness, communication, coordination, group decision making and team building levels of social interaction (Mendling et al., 2012). In addition, they implemented replay functionality in the system to track and evaluate team processes. The researchers planned to develop visualizations, algorithms and metrics to make qualified assertions on cBPM. Then, the researchers extended CEP to collaborative CEP (cCEP) and developed hypotheses to examine process of cBPM in the future studies (Forster, Pinggera, & Weber, 2013).

2.4 Joint Visual Attention

Joint attention plays a fundamental role in any kind of social interaction to establish common ground between individuals (Schneider & Pea, 2013). Researchers examined the effect of joint attention in the different contexts to understand the nature and organization of social coordination between human beings. For example, existing studies examined the role of joint attention in infancy (Bakeman & Adamson, 1984; Baldwin, 1991; Bates, Thal, Whitesell, Fenson, & Oakes, 1989; Brooks & Meltzoff, 2008; Carpenter, Liebal, & Seemann, 2011; Charman et al., 2000; Mundy & Jarrold, 2010; Mundy & Newell, 2007; Mundy, Sigman, & Kasari, 1990; Stern, 2009), in learning sciences (Barron, 2003; Roth, 2001; Schwartz, 1995), on joint action (Fiebich & Gallagher, 2013) and with virtual characters (Courgeon, Rautureau, Martin, & Grynszpan, 2014). According to the findings of the studies, Schneider & Pea (2013) concluded that meaningful interaction have been shown to be associated with the establishment and maintenance of joint visual attention. Tomasello (1995, p.86) defined joint attention as "the tendency for social partners to focus on a common reference and to monitor one another's attention to an outside entity, such as an object, person, or event". The definition of joint attention comprises a triple interaction which means two individuals coordinate their attention to an object of mutual interest (Bakeman & Adamson, 1984). In other words; individuals mutually orient towards an external entity (Fiebich & Gallagher, 2013). In that sense, researchers have widely studied gaze communication in the context of joint attention (Courgeon et al., 2014) to examine the visual tendency of individuals. It is important to state that, joint attention implies a shared intentional relation to the external entity, so it is much more than gaze following or simultaneous looking (Kaplan & Hafner, 2006). However, as stated

by Duchowski (2007), gaze examination with eye-trackers open a new window into the mind of the users and visual attention often reflects the cognitive processes (Schneider & Pea, 2013). In this regard, eye-tracking methodology is introduced in the following section to provide further information about this approach.

2.4.1 Eye-Tracking Methodology

Eye tracking is used to measure the eye movements to monitor both where an individual is looking at any given time and in which sequence the individual's eyes are moving from one position to another (Poole & Ball, 2006). Researchers have been interested with eye movements in their studies for almost 100 years (Rayner & Pollatsek, 1989). There are two main eye-movement measures, which are called fixation and saccades (Poole & Ball, 2006). A fixation describes a relatively stable eye-movement with some minimum duration that is approximately between 150 ms and 600 ms (Duchowski, 2007). Poole & Ball (2006) states that the interpretation of fixation depends on the context. For instance, in a web page browsing task, higher fixation frequency on a particular area can be indicative of greater interest or complexity and difficulty of the encoding activity. The other eye-movement measure saccade refers to the quick eye movements occurring between fixations (Poole & Ball, 2006). Such a fast eye-movement is characterized with short durations between 10 ms and 100 ms (Duchowski, 2007). Poole & Ball (2006) emphasizes that saccades do not say anything about the complexity or salience of an object, since any encoding does not take place during this measurement. However, regressive saccades defined as backtracking eye movements can be consider as a measure of processing difficulty during encoding (Rayner & Pollatsek, 1989).

Eye tracking is highly popular methodology employed in human computer interaction (HCI) research field for many years (Jacob & Karn, 2003). Jacob & Karn (2003) summarized the history of eye-tracking in HCI. The first eye tracking technique was developed by Dodge and Cline (1901) and this technology used the light reflected from the cornea. Two important features of this technology were that participants' head must be motionless and only horizontal eye movements could be recorded onto a falling photographic plate. Afterwards, Judd, McAllister and Steel (1905) developed a technique to record the temporal aspects of eye movements in two dimensions with motion picture photography. This technique recorded the movement of a small white speck of material inserted into the participants' eyes instead of the light reflected directly from the cornea. In 1930, photographic techniques were applied in eye tracking technology to examine peoples' reading speed and how print size, page layout, etc. affect their reading abilities. In 1947, eye tracking technology was started to be employed in usability studies. Motion picture cameras were used to examine pilots' eyes as they used cockpit controls and instruments to land an airplane (Fitts, Jones, & Milton, 1950). This research is the first example of eye tracking use in the context of usability engineering. Users' interaction with products was considered to improve product design. In 1948, first head-mounted eye tracker was used and until 1960 head-mounted eye tracking systems were improved to make them more comfortable for the participants. After 1970, eye tracking technology has

been improving and researchers have focused on cognitive factors like learning, memory, workload and deployment of attention. Since 1980, eye tracking technology has been used in HCI for usability studies, especially with a focus on disabled users, work in flight simulators and computer mediated communication.

In general, eye movements are measured with two techniques (Duchowski, 2007). The first technique measures the orientation of the eye in space by measuring the position of the eye relative to the head (Young & Sheena, 1975). The second technique is called point of regard, which is commonly used to identify the elements in a visual scene like graphical interactive applications by using video-based corneal reflection eye tracker (Young & Sheena, 1975). In this technique, the head must be fixed or multiple ocular features must be measured to disambiguate head movement from eye rotation. Generally, there are four categories of eye movement measurement methodologies, which are Electro-OculoGraphy (EOG), Scleral Contact Lens/Search Coil, Photo-OculoGraphy (POG) or Video-OculoGraphy (VOG), and video-based combined pupil and corneal reflection (Duchowski, 2007). EOG technique has been commonly using for 40 years. In this technique electrodes are placed around the eye in order to measure the skin's potential electrical differences. This technique measures eye movements relative to head position. Therefore, this technique is not suitable for point of regard measurements unless head position is also measured. Scleral Contact Lens/Search Coil technique is one of the most precise eye movement measurement methods, however, it is also the most difficult method to apply. Mechanical or optical reference objects are placed on a contact lens, and then the lens are worn directly on the eye. This technique has some difficulties like insertion of the lens requires care and practice, and wearing of the lens causes discomfort. In addition, this technique is not suitable for point of regard measurement because this method measures eye position relative to the head. POG or VOG techniques are successful to measure different features of eyes under rotation like the apparent shape of the pupil, the position of the limbus – the iris sclera boundary- and corneal reflections of a closely situated directed light source (often infra-red). As a disadvantage of these techniques, measurement of ocular features may or may not be made automatically, and the evaluation of visual records are performed manually (e.g., stepping through a videotape frame-by-frame). Therefore these methods can be extremely tedious and prone to error, and limited to the temporal sampling rate of the video device. Also, these techniques often do not provide point of regard measurement. Video-Based Combined Pupil/Corneal Reflection measurement technique is based on point of regard measurement. In other words, head movement is disambiguated from eye rotation by measuring corneal reflection and pupil center features. In this technique, the positional differences between the pupil center and corneal reflection changes with pure eye rotation are measured. The distance between pupil center and corneal reflection stay constant with minor had movements. The corneal reflection of the light source (typically infra-red) is measured relative to the location of the pupil center.

In this thesis, two portable eye-trackers Tobii X2-60 were used (Tobii, 2014). This device provides larger head movement tolerance as well as stable and reliable eye tracking

calibrations. The eye-tracker uses infrared illuminators to generate reflection patterns on the corneas of the participant's eyes. The image sensors of the device collect these reflection patterns and the other visual data about the participant. 3D position of each eyeball, and finally the gaze point that states where the participant is looking are calculated with complex trigonometric transformations.

2.4.2 Dual Eye-Tracking

More recently, eye tracking technology has been using to study the interaction between people by tracking and analyzing eye-movements of two persons synchronously (Nüssli, 2011). This technique is attracting increasing interest from researchers who study collaboration and interaction in general; because, it allows researchers to gain insights into the cognitive processes of participants while they engage in social interaction. To be more precise, this interaction is performed synchronously via remote and shared environment in that study. In particular, this method allows researchers to observe the degree of overlap between the eye gaze of participants during the course of collaborative, which is considered as a strong indicator of the degree of joint attention among the group members.

2.4.3 Related Studies of Dual-Eye Tracking and Joint Attention Studies

Recently, researchers have been using several eye-tracking technologies in parallel to measure the level of synchronization among individuals to understand how they allocate their focus of attention in real time. Brennan, Chen, Dickinson, Neider, & Zelinsky (2008) conducted a dual-eye tracking study to explore the effect of shared gaze and speech during visual search. The researchers found that the shared gaze condition was the best among all conditions, which included shared-gaze, shared-voice, and shared-gaze-plus-voice. Shared gaze search condition was faster than the other conditions and it was twice as fast and efficient as solitary search.

Schneider and Pea (2013) performed a dual-eye tracking study on collaborative problem-solving dyads who remotely collaborated to learn from the cases which involved basic concepts related with how the human brain processes visual information. The researchers evaluated two situations; in the first condition, the dyads saw the eye gaze of their partner on the screen, and in the second condition, they did not have such an information. The result of the study showed that the participants in the first condition achieved joint attention more often than the participants in the second condition. In addition, the researchers found that real time mutual gaze sharing applied in the first condition leads to higher level of collaboration quality and learning gains.

Liu et al. (2009) employed a machine-learning algorithm to analyze the eye gaze patterns of collaborating dyads to predict which participant is more expert than the other. The studied approach was successful in predicting expertise level as early as one minute into the collaboration with 96% accuracy.

Nüssli et al. (2009) performed a dual-eye tracking study to show that eye-gaze data and raw speech data can be used to build predictive models of performance in collaborative tasks. The researchers were able to predict participants' problem solving success with an accuracy rate of up to 91% by using only raw measures of speech and gaze features.

Cherubini, Nüssli, & Dillenbourg (2010) examined the relation between deixis and eye movements in remote collaboration by using dual-eye tracking methodology. The researchers performed experiments in which the pairs had to collaborate using chat tools that differed in the way messages could be enriched with spatial information from the map in the shared workspace. The researchers are mainly interested with the effect of explicit referencing on the coordination of the eye movements of the participants. They found that explicit referencing did not produce any significant effect on the gaze coupling. However, the researchers found a significant relation between the pairs' recurrence of eye movements and their task performance.

Jermann & Nüssli (2012) performed a dual-eye tracking study to examine the effect of sharing selection between the collaborators in a remote-pair programming case. The researchers examined the relation of gaze cross-recurrence with interaction quality and referential selection. The study showed that gaze-recurrence is higher for pairs with high interaction quality which was evaluated with division of labor, participation symmetry, efforts to sustain shared understanding, as well as the pairs' capacity to agree on the problem-solving strategy. Also, there was a relationship between gaze cross-recurrence and referential selection.

Jermann, Nüssli, & Li (2010) performed a dual-eye tracking study in a collaborative game setting involving Tetris. The researchers implemented a multiplayer version of the classical Tetris game, in which two pieces fall at the same time in the same game area. Each player can control one of the pieces with the usual Tetris movements, such as left or right translation, rotations, down accelerations and drop. The participants were divided into two types as novices and experts based on the subjects' score during the individual training phase. The study showed that players adapt their behavior to the social context of interaction. In other words, experts and novice participants adapt their playing style when interacting in mixed ability pairs.

Sangin, Molinari, Nüssli, & Dillenbourg (2008) examined eye-gaze patterns of collaborating students with dual-eye tracking in the context of concept-map development. The researchers explored the way learners used the Knowledge Awareness Tool (KAT) during the course of collaboration and its relation with learning outcomes and verbal interactions. The study showed that there is a significant and positive correlation between the number of fixations on KAT and the learners' relative learning gain. Gaze recordings showed that students refer KAT information broadly at the beginning when they discuss about the strengths and weaknesses of each other's knowledge. Also, they refer to KAT information when the peers provide verbal cues about the quality of their knowledge.

Pietinen, Bednarik, & Tukiainen (2009) performed dual-eye tracking research to examine visual attention of two program developers in the case of pair programming. The researchers presented a descriptive analysis of visual attention throughout the pair programing task. As a result, they interpreted that pair-programming protocol is partly visible in both developers' eye-movements and this protocol can be used as an additional source of evidence when examining the true protocol that the pair actually follows. Pietinen et al. (2009) also planned to investigate the role of visual-attention in the pair-programming context to devise better methodologies to evaluate dual-eye tracking data and build gaze-aware integrated development environments to improve the collaboration processes in programming.

Pietinen et al. (2010) presented a methodological framework to examine visual attention of pair programmers with a single display. The researchers presented the requirements for the dual eye-tracking setup and the challenges of such research when applied in the real-world setting.

Richardson & Dale (2005) conducted a dual-eye tracking study to investigate the coupling between a speaker's and a listener's eye movements. The researchers performed cross-recurrence analysis and found that the listener's eye movements most closely matched the speaker's eye movements at a delay of 2 sec. The researchers emphasized that coupling between the speaker's and listener's eye movements reflects the success of the peers' communication.

Richardson, Dale, & Kirkham (2007) examined the relation between pairs' eye-movements when they discuss about something they can see in front of them. The researchers found that the pairs' eye-movements were coupled across several seconds, and the coupling also increased if the participants heard the same background information prior to their conversation. The research provided direct quantification of joint attention during unscripted conversation. Also the findings showed that knowledge in common ground positively influenced joint attention in a spontaneous dialogue.

2.5 Discussion of Related Research

In recent years, cBPM has attracted the attention of many researchers as they examined cBPM from different perspectives. Some studies investigated cBPM in the context of computer supported collaborative learning. Some of them criticized and evaluated BP modeling tools in terms of their collaboration capabilities. In some studies, researchers evaluated a single user BP modeling activity with eye-tracking methodology to assess user satisfaction, to understand the formalization phase of process modeling and to understand the relationship between the relevant region of process model and the answer given to the comprehension question (Hogrebe, Gehrke, & Nüttgens, 2011; Petrusel & Mendling, 2013; Pinggera et al., 2013).

To the best of our knowledge, investigation of teams' interaction quality throughout the CSCBPM is a relatively untouched area in current state of the art. In order to fill this gap in the literature to some extent, we aim to examine the CSCBPM processes in detail by employing a dual-eye tracking experimental approach. Our main goal is to identify the aspects of collaborative process that are crucial for successful interaction and modeling activities in the context of CSCBPM. Moreover, the relationships between these collaboration quality aspects and joint visual attention have not been examined in the context of CSCBPM, yet. So this thesis study aims to cater to this gap by investigating the relationships between collaboration quality aspects and joint visual attention.

The outcome of a collaborative activity is an important indicator for the evaluation of collaboration quality. For instance, in the context of computer supported collaborative learning, collaborative work product/outcome is generally evaluated with performance scores by using a pre- and post-test approach to measure how much students learn after collaborative problem solving activities (Nüssli, 2011). Researchers identified positive relations between collaborative interaction and collaborative outcome quality in the CSCL context (Schneider & Pea, 2013; Spada et al., 2005). However, there is a weak relation between the level of understanding and the quality of collaboration in the CSCW context (Jermann & Nüssli, 2012). In addition, the relation between joint attention and quality of collaborative outcome has attracted the attention of researchers. Consequently, the relation of joint attention with problem solving success (Nüssli et al., 2009), learning gain (Schneider & Pea, 2013), task performance (Cherubini et al., 2010) and level of understanding (Jermann & Nüssli, 2012) were examined. To the best of our knowledge, there is no study examining the relations between collaboration quality and quality of collaboratively produced process models. Moreover, we could not identify any studies investigating the relationship between joint attention and the quality of collaboratively produced process models. Therefore, we aimed to fill this gap in state of the art by investigating these relationships.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter includes four main sections. In the first section, the design details of the pilot study is introduced. In the second section, the design of the main study is introduced. In the third section, the qualitative and quantitative data analysis methodologies are introduced in detail. Lastly, the ethical consideration is presented.

3.1 Study Setting for the Pilot Study

In this study, collaborative nature of quasi-synchronous CSCBPM was examined in CSCW environment. A prototype environment was setup for CSCBPM practices where more than one stakeholder worked as a geographically distributed project team. A pilot study was conducted to identify the following points before performing the main study;

- Platform for CSCBPM activities and BP modeling notation
- Cases for business processes
- Characteristics of participants
- Number of group members and roles assigned to the team members
- Questions for survey instrument and semi-structured interview questions
- Research setup and data collection procedure

3.1.1 Groupware for Pilot Study and BP Modeling Notation Selection

There were several computer-mediated communication options to facilitate BP modeling practices were examined such as Logizian 10.2, COMA, CoMoMod, cCEP. However, commercial BP modeling tools predominantly support asynchronous modeling (Riemer et al., 2011) and most of them were not publicly available. Therefore, VMT Chat and ARISalign CSCW systems were selected as quasi-synchronous communication channels to conduct the pilot experiments. VMT Chat is a groupware providing a set of features to help users to manage their activities across multiple interaction spaces. VMT Chat was developed as part of the Virtual Math Teams project at Drexel University to support collaborative learning of mathematics online (Stahl, 2009). VMT Chat is built over the concert chat architecture which was developed as a generic CSCW tool by the Fraunhofer Integrated Publication and Information Systems Institute (Mühlpfordt & Wessner, 2005). VMT Chat is java-based and enables internet communication through the interrelated whiteboard and chat tools. A screenshot of the VMT Chat interface is shown in Figure 4.

Stahl, Ou, Cakir, Weimar, & Goggins (2010) state that whiteboard and chat tools provide spaces for the individuals' interaction. The whiteboard is a shared, dynamic workspace where participants can enter textboxes, draw lines and ellipses, and use other tools similar to those in popular word processing software. All the team members can use the shared whiteboard area at the same time. During the modeling activities, participants can work on the same object or a different part of the model separately. The shared whiteboard area of the system is limited in size, so additional tabs were created in case the current whiteboard area would not be sufficient to complete the model. The other main communicative space is the chat on the right side of the screen where each member of a chat team has a distinct color for their typed entries and members' contributions become visible to other members in the room. Also the system displays an awareness message at the bottom of the message window about the user who is typing a message at that time. VMT Chat provides a special referencing tool that participants can use to point from chat to whiteboard to direct teammates' attention to a particular part of the whiteboard. The same referencing feature can be used to link messages, which is particularly useful in terms of conveying who is responding to whom during chat with multiple participants. The system has a Current Users window that shows the online team members. The system has a history bar that enables the team members to see the previous version of the models.

VMT Chat does not support any BP modeling notation. The system was redesigned by placing Extended Event-Driven Process Chain (eEPC) notations in the shared whiteboard area. eEPC was selected as BPM notation rule because it is one of the most frequently used modeling notation (Pesic & van der Aalst, 2005) and it provides easy model readability by not only for process analysts but also for process users who are not familiar with process models.

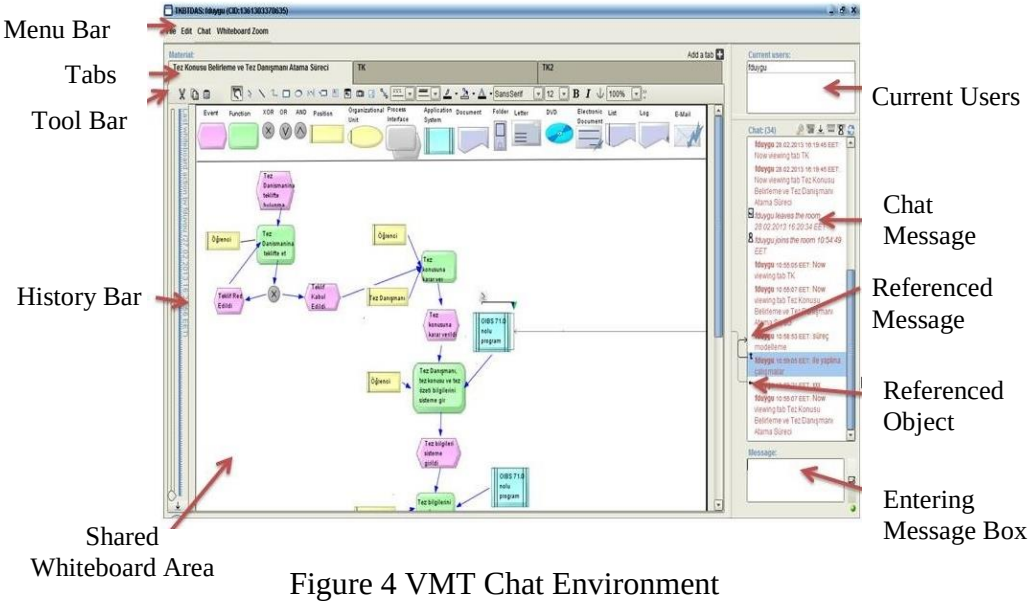

Figure 4 VMT Chat Environment

ARISalign groupware system has a shared whiteboard area as shown in Figure 5; however the team members cannot use this area at the same time. Only the active user, who has accessed the model first, has the right for editing the model, and the other users have to wait for the active user to complete his editing on the whiteboard. The system has a discussion board (in Figure 6) for establishing communication among team mates. Discussion board and the whiteboard area are on different pages of the system. ARISalign supports the subset of BPMN notations; therefore this notation was used as the modeling rule for the CSCBPM activities in this study.

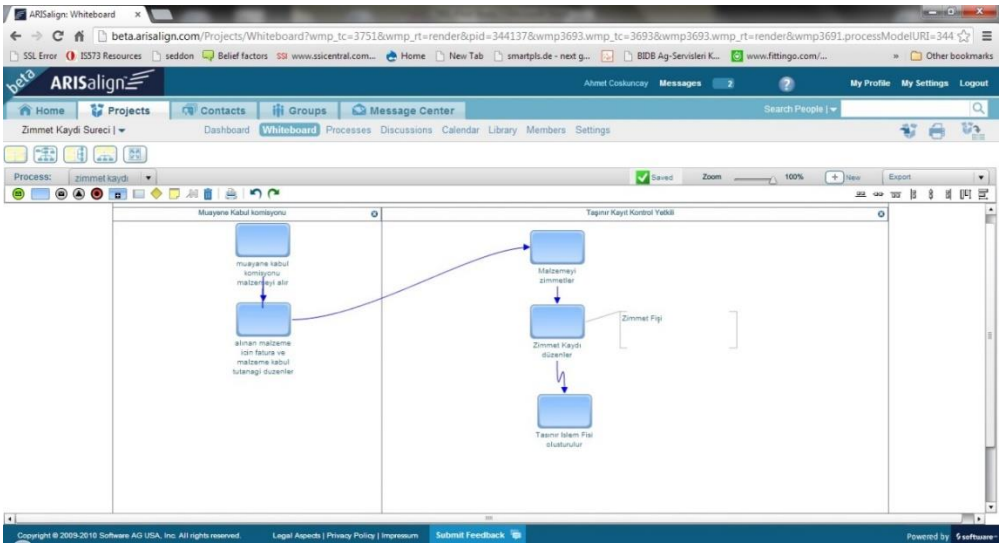

Figure 5 ARISalign Whiteboard Area

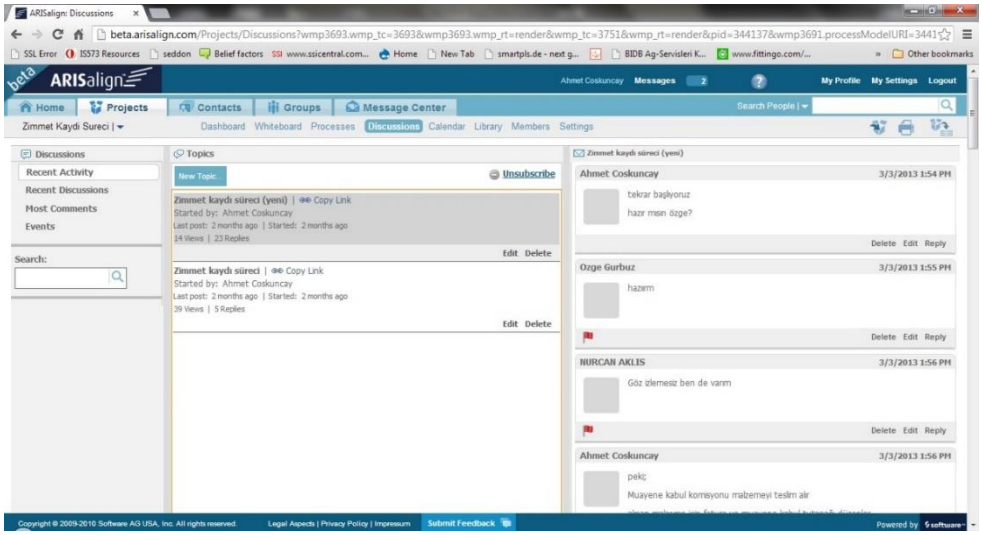

Figure 6 ARISalign Discussion Panel

VMT Chat and ARISalign promote the following collaboration support features shown in Table 1;

Table 1 Collaboration Support Features of Groupwares

Collaboration Features (Malone & Crowston, 1994)	**ARISalign**	**VMT Chat**
Awareness	▪ Network activity overview (Tracking the changes made by each stakeholders)	▪ Network activity overview with History tool (Tracking the changes made by each stakeholders)
Communication	▪ Discussion groups ▪ E-mailing and text messaging with users	▪ Text messaging with chat ▪ Commenting on process models
Coordination	▪ Search function ▪ Link between whiteboard and process modeling tool	▪ Track history (restoration of a previous version, comparing versions) ▪ Shared resources (wikis) ▪ Link between whiteboard and text messages
Group Decision Making	▪ Discussion groups where documents can be attached	▪ Commenting functionality with reference tool ▪ History feature for repeating collaborative activities (instead of pure logging functionality)
Team Building	▪ Project access control ▪ Searching connections ▪ User role management ▪ Shared workspace functionality (Synchronous editing is not possible though, but saved changes are made available to all other users)	▪ Project access control ▪ Concurrent shared workspace functionality (the joint administration of shared document)

3.1.2 Definition of Business Processes Used in Pilot Study

In the scope of this study, three ecologically valid cases were selected for collaborative business process modeling activities, which are ongoing administrative process at Middle East Technical University (METU). The cases were selected carefully to ensure that the team members had no detailed information about the cases. Case-I was titled ‘New course proposal evaluation process-Yeni ders açma önerisi değerlendirme süreci’, Case-II was titled ‘Taking semester leave due to military service - Askerlik nedeniyle kayıt dondurma süreci’ and Case-III was titled ‘Debit entry process - Zimmet kaydı süreci’. Process descriptions in natural language are in Appendix A.

Case-I and Case-II were modeled in VMT Chat groupware by using the eEPC notation and Case-III was modeled in ARISalign groupware by using a subset of the BPMN notation.

3.1.3 Participants of the Pilot Study and Survey Instrument Development

In this study, a prototype environment was setup to support and investigate quasi-synchronous CSCBPM practices where more than one user worked as a geographically distributed project team. One collaborative business process modeling team (cBPM team) was established with three participants who are PhD students in the Information Systems (IS) program at the Informatics Institute (II) of METU. One of the team members was assigned the Domain Expert (DE) role and the other two were designated as Process Analysts (PAs), PA1 and PA2. PAs were responsible for modeling the business processes according to the information given by DE. No prior information about the processes was given to PAs.

Since team members were Turkish natives, in order to scope out any possible language barriers or biases, Turkish was selected as the interaction language. Therefore, the processes and process elements were named in Turkish and communication during BP modeling practices were conducted in Turkish.

Before the experiments were conducted, a basic training about modeling notations and systems was given to the team members. Firstly, VMT Chat environment was introduced to all team members. Although the modelers were familiar with modeling notations used during the experiments, model elements were introduced as a reminder. In the scope of this elucidating, some tips for using the systems' features were provided to the participants. For example, usage of the chat and the messaging windows, the referencing tool and its utilization in the whiteboard area and the chat window, duplication of model elements with copy-paste method and making connection between them were demonstrated to the participants. Small modeling exercises were performed before the experiment with the modelers to ensure that they got acquainted with the VMT Chat system. ARISalign was also introduced to the team members before the experiment session. They were informed about the communicational features of the system, as well as features for using model elements and managing the shared whiteboard page.

Before the experiment was conducted, a questionnaire was administered to team members to collect information about their demographic profiles and their previous BP modeling experiences and capabilities. Different questions were asked to DE (in Appendix B) and PAs (in Appendix C). In addition, some semi-structured interview questions (in Appendix D) were prepared to get information about the participants' CSCBPM experiences in the CSCW environment after the experiment. Content validity of the questionnaires were assessed by an expert panel that includes an Assistant Professor, two PhD candidates, and two master students.

Demographic profiles of the team members is shown in Table 2. According to the questionnaire results, PAs reportedly had abilities and experiences related to BP modeling. In addition, DE had prior experience on BP modeling and capable of model reading. Therefore, the team had the required background to engage with CSCBPM scenarios.

Table 2 Demographic Profile

Demographic Characteristics of Information Provider	**DE**	**PA1**	**PA2**
Gender	Male	Female	Female
Age	29	30	25
Occupation	Research Assistant	Research Assistant	Research Assistant
Familarity with peers	Yes	Yes	Yes
Ability on group works	Good	Good	Good
Member's thought about team strength	Not very strong but strong enough	Strong	Strong
Previous experiences on CSCW environments	Google Drive (Docs)	-	-
Previous experiences on BPM with CSCW environment	-	-	-
Member's evaluation on own process modeling ability	-	Neutral	Pretty Good
Previously used BPM notations	-	UML Activity Diagram, Data Flow Diagram, eEPC	UML Activity Diagram, Data Flow Diagram, eEPC
Previously used BPM environments	-	Microsoft Office Visio and Enterprise Architect	Microsoft Office Visio and ARIS Business Architect

3.1.4 Research Setup and Data Collection Procedure of the Pilot Study

In the design of the research, eye tracking technology, especially dual-eye tracking technique was used. In order to form a geographically dispersed team, PA1 attended the experiments at the TEL Lab of Computer Education and Instructional Technology department of METU. PA2 attended the experiments at the Human Computer Interaction Research and Application Laboratory located in the Computer Center of METU. TOBII T120 and T1750 Eye-Trackers are used in these laboratories (shown in the Figure 7 and Figure 8). The participants were seated at a distance of approximately 60 cm from the eye tracker. DE attended the experiment with his own computer in a separate room.

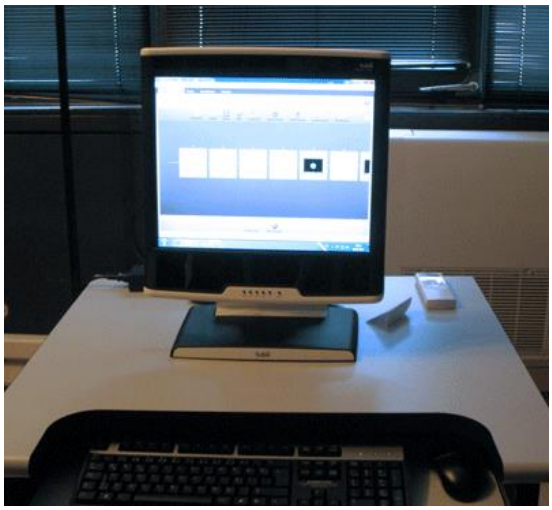

Figure 7 TOBII T120

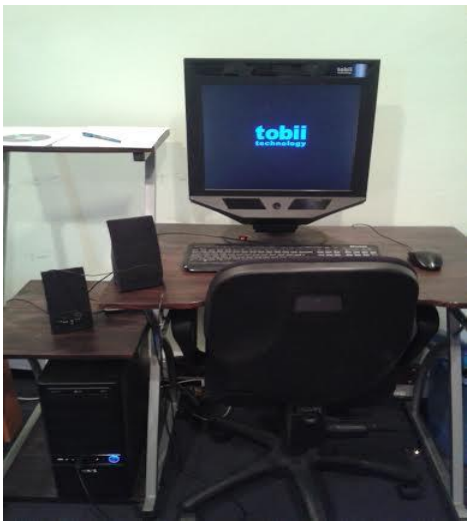

Figure 8 TOBII T1750

The experiment was conducted in three sessions. In the first session, Case-I was discussed and modeled in the VMT Chat environment. The first session was completed in 63 minutes. After 45 minutes break time, the second session was conducted for Case-II in VMT Chat again. Modeling of the process was completed in 48 minutes. After 60 minutes break time, the third session was performed for Case-III in ARISalign. In total, the team spent 48 minutes to complete the third session.

In the first and second sessions, data gathered from eye-trackers and the communicational contents exchanged by the group members in the form of chat messages and shared diagrams were obtained from VMT Chat's system logs constituted the primary data source. In the third session, PA1's eye tracking data could not be taken because of the unexpected technological problems. Therefore, only the chat stream on the discussion board and eye tracking records of PA2 were collected to examine the collaborative model building session for Case-III.

3.2 Study Settings for the Main Study

Research setting of the main study was designed after the examination of advantages and disadvantages of the research setting of the pilot study. As a result, major changes were applied on the research design of the study. The changes and their reasons are explained in the next subsections. The following tasks were carried out to design the main study. Firstly, VMT Chat groupware was designed to host the modeling activities and BP modeling notations were selected to be used during the experiments. Secondly, two cases were selected for CSCBPM activities and their complexities were examined. Thirdly, team members were selected and their roles were assigned and survey instrument was applied to collect data from the participants. Lastly, research setup and data collection procedures were designed.

3.2.1 Groupware for the Main Study and BPM Notation Selection

After the pilot study, interaction analysis was conducted on the chat messages and shared diagrams to identify appropriate tool and interaction design of the systems for the next experiments. The detailed examination of the interaction analysis can be found in section 4.1. Interaction of the participants and semi-structured interview results showed that ARISalign groupware was not successful to support coordination aspects such as communication, coordination, awareness, group decision making in a real interaction scenario. Therefore this system was eliminated and only the VMT Chat groupware was used as a quasi-synchronous communication channel for the next experiments. The detailed information about the VMT Chat groupware can be found in section 3.1.1.

eEPC and UML Activity Diagram modeling notations were selected as the modeling notations because these methods are well-established and popular in BPM practice and commonly used for the formalization of the process definitions. Both were established in 90s and have a strong functional behavior. While eEPC was born in the business domain and essentially used in business analysis, UML Activity Diagram was burn in software domain and essentially used in software analysis. Also, eEPC has stronger information perspective and support behavioral perspective when compared to the Activity Diagram. In addition, PAs had already experienced with eEPC and UML Activity Diagram modeling notations; therefore this standard was selected as the modeling rule to eliminate any threats that might be caused because of inexperience on the modeling notation. For the main study, the system was redesigned by placing eEPC and UML Activity Diagram pallets that include the notation elements to be used in the shared whiteboard area (shown in Figure 9 and Figure 10).

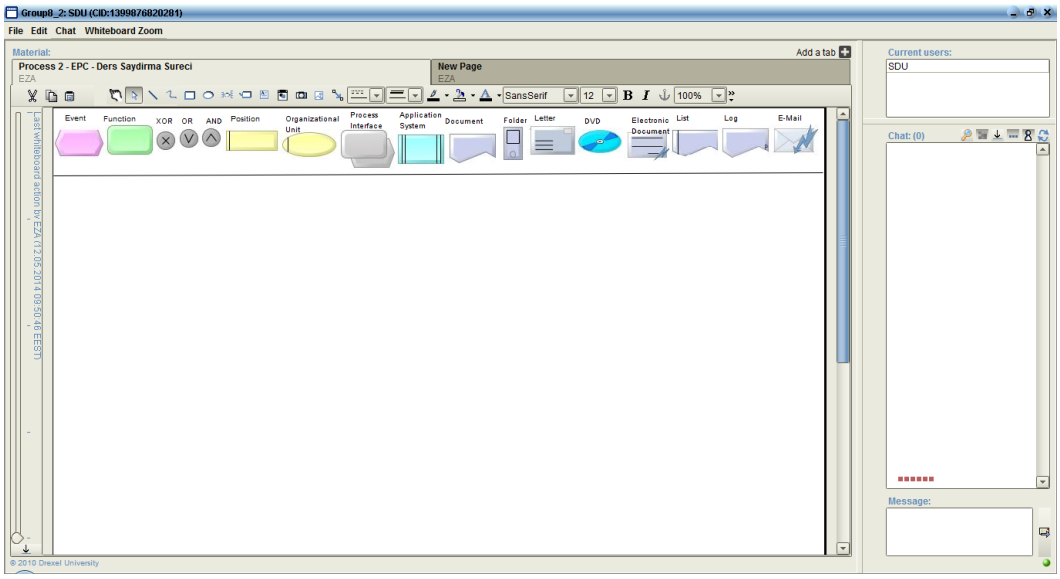

Figure 9 VMT Chat with eEPC Pallet

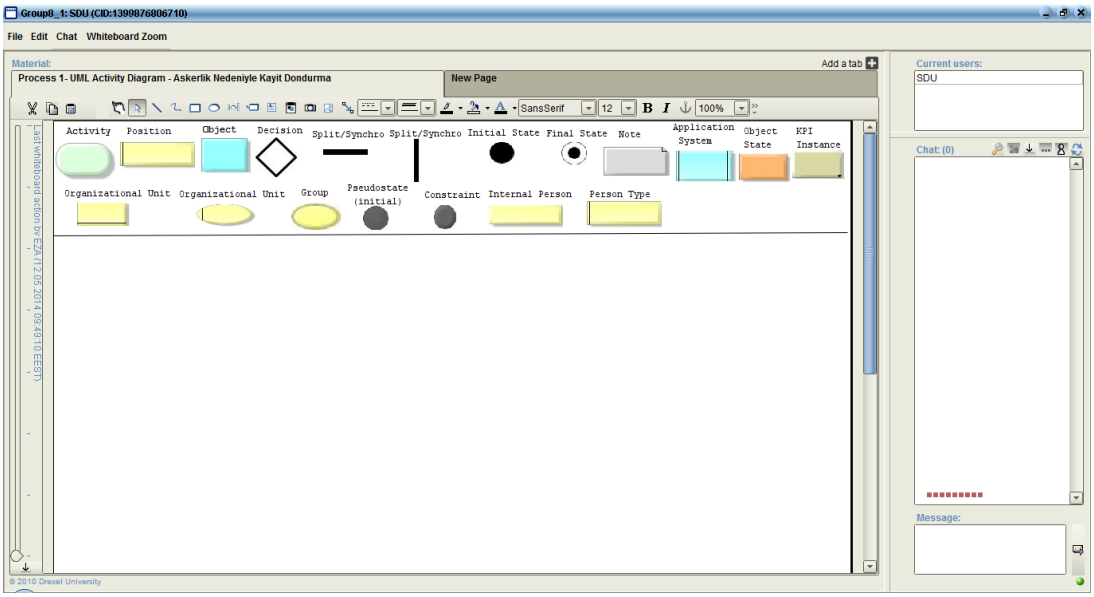

Figure 10 VMT Chat with UML Activity Diagram Pallet

3.2.2 Definition of Business Processes Used in Main Study

In the main study, two ecologically valid cases were selected for collaborative business process modeling activities, which are ongoing administrative processes at METU. Case-I was titled 'Taking semester leave due to military service - Askerlik nedeniyle kayıt dondurma süreci (ANKDS)', which was previously used in the pilot study, and Case_II was titled 'Course exemptions process - Ders saydırma süreci (DSS)'. The descriptions of the processes in natural language are in Appendix E.

The processes were selected carefully to ensure that the participants had no familiarity and in depth knowledge about the cases. In addition, in selecting the processes, it was considered that the processes would have similar complexity to prevent any biases that could be due to nonequivalent business processes. Complexity measures tell us whether a model is easy or difficult to understand (Gruhn & Laue, 2006). Therefore, the size and the complexities of the processes were measured with the number of activities (adapted from Line of Code - LOC), Cross-Connectivity (CC) measures and Control Flow Complexity (CFC) which are used for process complexity measurement (Aysolmaz, İren, & Demirörs, 2013; Gruhn & Laue, 2006). According to these measures, the processes (in Table 3) approximately have the same complexity.

Table 3 Complexity Measures of the Processes

Process Model	Complexity Metrics	Measured Value of the Complexity Metrics
ANKDS	CFC	4
	CC	0,056
	LOC	4
DSS	CFC	4
	CC	0,057
	LOC	4

ANKDS was modeled with UML Activity Diagram and DSS was modeled with eEPC. Process definitions were modeled in reverse order by each cBPM team to prevent any threat that may arise because of the learning effect of the system usage. The cBPM teams and the modeling order of the processes are shown in Table 4.

Table 4 Modeling Order of the Processes and Used Notations

cBPM Team	Firstly Modeled Process and Used Modeling Notation	Secondly Modeled Process and Used Modeling Notation
Group1	DSS	ANKDS
Group 2	ANKDS	DSS
Group3	DSS	ANKDS
Group 4	ANKDS	DSS
Group 5	DSS	ANKDS
Group 6	ANKDS	DSS
Group 7	DSS	ANKDS
Group 8	ANKDS	DSS
Group 9	DSS	ANKDS

3.2.3 Participants of the Main Study

Team building process was similar to the pilot study and the detailed information can be found in section 3.1.3. In the main study, 18 CSCBPM experiments were conducted with 9 cBPM teams and each team included 3 participants. One of the team members was assigned the role of DE and the other two, who had 2-5 years of work experience in professional software development, claimed the role of PAs. The participants were graduate students in the IS program at the II of METU.

The survey instruments prepared in the pilot study were administered before the experiments to collect information about team members' relevant BP modeling skills and experience. The detailed explanation about the survey instruments can be found in section 3.1.3.

The characteristic properties of the team members are presented with the following aspects. Demographic profile of the participants includes team members' age, gender, educational background, department and occupation. Some descriptive statistics are given

about computer experience, computer usage skills, Internet usage period, prior knowledge about groupware used in the experiment and prior experiences with chat programs, BP modeling, CSCBPM, BP modeling notations and BP modeling tools. Also familiarity of the team members, their experiences and tendency of collaborative group work are presented.

Participants' ages varied between 24 and 40, and their mean age was 29.8. 18 of them were female, and 9 of them were male. 7 participants were in M.Sc., and 20 of them were in Ph.D. degree programs at METU. 23 of the participants' most recent major was IS and 4 of the participants' was Medical Informatics. One of the participant was software engineer and remaining were research assistant at METU.

All of the participants had been using computers for 10 years or above. 16 of the participants rated their computer usage skills as very good, 8 of them as good, and 3 of them as average, respectively. 22 participants had been using Internet for 10 years or above, and 5 of them for 7 to 9 years respectively. 4 of the participants indicated that they had used the VMT Chat before, and their usage frequency was rare. All of the participants had used a chat program before. 16 of the participants rated their chat program usage frequency as very often (almost every day), 7 of them as often (at least once a week), 3 of them as sometimes (at least once a month) and 1 of them as rarely (at least once in two months or less).Chat programs used by the participants were WhatsApp, Skype, Hangouts, MSN Messenger, MS Lync and Facebook.

The participants who had the DE role had not performed such an information provider role during their past BP modeling experiences. All of the participants, who had the PA role, previously had experience with BP modeling. 3 of the participants who had the PA role rated their BP modeling capability as pretty good, 7 of them as good and 8 of them as average. 3 of the participants, who performed the PA role, reported that they had prior CSCBPM experience, and 15 of them reported that they have never had such a process modeling experience.

PAs who reported prior experience with BP modeling notations all mentioned that they used both UML Activity Diagram and eEPC. In addition to this, some of the PAs mentioned that they had experience with other BP modeling notations such as Data Flow Diagram, Business Process Model and Notation and Petri Nets. PAs who reported prior experience with BP modeling tools all mentioned that they used Microsoft Office Visio, ARIS Business Architect and Enterprise Architect. In addition, some participants mentioned other BP modeling tools such as ARISalign, Signavio Process editor, iGrafx Process Modeler 2011 and UPROM.

3 of the participants were not familiar with their team mates. The remaining participants were familiar with their teammates and 1 of them rated their social interaction with group members as no communication, 1 of them as very limited, 5 of them as average, 14 of them as good communication and 3 of them as pretty good. 13 of the participants have

experienced with computer supported collaborative group work and 14 of them have not yet experienced such an activity. 3 of the participants rated their tendency for group studies as pretty good, 20 of them as good and 4 of them as average, respectively.

3.2.4 Research Setup and Data Collection Procedure of the Main Study

In the scope of this study, eye tracking technology was used to examine eye movements of the PAs to understand both where they were looking at any given time and the sequence in which the modelers' eye gaze was shifting from one location to another. Specifically, dual eye tracking technique was used to understand the interaction between PAs by tracking and analyzing their eye-movements synchronously.

At the data analysis stage of the pilot study, it was recognized that the research setup had pitfalls to perform quantitative analysis on eye-tracking data. The monitors used in the pilot study were not large enough to fully display the shared business process model, so the PAs needed to make scrolling to navigate on the shared modeling area. Because of the scrolling actions of the PAs, we needed to use dynamic AOIs (look section 3.3.4 for the details of AOIs) to measure the degree of overlap and coordination among the participants' fixation sequences. However, it was realized that dynamic AOIs in not a suitable method to analyze long interaction recordings. Due to this limitation, in the next experiments, "Whiteboard Zoom" option of the VMT Chat system was used as 75% to make the shared modeling area smaller to prevent scrolling that would cause difficulty in the quantitative analysis of dual eye tracking data. In addition, research setting was rearranged for the main study by changing eye-tracker devices and size of the monitors.
Unlike the research setup used in pilot study (look at section 3.1.5), two TOBII X2-60 eye trackers were used in the main study as shown in Figure 11. Eye-trackers were attached to the 19 inch widescreen LCD monitors which had 16:10 aspect ratio and 1440 x 900 screen resolution. Screen size was large enough to see the shared working area as a plain document and make the modeling without any scrolling to prevent the any problems that were faced during the quantitative analysis of the pilot data. In order to build geographically dispersed teams, team members were located in different room. PAs attended the experiments with the computers attached with the eye tracker devices. The participants were seated at a distance of approximately 60 cm from the eye tracker. DE used another computer which had internet connection.

Figure 11 TOBII X2-60

Time to complete the modelling sessions for ANKDS and DSS is given in Table 5. The cBPM teams on average took 62 minutes to complete the modeling of two business process models assigned to them.

Table 5 Total Experiment Time for Groups

cBPM teams	Time to complete ANKDS	Time to complete DSS	Total time
Group 1	38 minutes 47 seconds	32 minutes 42 seconds	71 minutes 29 seconds
Group 2	45 minutes 41 seconds	34 minutes	79 minutes 41 seconds
Group 3	20 minutes	36 minutes	56 minutes
Group 4	41 minutes	33 minutes	74 minutes
Group 5	30 minutes	39 minutes 39 seconds	69 minutes 39 seconds
Group 6	35 minutes 19 seconds	14 minutes 09 seconds	49 minutes 28 seconds
Group 7	31 minute 25 seconds	37 minute 16 seconds	68 minutes 41 seconds
Group 8	30 minutes 29 seconds	18 minutes 17 seconds	48 minutes 46 seconds
Group 9	15 minutes	27 minutes 46 seconds	42 minutes 46 seconds

In addition to data gathered from the eye-trackers, VMT Chat logs will be used as data source which includes the communicational contents exchanged by the participants in the form of chat messages and shared diagrams. The logs of the system includes the participants' text messages, actions performed on the whiteboard area, date, start time, post time, duration, event type and user information. The system automatically produces log files; therefore, no extra effort is required to transfer chat logs into text format.

3.3 Data Analysis

After the experiments were conducted, collaborative interaction is investigated by using mixed methods incorporating qualitative and quantitative analysis techniques. In order to examine the research questions the following data resources are used; system logs (include communicational contents and share diagrams) and dual eye tracking recordings of collaborative model building sessions; The first research question 'Which factors affect the interaction quality of collaborative work groups in a synchronous CSCBPM context?' is examined through a qualitative analysis of the communicational content exchanged by participants in the form of chat messages and shared diagrams. Content analysis and interaction analysis are performed to investigate the factors affecting interaction quality. The remaining research questions are investigated with quantitative research methodologies that are complemented with qualitative measures obtained from the communicational contents exchanged between group members and semi-structured interviews. The second research question 'What are the relationships between the factors that affect interaction quality?' includes the interaction quality dimension, which is quantified in terms of the factors investigated in the first research question by examining and rating the collaborative interaction. This research question examines the relationship between the factors that affect interaction quality. The third research question, 'What are the relationships between the degree of joint attention and the factors that affect interaction quality?' includes two dimensions, namely joint attention and interaction quality. Joint

attention is measured quantitatively based on dual eye-tracking data, which indicate how participants allocate their attention on the shared workspace as well as the degree of overlap and coordination among their fixation sequences. Cross-recurrence analysis is performed to measure the degree of gaze coordination that is indicative of joint attention among the participants. The other dimension of this research question is the interaction quality which is mentioned in the previous research question. The fourth research question 'How do interaction quality factors affect the quality of the collaboratively produced business process models?' includes two dimensions, namely interaction quality and collaboratively produced BP model quality. The interaction quality dimension of this research question is mentioned in the second research question. The model quality dimension is investigated with semantic, syntactic and pragmatic approaches. The last research question 'How does the degree of joint attention affect the quality of collaboratively produced business process models?' includes two dimensions, namely joint attention and collaboratively produced BP model quality. Joint attention dimension is mentioned in the third research question and collaboratively produced BP model quality dimension is mentioned in the previous research question.

3.3.1 Identification of the Factors that Affect Interaction Quality in CSCBPM Context

Interaction quality is an important indicator for the success of collaboration. The process of collaboration is needed to be examined deeply to understand the process and the factors that affect interaction throughout the collaborative activities. In order to identify the factors that affect interaction quality and clarify the process of collaborative work, qualitative content analysis was performed on the communicational contents exchanged by the participants in the form of chat messages and shared diagrams. Qualitative content analysis was conducted with a recommended procedure which includes identification of contextual constraints, data preparation, threading, preparation of memos, defining unit of analysis, describing coding categories and coding definitions (Elo & Kyngäs, 2008; Strijbos, Martens, Prins, & Jochems, 2006; Zhang & Wildemuth, 2009).

Identification of Contextual Constraints

Qualitative content analysis was adapted according to the nature of quasi-synchronous chat communication and interaction of the participants' in synchronous collaborative work environment. Qualitative content analysis is a common method in research practice to examine the nature and organization of interaction among the participants in a chat environment (Strijbos et al., 2006; Strijbos & Stahl, 2007; Zemel, 2005).

Data Preparation

All written form of communication elements that form the contributions to the online discussions makes the process of collaboration more transparent for the researchers; because transcript of such text messages can be used to evaluate both the collaborative

process and the contribution of each individual to that process (Macdonald, 2003). In this study, qualitative content analysis is applied on the logs of the VMT Chat system that includes communicational contents exchanged by participants in the form of chat messages and shared diagrams. The logs of the system includes the participants' text messages, actions performed on the whiteboard area, date, start time, post time, duration, event type and user information. The system automatically produces the log files; therefore, no extra effort was required to transfer chat logs into text format.

The nature of the study inevitably affects the design of the qualitative content analysis. During a collaborative group work mediated by a quasi-synchronous chat environment, participants post their messages and respond to the related messages quickly, commonly using multiple short text messages. Due to the characteristics of chat communication, chat messages can be interleaved with each other in a non-sequential manner. To be able to understand the flow of interaction (e.g. who is responding to whom, which chat line is an extension of a prior chat line etc.) among the participants and identify the unit of analysis, the chat logs should be arranged by unit fragmentation and restructured according to the response structures observed in the data (Strijbos & Stahl, 2007). Before the identification of unit analysis and coding, unit fragmentation and response structuring issues should be handled by threading.

Threading

Communicational threading is an important step applied to understand the flow of the communication and interaction among the participants. Threading includes two issues that are unit fragmentation and reconstruction of the response structure. These issues should be addressed simultaneously before the coding categories are assigned to the segments (Strijbos, 2009). According to Strijbos's terminology (2009) unit fragmentation in a chat communication refers to those cases where a single utterance sent by an author spans across multiple chat lines. Such a chat utterance makes sense only if it is considered as a whole. To be able to understand the messages sent by an author, the connections between the separated messages should be examined. The other issue is the reconstruction of the chat's response structure. Response structuring enables the researches to understand who responds to whom. Detailed examination of chat interactions at this level enables the researchers to understand the interaction more clearly.

In this study, before selecting the unit of analysis and performing the coding, chat transcripts were examined in detail to identify the unit fragments. Examination of the unit fragments enabled us to merge multiple chat posts by the same author and treat the fragments as a whole message. In addition, the messages were also examined in detail to understand the relation between the messages and the response message (target message). Unit fragmentation and response structure of the discussion were examined in parallel; this examination made it easier to understand the nature of the communication and the identification of interaction units.

Table 6 shows an interaction episode and how the threading was conducted in the transcripts of the system. Combination of the lines 475, 476 and 477 creates the single message sent by PA1. Combination of lines 479 and 481 creates the single message given by DE as a response for the message (combination of 475, 476 and 477) sent by MO. Line 491 sent as a response for the message combination of 479 and 481. Then the combination of the messages in lines 487, 492 and 465 creates single message gives information about the process.

Table 6 Threading

Line	Post Time	Event Type	Users	Message	Linked to & Response for
475	04:22:21	chat	PA1	Şimdi ahmet	
476	04:22:26	chat	PA1	onaylanınca bitiyor mu	Linked to line 475
477	04:22:39	chat	PA1	dur ahmet desin burda yapacağımı bişi yoksa geçelim	Linked to line 475
478	04:22:31	wb	PA2	modeler_two copied some object/s	
479	04:22:34	chat	DE	Hayr	Response for the combination of lines 475, 476 and 477
480	04:22:33	wb	PA2	modeler_two moved some object/s	
481	04:22:47	chat	DE	güncelleme talebi geldiyse süre başa gonüyor	Linked to line 479
482	04:22:36	wb	PA2	modeler_two moved some object/s	
483	04:22:40	wb	PA2	modeler_two deleted some object/s	
484	04:22:42	wb	PA2	modeler_two moved some object/s	
485	04:22:46	wb	PA2	modeler_two created a connector between textbox and image	
486	04:22:49	awareness	DE	[fully erased the chat message]	
487	04:23:17	chat	DE	onay ise Enstitü Kurulu son bir değerlendirme yapıyor	
488	04:22:51	wb	PA2	modeler_two created a connector between image and textbox	
489	04:22:55	wb	PA2	modeler_two created a connector between image and textbox	

490	04:22:58	wb	PA2	modeler_two created a connector between image and textbox	
491	04:23:09	chat	PA1	en başa mı	Response for 481
492	04:23:48	chat	DE	ve enstitü sekreteri OIBS'de yeni dersi derskataloğuna ekliyor	Linked to line 487
493	04:23:35	wb	PA1	modeler_one created a connector between textbox and image	
494	04:23:44	wb	PA1	modeler_one deleted some object/s	
495	04:24:14	chat	DE	OIBS bizim öğrenci işleri bilişim sistemimiz	Linked to line 487

Defining the Unit of Analysis (Segmentation)

As stated previously, short and rapid messages are posted during the communication on the chat environment; which means a single declarative message may be spread over multiple postings (Strijbos, 2009; Zemel, Xhafa, & Cakir, 2007). It is often the case that, an individual chat posting is not adequate of identifying the nature of the communication, analytical organization of participation, and relation between the other chat messages (Zemel et al., 2007). Rather than the examination of single chat postings, we tried to understand what was happening during the interactions of the participants - how they communicated with each other, how they shared their knowledge, how they evaluated the performance of each other, how they handled the encountered problems, what kinds of system limitation(s) affected their performance and what kinds of system affordances provided effective interactions – to obtain insights about the factors affecting synchronous cBPM. In examination of the interaction from this perspective enabled us to observe that a combination of given messages, responding messages and actions of the participants in the shared whiteboard area generated meaningful activities.

The whole interaction of the participants in an experiment was segmented into approximately 10 minutes long blocks to reduce the memory load of the researchers during the examination of interactions. The segments include interaction units which have their own intention and objective to deal with and named as long sequences in which the participants organized their interactions (Zemel et al., 2007). The objectives of the interaction units enabled us to identify the boundaries of the long-sequences. There could not be defined strict and fixed length unit boundaries. While some of the long-sequences included only one message posting or activity in the shared whiteboard area; some of them included the combination of more than one message posting and several activities on the shared whiteboard area. Also, in some cases, the interaction units had more than one objective; and in some cases, interaction units were overlapped with each other.

For example, the following interaction unit shown in Table 7 was related with task coordination addressing how the modeling activity would be handled. The team members

made a consensus about the progress of the modeling process. They decided to perform modeling through an iterative approach, which means after DE shared a piece of information about the business process, the PAs would formalize the related information and then request a new information piece to continue the modeling. Also, this interaction sequence was an example of a group decision making to reach a consensus about the progress of the modeling effort.

Table 7 Example of a Segment

Line	Post Time	Event Type	User	Message	Codes
17	03:43:58	Chat	PA2	Nurcan, shall we model at the end or while Ahmet is giving the information? / *Nurcan en son mu modelleyelim yoksa ahmet anlatırken mi modelleyelim?*	**Task Coordination_1**
18	03:44:12	Chat	PA1	I think we should model while Ahmet is giving the information / *Ahmet anlatırken modelleyelim bence*	
19	03:44:19	Chat	PA2	I think so / *Bence de*	
20	03:44:32	Chat	DE	In that case, I will stop now and then to give you time to model / *Ben aralarda durup bekliyorum o halde sizi*	
21	03:44:28	Chat	PA1	Let's go / *lets go ozaman :)*	
22	03:44:38	Chat	PA2	OK / *Ok*	
23	03:44:42	Wb	PA2	modeler_two copied some object/s	**Formalization**
24	03:44:43	Chat	PA1	OK /*ok*	**Task Coordination_1**

Peparation of Memos

The chat lines of the experiments were read line by line by considering the threading issues. In addition, interactions throughout the collaborative model building were observed again and again by using the replay feature of the system as parallel with the videos that includes the gaze traces of the modelers. Throughout the detailed examination of the communicational contents and the interactions on the shared whiteboard area, memos were written for the experiments. Memos included the descriptions of the interactions among the participants.

Describing Coding Categories and Coding Definitions

Coding and segmentations were performed in parallel. The semantic content of the interaction units was examined to identify coding definitions. The long-sequences were named by considering the general objective of interaction performed in the related sequence. For example, the following interaction sequence (in lines 193 and 197) shown in Figure 12 is related with the correction of the created model. Therefore this interaction

sequence was named as validation. If an interaction unit had more than one objective, this sequence was named with more than one coding category. If there was an overlap between the interaction units, these sequences were named with different coding categories.

The whole logs of the system were marked to identify each long-sequence. The long-sequences that had the same objective were labelled with the same name by sorting with ascending number (Coding Name_n; e.g. Validation_5) and marked with the same color. Segmentation and coding categories were refined with five iterations and also these processes were reviewed by an expert who is an Assistant Professor. Figure 12 shows how the system logs were designed to separate the long sequences from each other. This interpretation of the interactions also shows that how the interaction units were interleaved with each other.

Line	Date	Start Time	Post Time	Duration	Event Typ	User	Message	Code
190	4/30/2014	07:32:13.243	07:32:24.928	0:00:11	chat	BS	ABD ye gönderildikten sonraki process e geçiyorum	Task Coordination_8
	4/30/2014		07:32:27.274	0:00:02	wb	SP	SP moved some object/s	
	4/30/2014		07:32:28.681	0:00:01	wb	SP	SP moved some object/s	
	4/30/2014		07:32:29.941	0:00:01	wb	SP	SP moved some object/s	
	4/30/2014		07:32:31.715	0:00:01	wb	SP	SP moved some object/s	Formalization
	4/30/2014		07:32:37.774	0:00:06	wb	SP	SP resized some objects	
	4/30/2014		07:32:39.550	0:00:01	wb	SP	SP moved some object/s	
	4/30/2014		07:32:45.443	0:00:05	wb	SP	SP changed the text to: AND	
191	4/30/2014	07:32:45.246	07:32:46.234	0:00:00	chat	BS	bi dk	
192	4/30/2014	07:32:37.025	07:32:49.772	0:00:12	chat	NA	Şimdi onaylayınca ne oluyor onu halledelim sonra abdyden devam edelim olur mu	
	4/30/2014		07:32:49.846	0:00:00	wb	SP	SP changed the text to: AND baskanı degerlen...	Formalization
193	4/30/2014	07:33:01.551	07:33:06.218	0:00:04	chat	SP	bilge dogrumu su haliyle sence	Validation_7
	4/30/2014	07:33:04.089	07:33:16.994	0:00:12	awareness	BS	[fully erased the chat message]	
	4/30/2014		07:33:19.147	0:00:02	wb	NA	NA resized some objects	
	4/30/2014		07:33:21.986	0:00:02	wb	NA	NA moved some object/s	
194	4/30/2014	07:33:24.532	07:33:34.489	0:00:09	chat	NA	serhat çok büyük koyuyorsun notasyonları azcık küçük koy	Verification_5
	4/30/2014	07:33:35.855	07:33:37.985	0:00:02	awareness	NA	[fully erased the chat message]	
195	4/30/2014	07:33:39.494	07:33:40.464	0:00:00	chat	SP	temem	
196	4/30/2014	07:33:41.113	07:33:41.599	0:00:00	chat	SP	:)	
197	4/30/2014	07:33:24.085	07:33:42.859	0:00:18	chat	BS	doğru nurcan danışman kabul ettiyse form başka bir yere gitmiyor elimdeki bilgiye göre	Validation_7
198	4/30/2014	07:33:44.961	07:33:48.609	0:00:03	chat	NA	AND başkanı neyki	
	4/30/2014	07:33:56.114	07:33:57.105	0:00:00	awareness	NA	[fully erased the chat message]	Validation_8
199	4/30/2014	07:33:57.690	07:34:00.308	0:00:02	chat	SP	anabilim dalı baskanı	
200	4/30/2014	07:34:00.934	07:34:03.736	0:00:02	chat	NA	orda kalıyor ozaman	
201	4/30/2014	07:34:07.661	07:34:08.641	0:00:00	chat	SP	bitimi	Task Coordination_9
202	4/30/2014	07:34:04.751	07:34:09.026	0:00:04	chat	NA	tamam abdye dönelim o zmana	

Figure 12 Long sequence organization of a sample log file

After the segmentation and coding process was completed for the pilot experiments, the same methodological steps were applied on the main experiments. Then, a hierarchical

abstraction process was performed by extracting some of the coding categories from the coding schema and grouping them under broader categories. After the abstraction, initial factors were obtained; Exposition, Socializing, Communication Flow, Task Coordination, Awareness, Group Decision Making, Elicitation, Formalization, Validation, Verification, Technical Support and System Affordances.

Our factors were similar with the aspects identified by Meier, Spada, & Rummel (2007) and Kahrimanis et al. (2009) who examined the interaction quality of collaborative processes based on desktop-videoconferencing and CSCW contexts, respectively. Therefore, our factors were blended with the already studied aspects whose reliability and validity issues were established. In total, eleven factors that affect the collaboration process were grouped under the Communication, Coordination, Group Decision Making, Awareness, Motivation, Domain Knowledge and Support, which bring together important theoretical viewpoints for studying collaboration and cooperation. The results of the qualitative content analysis and final version of the interaction quality factors can be found in section 4.2.

3.3.2 Evaluation of Interaction Quality

Interaction quality of the groups is evaluated with respect to these factors by following a method that is proposed by Meier et al. (2007). This method enables the researchers to assess process quality rather than making an assessment of the frequency of specific behavioral indicators or types of utterances (Meier et al., 2007). To conduct this method, a rating handbook was prepared which includes the detailed description of the factors and illustrations related with the good or bad exemplars of the factor. The rating handbook is used for rater training to standardize the judgments and improve their objectivity. Then, a rating schema was developed to assess the quality of the interaction units within a segment which takes approximately 10 minutes. The raters observed interactions in a segment again and again by using the replay feature of the system in parallel with the videos that includes the gaze traces of the modelers. The raters evaluated the quality of the process by comparing the observed interaction with the rating instructions which includes the ideal state of the dimension. Then s/he rated each dimension on a 5-point likert scale ranging from ‘very bad’ to ‘very good’. For the factors, group members’ performance could be varied throughout the interaction in a segment; so, the rater evaluated the process quality via the aggregated impression on how well the group members performed with respect to the related factor.

An inter-rater reliability analysis was conducted to ensure both the reliability of ratings and the definition of the factors. The inter-rater reliability assessment was performed with three raters. The raters were trained about the research and rating process with pilot study experiments which will not be included in the analysis. The raters were informed about the rating handbook that include factor definitions and illustrations. They were informed to take notes on the handbook, if they thought an inconsistency between the definition of the factor and the interaction of the group members. No feedback was obtained about the

definition of the factors. For inter-rater reliability evaluation, %10 to %20 of the total sample should be evaluated (Neuendorf, 2002; Wimmer & Dominick, 2013). In the present study, interaction quality was performed for 60 segments in total and 9 of them were used for the inter-rater reliability assessment. Krippendorf's alpha scores were calculated for each factor (in Appendix F) to assess their inter-rater reliability. Reliability measures for each factor were above 0.7, which exceed the recommended threshold for ensuring satisfactory level of reliability (Krippendorff, 2004).

3.3.3 Evaluation of Joint Attention

Quantitative measures obtained from the dual eye-tracking setup were used to monitor how participants allocate their attention on the shared workspace and to measure the degree of overlap and coordination among their fixation sequences. This method is called cross-recurrence analysis which was initially applied to dual-eye gaze data in the studies of Richardson and Dale (2005) and Richardson et al. (2007). Tobii Studio 3.2.1 and a packet java program were used for the analysis of gaze data.

Eye movements of the participants were observed in the form of fixation and saccadic movements (Poole & Ball, 2006). A fixation event describes points where the eye is relatively still and concentrating directly on an object in the visual field. During a fixation event the eyes are relatively stationary to take in or encode the information in that location. Average fixation duration is typically in the range of 66 to 416 milliseconds. Interpretation of fixation depends on the context. For example, fixation duration typically indicates the amount of information processing and longer fixation durations tend to indicate that more time is needed to interpret the data. Saccadic movements refer to the quick eye movements occurring between fixations. This measurement cannot say us anything directly about the complexity or salience of an object on the interface because no encoding takes place during saccades. However, regressive saccades defined as backtracking eye movements can be a measure of processing difficulty during encoding.

Eye-tracking data of PAs were divided into segments as parallel with the segmentation of interaction units for further examination with the Tobii Studio software. Segmentation of the experiments enabled us to examine the eye-movements of the modelers with more manageable units and observe changes in gaze coordination during different episodes of interaction. Each segment took approximately 10 minutes.

Segments were synchronized to be able to track the modelers' eye-movements simultaneously. Each of the segments was converted to avi format to get ready for use in Transana software. This program places two videos (that showed the each modeler's eye-movements) side by side. Through Transana, eye-movements of modelers could be observed concurrently and it was possible to monitor how modelers allocate their attention on the shared workspace. Figure 13 shows the Transana environment.

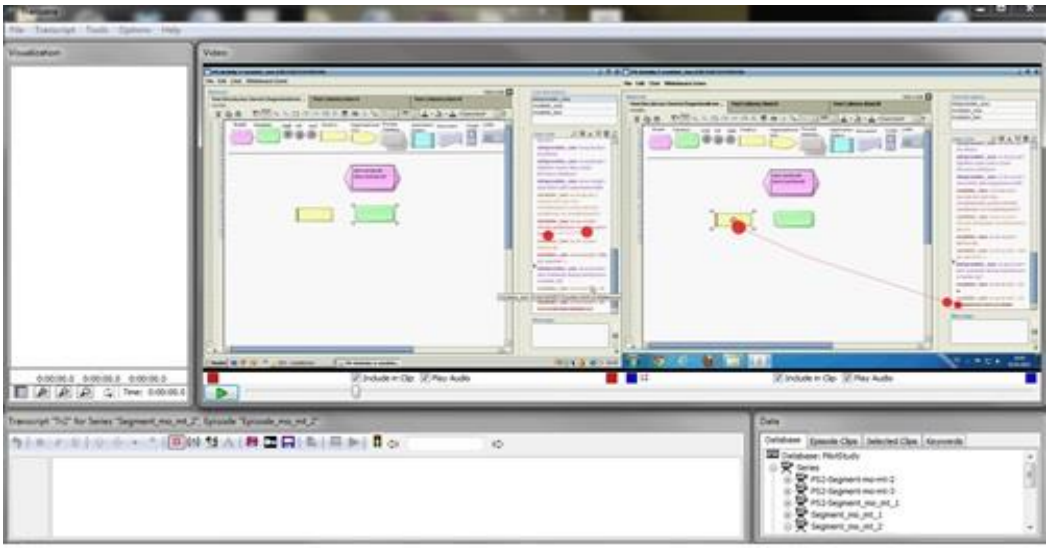

Figure 13 Transana Transcription and Analysis Software

After the segments were synchronized, scenes were created for further examination. 16 Area of Interests (AOIs) were defined over each scene as shown in Figure 14. Each AOI represents the part of the screen over which the participant focused on at any time. Since 19 inch displays with 16:10 ratios were used in the experiments, the width and the length of the screen was 38,2 cm and 22,4 cm. Parceling the screen with 16 equal non-overlapping rectangular AOIs covers an area approximately 9,7 cm wide and 5,6 cm long.

Figure 14 The shared screen was split into 16 AOIs for the measurement of gaze coordination among the process modelers

In order to monitor gaze overlap, the same AOI definitions were used for both participants' screens; since the participants' monitors were divided equally. The probability that the participants allocate their attention over the same AOI is 1/16x1/16 = 1/256. So, gaze overlap of 2 people is unlikely to be repeated systematically by chance (Uzunosmanoğlu & Çakir, 2014). After the AOIs were defined, eye-tracker data were exported from Tobii software for both screens to perform the cross-recurrence analysis. Cross recurrence analysis uses recording timestamps, local time stamps, coordination of gaze points (GazePointX (ADCSpx) and GazePointY (ADCSpx)) and area of interests of the eye movements values.

The program written in Java was used to perform the cross recurrence analysis, which uses the exported data as input and produces a scarf plot and a gaze overlap distribution graph.

Scarf Plot

A scarf plot gives information about the instances that participants gaze on the AOIs of the computer screen. Also it provides information about when and over which AOIs the partners' eye gaze overlap with each other. Figure 15 is a segment's scarf plot that shows a single pair of participants' eye gaze distribution over the 16 AOIs. In this segment, the pair worked on process modeling which took approximately 600 seconds. In the scarf plot, row 0 represents the first participant's eye gaze distribution and row 1 represents the second participant's eye gaze distribution. Each AOI is coded with red, purple, green and gray tones that represent the first, second, third and fourth rows of the AOI matrix defined on the participants' screen respectively. For example, code labelled with '11' refers the related AOI in the screen located in the first row and first column, and '34' refers to the related AOI in the screen located in the third row and fourth column. Area C that is color coded with white refers to the gaze instances where participants are not looking at any specific area on the screen. This may occur because of the excessive head movements or typing on the keyboard; as most participants look at the keyboard instead of the screen while they are typing. Row 2 includes gray lines representing the time intervals when the participants' eye gazes overlap or intersect. In addition, the plot indicates the total duration of gaze overlap that is 82 seconds in the specified segment.

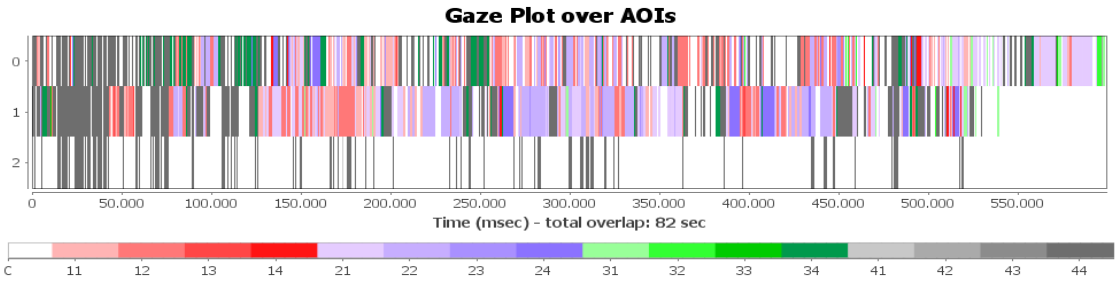

Figure 15 Gaze Plot over AOIs

Finally, the plot allows making zoom-in and zoom-out as shown in Figure 16 that will be beneficial in qualitative analysis to understand whether there is a high or low degree of gaze overlap.

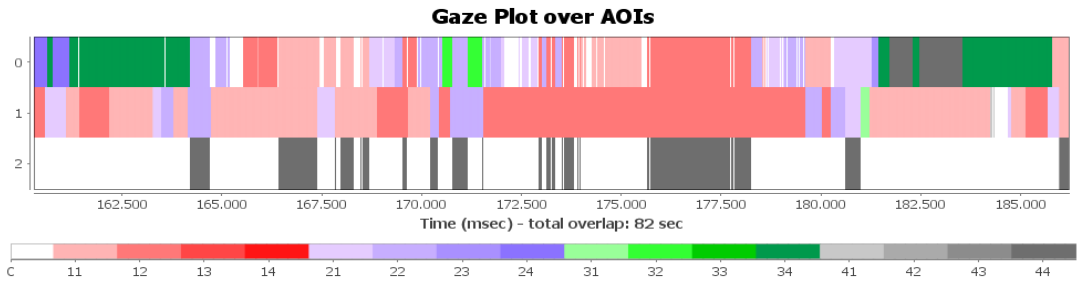

Figure 16 Zoom-in View of Scarf Plot

Gaze Overlap Distribution Graph

In addition to the scarf plot, the software also produces gaze overlap distribution plot as shown in Figure 17. This graph shows the distribution of recurrence percentages among the gaze patterns of the pair with time lag that ranges between +4 and -4 seconds during the same segment. The reason of the selection of the time interval as +4 and -4 seconds is based on the study of Richardson and Dale (2005), where they examined the level of recurrence among speakers' and listeners' eye gaze patterns during a problem solving session. Richardson and Dale found that the listeners tend to look at the same location where speakers looked with a delay of 2 seconds. In our study, we want to examine the recurrence of both participants' eye gaze during a process modeling activity in which the communication is performed via a chat tool. In order to explore gaze overlap patterns in our case, the time interval value +2 and – 2 seconds used in speaker-listener collaboration is extended to +4 and -4 seconds, since chat was the primary medium of communication during our experiments. Tracking the changes in the chat window and finding the part of the model referenced from a chat message typically requires more time than decoding utterances with similar content during face to face conversation.

The visualization includes Actual and Shuffle recurrence percentage distributions. The actual recurrence percentage distribution (the red curve in Figure 17) at time lag 0 msec on the graph shows the recurrence percentages among the gaze patterns where both pairs' gaze events totally overlap. When time lag is equal to x msec (x ranges between -4000 and +4000 msec), the recurrence percentage among the gaze patterns are recalculated in reference to the segment's length by shifting one of the participants' gaze sequence by x msec. The software makes this calculation by shifting one of the participants' gaze patterns by 20 msec until reaching the +4000 and -4000 boundaries. The software can plot the recurrence chart in any range and resolution.

For the shuffle recurrence percentage distribution (the blue curve in Figure 17), the order of gaze sequences are randomly shuffled without changing the duration of each gaze event to create a baseline for comparing against the observed actual recurrence distribution.

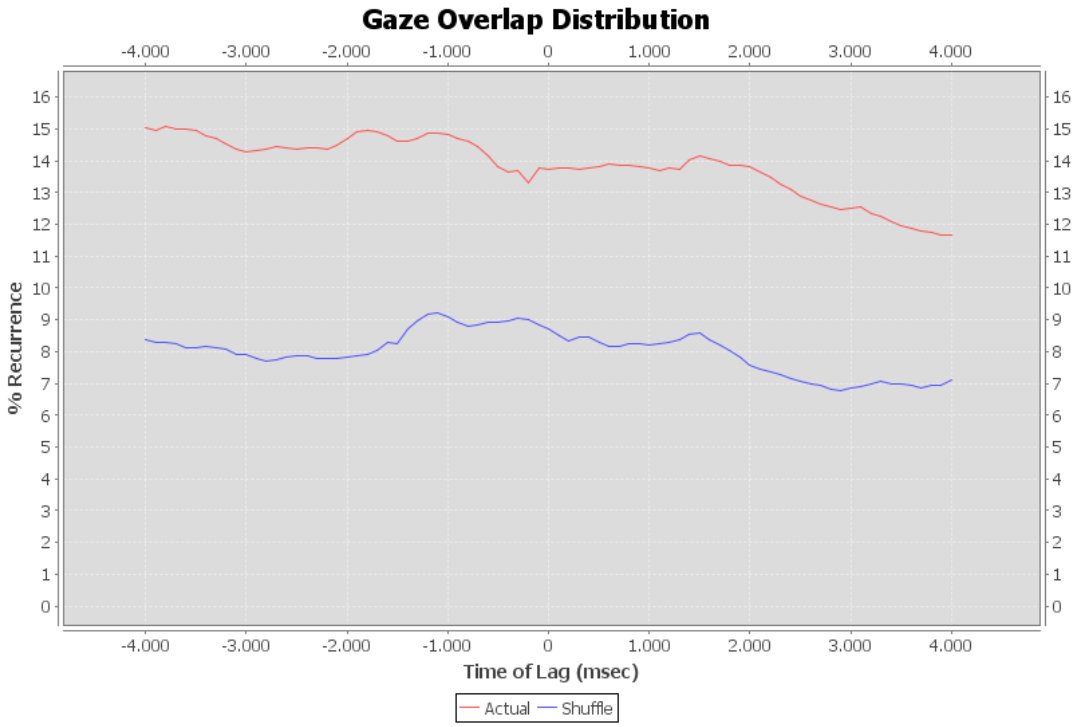

Figure 17 Gaze Overlap Distribution

Each group's modeling session was divided into approximately 10 minutes long segments and recurrence percentage plot in Figure 17 was formed for each segment to observe the tendency of the gaze overlap in the segments and how gaze overlap is changing throughout the modelling period. Then, we formed an overall recurrence percentage plot for each pair as exemplified in Figure 18. These recurrence percentage plots of each pair combines the pair's experience throughout the experiment in a single summary plot. Thus, each pair's data in different segments of the pair's experiment is accumulated in the same graph. Our goal is to present the gaze patterns of each pair shown throughout their experiment; so that each pair's global gaze patterns can be identified. Global gaze patterns can be deduced from these plots such as whether gaze following is balanced between the partners or one partner's gaze tends to follow the other's. In these summary plots, similar to the plots that belong to a single segment of a pair, the horizontal axis represents the lag range between -4000 msec and 4000 msec and the vertical axis represents the percent recurrence values. Curves for percent recurrence based on actuals and baseline values are also represented. Bars below and above the curves refer to the standard error of percent recurrence that is caused by the deviation in the data. The groups' (except Group1_1, Group1_2 and Group

5_2, whose cross recurrence analysis could not be performed on the gaze records because of the technical problems) overall reccurence graphs are shown in Appendix G.

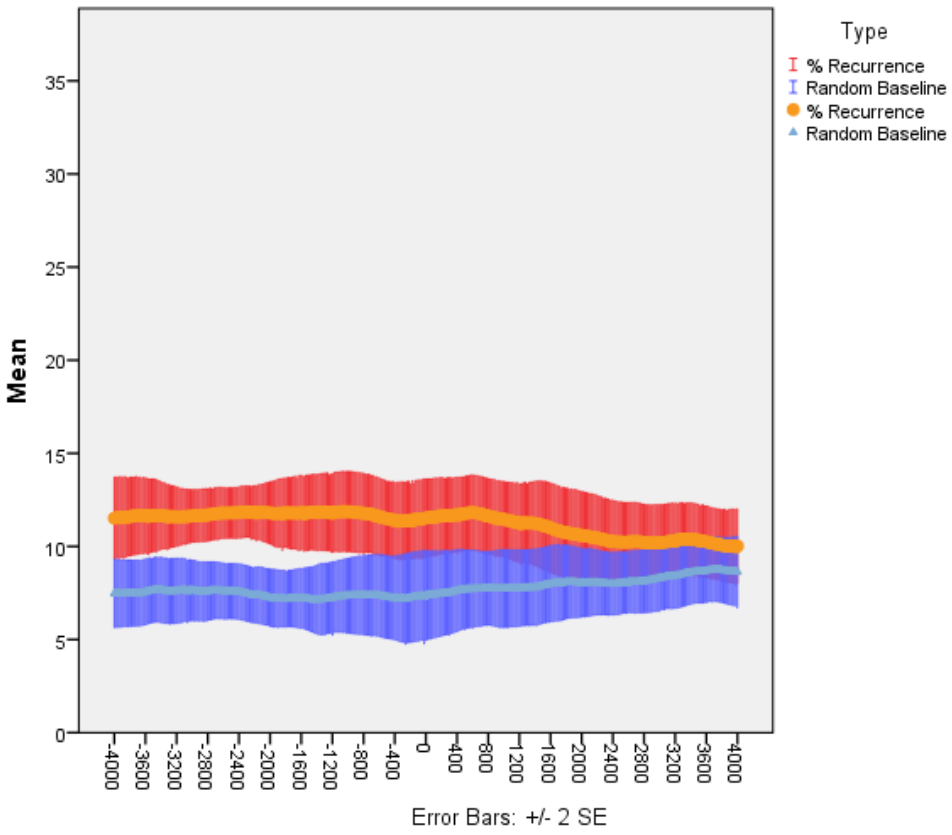

Figure 18 Overall Recurrence Graph of Group 2_1

3.3.4 Evaluation of Product Quality

The quality of the outcome obtained through a collaborative activity is often considered as another indicator for the evaluation of the quality of collaboration. In the context of computer supported collaborative learning, the collaborative product/outcome is generally evaluated with performance scores by using a pre- and post-test approach to measure how much the students learnt after collaborative problem solving activities (Nüssli, 2011). In the present study, business process models are collaborative products created through computer supported collaborative interaction and it is expected that product quality will be an indicator for the overall quality of interaction. In the BPM context, what constitutes a good process model is not well-specified in operational terms (Vanderfeesten, Reijers, Mendling, van der Aalst, & Cardoso, 2008) and quality for a business process is a very abstract term (Sánchez-González, García, Ruiz, & Mendling, 2012). In order to evaluate quality assurance in the process modeling context, there is a need for a framework with multiple dimensions, including syntactic, semantic and pragmatic aspects (Dumas, La

Rosa, Mendling, & Reijers, 2013). In this study quality assessment of collaboratively produced process models are performed within this framework.

Dumas et al. (2013) explained syntactic, semantic and pragmatic quality dimensions as follows. *Syntactic Quality* evaluates a process model's conformity with the syntactical rules and guidelines. In this evaluation, formal properties of the model are verified without knowing the real-world processes. In order to verify syntactic quality, structural correctness and behavioral correctness are investigated. In structural correctness, types of model elements which belong to the modeling language in use and how the elements were connected to each other are verified. In terms of behavioral correctness, the execution of the process model is evaluated in reference to the soundness property, which states that the model should never be able to reach a deadlock or livelock.

Semantic Quality validates the model by comparing the process model with the real-world business process. There is no set of formal rules to evaluate the fitness of the model with the real-world domain. However, semantic quality can be evaluated with two essential aspects which are validity and completeness. Validity implies that all statements in the model are correct and related with the problem domain. Completeness implies that the model contains all relevant statements on a process that would be correct.

Pragmatic quality relates to the usability of a process model by checking the interpretability, the main abilities and the learning aspects of the process model. Characteristics of a process model such as size, structural complexity and graphical layout affect the usability of the process models. Also meaningful labels affect the understandability of the process models, so the activities and the other model elements should be created in reference to specific naming conventions.

In the present study, the mentioned quality aspects were considered to evaluate the collaboratively produced process models by two experts. The final models are presented in Appendix H. For the syntactic quality, the experts examined structural and behavioral correctness of process models which were created with eEPC and UML Activity diagram modeling languages. *Syntactic quality* was evaluated with eEPC and UML Activity diagram modeling language rules. Grammatical examinations for element labels were performed by the experts while examining the structural correctness of the process models. Inter-rater reliability for the experts' assessment of the syntactic quality was .880, which exceeded the recommended threshold (0.7) for ensuring satisfactory level of reliability (Krippendorff, 2004). The syntactical rules applied for UML Activity diagram and eEPC are presented in Appendix I.

For the *semantic quality*, the experts investigated what the model stated and what is possible in reality. Then they gave a score for the models' validity and completeness. Inter-rater reliability for the experts' assessment of the semantic quality was .751. After the experts evaluated the collaboratively produced process models with syntactic and

semantic approaches, the average of the scores for each approach were assigned as the syntactic and semantic quality scores.

For the *pragmatic quality*, an important guideline for process modelers is to create process models in such a way that they are easy to understand for people while reducing the risk of errors (Vanderfeesten et al., 2008). Based on this idea, the quality of BPMs is assessed in terms of their understandability and prone to error via the Cross-Connectivity (CC) measure (Vanderfeesten et al., 2008). The CC measure aims to evaluate the cognitive effort to understand the relationship between any pair of process model elements. In this approach, "a lower (higher) CC value is assigned to those models that are more (less) likely to include errors, because they are more (less) difficult to understand for both stakeholders and model designers" (Vanderfeesten et al., 2008, p.3). The CC measure captures the routing elements that can be represented with standard modeling languages like EPCs, UML Activity Diagram, Petri Nets, BPMN and YAWL. So, in this study, it was possible to examine this measure for the model created with eEPC and UML Activity Diagram. CC value was calculated for the eighteen collaboratively produced process models by hand with the formula stated in the study of Vanderfeesten et al.(2008). A sample CC measure calculation is presented in Appendix J. In order to verify the results, the Automated Quality Measurement (AQM) tool was used for calculating the CC value (Gürbüz, 2011). The results obtained with manual calculation matched with the results of the automated calculation. Another dimension to evaluate pragmatic quality is graphical layout which is concerned with the position of the model elements in the process model. The elements should be positioned in a meaningful order which enables people to follow the flow of the activities. In this study, the graphical layout approach was ignored while evaluating the models' quality due to the collaboration tool's limitation for not having an unlimited working area. Because of this limitation, the modelers could not place the model elements in the working area appropriately.

3.4 Ethical Clearance

This study was approved by the Human Subjects Ethics Committee at the Middle East Technical University (in Appendix K).

CHAPTER 4

RESULTS

This chapter includes five main sections. Firstly, interaction analysis results for the pilot study is given. Secondly, the interaction quality factors and the rating of the interaction process quality are presented. Thirdly, cross-recurrence analysis results are provided. Fourthly, the interrelatedness of joint attention and interaction quality factors & the causal relationship between joint attention and theoretical interaction quality dimensions are presented. Lastly, the interrelatedness of joint attention, factors that affect interaction quality and collaboratively produced BP Model quality are introduced.

4.1 Pilot Study

In the pilot study, it was aimed to examine how different interaction methodologies affect synchronous process modeling in the light of Coordination, Awareness, Communication, Team Building and Group Decision Making aspects of collaboration (Malone & Crowston, 1994). VMT Chat and ARISalign offer different CSCW interaction methods, therefore these systems were selected in the pilot study to decide the most suitable interaction methodology for the main study. In the VMT Chat platform, stakeholders can use the whiteboard area concurrently. However, in ARISalign, only the active user, who has accessed the model first, has the right for editing the model, and the other users have to wait for the active user to complete his editing on the whiteboard. The communicational contents exchanged by participants in the form of chat messages and the interaction on the shared whiteboard area as well as semi-structured interview results enabled us to evaluate the platforms' appropriateness for CSCBPM.

4.1.1 VMT Chat: Interaction Analysis based on the Aspects of Collaboration

Coordination: The coordination of team members was observed throughout the synchronous process modeling in VMT Chat. The following examples illustrate how the system supported coordination during this process. No instruction was given to the team members about the coordination of the BPM phases before the experiment to ensure that BPM was performed spontaneously. At the beginning of the modeling session, team members discussed the preferred modeling approach to reach a consensus on how they would coordinate the group to accomplish the modeling activity. The related interaction is presented in Table 8. After the team members greeted each other, the DE informed the modelers about the name of the process and gave brief information about the process (see Lines 8, 14 and 15). However, the information transfer was interrupted by PA2's message

in Line 16 that queried the modeling approach they would take. PA2 wanted to ask for PA1's opinion about the coordination of the modeling activity; whether they would perform the modeling after the DE gave all the information about the process or during the information transfer. PA1 stated that she preferred the second modeling approach, which was confirmed by PA2 (in Line 18) and the DE (in Line 19). The team members proceeded with the agreed modeling approach, in which elicitation and formalization stages did not occur in a linear order. It is seen that the team members preferred to conduct these phases concurrently; rather than first taking the whole information about the process (elucidation) and then performing modeling (formalization).

Table 8 A snippet of chat communication for coordination

Line	Timestamp	Team Member	Statement
1	03:41:32	DE	Hi guys / *Merhaba arkadaşlar*
2	03:41:37	DE	I am Ahmet / *Ben Ahmet*
3		PA1	Hi / *Merhaba*
4	03:41:39	PA1	I am Nurcan / *Ben Nurcan*
5	03:41:43	PA2	Hi / *Merhaba*
6	03:41:43	PA2	Özge / *Özge*
7	03:41:48	DE	All right / *Pekala*
8	03:41:59	DE	We are modelling the evaluation process of a new course proposal / *Yeni ders açma önerisi değerlendirme sürecini modelliyoruz*
9	03:42:19	DE	If you are ready, I will describe the process / *hazırsanız anlatablirim*
10	03:42:30	PA2	Yes / *Evet*
11	03:42:34	PA1	OK, we are ready / *Ok hazırız*
12	03:42:40	DE	OK /*Tamam*
13	03:42:48	DE	First of all / *Öncelikle*
14	03:42:54	DE	The lecturer fills in the course proposal form / *Öğretim üyesi ders öneri formunu doldurur*
15	03:43:08	DE	Then, sends it to the head of the department / *Ana bilim dalı başkanına iletir*
16	03:43:19	PA2	Nurcan, shall we model at the end or while Ahmet is giving the information? / *Nurcan en son mu modelleyelim yoksa Ahmet anlatırken mi modelleyelim?*
17	03:43:58	PA1	I think we should model while Ahmet is giving the information / *Ahmet anlatıken modelleyelim bence*
18	03:44:12	PA2	I agree / *Bence de*
19	03:44:19	DE	In that case, I will stop now and then to give you time to model / *Ben aralarda durup bekliyorum o halde size*
20	03:44:32	PA1	Let's go / *Lets go ozaman :)*
21	03:44:28	PA2	OK / *Ok*
22	03:44:38	PA1	OK / *Ok*

In another interaction episode given in Table 9, the modelers coordinated the work for which they had different objectives to achieve. During the process modeling, PA2 had to log off since her whiteboard was frozen for a while. In the meantime (04:06:47 – 04:11:43), PA1 continued the modeling on her own. When, PA2 returned to the modeling environment, PA1 asked PA2 to review the changes she had made during PA1's absence (Line 8). When PA2 saw this request, she read all the information given by the DE and went through the modifications to the model. While PA2 was reviewing the model, PA1 read the new piece of information (Line 9) and continued modeling. During this time, each modeler independently worked on the same model. After PA2 completed her review, PA2 read DE's last message (Line 9) and contributed the PA1's modeling activity with, "Now, we need a decision element" (Lines 16 and 17), which highlights the need to put a decision model element. This message implied that PA2 could now continue to model in collaboration with PA1.

It is clear that in VMT Chat, the team members could easily coordinate their work on the same model. In addition, the modelers were able to switch between cooperative modeling and collaborative modeling modes whenever needed. This means that the modelers could perform individual modeling activities while, at the same time, working collaboratively on the same model.

Table 9 A snippet of chat communication for coordination

Line	Timestamp	Team Member	Statement
1	04:11:43	PA2	Joins the room
2	04:12:06	PA2	I am back / *Geldim*
3	04:12:15	PA1	What will the academic committee do with completed form and the evaluation of the head of the department / *Şimdi akademik kurul aldığı form ve ABD nin değerledirmesi ile ne yapacak?*
4	04:12:29	DE	Shall I continue to explain? / *Devam edeyim mi anlatmaya*
5	04:12:27	PA1	What will the committee do? / *komite napacak*
6	04:12:33	PA1	Yes / *Evet*
7	04:12:40	DE	All right / *Peki*
8	04:12:48	PA1	Özge, could you check what I have done to see whether there is any problem with it? / *Özge sen yaptıklarıma bakarmısın sorun var mı diye*
9	04:13:10	DE	The academic committee assesses the form and decides to approve, reject or request changes to it / *Akademik komite formu alır ve onay, red veya güncelleme talebi kararlarından birini verir*
10	04:12:58	PA2	OK / *ok*
11	04:14:28	PA1	Özge / *Özge*
12	04:14:33	PA1	[We use 'organizational unit'] for a committee or a unit / *Komite ve unit olunca*
13	04:14:43	DE	I think, we should call this evaluation, too / *Buna da değerlendirme diyebiliriz bence*

14	04:14:51	PA1	We are using the 'organizational unit' model element, aren't we? / *organization uniti kullanıyoruz dimi*
15	04:15:26	PA2	Yes / *Evet*
16	04:16:30	PA2	Now / *Şimdi*
17	04:16:33	PA2	We need a decision element / *decision var*
18	04:16:37	PA1	Yes / *Evet*

The integrated chat component of the system allowed the team members to easily achieve the coordination aspect of collaboration. They were able to send each other instant requests regarding process modeling and make comments on the changes made by other members. For example, "Özge, could you revise this?", "Stop! Ahmet should tell us whether we need to do anything else here, if not, let's skip it", "Özge, could you check what I have done to see whether there is a problem with it?", "No space is left on the screen, let's move onto a new tab".

Group Decision-Making: The interaction analysis showed that the group decision-making characteristic of collaboration could be observed in the synchronous collaborative modeling session in the VMT Chat environment.

The interaction episode in Table 10 illustrates the decision-making process during which the team members simultaneously worked on the model element. This interaction episode is also interesting since it shows that the modelers differed in terms of their attitudes towards decision-making on the use of the model element. After the DE gave information given about the process (Table 9, Line 9) both modelers deliberated over the use of the correct model element. At this point, PA2 asked for DE's opinion to decide on the model element that best represented the case (Line 5). The DE suggested that only one of the three options should be selectable at a time (Line 6). In response to DE's message, PA1 recommended using 'OR' (Line 7). However, PA2 considered that the use of 'XOR' would probably be better (Lines 8 and 9). The further communication between the team members shows that PA2 was not sure about the use of the 'XOR' element (Lines 3 and 9) and asked for DE's opinion again whereas PA1 immediately accepted PA2's suggestion (Line 11). Following the confirmation of 'XOR' by the DE (Line 10), PA1 referred to PA2 for her approval, which indicates that PA1 left the decision-making responsibility to PA2 (Lines 12 and 13).

This interaction episode shows that the team members could discuss an issue and easily reach a consensus to create the process model. In addition, this interaction episode indicates that PA2 took much more responsibility than PA1. Furthermore, PA2 seemed to be more motivated than PA1 to identify the correct model element. Another important factor affecting the performance of BPM in this process was found to be DE's model reading capability.

Table 10 A snippet of chat communication for group decision-making

Line	Timestamp	Team Member	Statement
1	04:16:54	PA2	An event comes after this / *Bundan sonrasına bir event gelecek*
2	04:17:17	PA2	Then, this event branches with XOR / *Sonra o event xor ile dallanacak*
3	04:17:22	PA2	Either that or with 'OR', I am not sure / *yada or da olabilir emin değilim*
4	04:17:54	PA1	I will put 'OR' / *or koyuyorum*
5	04:18:41	PA2	Dear referee Ahmet, what do you think about this? / *Sayın bilir kişi Ahmet bey sizin bu konudaki fikriniz nedir?*
6	04:19:32	DE	Only one of the three decisions should be taken / *Yani 3 karardan sadece biri verilmeli*
7	04:19:41	PA1	OR / *Veya*
8	04:19:52	PA2	Yes / *evet*
9	04:19:57	PA2	In that case, it should probably be XOR / *O zaman xor olmali galiba*
10	04:20:28	DE	I agree, it should be XOR because two decisions cannot be taken at the same time / *Bence de xor, çünkü iki karar çıkamaz oradan*
11	04:20:16	PA1	Let's use XOR / *xor olsun hadi*
12	04:20:25	PA1	Do you approve XOR? / *Onaylandın mı xor*
13	04:20:35	PA2	Yes I do / *evet onaylıyorum*

Awareness: The interaction analysis and eye-tracking data showed that the team members were able to access and use the same objects on the shared whiteboard, read all the messages sent by other team members and view the latest version of the process model. The awareness aspect of collaboration was also supported by the use of different colors to represent each team member and the notifications about the person writing the message. In addition to these system features, the reference tool played an important role in preventing any communicational complexities and awareness problems during the interaction between the team members and regarding the use of the shared whiteboard (Stahl et al., 2006). The following examples of interaction show how the reference tool made the communication much easier and increased mutual intelligibility among the team members.

As shown in Table 11, after the DE gave a piece of information about the process (Line 4), PA1 asked a question, "We link to the top from here, is this right?" (Line 9) and used the reference tool to point to 'here' in her message. The eye-tracking data of PA2 showed that she read the message sent by PA1 and followed the reference link to see the related model element (Figure 19). After PA2 implemented the event element, she responded to the question with a message (Line 11).

A similar use of the reference tool was seen many times throughout the process modeling (see Lines 12, 13 and 16), in which the modelers referred to the model elements on the whiteboard only using the deictic pronouns such as 'here' and 'this'.

Table 11 A snippet of chat communication for awareness

Line	Timestamp	Team Member	Statement
1	04:22:21	PA1	Now, Ahmet / *Şimdi Ahmet*
2	04:22:26	PA1	Is it [the process] finished once it is approved? / *Onaylayınca bitiyor mu*
3	04:22:31	DE	Nothing else / *Hayır*
4	04:22:33	DE	If there is a request for changes, then the process returns to the beginning / *Güncelleme talebi geldiyse süreç başa dönüyor*
5	04:22:49	DE	If it [the course] is approved, the Institute Committee makes a final evaluation / *Onay ise Enstitü Kurulu son bir değerlendirme yapıyor*
6	04:22:58	PA1	Does the process start again from the top? / *En başa mı?*
7	04:23:09	DE	Also, the institute secretary adds the new course to the course catalogue in OIBS / *ve enstitü sekreteri OIBS'de yeni dersi ders kataloğuna ekliyor*
8	04:23:44	DE	OIBS is the student information system / *OIBS bizim öğrenci işleri bilişim sistemimiz*
9	04:25:09	PA1	We link to the top from here, is this right? / *Burdan başlangıca ok götürücez dimi*
10	04:25:39	PA2	Yes / *Evet*
11	04:25:47	PA2	These arrows cannot be bent, so they don't look good. But we cannot do anything about it / *Burdaki oklar kıvrılmadığı için kötü gözüküyor ama başka çare yok*
12	04:26:11	DE	Shall we call this 'Request for Change'? / *Bunun adı güncelleme isteği olabilir mi?*
13	04:26:27	PA2	What about OIBS for this? / *Bu oibs olsun mu?*
14	04:27:06	PA1	OK ☺ / *olsun :)*
15	04:27:12	PA1	It is too similar / *Çok benziyo*
16	04:27:55	PA2	I made a joke. This should be OIBS / *Şaka yaptım bu oibs olcakmış*

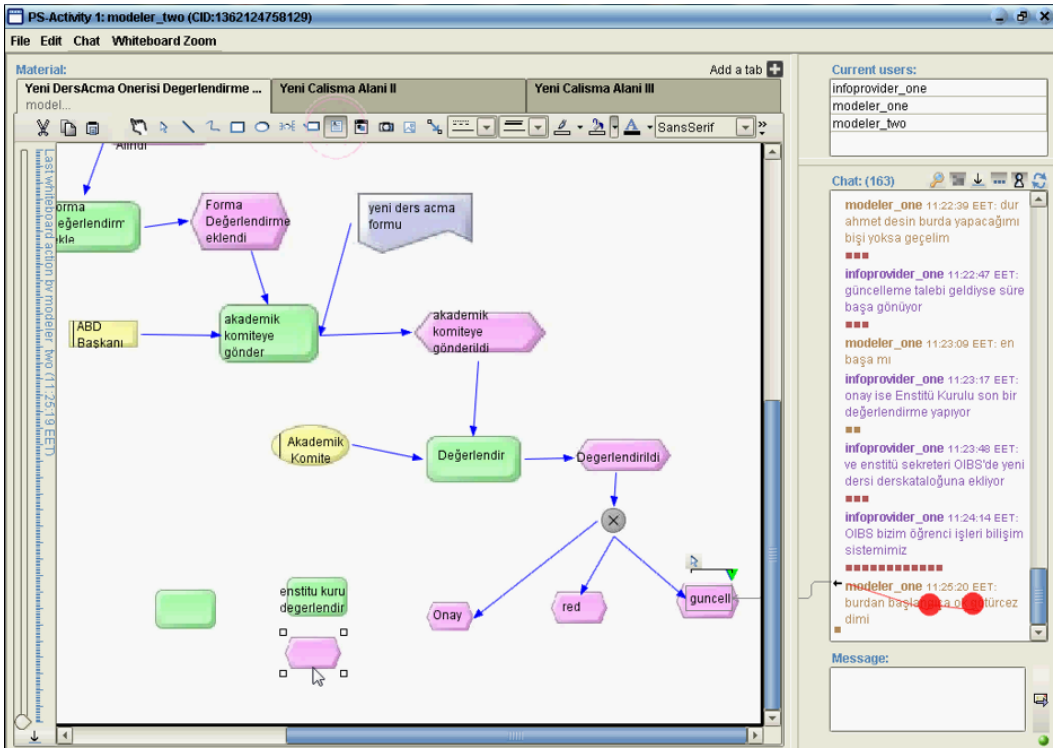

Figure 19 Use of the Reference Tool on the Whiteboard.
(Red dots over the chat window represents the eye movements of the modeler who was reading the message including a referential link to the whiteboard.)

It was observed that the reference tool supported the awareness aspect to reduce possible communication complexities by referring not only to the whiteboard area, but also to the chat window. As shown in Figure 20, PA2 sent the message, "That's it" pointing to the message sent by the DE at 11:23:48. The reference link not only attracted the attention of PA1, but also simplified PA2's work since she did not have to rewrite the message.

It is clear that the reference tool facilitated the communication and increased mutual intelligibility by making the team members aware of the objects on the whiteboard and the messages in the chat window. The team members could point to the model elements only by using the expression, 'this' rather than repeating the long names of the model elements.

Communication: The communication aspect of collaboration was supported throughout the modeling session with the integrated chat window shown in Figure 21. The team members were able to send and receive messages using this component. The chat window provided an interactive discussion platform also supporting the awareness aspect of collaboration. The team members were notified when one of their peers was writing a message. In addition, the active team members were shown in the current users window

and their messages were displayed in the chat window using different colors to increase their readability. Furthermore, the referencing function of the system could be used on the chat messages. Figure 21 illustrates the chat window of the system.

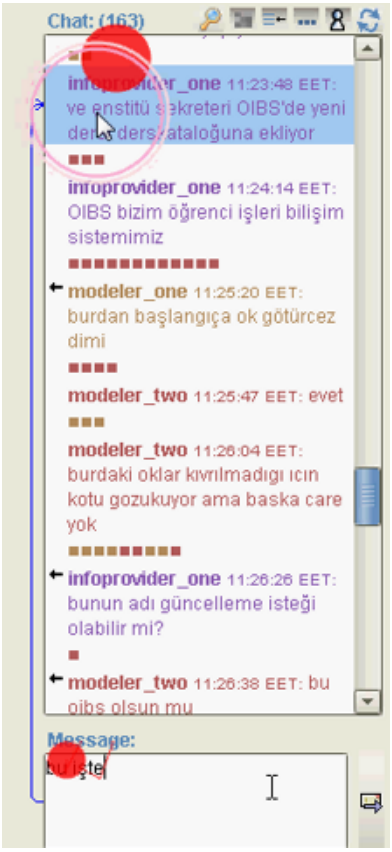

Figure 20 Use of the Reference Tool in the Chat Window

Figure 21 Chat Window

Team-Building: The roles of the team members were assigned prior to the modeling session. The system does not have any features to restrict the responsibilities of the team members and their access rights on the shared whiteboard. However, interaction among the team members showed that the team members were successful in performing their roles throughout the modeling activity. The DE informed the modelers about the business process and the modelers performed the modeling activity based on this information. The DE and PAs were able to conduct elicitation, formalization validation and verification phases of cBPM as necessary. The interaction analysis showed that the team members were self-motivated to conduct their responsibilities; therefore, they did not have any problems due to the system's limitation to restrict user permissions according to their roles.

4.1.2 ARISalign: Interaction Analysis based on the Aspects of Collaboration

Table 12 presents the whole interaction episode for the synchronous collaborative modeling session conducted in ARISalign.

Table 12 Chat communication conducted in ARISalign

Line	Timestamp	Team Member	Statement
1	1:05 PM	DE	Hi guys, here we go. / *Merhaba arkadaşlar, başlıyoruz.*
2	1:08 PM	DE	Are you there? / *Geldiniz mi?*
3	1:09 PM	PA2	I am here / *Geldim*
4	1:10 PM	DE	Welcome Özge, we will start when Nurcan arrives / *Hoşgeldin Özge, Nurcan da gelsin başlayalım*
5	1:13 PM	PA2	Ok, I am waiting / *ok bekliom*
6	1:19 PM	PA1	Hey there / *Heyoo*
7	1:54 PM	DE	Let's start again, are you ready Özge? / *Tekrar başlıyoruz, hazır mısın Özge?*
8	1:55 PM	PA2	I am ready / *Hazırım*
9	1:56 PM	PA1	I am in, too / *ben de varım*
10	1:56 PM	DE	All right; the examination committee purchases the materials. The committee prepares a receipt and a certificate of acceptance for the received purchased materials. / *Peki; Muayene kabul komisyonu malzemeyi teslim alır. Alınan malzeme için fatura ve muayene kabul tutanağı düzenler*
11	1:57 PM	DE	Welcome to you, too / *Sen de hoş geldin*
12	2:00 PM	PA2	Nurcan, can you see the task that I have just created / *Nurcan görebiliyon mu koyduğum taskı?*
13	2:02 PM	PA2	I have done what you said, you can continue / *Bu dediklerini yaptım devam edebilirsin*
14	2:02 PM	DE	Who is editing the process now? / *Şu an kim edit ediyor süreci?*
15	2:02 PM	PA1	Özge, first we need to create the roles; then add the activities under these roles / *Özge, önce rolleri koyup içine aktivite koyacaktık*
16	2:04 PM	PA2	I performed the last editing, I am waiting for your progress. I have added 2 tasks / *En son ben ettim, devam etmeni bekliyom. 2 tane task koydum*
17	2:04 PM	DE	Then, the movable records control officer transfers the purchased materials to the related people by preparing a debit entry. He prepares a movable transaction receipt for each debit entry / *Daha sonra taşınır kayıt kontrol yetkilisi alınan malzemeyi kişiler üzerine zimmetler, bunun için zimmet kaydı düzenler, her zimmet kaydı için bir taşınır işlem fişi oluşturulur*
18	2:05 PM	PA1	Özge, I have assigned the material receiving committee as a role / *Özge muayene kabul komisyonunu rol olarak atadım*
19	2:07 PM	DE	The documents produced for the activity of "receiving the material" are: receipt and certificate of acceptance / *"alınan*

			mazleme icin kabul tutanagı duzenlenir " isimli aktivite ile ilgili olarak düzenlenen belgeler: fatura ve malzeme kabul tutanağı
20	2:08 PM	PA2	It seems like Nurcan is editing, so I am just looking. But I can't see it / *Nurcan edit ediyor gözüküyor o yüzden suan bakıyorum sadece. Gerci göremiom*
21	2:11 PM	DE	Sorry about that, it [the system] assigned editing to me. I have closed it now /*Kusura bakmayın bana vermiş editing'i. kapattım şimdi*
22	2:14 PM	PA2	Who is editing?? Nurcan, you seem active but you haven't put anything in, either / *Kim edit ediyor?? Nurcan sen gozukuon ama sende bısı koymuonnnn*
23	2:14 PM	DE	Come on friends, model this / *Hadi arkadaşlar, modelleyin şunu*
24	2:16 PM	PA2	Nurcan, I assigned it to you / *Nurcan sana devrettim*
25	2:17 PM	DE	Who is modeling? Is she really modeling? It is not certain. It is just waste of time. We cannot even do such a small process / *Kim modelliyor, gerçekten modelliyor mu hiç belli değil. Zaman kaybı sadece. bu kadar küçük bir süreci bile yapamadık*
26	2:18 PM	PA1	I added what I have understood, could you check it? / *Ben anladıklarımı ekledim bir kontrol edermisiniz?*
27	2:19 PM	PA2	Guys, I am leaving now. Please check the model one last time / *Ben çıkıyorum arkjadaşlar. Siz de modeli son kez gözden geçirin lütfen*
28	2:20 PM	DE	Guys; when a debit entry is created, the system also needs to create a movable transaction receipt at the end of them model / *Arkadaşlar; Zimmet kaydı oluştururken bir de taşınır işlem fişi (TİF) oluşturması gerekiyor en sonda*
29	2:22 PM	DE	Yes guys, I am waiting for you. Are you doing what I last said / *Evet arkadaşlar sizi bekliyoruz. Yapıyormusuz son söylediğimi?*
30	2:23 AM	PA2	That message didn't arrive. It is not possible to model with this program, I can't interact. I want to model but I can't because it is always in-use mode / *Bana hic msj filan gelmio. Bu programla modellemek mumkun degil. iletişim kuramıyorum. modellemek istesem modelleyemiyorum cunku hep ın use yazıyor*
31	2:28 AM	DE	It seems good, bless you, but we shouldn't use this program again. / *İyi gözüküyor, elinize sağlık, ama bir daha bu programı kullanmayalım*
32	2:28 AM	DE	See you soon. / *Görüşmek üzere.*

Coordination: Unlike the modeling experiment in the VMT Chat environment, the participants did not discuss the coordination of the modeling process in ARISalign. This was probably because they had already gained experience in the first collaborative modeling session. It was observed that the team members coordinated the modeling activity in stages as in the VMT Chat activity. This means that after the DE gave brief information about Process II, the modelers created the model and then discussed the validity of the model. However, the interaction of the team members showed that they could not efficiently perform modeling using this approach. In ARISalign, the discussion board and the whiteboard for modeling are on different pages. Therefore, the modelers had difficulty following the messages sent by the DE and perform the modeling concurrently. The eye movements of PA2 showed that she read the information given by the DE several times, and then switched to the whiteboard page to draw the model. After

PA2 completed a task, she returned to the discussion board to read the information again. Although PA2 had already read the information carefully first time, she could have forgotten the details when switching between the pages. This indicated a weakness in the system design in terms of facilitating coordination between the communication channel and the modeling area. Therefore, the team members could not effectively coordinate the modeling process.

Communication: The communication aspect of collaboration was supported with the discussion board. Team members could create a new topic and sustain their communication using this platform. However, the communication platform and the modeling area of the system were on two different pages. The interaction analysis showed that the team members had difficulties in communicating with each other due to the system design. The eye movements of the modelers showed that they often had to switch between the discussion board and the whiteboard area to see whether there was a new message. An example of this is PA2's message, "That message didn't arrive. It is not possible to model with this program, I can't interact. I want to model but I can't because it is always in-use mode" (Line 30).
In addition, the team members experienced technical problems in the communication platform of ARISalign. The system could not immediately display the messages on the discussion board. This technical problem caused communication complexities since team members ended up not reading some of the messages in the correct order. For example, PA2 sent the message, "Özge, first we need to create the roles; then add the activities under these roles" (Line 15) to verify her modeling activity. However, PA1's message was displayed on PA2's discussion board two minutes later only after PA2 refreshed the page.

Awareness: The following awareness problems in the system can be listed as obstructing efficient collaboration among team members. The system did not give any notifications about the new messages on the discussion board or the availability of the whiteboard area for modeling. Due to these limitations, the users often had to switch between the discussion board and whiteboard. This frequent navigation between pages distracted the team members and caused problems in process modeling. Besides, the team members were not made aware whether the messages they sent were read by the other team members. Moreover, the modelers had to wait for each other to complete the modifications to the modeling without knowing what changes were being made by the other person or how long it would take her to complete the action.

Team Building: The system was capable of building a team and assigning different roles to the team members such as project owner, contributor, administrator and reviewer. The current experiment required a DE that would own the business process and two modelers, who were responsible for converting the process into a formal representation. Therefore, the DE was assigned the project owner role and the modelers were given the project contributor role. Both the DE and modelers could use the shared whiteboard. The

interaction analysis showed that the team members did not had any difficulties building the team and carrying out their responsibilities.

Group Decision-Making: The interaction analysis of the synchronous process modeling activity using ARISalign showed that the team members had poor communication and interaction with each other. Therefore, they could not achieve a sufficient level of maturity in their communication to discuss an issue in detail to arrive at a decision. The members merely tried to communicate with each other throughout the session. Therefore, the team could not achieve the group decision-making aspect of collaboration in this session. In summary, reaching a decision requires good communication and interaction, a process that involves proposing and evaluating alternatives and making choices. Poor communication and interaction between team members pose an obstacle to initiating discussions and reaching a consensus.

4.1.3 Summary of the Pilot Study Findings

VMT Chat was successful in supporting aspects of collaboration and interactivity among the team members. Modeling with VMT Chat enabled them to make division of labor whenever they want. Team members found synchronous modeling with CSCW beneficial; because they were able to communicate with each other whenever they want. However, the team members complained about the frozen whiteboard area. They had to login to the system multiple times because of this problem. In general, the statements show that team members were satisfied with cBPM in VMT Chat environment.

The following statements made by the group members highlight the positive and negative features of the VMT Chat environment.

> **Question:** What are the difficulties that you encounter while interacting with your teammates through VMT Chat?
>
> **PA1:** I had some difficulties related with drawing in VMT Chat, I had some difficulties while using notations. Besides, the system froze a few times, while I was referencing. Except these, I did not experience any difficulties. / *VMT Chat'de çizimle ilgili bazı zorluklar yaşadım, notasyonları kullanırken. Ayrıca bir kaç kez referans verirken sistem dondu. Bunu dışında bir zorluk yaşamadım.)*
>
> **PA2:** The system froze while I was referencing. There was not another problem. / *Referans verirken sistemde donma yaşandı. Başka bir sorun olmadı.*
>
> **DE:** We did not have any problem except system frozen. / *Sistemin donması dışında bir problem yaşamadık.*
>
> **Question:** What are the positive aspects of interacting with your teammates through VMT Chat?

PA1: VMT Chat was successful. It was nice to have chat platform. Because, I was able to see what messages everyone writes at the same time. As modelers, we were able to interfere the model at the same time in the modeling area. / *VMT Chat başarılıydı. Chat ortamının olması güzeldi. Çünkü herkesin aynı anda ne yazdığını görebildim. Modelleme ortamında da biz modelleyici olarak modele aynı anda müdehale edebiliyorduk.*

PA2: I was able to see the works performed on the model by my modeler teammate. We were able to model at the same time with work sharing. Therefore, I modeled without getting bored. We could speak about model by referencing, in this way we could match messages and parts of the model. / *Modelleyici arkadaşımın model üzerinde yapmış olduğu işlemleri görebiliyordum. İş paylaşımı yaparak aynı anda modelleme yapabiliyorduk. Bu nedenle sıkılmadan modelleme yaptım. Referanslayarak model hakkında konuşabildik, böylece mesajlar ile modeli eşleştirebildik.*

DE: I was able to follow the modelers and I interfered to the model whenever I want. I was able to share information about process whenever I want. / *Modelleyicileri takip edebildim ve istediğim zaman modele müdehalede bulundum. Süreç hakkında istediğim zaman bilgi paylaşabildim.*

On the other hand, the following chat messages show that the team members suffered from modeling with ARISalign;

DE: Let's guys, model that! / *Hadi arkadaşlar, modelleyin şunu!*

PA1: Who is modeling, is she really modelling? It is not certain. Loss of time only. We couldn't model even such a small process. / *Kim modelliyor, gerçekten modelliyor mu hiç belli değil. Zaman kaybı sadece. Bu kadar küçük bir süreci bile yapamadık.*

PA2: There is not any message come to me. It is not possible perform modeling with this tool. I cannot communicate. If I wanted to model, I couldn't, because it gives always in use warning. / *Bana hic mesaj filan gelmiyor. Bu programla modellemek mumkun degil. İletişim kuramıyorum. Modellemek istesem modelleyemiyorum çünkü hep in use yazıyor.*

DE: It looks good, god bless your hands, but we won't use this program once again. / *İyi gözüküyor, elinize sağlık, ama bir daha bu programı kullanmayalım.*

In addition, the following statements of the group members highlight the negative features of ARISalign environment.

Question: What are the difficulties that you encounter while interacting with your teammates through ARISalign?

PA1: Communication medium was not like chat, rather it was like an e-mail. I had an inbox that I had to check constantly, chat is not like that. It would be better, if there was a chat and I could see the message at the corner of the screen. However, this system was not like that, I constantly check inbox to control whether there was a new message or not. This was a problem, because it reduced my communication. Following the messages was difficult. / *İletişim ortamı chat gibi değildi, daha ziyade mail gibiydi. Sürekli bakmam gereken bir inboxum vardı, chat öyle olmuyor çünkü. Chat ortamı olsaydı mesajları ekranın bir köşesinde görseydim daha iyi olurdu. Ama bu sistem öyle değildi, sürekli inboxa girip mesaj gelip gelmediğini kontrol etmem gerekti. Bu bir sıkıntıydı çünkü o anki iletişimimi düşürüyordu. Gelen mesajları takip etmek zordu.*

PA2: Both of the modelers should perform modeling at the same time. While waiting, the system does not show the works performed by the other modeler. I only know that the other modeler does something, but I don't know what she does. We should see this. Such waiting time is boring. Because, we cannot see what she does and we have to wait for her. Waiting was too boring. / *İki modelleyici aynı anda modelleyebilmeli. Beklerken, diğer kişinin yaptığı işlemleri göstermiyor mesela. Sadece diğer kişinin birşeyler yaptığını biliyorum ama ne yaptığını göremiyorum. Bunu görmemiz gerekir. Bu bekleme süreci sıkıcı oluyor. Çünkü o kişinin ne yaptığını görmüyoruz ve onu beklemek zorundayız. Beklemek çok sıkıcıydı.*

DE: I could not understand whether the information shared by myself was read or not. I had difficulty to establish communication. I was too bored, so I did not want to review the model. / *Süreç hakkında paylaştığım bilgileri okuyup okumadıklarını anlayamadım. İletişim kurmakta çok zorlandım. Çok sıkıldığım için modeli gözden geçirmek bile istemedim.*

Question: What are the positive aspects of interacting with your teammates through ARISalign?

PA1: I cannot say any positive thing about this system. / *Bu system hakkında olumlu birşey söyleyemeyeceğim.*

PA2: I don't want to use this system never again. / *Bu sistemi birdaha kullanmak istemiyorum.*

DE: I don't have any positive comment. / *Olumlu bir yorumum yok.*

Semi-structured interview results and chat messages of the team members show that ARISalign was not as successful as VMT Chat to support collaboration among team members. The system had poor support of communication, coordination and awareness factors of collaboration. Because of these limitations the team members could not interact with each other efficiently; therefore group decision making factor for collaboration could not occur. Team members complained about ARISalign because they could not perform modeling synchronously. In addition they could not communicate with each other efficiently. Therefore they were bored and they wanted to exit from the system as soon as possible. Also the team members reached a consensus on not using ARISalign never again for process modeling, because they spent too much time to model such a small process. The following encountered problems constrained the efficient collaboration in ARISalign.

- The system did not show any warning messages about new messages on the discussion board or the availability of whiteboard area for modeling. Because of these limitations, the users had to make too many switches between the discussion board and the whiteboard area to follow the messages and the availability of the modeling area. The frequent navigation between pages distracted the team members and hampered the point process modeling effort.
- Team members were not aware whether the sent messages were seen by the other team members or not.
- The modelers had to wait for each other to take turns on model building without knowing what she was doing at that time and how long her action would take.
- Team members were too bored during BP Modeling.

In brief, ARISalign was not used in the main study, due to the encountered inefficiencies and the complaints of the team members. VMT Chat was the selected as the interaction medium for the cBPM activities in the main study. The following sections describe the findings of the main study.

4.2 Identification of the Factors that Affect Interaction Quality in Quasi-Synchronous CSCBPM Context

Qualitative content analysis showed that some of the coding categories and their objectives were similar with the aspects identified by Meier et al. (2007) and Kahrimanis et al. (2009) who examined the interaction quality of collaborative processes based on desktop-videoconferencing and CSCW contexts, respectively. Therefore, our factors were blended with the already studied aspects whose reliability and validity were established. In total, eleven factors that affect the collaboration process were grouped under the Communication, Coordination, Group Decision Making, Awareness, Motivation, Domain Knowledge and Support, which bring together important theoretical viewpoints for studying collaboration and cooperation (Table 13).

Table 13 Theoretical Dimensions and Factors of Collaborative Interaction

Theoretical Dimensions of Collaboration	**Factors that Affect Interaction Quality**
Communication (Com)	Sustain Mutual Understanding (SMU) Communication Flow (CF)
Coordination (Coord)	Structuring Modeling Process (SMP) Cooperative Orientation (CO)
Group Decision Making (GDM)	Knowledge Exchange (KE) Reaching Consensus (RC) Validation & Verification (V&V)
Awareness (AW)	Awareness (AW)
Motivation (M)	Group Motivation (GM)
Domain Knowledge (DK)	Modeling Competency (MC)
Support (S)	Technical Support (TS)

Communication: Communication was performed through a quasi-synchronous communication channel, more specifically via chat messages. Due to the characteristics of chat communication, chat messages can be interleaved with each other in a non-sequential manner. Participants need to read each statement to be able to understand the flow of interaction (e.g. who is responding to whom, which chat line is an extension of a prior chat line etc.) by relying on the sequential unfolding of events and the semantic/referential cues in the messages in this environment. Throughout the communication process SMU and CF aspects were observed as success indicators for the communication process. For the evaluation of SMU, it was expected that group members post messages that can be easily understood by the receivers, which is evidenced in terms of explicit agreements and in the way they organize the contents of their messages. Messages posted on the chat window and activities performed on the shared whiteboard area should make sense for the teammates. Group members should attend to each others' statements and monitor each others' understanding by sending accept or reject signals, such as saying "Ok", "Yes", or "No" or by making comments. If a group member did not fully understand an explanation, it was expected that such members would raise questions and other members provide explanations to sustain mutual understanding at the group level. Moreover, for the evaluation of CF, it was expected that group members communicate in a seamless way, which is evidenced in terms of lack of breakdowns in communication and progressivity in turn-taking organization. Group members are expected to follow which message was sent by whom and for what purpose.

Coordination: The main focus of the coordination dimension is to capture the extent collaborative group members worked together harmoniously (Malone & Crowston, 1994). The coordination dimension is composed of SMP and CO indicators. SMP qualifies the group members' interaction style in terms of how they organized the modeling process,

which is evidenced in their ordering of modeling activities and assigning sub-tasks to related group members. It was expected that the group members successfully manage the modeling process by discussing their progress in the modeling task. In other words, the evaluation focuses on whether they were able to allocate tasks to each other and perform their own responsibilities successfully. Moreover, CO evaluates the coherence among group members' actions during collaboration, which focuses on whether the group members perform symmetric actions and complement each other to achieve the joint goal (Dillenbourg, 1999; Rummel & Spada, 2005). It was expected that the group members interact with each other and perform the modeling activities in harmony. They shouldn't compete for power and try to dominate their teammates. Although each member had different roles and performed different activities, there should be a symmetry and reciprocity among their contributions throughout the collaborative interaction. Group members are expected to be attending to their teammates' messages on the chat window and the activities performed on the shared whiteboard area.

Group Decision Making: Group Decision Making is concerned with how group members working collaboratively on a task communicate about the goals, propose alternatives for addressing those goals, evaluate the proposed alternatives, and the final choices they make (Malone & Crowston, 1994). During Group Decision Making episodes in our sample, group members typically shared knowledge and gave explanations to handle the encountered problems, engaged in critical discussions to reach a consensus, proposed and evaluated alternatives about the related issues and communicated in some form to validate and verify the created model pieces. Therefore, the Group Decision Making dimension is evaluated with respect to KE, RC and V&V indicators. For evaluating KE, it was expected that collaborative group members use their own sources of information to handle the problems encountered and present detailed explanations to their teammates regarding these problems. In addition to this, they were expected to solicit their teammates' participation as a knowledge resource while discussing possible solutions to the shared problems. Moreover, group members could present information about the tasks they handled by explaining what they did and why. For evaluating RC, it was expected that group members engage in critical discussion about the modeling activities by asking questions and providing justifications for the proposed solutions. If the group members did not reach an agreement on a solution suggestion or justification, they could continue to discuss until they found a better argument and reached a consensus. For evaluating V&V, it was expected that group members, who assume the DE role, check the co-constructed model's correctness by comparing the process definitions and the resulting process models during or after the modeling activity. DE should request PAs to address the issues detected. Also, PAs should request confirmations from the DE about the proposed fixes to the model. Such an argumentation among the group members is called as Validation. In addition to this, it was expected that the group members who had the PA role to check the structure, the appropriate use of notations and the correctness of the process models co-constructed with their partners. PAs could ask questions about the part of the model where they suspect about its correctness. Such an argumentation among the PAs is called as Verification.

Awareness: Awareness refers to the understanding of others' activities, which provides a context for one's own activity (Dourish & Bellotti, 1992). The dimension is a single item construct that evaluates whether the group members were aware of who did what modeling activity and who sent a message in reference to which topic. Throughout the collaborative interaction process, the level of mutual awareness of collaborative group members regarding the chat messages and the activities performed on the shared whiteboard area guide their interaction. For evaluating AW, it was expected that group members maintained mutual awareness and they were aware of their teammates' current tasks. Also they should follow each other in a symmetric way, which means not only one group member follows the others, but every group member follow each other equally. They should be eager to be aware of their teammates' current status of work.

Motivation: Social motivation indicates the physiological state of an individual who joins a community of collaborative innovation (Battistella & Nonino, 2012). Membership in a small group has a powerful impact on the group members' motivation and behavior (Dörnyei & Ushioda, 2013; Dörnyei, 2003). Motivation dimension is a single item construct, which evaluates the effect of GM on interaction quality. We evaluated the groups' cohesiveness in terms of the group members' motivation to exchange information (Ridings & Gefen, 2004), promoting sense of cooperation (Antikainen, Mäkipää, & Ahonen, 2010) and effort to encourage their partners to contribute to the ongoing interaction.

Domain Knowledge: Domain knowledge contributes to success in many cognitive tasks (Hambrick & Engle, 2002). It was observed that collaborative group members' knowledge level about business process modeling affects the groups' interaction style and quality. Therefore MC was evaluated under this dimension to understand how the PAs' competence in modeling and the DEs' skills in model reading affect the overall quality of interaction.

Support: Characteristics of the groupware inevitably affect the interaction process of collaborative group members. In particular, technical difficulties encountered during collaboration may influence the group members' interaction quality. TS was investigated under this dimension by considering how the technical difficulties affected the groups' interaction process and how the group members collaboratively handled such problems. Ideally, it was expected that group members had technical competence to use the groupware and accompanying tools in the system. However, members encountered some tool related technical difficulties while using the system. In such circumstances, the teammates should provide technical support to each other to handle such problems.

4.2.2 Rating of the Interaction Process Quality

The following descriptions of the factors were used to rate the interaction quality of the segments. Some illustrative excerpts are presented to show good or bad representations of the related interaction factor.

Sustain Mutual Understanding: Team members should be sensitive and careful when communicating and interacting with each other, which means any sent messages on the chat window and performed activities on the shared whiteboard area should make sense on the teammates. They should reflect their understanding and misunderstanding by sending accept or reject signals, such as 'Ok', 'Yes', 'No' and etc. or making comment on the message. If there is a misunderstanding, it is expected that the members ask question or make explanation about this unintelligibility. If a team member ask a question, the related member should respond his/her question clearly.

In this interaction excerpt, PA1 wanted to organize the modeling process, for this purpose, he sent a message to inform the teammates about his idea. After, PA2 and DE realized the message, they reflected their understanding to PA1 by sending positive signals.

> **PA1:** I think, we should model thus far, then we continue. / *Bence buraya kadar modelleyelim, sonra devam edelim.*
> **PA2:** All right. / *Olur.*
> **DE:** OK I am waiting. / *Tamam bekliyorum.*

In this interaction excerpt, PA2 made a correction on the model by stating a need for an activity model element. We can observe that, PA1 reflected her understanding by sending a confirmation feedback. In addition to this message, PA1 made correction on the model by adding a new activity element. This action also reflected the team members' mutual understanding.

> **PA2:** There's no need for that OR, more precisely there should be an activity before OR. / *Bu OR'a gerek yok, daha doğrusu OR'dan önce aktivite olacak.*
> **PA1:** Yes, as you said, there is an activity before OR. / *Evet dediğin gibi daha önce aktivite olacak.*

Communication Flow: It is expected that there is a seamless communication flow when the team members work on a joint work and communicate via chat messages. The team members should understand that which message is sent by whom and for what purpose. There shouldn't be communicational complexity because of any misunderstandings.

In the following excerpt, the team members' messages were interleaved with each other in a non-sequential manner. Therefore, the team members had communicational issues. In the interaction unit, DE sent a validation message. Right after, PA2 sent "It is not an Event" and "Nurcan" verification message. PA1 sent "Yes!" message in response to

"Nurcan" message. Then, PA2 sent "I've changed." message in reply to the validation message of DE. Meanwhile, PA1 assumed that "I've changed." message was sent for herself and tried to understand meaning of the message. She had difficulty to understand what PA2 was talking about and sent "What did you change?" message to seek for clarification. Then PA2 sent "It is not correct." message by referencing to the related model element on the shared whiteboard area to handle this problem. PA1 followed the reference link and realized the problematic model element. After all, PA1 understood what PA2 was talking about.

> **DE:** "The new course is established" seems like not fully express. / *"Yeni açılacak ders belirlendi" tam ifade etmiyor sanki.*
> **PA2:** It is not an Event. / *Event değil o*. // This message was sent without referencing.
> **PA2:** Nurcan. / *Nurcan.*
> **PA1:** Yes! / *Efendim.* // Sent as response to "Nurcan" mesage.
> **PA2:** I've changed. / *Değiştirdim* // PA2 have made correction on the model as reponse to the validation request of DE and sent this message to inform DE.
> **PA1:** What did you change? / *Neyi değiştirdin?* // PA1 took the previous message personally and she did not understood what PA2 had changed. Therefore, PA1 sent this message to clarify the meaning of the previous message.
> **PA2:** It is not correct. / *Bu olmadı*. // In order to handle the problem on the communicational flow, PA2 sent this message by referencing the related model element.
> **PA1:** Why? / *Neden?* // PA1 followed thhe reference link and understood what PA2 was talking about. At that moment, she tried to understand why PA2 thought that the referenced model element was uncorrect.

Structuring Modeling Process: It is expected that the team members successfully manage collaborative modeling process. They should organize modeling by discussing on the progress of the modeling process. It is evaluated that whether the team members are able to make work sharing and perform their own responsibility successfully based on the consensus or not. In other words, it is expected that collaborative team members make an effort to structure the modeling process and they are able to complete the works that are assigned to them collaboratively.

In the next excerpt, the team members made a consensus about the progress of the modeling process. They decided to perform modeling through an iterative approach, which means after DE shared a piece of information about the business process, the PAs would formalize the related information and then request a new information piece to continue the modeling. Throughout the interaction process, group members organized the modeling process based on their consensus.

PA2: Nurcan, does we model at last, or? / *Nurcan en son mu modelleyelim yoksa?*
PA1: I think we model while Ahmet describing. / *Ahmet anlatırken modelleyelim bence.*
PA2: I think so. / *Bence de.*
DE: I will cease and wait you in break. / *Ben aralarda durup bekliyorum o halde sizi.*
PA1: Lets go then ☺ / *Lets go o zaman ☺*
PA2: OK. / *Ok.*
PA1: OK. / *Ok.*

The following excerpt illustrates the work sharing among the PAs. PA2 requested PA1 to check the modeling activities she has performed. PA1 accepted this request and checked the correctness of all the modeling activities performed by PA2.

PA2: Özge, Can you check what I did to control is there any problem? / *Özge sen yaptıklarıma bakar mısın sorun var mı diye?*
PA1: OK. / *Ok.*

Cooperative Orientation: It is expected that the group members interact with each other and perform the modeling activities in harmony. Collaborative group members should undertake symmetric and complementary roles. They shouldn't compete for power and try to dominate their teammates. In brief, although each member has different roles and perform different activities, they should be symmetric and active throughout the collaborative interaction. Team members, should mind the teammates' messages on the chat window and activities performed on the shared whiteboard area. The situation, in which case team members carry the interaction process dominantly and refuse the teammates activities and messages, shouldn't occur.

The following interaction excerpt illustrates that there is a weak cooperative orientation among team members. PA2 did not read the teammates' messages, cared the modeling activities performed by PA1, and performed modeling activities according to the information pieces shared by DE. It was observed that there is an asymmetry between PAs, which means PA2 performed the modeling activities dominantly without considering the modeling activities of PA1.

DE: I thought we will go step by step. / *Ben asama asama gideriz diye düşündüm.*
PA1: No, it seems like we come to that stage. / *Yok sanki o asamaya geldik gibi.*
PA1: Ebru is fully immersed in modeling. / *Ebru kaptırdı gidiyor.*
DE: Ebrucum stop wait don't go. / *Ebrucum dur bekle gitme.*
PA1: Ebru do you draw these with your imagination :D / *Ebru bunları hayal gücünlemi çiziyorsun :D*

Knowledge Exchange: Collaborative team members use their own source of information to handle an encountered problem and present detailed explanation to their teammates.

Besides, they can use the teammates as knowledge source to require detailed information from them. Moreover, team members can present information about the works handled by them and explain what they did and why they performed the related job. In this factor, information exchange due to the technical complexities is not included. The information should be related with the modeling task.

In the following message PA2 shared her knowledge about modeling rule with PA1.

> **PA2:** There are no two arrows for an Event, there should be a gateway between. / *Bir Event'e iki tane ok giremez, arada bağlaç olmalı.*

In the following interaction excerpt, PAs informed each other about the works that they will be performing. PA2 sent "Let's add a form, student form." message to inform her teammates about the action that would be performed by herself before adding the related form model element. Then PA1 sent "OK, I add the names, then." to confirm PA2's message and similarly, inform her teammate about the related action that would be performed by herself. After then, PA1 sent "Now, we need a function which is for transmitting the form by the student." to inform her teammate about the action that would be perfomed by herself before conducting. Also, she expressed why they needed a function model element with this message.

> **PA2:** Let's add a form, student form. / *Birde form ekleyelim öğrenci formu.*
> **PA1:** OK, I add the names, then. / *Tamam ben de isimleri ekliyorum o zaman.*
> **PA1:** Now, we need a function which is for transmitting the form by the student. / *Şimdi bir functionumuz olacak öğrencinin formu iletmesi için.*
> **PA2:** OK. / *Tamam.*

Reaching Concensus: Team members make critical discussion throughout the modeling process. For example, team members can ask questions and provide justification about the proposed solution recommendations. If the partners do not reach an agreement on the solution suggestion and justification, they continue to discuss until they find a better argument and reach a consensus.

> **PA2:** Now, there is a decision, then that event will branch out with XOR. / *Şimdi decision var, sonra o event XOR ile dallanacak.*
> **PA1:** Yes. / *Evet.*
> **PA2:** Either it can be OR I am not sure. / *Yada OR'da olabilir emin değilim.*
> **PA1:** I'll put OR. / *OR koyuyorum.*
> **PA2:** Ahmet, whait is your opininon about this issue. / *Ahmet senin bu konudaki fikrin nedir?*
> **DE:** In a sense, it should only be given one of three decision. / *Yani üç karardan sadece biri verilmeli.*
> **PA2:** Yes, then probably XOR will be. / *Evet, o zaman XOR olmalı galiba.*

DE: I think XOR should be, because two decisions can not arise from there. / *Bence de XOR, çünkü iki karar çıkamaz oradan.*
PA1: Let's get XOR, do you approve XOR? / *XOR olsun hadi, onayladın mı XOR'u?*
PA2: Yes, I approve. / *Evet onaylıyorum.*

Validation & Verification: The team member who have DE role checks the model's correctness by making comparison between process definitions and performed modeling activities while PAs work on the model or after they complete it. DE requests correction for the false representations from the PAs. Also, PAs request confirmations from DE. Such an argumentation among the team members called as Validation. In addition, the team members, who have PA role, check the structure, notation use and correctness of the modeling activities performed by themselves or their partner. PAs can ask question about the part of the model where s/he thinks about it is wrong. Such an argumentation among the process analysts called as Verification.

In this excerpt, DE made a validation on the label of the model element. Then PA2, performed this validation request and change the label.

DE: It seems like "Open a new course" does not fully express. / *"Yeni açılacak ders" tam ifade etmiyor sanki.*
PA2: OK, I've changed. / *Ok, değiştirdim.*

In this excerpt PA1 wanted a confirmation for DE. After DE gave the correct information, PA1 proceeded the modeling.

PA1: Ahmet, does it just approve, isn't it? / *Burda sadece onay olacak dimi ahmet?*
DE: Approve or reject / *Onay veya red.*
PA1: OK. / *Tamam.*

In this excerpt, PA1 request a confirmation from the other PA. PA1 tried to verify the modeling activities that she planed to perform.

PA1: Özge. / *Özge.*
PA2: Yes! / *Efendim.*
PA1: It should be put this document in evey related place in the model, shoudn't it? / *Bu dökumanı ilgili heryere koymak gerekiyor dimi.*
PA2: Yes. / *Evet.*

Awareness: Team members should maintain mutual awareness and follow the teammates' present works. The group members should follow each other symmetrically, which means not only one group member follow the others, every group members should

follow each other equally. They should be eager to be informed about the teammates' current status.

In this interaction excerpt, the group members were not aware of each other and the interaction process suffered from this weak level of mutual awareness. At the begining of the interaction unit, DE wanted to share a new piece of information with PAs. However, PA1 stated that he was not aware of PA2 and he wanted to be informed about the current status of PA2. In addition to that, DE stated that she was not aware of which modeling activity was performed by whom. PA2 was also not aware of these messages and he noticed the messages sent by PA1 and DE too late. After he realized the teammates' awareness issue, he stated his activeness in modeling.

> **DE:** I am writing rest of the definition. / *Devamını yazıyorum.*
> **PA1:** Wait, where is the Mahir. / *Dur, Mahir hocam nerde.*
> **PA1:** I cannot see. / Ben göremiyorum.
> **PA1:** He does not write anything. / *Bir şeyde yazmıyor.*
> **DE:** He gets bored and run away :P / *Sıkılıp kaçmış :P.*
> **DE:** I do not realise who is doing. / *Ben kimin yaptığını anlamıyorum tabi.*
> **PA2:** I am doing. / *Ben yapıyorum.*

Group Motivation: Team members should be eager and ready to perform their roles and responsibilities. Also, they should be active and promote each other to be active throughout the modeling process. In other words, team members should motivate and encourage each other to complete modeling activity properly.

In this interaction excerpt, it is observed that PA2 was unwilling to perform his modeling responsibilities. Motivation of PA2 was too low to discuss about definition of the model with her teammate and reflect this situation on the model. She intended to terminate the modeling activity as immediately as possible without concerning the possibility of completing the model incorrectly.

> **PA1:** What happaned with the equivalency when it is accepted? / *Kabul olunca denklik ne oluyordu?*
> **PA2:** Oh! Don't go there. / *Ya karıştıma işte.*

In the following message, PA1 also motivated her teammate via encouraging her modeling activity.

> **PA1:** You are doing well, Nurcan / *Güzel gidiyorsun Nurcan.*

Modeling Competency: The team members should have sufficient domain knowledge about BP modeling with eEPC and UML Activity Diagram modeling notations. It is expected that PAs have enough domain knowledge to build and read valid models. It is

also expected that DE have ability to read model to compare formalized model with process definition.

In an excerpt, it is observed that PA1 linked two event model elements as shown in Figure 22. Although PA2 realized this connection, he did not warn his teammate or correct the related mistake. This interaction unit shows that the PAs did not have enough modeling competency to know that two event model element cannot be linked directly.

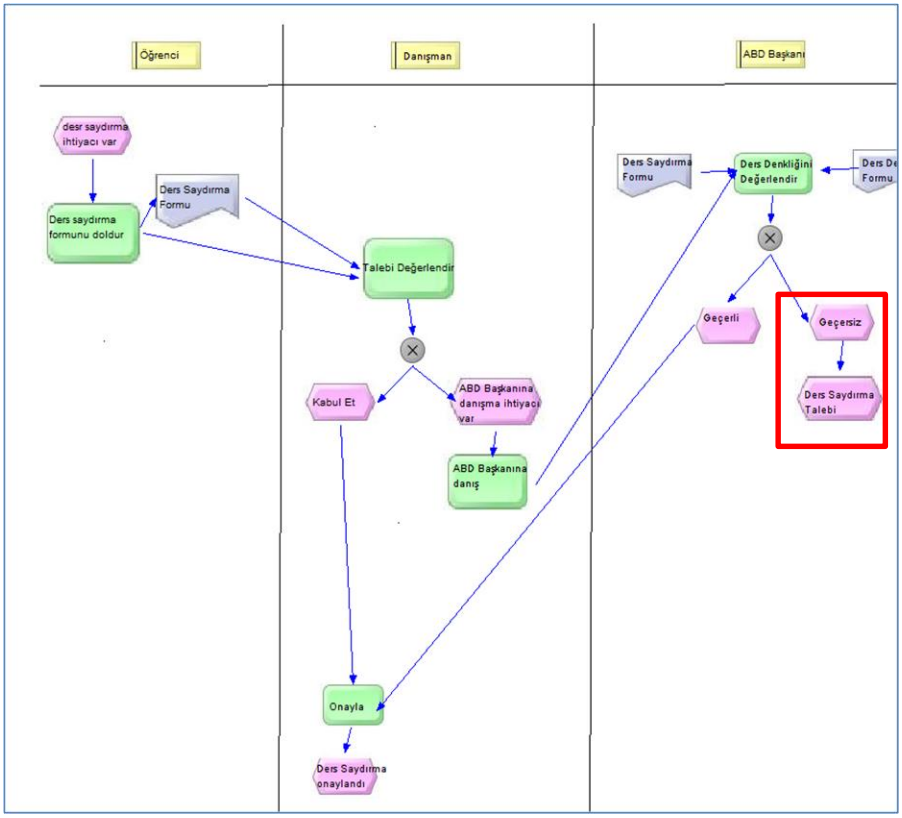

Figure 22 Process Model of Group 9_1

In this interaction episode, it is observed that PAs did not have enough domain knowledge to select correct gateway model element. At the beginning of the interaction unit, DE warned PAs about the correctness of used OR model element and she stated that XOR should be used. After this warning message, PA1 made an explanation about XOR and OR model elements and PA2 confirmed his statement. However, the PAs explanations about XOR and OR usage rule were not correct.

> **DE:** Besides, does not have to be XOR, instead of OR? / *Bir de Veya değil de Xor olması gerekmez mi?*
> **PA1:** Both can be in XOR, only one can be in OR. / *XOR'da ikisi de olabiliyor, or olunca sadece birisi olabiliyor.*

PA2: Yes. / *Evet.*
DE: Are you sure? / *Emin misin?*
PA2: I know as Murat's knowledge. / *Bende Murat'ın bildigi gibi biliyom.*
DE: OK, I am not a process analyst, so I don't force. / *Oki süreççi olmadığım icin bastırmıyıcam :)*
PA1: Both have to be in AND, only one in OR, at least one in XOR. / *And'de ikisi de olmak zorunda, or'da sadece birisi, xor'da en az birisi.*
PA1: :)

Technical Support: Ideally, it is expected that team members should have technical competence to use the groupware and specialized technical tools of the system and require no support. However, members may encounter some tool related technical difficulties in using the system. In such circumstances, the teammates should provide technical support to each other in handling the problem. In the worst case, teammates do not help each other when one of them experienced with any technical problem.

In this interaction excerpt, it is observed that PA1 was not qualified to use model elements despite training was given about the usage of system and model notations. PA1 asked for help with "Mert, how can we do movement action?" message. PA2 informed PA1 about how to duplicate model elements. Although, PA1 applied recommendations of PA2, he was unsuccessful to move the model notation on the shared area. Once again, PA1 stated his incompetency, which was about putting the model element on the shared area. Then, PA2 recommended to restart the system to handle the problem. In this excerpt, the technical difficulty experienced by PA1 affected the group's interaction process negatively; however help of PA2 prevent the possibility of having this difficulty for a longer time.

PA1: Mert, how can we do movement action? / *Mert şu taşıma işlemini nasıl yapıyorduk?*
PA2: First, select it, pal. / *Önce seçeceksin abi.*
PA2: Take in a square. / *Kare içine al.*
PA2: With mouse. / *Mouse ile.*
PA1: I cannot drag. / *Sürükleyemiyorum.*
PA2: Try to restart to the system. / *Sistemi yeniden başlatmayı denesene.*

4.3 Evaluation of Joint Attention

The degree of gaze overlap observed during each modeling session is used as an indicator for the level of joint attention (JA) among the PAs in the group. Table 14 shows each group's modeling sessions which were segmented into episodes. The table summarizes the total duration of the segment, the gaze overlap time, the percent of the gaze overlap for each segment and the total gaze overlap percentage of the modeling sessions. Due to the technical problems, cross recurrence analysis could not be performed on the gaze

records of Group1_1, Group1_2 and Group5_2. Therefore, these groups were excluded from further analysis.

Table 14 Joint Attention Measures

Group	Segments	Total Time (Sec)	Overlap Time (Second)	Percentage	Total percentage
Group2_1	Segment1	599	214.688	%36.92	%34.90
	Segment2	567	186.795	%35.94	
	Segment3	526	156.964	%33.89	
	Segment4	591	166.912	%32.63	
	Segment5	437	140.982	%34.90	
Group2_2	Segment1	565	195.047	%34.48	%35.55
	Segment2	644	266.803	%41.40	
	Segment3	728	224.385	%30.79	
Group3_1	Segment1	539	123.044	%22.82	%23.22
	Segment2	608	121.338	%19.93	
	Segment3	639	190.15	%29.75	
	Segment4	380	77.717	%20.41	
Group3_2	Segment1	560	146.698	%26.15	%24.69
	Segment2	358	83.629	%23.35	
	Segment3	287	70.794	%24.59	
Group4_1	Segment1	717	257.761	%35.94	%35.6
	Segment2	630	182.893	%29.01	
	Segment3	812	298.58	%36.75	
	Segment4	314	128.053	%40.70	
Group4_2	Segment1	654	193.499	%29.57	%33.51
	Segment2	573	197.805	%34.47	
	Segment3	756	275.936	%36.49	
Group5_1	Segment1	571	267.913	%46.84	%47.51
	Segment2	581	243.232	%41.82	
	Segment3	582	328.317	%56.33	
	Segment4	648	291.977	%45.05	
Group6_1	Segment1	589	259.229	%43.96	%42.55
	Segment2	607	237.142	%39.05	
	Segment3	603	287.415	%47.63	
	Segment4	383	151.92	%39.59	
Group6_2	Segment1	406	184.677	%45.46	%41.94
	Segment2	518	199.225	%38.42	
Group7_1	Segment1	634	211.364	%33.32	%33.97
	Segment2	647	185.377	%28.61	
	Segment3	563	182.538	%32.36	
	Segment4	407	169.793	%41.62	
Group7_2	Segment1	484	158.967	%32.82	%34.78
	Segment2	537	209.564	%38.99	
	Segment3	407	114.32	%28.07	
	Segment4	476	186.963	%39.27	
Group8_1	Segment1	606	207.581	%34.23	%25.45
	Segment2	433	69.214	%15.98	
	Segment3	787	205.979	%26.16	
Group8_2	Segment1	476	166.99	%35.01	%35.62

	Segment2	618	224.26	%36.23	
Group9_1	Segment1	584	196.192	%33.59	%33.30
	Segment2	617	213.277	%34.51	
	Segment3	220	78.617	%35.59	
	Segment4	346	102.434	%29.54	
Group9_2	Segment1	463	141.243	%34.90	%35.00
	Segment2	427	138.734	%35.10	

4.4 The Interrelatedness of Joint Attention and Interaction Quality Factors & the Causal Relationship between Joint Attention and Theoretical Interaction Quality dimensions

The correlation of JA and the factors that affect interaction quality in quasi-synchronous CSCBPM context were examined. In addition, a multi-dimensional research model was proposed to evaluate whether the observed interaction quality factors represent the theoretical dimensions as an indicator or not. Besides, the model evaluated the theoretical dimensions' effect on each other. Influence of JA measures on the theoretical dimensions was also examined in the proposed structural model.

Conceptual models generally link concepts which are multidimensional (Bry, Verron, & Redont, 2010). In this regard, different dimensions were considered to investigate external variables of the proposed research model. Structural equation modeling, specifically partial least square (PLS-SEM) based model was applied to assess the proposed multi-dimensional research model via SMART-PLS software. PLS-SEM is used since it is a method suitable for cases when relationships among theoretical constructs are explored and overall nomological network has not been well defined (Peng & Lai, 2012). Before the evaluation of the structural model, sample size requirement and preliminary data analysis including outlier detection, missing value analysis, multicollinearity analysis and normality checks were performed (Hair, Black, Babin, Anderson, & Tatham, 2006). The minimum sample size requirement was calculated with respect to the "10 times" rule of thumb, which means PLS only requires a sample size of 10 times the most complex relationship within the research model (Peng & Lai, 2012). According to this rule, our sample size of 51 was well above the minimum sample size requirement of 10. Outliers were detected in GM and TS factors and these values were removed from the data set. Missing data level was under 10%, so mean imputation was applied to handle missing values (Hair et al., 2006). VIF values were less than 5 (Hair, Ringle, & Sarstedt, 2011) indicating that there was no multicollinearity issue between the interaction factors. Skewness and kurtosis values were checked for the normality assumption (Field, 2009). Except the TS and MC factors, all of the factors were normally distributed. Inter-relations among the interaction quality factors and the joint attention were examined and shown in Table 15. Small, medium and large effect size correlations were observed between interaction quality factors. Also it was observed that small in size correlation was observed between JA and KE (r: .289, $p<0.05$). Medium in size correlations were observed between the JA and SMU (r: .407, $p<0.01$), JA and SMP (r: .308, $p<0.05$), JA and AW (r: .416, $p<0.01$) and JA and GM (r: .445, $p<0.01$).

Table 15 Correlation Matrix of Interaction Factors and Joint Attention

Interaction Factors	**SMU**	**CF**	**SMP**	**CO**	**Aw**	**KE**	**RC**	**V&V**	**GM**	**TS**	**MC**	**JA**
SMU	1	**.477****	**.451****	**.495****	**.656****	**.446****	.245	.243	**.535****	**.319***	.000	**.407****
CF		1	**.489****	**.451****	**.517****	.220	**.300***	**.311***	**.282***	**.467****	.093	.127
SMP			1	**.469****	**.511****	**.508****	**.347***	.224	**.512****	**.353***	-.120	**.308***
CO				1	**.565****	**.279***	**.343***	**.321***	**.640****	**.286***	.205	.210
Aw					1	**.394****	.200	.200	**.628****	**.303***	.073	**.416****
KE						1	.198	.112	**.325***	.152	-.107	**.289***
RC							1	**.339***	.172	.164	**.355***	.049
V&V								1	**.450****	.206	**.635****	.127
GM									1	.088	.262	**.445****
TS										1	-.103	.050
MC											1	.172
JA												1

*Significant at 0.05 level; **significant at 0.01 level

The research model was evaluated based on an assessment of the measurement model and the structural model. The measurement model was evaluated with confirmatory factor analysis (CFA) to ensure that the factors that affect interaction quality were related with the theoretical dimensions. CFA assesses the measurement model with convergent validity and discriminant validity. Convergent validity performed with Factor Loadings (FL), Composite Reliability (CR) and Average Variance Extracted (AVE) methods. The standardized FL should be ideally 0.7 or higher to ensure that variances are shared between the items and the construct, whereas standardized FLs of 0.5 or higher are also acceptable (Hair et al., 2006). CR value should be 0.7 or higher to ensure internal consistency, which means that all measures consistently represent the same latent construct (Hair et al., 2006). AVE value should be computed for each latent construct and should be 0.5 or higher to ensure adequate convergent validity. As shown in Table 16, standardized FLs ranged between 0.611 and 1.00. All CR values ranged from 0.729 and 1.00; therefore, the measurement model was found to have good reliability. AVE values were between %73 and %100 and these results indicated that each construct was strongly related to its respective indicators.

Table 16 Convergent Validity

Theoretical Dimension	**Interaction Factors**	**Factor Loadings**	**Composite Reliability (CR)**	**Average Variance Extracted (AVE)**
Com	CF SMU	.822 .893	.848	%74
Coord	CO SMP	.860 .854	.847	%73
AW*	AW	1.00	1.00	%100
GDM	KE RC V&V	.703 .736 .621	.729	%50
M*	GM	1.00	1.00	%100
DK*	MC	1.00	1.00	%100
S*	TS	1.00	1.00	%100
JA*	JA	1.00	1.00	%100

*Single item construct

Discriminant validity indicates that a measure does not correlate so highly with another measure (Peter, 1981). In order to ensure discriminant validity, square root of the AVE calculated for each construct should be greater than the correlation between a given construct and all other constructs. Table 17 shows that square root of AVE for each construct on the diagonal was greater than the other values.

Table 17 Discriminant Validity of Measurement Model

Constructs	AW	Com	Coord	DK	GDM	M	JA	S
AW	**Single Item Construct**							
Com	0.690	**0.858**						
Coord	0.628	0.639	**0.857**					
DK	0.073	0.048	0.051	**Single Item Construct**				
GDM	0.398	0.504	0.580	0.363	**0.688**			
M	0.628	0.491	0.673	0.262	0.443	**Single Item Construct**		
JA	0.416	0.329	0.302	0.172	0.236	0.445	**Single Item Construct**	
S	0.308	0.363	0.330	-0.104	0.241	0.094	0.050	**Single Item Construct**

Structural model was evaluated with the statistical significance of each path coefficient values that are standardized betas. T-values that should be greater than 1.96 are used to evaluate the significance of the standardized betas. The data set composed of 51 samples, which were analyzed with a bootstrapping procedure to assess the significance level of the relation between the constructs. The estimated path coefficients of the structural model, their significance level and T-Values are shown in Table 18.

Table 18 Structural Estimates

Relationships	**T-Values**	**β**	**Power**
Com ->Coord	2.662	0.312**	0.9999
Com->M	3.263	0.414***	0.9949
Coord->GDM	6.870	0.580***	0.9988
AW->Com	7.832	0.690***	0.9999
M->Coord	4.117	0.541***	0.9999
JA->AW	3.924	0.416***	0.8987
JA->M	2.201	0.250*	0.9949

*p < 0.05; **p < 0.01; ***p<0.001

T and β values show that there was a strong positive relation between Com and Coord at the p<0.01 significance level. In addition, the relation between Com and M, Coord and GDM, AW and Com, M and Coord, JA and AW had a positive strong relation at the p<0.001 significance level. Also JA had a positive and significant relation with M at the p<0.05 level. DK and S did not have any significant relationship with the other theoretical dimensions and JA. The research model is shown in Figure 23.

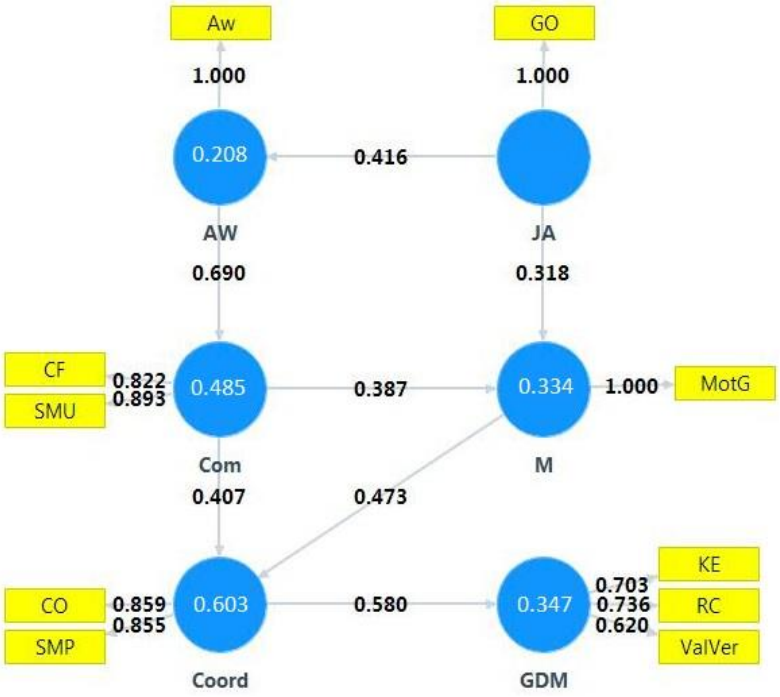

Figure 23 Research Model

Statistical post-hoc power analysis should be performed to ensure that sample size used in the analysis is adequate (Marcoulides & Saunders, 2006). Post-Hoc power analysis was calculated for each structural path and for the dependent latent variable with the largest number of independent latent variables influencing it (Peng & Lai, 2012). As shown in Table 19, power of each path was much greater than 0.8 and in our research model the latent variables AW that was predicted by JA independent variable had 0.8604 statistical power.

Table 19 Variance Explained (R^2), Effect Size (f^2) and Predictive Relevance (Q^2)

Dimensions	**R^2**	***f^2***	***Q^2***
Com	0.48	-	0.330
Coord	0.60	-	0.388
AW	0.20	-	0.156
GDM	0.34	-	0.128
M	0.33	-	0.218
Joint Attention	-	0.25	-

After performing bootstrapping procedure, structural model was assessed with explained variance (R^2), Cohen's f^2 and Stone-Geisser's Q^2 (Peng & Lai, 2012). R^2 was used to evaluate predictive power of research model. R^2 of endogenous variables were 0.48, 0.60, 0.20, 0.34 and 0.33 for Com, Coord, AW, GDM and M respectively. Com and Coord appeared to be between medium and strong, GDM and M appeared to be medium and AW

appeared to be weak (Chin, 1998). Effect sizes of predictive constructs are examined with f^2. According to Cohen (Cohen, 1988), JA has medium effect size with 0.25. Predictive relevance is calculated with Q^2 for endogenous variables (Geisser, 1975; Stone, 1974). Stone-Geisser's Q^2 values are 0.330, 0.388, 0.156, 0.128 and 0.218 for Com, Coord, AW, GDM and M respectively and higher than 0 that indicates acceptable predicting relevance (Peng & Lai, 2012).

4.5 The Interrelatedness of Joint Attention, Factors that Affect Interaction Quality and Collaboratively Produced BP Model Quality in Quasi-Synchronous CSCBPM Context

Quality of the process models was evaluated with syntactic, semantic and pragmatic perspectives. Detailed explanations of these approaches are presented in section 3.3.4. Average Expert Review (ER) score for syntactic and semantic quality aspects ranged between 55 and 96.75 and CC value for pragmatic quality ranged between 0.043 and 0.071.

The correlation coefficient test was used to examine the relationship between the quality of collaboratively produced business process models and the interaction quality factors as well as the degree of JA among the modelers. The quality of the model was quantified with two measures, namely the ER measure that evaluates the syntactic and semantic quality of the model, and the CC measure that evaluates the pragmatic quality of the model. The correlations between the quality measures of business process models and the interaction quality factors as well as the JA scores are shown in the Table 20.

Table 20 Correlation Results

Factors	ER	CC
JA	.727**	-.617*
SMU	.582*	-.393
CF	.251	-.303
SMP	.576*	-.178
CO	592*	.063
AW	.386	-.180
KE	.571*	-.106
RC	.281	-.121
V&V	.593*	.116
GM	.680**	-.093
TS	.405	.082
MC	.587*	-.111

*Significant at 0.05 level; **significant at 0.01 level

Table 20 suggests that there was a strong positive correlation between the ER and SMU (r=.582, p<.05), ER and SMP (r=.576, p<.05), ER and CO (r=.592, p<.05), ER and KE (r=.571, p<.05), ER and V&V (r=.593, p<.05), ER and GM (r= .680, p<.01) and ER and

MC (r= .587, p<.05). However, there was not any significant relation was found between interaction quality factors and CC measure.

Note that the JA measure was used to examine the degree of joint attention among the modelers in a group and the ER measure was calculated to quantify the success of the models that were collaboratively produced. We found a strong positive correlation between JA and ER (r=.727, p<.01), which suggests that as the degree of gaze overlap between the modelers increases the collaboratively produced models in the CSCW environment tends to be of higher semantic and syntactic quality.

In order to further investigate the relationship between gaze coordination and the co-constructed process models, the teams were split into three groups (low, medium, high) based on the degree of gaze overlap observed during their sessions. A one-way ANOVA was then conducted over mean ER measures of these three groups to test for group differences. Levene's test indicated that group variances were equal for the groups, $F(2,12) = 0.221$, p>.05 (ns), and since groups were of different size Hochberg's GT2 post hoc test procedure was used. As a result, one-way ANOVA showed that the group differences were statistically significant, $F(2,12) = 7.846$, p<.05, r = .75. Post hoc tests found a significant difference between the groups that had high and low JA (MD = 28.41, p<.05) and the groups that had medium and low JA (MD = 17.83, p<.05). These results showed that the groups that exhibited more gaze coordination created more successful models in terms of their syntactic and semantic quality. The bar chart in Figure 24 below shows that the groups that had high gaze coordination had an average expert rating of 90.00%, which is followed by the groups that had medium and low gaze coordination with average expert ratings of 79.41% and 61.58% respectively.

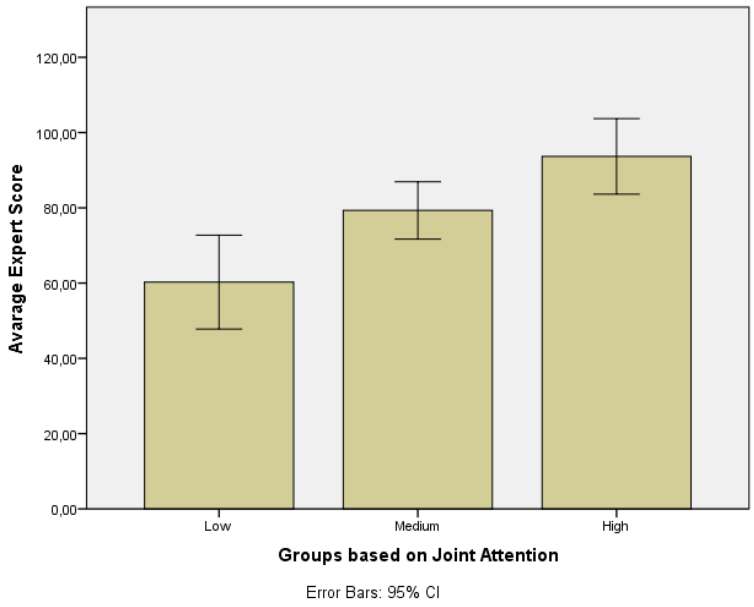

Figure 24 Joint Attention versus Average Expert Score

The CC measure was used to quantify the complexity of the final process models. Lower CC values indicate more complex and less understandable process models. As shown in Table 20 there was no significant relationship between the complexity of the collaboratively produced business process models and the interaction factors.

We found a significant negative correlation between JA and CC values ($r=-.617$, $p<.05$), which suggests that higher JA leads to lower CC values. In other words, modelers who had a high degree of joint attention were inclined to co-construct more complex models for the given process definitions. However, the CC value alone does not provide any information about the models' correctness. For instance, if the process definition is complex it might be expected that the created model would be complex as well, whereas if the process definition is simple one could expect the final model to be simple. Therefore, groups that produced models with higher CC values may not necessarily be more successful in producing correct models. For that reason, to make a better evaluation of the teams' success by using the CC scores, we classified the teams into two groups based on their models' similarity to the CC score of the corresponding baseline model developed by the experts for the same process.

The teams were classified as successful teams whose process models have similar complexity values as compared to the baseline model, which had a CC measure of 0.057. The remaining teams were classified as unsuccessful due to their complexity measures as compared to the baseline model (Group5_1 was excluded from the analysis as an outlier). An independent t-test was conducted to investigate whether the teams classified based on their CC measures differed in terms of their JA scores. Levene's test indicated that variances of JA scores were not equal among these groups ($F(1, 12) = 8.279$, $p<.05$), and the group sizes were slightly different. An independent t-test adjusted for homogeneity of variance showed that there is a significant difference between these two groups in terms of their mean gaze overlap values, $t(7.84) = 2.323$, $p<.05$, $r=0.63$. As shown in Figure 25, the teams that produced successful models in terms of their deviation from the baseline model's complexity ($M=36.34\%$, $SD=3.72$) exhibited significantly more gaze coordination as compared to the less successful group ($M=29.88\%$, $SD=6.00$).

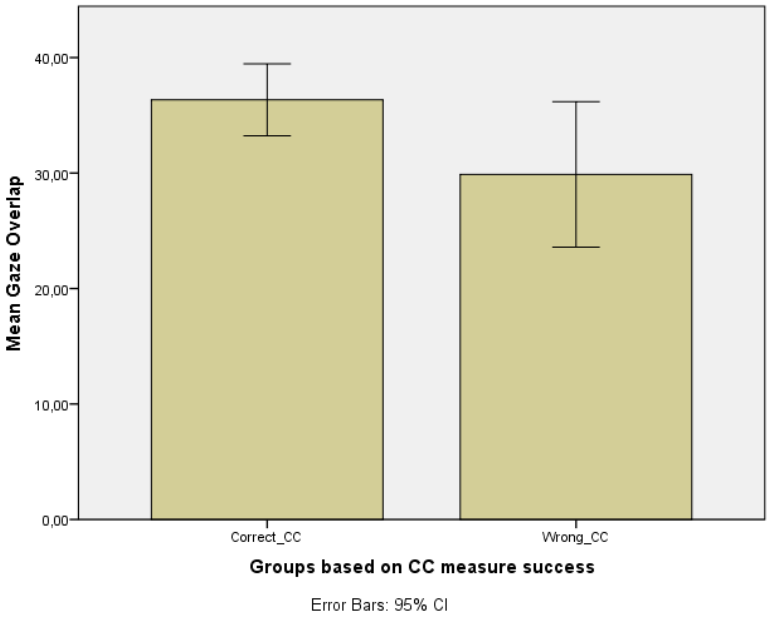

Figure 25 CC Measure Success versus Gaze Overlap

4.6 Summary of the Main Study Findings

In the main study, SMU, CF, SMP, CO, KE, RC, V&V, AW, GM, MC and TS interaction quality factors were identified and grouped under Com, Coord, GDM, AW, M, DK and S theoretical dimensions. Then collaborative interaction process quality was evaluated within the boundry of identified quality factors. Joint attention was evaluated as an indicator of the PAs gaze overlap measure.

Relationships between interaction quality factors were assessed and a research model was developed to prove that the observed interaction quality factors represented the theoretical dimensions as an indicator or not. Also the research model showed the theoretical dimensions' effect on each other and influence of JA measure on the theoretical dimensions. According to correlation coefficient results, there were significant relationships between interaction quality factors. Also, the research model showed that there were strong positive relations between Com and Coord, Com and M, Coord and GDM, AW and Com, M and Coord, JA and AW and JA and M.

Lastly, the quality of the collaboratively produced business process models was evaluated as an indicator of the success of collaboration. The interrelatedness of joint attention, factors that affect interaction quality and collaboratively produced BP model quality was examined. The results showed that JA had significant and positive relation with ER that refers syntactic and semantic quality as well as JA had significant and negative relation with CC that refers pragmatic quality. Further investigation of the data showed that the groups that exhibited more gaze coordination created more successful models in terms of

their syntactic, semantic and pragmatic quality. In addition, ER had positive and significant relations with some of the interaction quality factors that were SMU, SMP, CO, KE, V&V, GM and MC. However, there was not any significant relation was found between interaction quality factors and pragmatic quality of the process models.

CHAPTER 5

DISCUSSION AND CONCLUSION

In this chapter, the results and findings of the research is discussed with respect to the literature, then limitation of the study and recommendations for the future researches are presented.

5.1 Discussion

In this study, we investigated five research questions by examining the collaborative nature of CSCBPM from different methodological perspectives. Firstly, through a qualitative analysis of interaction episodes we identified quality factors that can be employed to characterize effective CSCBPM activities. Then we developed operational measures to quantify those quality factors as items, and constructed a model to explore whether the observed interaction quality factors represent the theoretical dimensions as an indicator or not and the theoretical dimensions' effect on each other. Moreover, we identified the relationships between the degree of joint attention and the factors that affect interaction quality. Lastly, we examined the relationships between the quality of collaboratively produced BPM with interaction quality factors and joint attention. The following subsections discuss our main findings.

Which factors affect the interaction quality of collaborative work groups in a synchronous CSCBPM context?

The primary motivation behind this study was to identify the factors that affect interaction quality in a CSCBPM context through a theoretically motivated qualitative content analysis of empirical data. Our analysis revealed that Communication, Coordination, Awareness, Group Decision Making, Motivation, Domain Knowledge and Support were the main theoretical dimensions that promote the collaborative interaction process.

The chat interface served as the basic communication channel for the collaborating group members throughout the CSCBPM. A closer investigation of the interaction process revealed that SMU and CF were crucial indicators for effective **Communication** (Malone & Crowston, 1994), in parallel with the findings of Rummel & Spada (2005), Meier et al.(2007) and Kahrimanis et al. (2009). During those cases where team members successfully conducted the communication process, they were able to sustain mutual understanding by communicating and interacting with each other. They contributed to the

communicative interaction by asking questions, responding to each other's questions and posting acknowledgement messages; such as "Ok", "Yes", "No" and etc.; thus they successfully reflected their understanding for a new message or an unfolding modeling activity. In addition to this, in the case of effectively collaborating teams, group members could maintain a seamless flow of communication on the chat window, even if some of them focused more on the modeling activity. The team members were able to follow which message was sent by whom and for what purpose successfully. There were no major communicational issues or breakdowns due to misunderstandings. If there were such issues of mutual intelligibility, team members asked questions about the problematic aspects and offered explanations to remedy such issues.

We observed that **Coordination** (Malone & Crowston, 1994) was performed with SMP and CO throughout the collaborative activity (Kahrimanis et al., 2009; Meier et al., 2007; Rummel & Spada, 2005). In cases where group members exhibited effective coordination, they were able to effectively structure and organize the collaborative modeling process. Members primarily managed the modeling process via planning their modeling activities (Fındık-Coşkunçay & Çakir, 2014). Moreover, such teams came up with ways to organize a division of labor among themselves and carried out their individual responsibilities successfully as agreed by the team. In brief, team members strived to organize the modeling process and made detailed discussions on their progress with the modeling task. As another aspect of effective collaborative interaction identified in this study, CO refers to the social side of the collaborative interaction for effective coordination (Kahrimanis et al., 2009; Meier et al., 2007; Rummel & Spada, 2005). The harmony among the group members is an important factor to enhance coordination quality. In effectively collaborating teams, group members undertook symmetric and complementary roles, and they did not compete for power and tried to dominate their teammates. Also, team members cared for and attended to the partners' messages on the chat window as well as the model-building actions performed on the shared whiteboard area. The interaction process was not dominated or shaped by a single group member who frequently ignored the others' activities and messages. In sum, although each member had different roles and performed different activities, the contributions were balanced and reciprocal throughout the instances of successful interaction.

Collaborative team members performed **Group Decision Making** (Malone & Crowston, 1994) with KE and RC interaction factors (Kahrimanis et al., 2009; Meier et al., 2007; Rummel & Spada, 2005). In addition to these, we observed that V&V emerged as an indicator of Group Decision Making. In the case of effective collaboration, group members shared their own sources of information to handle the problems encountered by the team during the modeling task. In other words, team members relied on their teammates as knowledge resources during business process modeling, where they both asked for information from others and provided information when required. Moreover, team members presented information about the tasks handled by them and explained what they did and why to each other. In the investigation of Group Decision Making, only the sharing of domain knowledge and information related to the common task were evaluated,

so information exchanges due to the technical complexities were not evaluated within this dimension. In addition to this, it was observed that some of the members endeavored to reach a consensus as a team during the interaction processes that were categorized as RC. Team members made critical discussions, asked questions and provided justifications about proposed recommendations for solutions. If the partners couldn't reach an agreement on the suggested solutions, they continued to discuss until they found a better argument and reached a consensus. Through V&V, model evaluation was performed by group members based on their roles. For instance, during an instance of an effective validation process, a team member who assumed the DE role checked the model's validity by comparing the process definitions and the model under co-construction, either while the PAs were working on the model or after they completed it. The DE requested from the PAs to fix the incorrect representations in the model. Moreover, the PAs often requested confirmations from the DE during the validation process in such cases. During an episode of effective verification, the team members, who were in the PA role, checked the structure, the notation used and the correctness of the modeling actions performed by each partner. In such cases, the PAs also raised questions about a part of the model where they thought were incorrect.

Awareness (Malone & Crowston, 1994), which was a single item construct, had a crucial role for the success of the interaction process. As evidenced in the dual eye tracking data, effectively collaborating team members noticed the messages that were sent by their partners on the chat window as well as the modeling activities performed on the shared whiteboard area. They followed the partners' messages and present modeling works to maintain mutual awareness.

Overall group energy was characterized with the GM indicator under the **Motivation** dimension. Team members' self-motivation overall raised the group's motivation. Group motivation was also increased when the team members encouraged each other to participate in the tasks and complete the modeling activity properly. In a highly motivated group, team members were more willing to perform their roles and responsibilities.

Domain Knowledge, which was qualified with MC, was another dimension that affected the quality of the interaction process. The participants, who were assigned the PA and the DE roles, reported that they had sufficient domain knowledge in process modeling before the experiments were conducted. However, it was observed that there were differences between the groups in terms of the DE's model reading skills and the PAs' process modeling skills and knowledge about modeling notations. Such differences affected the groups' interaction quality, so the group members' overall competency on model building and reading capabilities were investigated within the MC dimension.

Support, which was a single item construct, qualified with TS. Ideally, it was expected that the team members had the technical competency to use the groupware and specialized technical tools of the system. However, it was observed that some of the group members encountered some tool related technical difficulties while using the system. In such

circumstances, effectively collaborating groups provided technical support to each other to overcome such technical problems.

What are the relationships between the factors that affect interaction quality?

The second motivation of this study is to propose a research model that investigates the relationships between the observed indicators, which refer to the identified interaction quality factors and the specified theoretical dimensions related to the synchronous CSCBPM context. Within the defined indicators, interaction quality of collaborative groups were quantified with a rating procedure proposed by Kahrimanis et al. (2009), Meier et al. (2007) and Spada et al. (2005). The research model validated the measurement model, which showed that the observed indicators represented the specified latent theoretical dimensions. Moreover, the model validated the structural model, which represented how collaborative dimensions - Communication, Coordination, Group Decision Making, Awareness, Motivation, Domain Knowledge and Support - predicted each other.

The research model identified the following relationships among the theoretical dimensions. Firstly, the communication process had a strong effect on coordination, which is consistent with the previous studies (Miller & Moser, 2004; Zurita & Nussbaum, 2004). This relationship suggests that the groups which had high quality communication promoted better coordination throughout the interaction process, and those teams that could not maintain a well-structured communication struggled to coordinate the modeling process appropriately and collaboratively. Effective communication is a prerequisite for the coordination and the organization of the modeling process as well as effective task allocation. In addition to communication, motivation had a strong effect on coordination, which means highly motivated team members were prone to coordinate the modeling process and task allocation more effectively. Communication and motivation accounted for an impressive 60% of the variance in coordination.

In addition to this, the model showed that communication had positive effects on motivation. As Geister, Konradt, & Hertel (2006) argued, feedback has a positive effect on motivation in virtual teams. In this study, we observed that achieving a well-structured communication among group members improved the accuracy of the final model co-constructed by the team. Moreover, the model suggest that group motivation is related to the degree team members perform their responsibilities during the collaborative modeling task. Some of the group members who failed to establish an effective communication process were found to give up performing along their roles. Communication accounted for 33% of the variance in motivation.

The model also showed that, awareness was the single dimension that had a strong positive effect on communication. The group members who were aware of the activities performed on the shared white board area and the messages on the chat window were also successful

in giving feedback to each other and reducing the communicational complexities they encountered. Awareness accounted for 48% of the variance in communication.

Finally, the model showed that coordination had a great influence on group decision making. This relationship emphasizes that if the group members are inclined to make their decisions about the coordination of the modeling process collaboratively, they also tend to solve the encountered problems with mutual agreement. As Barron (2000) suggested, coordination is fundamentally important for facilitating knowledge exchange and common ground. In our model, coordination accounted for 34% of the variance in group decision making, which seems to support Barron's argument.

The research model was also successful to show that the observed indicators which refer interaction quality factors represented the specified latent theoretical dimensions. The model showed that awareness, motivation, domain knowledge and support were single item constructs. Besides, the model proved that communication was successfully represented by sustain mutual understanding and communication flow, coordination was successfully represented by structuring modeling process and cooperative orientation, group decision making is successfully represented by knowledge exchange, reaching consensus and validation & verification.

In addition to the relationships between theoretical dimensions, the relations between the interaction quality factors were examined as a theoretical contribution. In parallel with the study of Meier et al. (2007), who examined the interaction quality factors and their relations in synchronous interdisciplinary problem-solving activities mediated by videoconferencing systems. The relations between sustain mutual understanding and communication flow, structuring modeling process and sustain mutual understanding, structuring modeling process and communication flow, cooperative orientation and sustain mutual understanding, cooperative orientation and communication flow, cooperative orientation and structuring modeling process, knowledge exchange and structuring modeling process, knowledge exchange and cooperative orientation, reaching consensus and structuring modeling process, reaching consensus and cooperative orientation were positive and significant. In addition to these findings, the relations between knowledge exchange and sustain mutual understanding, reaching consensus and communication flow were positive and significant in our research case. Also, awareness, validation & verification, group motivation, technical support and modeling competency interaction quality factors were identified in our interaction analysis. Awareness has positive and significant relation with all of the interaction quality factors except reaching consensus, validation & verification and modeling competency. Validation & verification had significant relation with reaching consensus, communication flow and cooperative orientation. Group motivation had significant relation with all of the interaction factors, except reaching consensus, technical support and modeling competency. Technical support had significant relation with sustain mutual understanding, communication flow, structuring modeling process, cooperative orientation and awareness. Modeling

competency had significant relation with only reaching consensus and validation & verification.

In sum, the relations between the interaction quality factors in BP modeling context were examined as a theoretical contribution. Moreover, the model enabled us to observe that how theoretical dimensions of collaboration predict each other successfully as well as the relation between the observed interaction quality factors and the related theoretical dimensions.

What are the relationships between the degree of joint attention and the factors that affect interaction quality?

The third motivation of this study is concerned with the effect of joint attention on interaction quality. We examined the level of joint attention among the modelers by employing the dual-eye tracking paradigm, where we focused on how the modelers allocated their attention during collaborative modeling and how the differences in attention allocation among groups affected the quality of their interaction. For this purpose, we examined the effects of joint attention in the proposed research model and its relation with the theoretical dimensions.

The research model showed that joint attention was a significant predictor of awareness. The PAs who allocated their attention jointly during the solution critical moments for the modeling process were aware of the partners' activities on the shared whiteboard area and the chat window. Although it is possible that some degree of gaze overlap may occur by chance while the PAs were engaged with the modeling task, the significance of this relationship suggests that the degree of joint attention is a powerful indicator for the level of mutual orientation and awareness among the team members. Schneider and Pea (2013) examined eye-patterns of collaborative-problem solving dyads. The participants remotely collaborated to learn from the cases which involved basic concepts related with how the human brain processes visual information. The study evaluated the relation between degree of joint attention and participants' awareness on the partners' gaze. As parallel with the finding of this study, the researchers showed that the participants achieved more joint attention when they aware of the partners' eye gaze. In addition, the system used for collaborative modeling utilizes the referencing tool that enables the team members to refer to any object on the whiteboard and directly make comments about this object. Using this reference tool, the team member can also refer back to any previous message in the chat window. The reference tool played an important role in preventing any communicational complexities and awareness problems during the interaction between the team members and regarding the use of the shared whiteboard (Stahl et al. 2006). The result of our study also support that the usage of such a referencing tool increases joint attention. It is clear that the reference tool facilitated the communication and increased mutual intelligibility by making the team members aware of the objects on the whiteboard and the messages in the chat window. Moreover, the study of Jermann & Nüssli (2012) examined the relation between gaze cross-reccurence and referential selection in remote programming case. The

study showed that there was a relationship between gaze-cross reccurence and referential selection.

Moreover, joint attention strongly affected the motivation of collaboratively working team members, where the PAs who had high degree of joint attention were more prone to support and encourage their teammates to successfully complete the joint modeling activity. This finding resonates with Mundy & Newell (2007) argument that interpersonal and motivation factors like reward value of sharing experiences and attention to self are critical to some types of joint attention. In our study, interaction analysis showed that partners' self-motivation is important to increase group motivation. Although the research model emphasizes that there was a strong relation between the motivated group members who encouraged their teammates to perform their roles and responsibilities and joint attention, it was possible to observe different cases that do not make sense as the relation reflected in the model. In a collaborative interaction, some of the group members were inclined to perfomed modeling activities alone. Their self-motivation was high to perform individual modeling and such group members ignored their teammates and eager to terminate the modeling activity as soon as possible. Although the collaboration quality in terms of group motivation was too low in such a collaborating groups, it was observed that, the partner of the dominated group member was inclined to follow her modeling activities on the shared modeling area. In such an interaction style, it was possible to observe high gaze overlap; however, this measure did not reflect higher group motivation.

In addition to this, we found a positive correlation between joint attention and the SMU, SMP and KE interaction quality factors. In short, all these findings suggest an important relationship between joint attention and the indicators of good collaborative interaction reported in related literature concerning (a) the level of shared understanding (Jermann & Nüssli, 2012), (b) the effective coordination of joint modeling actions in the shared task environment (Sebanz, Bekkering, & Knoblich, 2006), and (c) the capacity to share knowledge with others (Bruner, 1975; Mundy & Jarrold, 2010).

How do interaction quality factors affect the quality of the collaboratively produced business process models?

The fourth motivation of this study is to identify the relationships between factors that affect the quality of collaborative interaction processes and the quality of collaboratively produced business process models. In the related literature, researchers examined the relationship between interaction quality and the quality of outputs such as a designed product, a specific learning outcome or a solution for a problem in different contexts. For example, Jermann & Nüssli (2012) investigated the relationship between the interaction quality of participants in a pair programming task and their level of understanding, and found that the researchers' ratings of the interaction revealed a weak relationship between the quality of interaction and the level of understanding. Similarly, Meir et al. (2007) investigated the relationship between the quality of collaboration during a complex patient case in a desktop-video conferencing system and the quality of the proposed solution for

the specified problem, and found no significant correlations between the process ratings and the solution quality. In this study, we evaluated the quality of the final models by considering their syntactic, semantic and pragmatic features and evaluated the relationships between these features with the interaction quality factors. The results suggest that the quality of collaboratively produced business process models in terms of semantic and syntactical approaches had significant relations with SMU, SMP, CO, KE, V&V, GM and MC factors. We found that the groups who sustained a higher level of shared understanding by attending and responding to each-others' messages tended to co-construct more successful process models. In addition to this, structuring and organizing the modeling process, work sharing and knowledge exchange factors were positively related with the quality of process models. Validation and verification processes were performed to ensure the co-constructed models' correctness and quality (Dumas et al., 2013). As it is expected, there was a significant positive relationship between V&V and semantic and syntactic quality of the models. Group motivation reflected the team members' willingness to produce process models correctly. The relationship between GM and model quality showed that the groups who are highly motivated to produce higher quality process models. Modeling competency was another important indicator that reflected the team members' domain knowledge related with reading and building business process models, and was found to be directly related with the quality of collaboratively produced models. In addition to semantic and syntactic quality of process models, we also evaluated the relationship between interaction quality factors and the pragmatic quality of the models, however we did not observe any significant relationship between these measures.

The tendency of the statistical results of this study showed that high quality of collaboration increases the quality of collaboratively produced process models. However, in the real cases it is possible to observe that the groups that experienced with low collaboration quality may produce high quality process models. A group member who may have less collaboration capability but s/he may have high modeling skills and domain knowledge. The group member may lead the modeling process alone and produce high quality models. In such a collaboration scenario, although the group produced high quality models, the remaining members do not satisfied. In our study, the group (Group1_1) experienced such an interaction style in which the PA1 had high modeling skill and dominate the modeling process alone. She did not respond the other group members' messages and comments as well as she did not follow the others' messages and modeling activities. The group was too weak to perform high quality of collaboration in terms of sustain mutual understanding, communication flow, structuring modeling process, cooperative orientation, knowledge exchange, reaching consensus, validation & verification, awareness and group motivation. However, the group was successful to produce medium quality process models in terms of semantic, syntactic and pragmatic approaches. If PA1 had high level domain knowledge about the case, she might be successful to produce high quality model. However messages of the other group members showed that they were not satisfied with this interaction.

DE: I thought we will go step by step. / *Ben asama asama gideriz diye düşündüm.*

PA1: No, it seems like we come to that stage. / *Yok sanki o asamaya geldik gibi.*
PA1: Ebru is fully immersed in modeling. / *Ebru kaptırdı gidiyor.*
DE: Ebrucum stop wait don't go. / *Ebrucum dur bekle gitme.*
PA1: Ebru do you draw these with your imagination :D / *Ebru bunları hayal gücünlemi çiziyorsun :D*

In order to prevent such limitations in collaboration process, it is necessery to consider the group members' ability of work in a group. If the group member prefers to work alone, diffetent interaction styles should be conidered instead of the sychrounous collaborative modeling.

How does the degree of joint attention affect the quality of collaboratively produced business process models?

The last motivation of this study is concerned with the effect of joint attention on collaboratively produced BPM. In the related literature, there are some studies suggesting that a high degree of gaze overlap between partners is related to a higher level of shared understanding (Cherubini, Nüssli, & Dillenbourg, 2008; Nüssli et al., 2009; Sangin et al., 2008; Schneider & Pea, 2013). Cherubini et al. (2008) performed dual-eye tracking to examine the collaborating participants task performance. The collaborating pairs had to use chat tools that differed in the way messages could be enriched with spatial information from the map in the shared workspace. The researchers found a significant relation between the pairs' reccurence of eye movements and their task performance. Nüssli et al. (2009) performed a dual-eye tracking study to show how eye-gaze data and raw speech data can be used to build predictive models of performance in collaborative tasks. The studied model was successful in predicting participants' problem solving success with an accuracy rate of up to 91% by using only raw measure of speech and gaze features. Sangin et al. (2008) examined eye gaze patterns of collaborating students with dual-eye tracking in the context of concept-map development. The study showed a significant and positive correlation between number of fixations and the learners' relative learning gain. Schneider and Pea (2013) performed a dual-eye tracking study on collaborative problem solving dyads. The problem was related with the understanding of how the human brain processes visual information. The researchers found that real time mutual gaze sharing leads to higher level of learning gain. Jermann & Nüssli (2012) examined eye-gaze patterns of collaborating programmers to examine the effect of sharing selection between the collaborators in a remote-pair programing case. The researchers found a significant relation between gaze cross-reccurence and referential selection.

However, to the best of our knowledge, none of the existing studies have examined the relationship between gaze overlap and the quality of a process model in terms of its syntactic, semantic and pragmatic aspects. Our inter-correlation analysis results suggest that the degree of joint attention and the quality of collaboratively produced business process models are highly correlated. In other words, we found that joint attention is strongly related with the syntactic and semantic qualities of the collaboratively produced

process models. In addition to this, we observed that gaze overlap is negatively correlated with the complexity of the co-constructed model, which suggests that higher degree of joint attention may lead to lower CC values. In other word, modelers who had a high degree joint attention were inclined to co-construct more complex formal models for the given process definitions. Finally, the groups that exhibited a high degree of gaze coordination created more successful models in terms of their syntactic, semantic and pragmatic quality. As parallel with the literature, the results show that quality of the output is strongly related with the gaze-movement patterns of the collaborating participants.

5.2 Practical Implications to Support Interaction Quality Factors

The group members may follow the following practical implications to support quality of interaction throughout the computer supported collaborative practices specifically in cBPM.

In order to support sustain mutual understanding;

- Any sent messages on the chat window and activities on the collaborative working area should be clear and understandable by the other group members.
- The group members should reflect their understanding and misunderstanding by sending accept and reject signals.
- If there is a misunderstanding, it is expected that the members ask question or make explanation about this issue.
- If a group member ask a question, the related member should respond his/her question clearly.

In order to support communication flow;

- The group members should communicate in a seamless way when team members work on a joint work and communicate via chat message.
- There shouldn't be any breakdowns in communication and progressivity in turn-taking.
- The message should be clear to easily understand which message is sent by whom and for what purpose to eliminate any communicational complexities.

In order to support structuring modeling process;

- The group members should organize the modeling process, order of modeling activities and assign sub-tasks to related group members.
- The group members should perform their own responsibilities based on the consensus on work sharing.
- The group members should discuss about their progress in the modeling task.

In order to support cooperative orientation;

- The group members should interact and perform their activities in harmony which means they should take symmetric and complementary roles.

- The group members shouldn't compete for power and try to dominate their teammates
- The group members should mind and attend to their teammates' messages on the chat window and activities performed on the modeling area.

In order to support knowledge exchange;

- The group members should use and share their own source of information to handle an encountered problems and present detail explanation to their teammates.
- The group members can use the teammates as knowledge source to require detailed information from them.
- The group members inform their teammates about the works handled by them and explain what they did and why they performed the related work.

In order to support reaching consensus;

- The group members should ask questions and provide justification about the proposed solution recommendations.
- The group members should discuss until they find a better argument and reach a consensus.

In order to support Validation & Verification;

- The group members who have domain expert role should check model correctness by making comparison between process definitions and performed modeling activities.
- Domain expert should request correction for the false representations from the process analysts.
- Process analysts should request confirmation from domain experts.
- Process analysts should check the structure, notation use and correctness of the modeling activities performed by themselves and their teammates.
- Process analysts should ask questions about the part of the model where it is thought as wrong.

In order to support awareness;

- The group members should maintain mutual awareness and they should be aware of the current tasks on the chat window and the modeling area.
- The group members should follow each other in a symmetric way, which means not only one group member follows the others, but every group member should follow each other equally.
- The group members should be eager to be aware of their teammates' current status of work
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In order to support group motivation

- The group members should be eager and ready to perform their roles and responsibilities.

- The group members should be active and promote each other to be active throughout the modeling process.
- The group members should motivate and encourage each other to complete modeling activity properly.

In order to support modeling competency;

- The group members should have sufficient domain knowledge about BP modeling.
- The group members who are process analyst should have enough domain knowledge to build and read valid models.
- The group members who are domain expert should have ability to read model to compare finalized model with process definition.

In order to support technical support;

- The group members should have technical competence to use the groupware and specialized technical tools of the system.
- The group members should provide technical support their teammates who may encounter some tool related technical difficulties.

5.3 Comparison of Different CSCW Design Methodologies for cBPM

This research also aimed to reveal how different interaction methodologies affect synchronous process modeling by examining the coordination, communication, awareness, group decision-making and team-building aspects of collaboration. For this purpose, VMT Chat and ARISalign were chosen as different CSCW interaction methods with different interface designs. In the VMT Chat platform, the stakeholders can use the whiteboard area concurrently. However, in ARISalign, only the active user, who first accesses the model, has the right to edit it, and the other users have to wait for the active user to complete his/her editing on the whiteboard. Based on these observations certain suggestions can be made regarding the system design.

The interaction analysis was used to evaluate the platforms' appropriateness for CSCW activities. It was clear that VMT Chat supported the five aspects of collaboration and promoted interactivity among the team members. Modeling with VMT Chat allowed the team members to coordinate the modeling process through discussions throughout the modeling activity. In addition, the system notified the team members of the new messages in the chat window and the modeling activities in the shared work area. Furthermore, the team members were able to communicate instantly whenever needed without experiencing any communicational complexity such as problems with the communication flow or misunderstandings due to the content of the messages. Before the modeling sessions, the team members were assigned the DE and PAs roles and throughout their interaction, they were able to perform their responsibilities and sharing the work when required. In

addition, it was observed that the team members could easily discuss the related issues and reach a group decision regarding how to resolve them. However, the team members encountered a system error, in which the shared whiteboard suddenly froze. Therefore, they could only continue their modeling activity after several attempts of reconnecting and logging into the system. Apart from this instance, the team members were generally satisfied with the VMT Chat environment, which was successful in supporting all the five collaboration aspects.

The ARISalign system, on the other hand, was not as efficient as VMT Chat in supporting the collaboration aspects; particularly coordination, communication and awareness. The team members tried to coordinate the collaborative modeling process based on their previous experience in the VMT Chat environment. However, they had difficulty coordinating and managing the modeling process due to the system's insufficient support for communication and awareness. In addition, since the platform failed to provide synchronous communication, the team members had difficulties making sense of each other's messages. Furthermore, the team members were not made aware of the messages on the discussion board and activities performed in the shared working area. This led to ineffective communication flow and poor coordination in terms of the messages and the modeling activities. The team members were assigned the DE and PAs roles that involved different responsibilities; however, they could not interact effectively to achieve an appropriate division of labor. In addition, the interaction of team members could not reach a sufficient level of maturity to achieve the group decision-making aspect. The interaction analysis showed that the team members complained about ARISalign because they could not perform the modeling concurrently or communicate with each other efficiently. Therefore, they lost interest and wanted to leave as soon as possible. Furthermore, all the team members agreed that they did not want to use this system again for process modeling since they spent too much time on modeling such a small process (See Lines 23, 25, 30 and 31 in Table 12).

Suggestions on System Designs for Effective Collaboration in cBPM Practices

The interaction analysis performed on different methodologies demonstrated the effects of different features on the five aspects of collaboration. Based on these results, the following suggestions can be made to achieve a system design that supports each of the five aspects.

To support the coordination aspect in cBPM;

- The communication window and the modeling area should be included in the same interface to easily coordinate the messages and the model elements. If the communication and modeling components of the systems are on different pages, then the modelers have to switch between the pages. This frequent navigation between the pages of the system causes problems such as losing interest in the

process and not being able to remember the given information when trying to find the right page.

- The modelers should be able to change the status of the modeling area to 'in-use' when required. If the system does not support this function, the modeler loses interest when waiting for the others to complete their editing.
- The system should be able to immediately display the changes that are applied.
- The modeling environment should support both cooperative and collaborative modeling which means the modelers should be able to work both on the same model element and different parts of the model.

To support communication aspect in cBPM;

- The system should be supported with a communication tool, which enables the team members to send instant messages when required.
- In long conversations, chat communication brings some limitations. For example, communicating via typing is time consuming. In addition, in instant messaging, short and rapid messages are posted during the communication on the chat environment; which means single declarative message spread over multiple postings (Strijbos 2009; Zemel et al. 2007). In the long conversations, it is difficult to follow the messages that are linked with each other. In order to reduce the communicational complexities that arise from the nature of chat communication, the system should also be supported with video conferencing.

Awareness is also critical for the success of the communication and coordination aspect of collaboration; therefore; the communication tools and shared whiteboard of the systems should have the following features to support awareness;

- The system should have a current user window to display all the active users.
- In the communication window, the users and their messages should be easily identifiable. Different colors can be used to differentiate between the messages of different users.
- The system should display a notification when a user is writing a message.
- The system should notify the users of new messages and when their messages have been read.
- The communication platform should be error-free, which means that messages should be displayed on the other participants' screen in real-time and in the correct order.
- The use of the reference tool in VMT Chat increases the traceability of the messages in the chat window and reduces the users' workload. This feature of the system allows the participants to follow the messages easily and send shorter messages without having to repeat what had already been written in a previous message. Therefore, the communication tool of the system should support such a referencing feature.

- The system should be able to establish a connection between messages written in the chat window and the modeling area. This easy referencing enables the participants to engage in rapid and understandable communication since they do not have to write the whole name of the model elements or spend time on searching the whole model to find the related element.
- The system should allow the team members to know which model element has been created by whom to increase personalized communication.
- The system should allow the users to be aware of the actions and all sorts of editing performed on the whiteboard and the model, and display a notification when a modeling activity is being performed.
- The system should provide an estimated completion time for a team member's editing process if it does not support simultaneous editing.

The system should provide an effective environment to support the coordination, communication and awareness aspects since group decision-making relies on these aspects to allow the participants to effectively discuss an issue and reach a consensus. In addition to these, the systems should have the following feature to support group decision-making.

- When the team members cannot discuss an issue in detail or select an appropriate model element to reflect the process information correctly, they may not be able to reach a consensus on that issue immediately. To allow the team members to easily refer back to this problematic issue at a later time, the related model element can be signed as 'unresolved'.

User permissions in the system should be flexible enough to fulfill members' requirements when performing their responsibilities. To support the Team Building aspect in cBPM, the following suggestions can be made regarding the permissions that can be extended to team members that have the DE or PAs roles;

- All the modelers should be able to edit the model at the same time and see the performed changes immediately. The latest version of the model should be available to the DE and modelers when they need, without having to wait for the completion of ongoing actions.
- The DE should be able to access and refer to the model when discussing it.
- It should be possible to lock certain parts of the model for editing since the modelers may want to change their working approach from collaborative to cooperative.

5.4 Limitations and Recommendations for Future Researches

This study aimed to evaluate the factors contributing to the quality of interaction among group members in the context of collaborative business process modeling. We examined the process of interaction among group members in detail to identify interaction quality

factors that are both empirically and theoretically grounded. We observed that evaluating the success of interaction requires a multidimensional approach; so different dimensions should be considered to investigate the external factors that affect interaction quality. In this model, the prediction power of the exogenous variables were 60%, 48%, 34%, 33% and 20% for coordination, communication, group decision making, motivation and awareness, respectively. Different external variables should be considered to enhance the prediction power of the research model. Future research may focus on exploring and testing the casual relationships among additional factors that affect the quality of interaction quality of collaborative group members. Further independent studies focusing on the identified factors would be also needed to confirm the validity of the proposed research model in different collaborative interaction scenarios.

The examination of the process of interaction among collaborative group members is a tedious and time-consuming undertaking in general, and the identification of important interaction units that affect the quality of interaction is not straightforward. Hence, in future research, we aim to develop a scale based on the identified interaction quality factors, which will enable researchers to evaluate the collaborating group members' perceptions of the quality of their interaction.

The research model developed was developed with component based structural equation modeling, specifically by using PLS-SEM. The model makes prediction based on the sample studied on it. In order to improve the model's generalizability, the research model should be studied with covariance based structural equation modeling with larger sample size to improve validity of the causal relations.

Observing how the modelers' allocated their attention on the chat and shared whiteboard area with the dual-eye tracking method revealed important aspect of the sequentially unfolding interaction of the participants. A close examination of the modelers' gaze coordination enabled us to evaluate the relationships between joint attention and interaction quality factors. However, because of the technical limitations we were able to collect only the two modelers' eye gaze information, and could not monitor the DE's eye movements. In the future, a setup with three synchronized eye trackers would provide further insights into the collaborative BPM processes.

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APPENDICES

Appendix A – Business Process Definitions Used in Pilot Study

Yeni Ders Açma Önerisi Değerlendirme Süreci

Öğretim üyesi ders öneri formunu doldurur. ABD. Başkanı ders öneri formunu değerlendirir. Değerlendirme sonucunu içeren ders öneri formu Akademik Komiteye gider. Akademik komite onay, red yada güncelleme kararlarından birini verir. Eğer güncelleme kararı çıktıysa öğretim üyesi ders öneri formunu tekrar ABD başkanı değerlendirmesine sunabilir. Eğer ders açma talebi Akademik Komite tarafından onaylandıysa, Enstitü Kurulu son bir değerlendirme yapar onay veya red kararı verir. Enstitü kurulunun kararı onay yönündeyse enstitü sekreteri OIBS sisteminde yeni dersi ders kataloğuna ekler.

Askerlik Nedeniyle Kayıt Dondurma Süreci

Öğrenci askerlik nedeniyle kayıt dondurmak için Kayıt Dondurma Başvuru Formu'nu doldurur ve ABD Başkanına iletir. ABD Başkanı onaylar veya reddeder. Eğer onayladıysa öğrenci kayıt dondurma dilekçesi yazar ve Asker Alma Dairesi Başkanlığı'ndan Askere Sevk Belgesi alır. Öğrenci Kayıt Dondurma Başvuru Formu'nu, Kayıt Dondurma Dilekçesi'ni ve Askere Sevk Belgesi'ni Enstitü Yönetim Kurulu'na iletir. Enstitü Yönetim Kurulu kayıt dondurma talebini değerlendirir. Değerlendirmesi olumluysa kayıt dondurma uygunluğunu resmi bir yazı ile öğrenci işleri daire başkanlığına gönderir.

Zimmet Kaydı Sürec

Muayene kabul komisyonu yeni satın alınan ve ihalesi yapılan malzemeyi teslim alır. Alınan malzeme için fatura ve muayene kabul tutanağı düzenler. İlgili makbuzlar düzenlendikten sonra, Taşınır Kayıt Kontrol yetkilisi alınan malzemeyi kişiler üzerine zimmet kaydını yapar. Herbir zimmet kaydı için Taşınır İşlem Fişi (TİF) oluşturulur.

Appendix B - Survey Instrument for Domain Expert

1. Cinsiyet:
- □ Kadın
- □ Erkek

2. Yaş: ……..

3. İş: ……..

4. Eğitim Durumunuz: □ Lisans □1. sınıf □ 2. sınıf □ 3. sınıf □ 4. sınıf
□ Yüksek Lisans Kaçıncı döneminizdesiniz?: _____
□ Doktora Kaçıncı döneminizdesiniz?: _____

5. Öğrenim Görmekte Olduğunuz Bölüm:_____

6. VMT Chat programını daha önce kullandınız mı? Evet □ Hayır□
Cevabınız Evet ise;
- □ Nadiren (2-3 ayda bir ya da daha az)
- □ Bazen (ayda en az bir defa)
- □ Sıklıkla (haftada en az bir defa)
- □ Çok sık (hemen hemen hergün)

7. ARISalign programını daha önce kullandınız mı? Evet □ Hayır□
Cevabınız Evet ise;
- □ Nadiren (2-3 ayda bir ya da daha az)
- □ Bazen (ayda en az bir defa)
- □ Sıklıkla (haftada en az bir defa)
- □ Çok sık (hemen hemen hergün)

8. Ne kadar süredir bilgisayar kullanıyorsunuz?:
- □ 1 yıldan az
- □ 1-3 yıl
- □ 4-6 yıl
- □ 7-9 yıl
- □10 yıl ve üzeri

9. Bilgisayar kullanabilme becerinizi nasıl tanımlarsınız?:
- □ Çok kötü
- □ Kötü
- □ Orta
- □ İyi
- □ Çok iyi

10. Ne kadar süredir İnternet kullanıyorsunuz?
- □ 1 yıldan az
- □ 1-3 yıl
- □ 4-6 yıl
- □ 7-9 yıl
- □ 10 yıl ve üzeri

11. Chat programları kullandınız mı?: Evet □ Hayır □

Cevabınız Evet ise;

Hangi Program(lar)ı Kullanıyorsunuz?:----------

Ne sıklıkla Kullanıyorsunuz?:

□ Nadiren (2-3 ayda bir ya da daha az)
□ Bazen (ayda en az bir defa)
□ Sıklıkla (haftada en az bir defa)
□ Çok sık (hemen hemen hergün)

12. Daha önce herhangi bir süreç modelleme deneyiminde süreç hakkında bilgi sağlayan rolünüz oldu mu?

□ Evet
□ Hayır

13. Takım arkadaşınızı tanıyor musunuz?

□ Evet
□ Hayır

14. Takımızı arkadaşlarınızla olan sosyal iletişimizini nasıl değerlendirirsiniz? (13. Sorudaki cevabınız Evet ise)

□ Hiçbir iletişimimiz yok
□ Sınırlı iletişimimiz var
□ Orta dereceli iletişimimiz var
□ İyi bir iletişimimiz var
□ Son derece açık bir iletşimimiz var

15. Daha önce bilgisayar ortamında eşzamanlı grup çalışması yaptınız mı?

□ Evet
□ Hayır

16. Grup çalışmalarına olan yatkınlığınızı nasıl değerlendirirsiniz?

□ Çok iyi
□ İyi
□ Orta
□ Kötü
□ Çok Kötü

Appendix C - Survey Instrument for Process Analyst

1. Cinsiyet:
- □ Kadın
- □ Erkek

2. Yaş: ……..

3. İş: ……..

4. Eğitim Durumunuz: □ Lisans □1. sınıf □ 2. sınıf □ 3. sınıf □ 4. sınıf
□ Yüksek Lisans Kaçıncı döneminizdesiniz?: ___

□ Doktora Kaçıncı döneminizdesiniz?: ___

5. Öğrenim Görmekte Olduğunuz Bölüm:----------

6. VMT Chat programını daha önce kullandınız mı? Evet □ Hayır □
- □ Cevabınız Evet ise;
- □ Nadiren (2-3 ayda bir ya da daha az)
- □ Bazen (ayda en az bir defa)
- □ Sıklıkla (haftada en az bir defa)
- □ Çok sık (hemen hemen hergün)

7. ARISalign programını daha önce kullandınız mı? Evet □ Hayır □
Cevabınız Evet ise;
- □ Nadiren (2-3 ayda bir ya da daha az)
- □ Bazen (ayda en az bir defa)
- □ Sıklıkla (haftada en az bir defa)
- □ Çok sık (hemen hemen hergün)

8. Ne kadar süredir bilgisayar kullanıyorsunuz?:
- □ 1 yıldan az
- □ 1-3 yıl
- □ 4-6 yıl
- □ 7-9 yıl
- □ 10 yıl ve üzeri

9. Bilgisayar kullanabilme becerinizi nasıl tanımlarsınız?:
- □ Çok kötü
- □ Kötü
- □ Orta
- □ İyi
- □ Çok iyi

10. Ne kadar süredir İnternet kullanıyorsunuz?

- 1 yıldan az
- 1-3 yıl
- 4-6 yıl
- 7-9 yıl
- 10 yıl ve üzeri

11. Chat programları kullandınız mı?: Evet Hayır

Cevabınız Evet ise;

Hangi Program(lar)ı Kullanıyorsunuz?:----------

Ne sıklıkla Kullanıyorsunuz?:

- Nadiren (2-3 ayda bir ya da daha az)
- Bazen (ayda en az bir defa)
- Sıklıkla (haftada en az bir defa)
- Çok sık (hemen hemen hergün)

12. Süreç modelleme ve iyileştirme üzerine herhangi bir ders aldınız mı? (örneğin IS526 Yazılım Kalitesi Yönetimi - Software Quality Management)

- Evet
- Hayır

13. Daha önce süreç modelleme deneyiminiz oldu mu?

- Evet
- Hayır

14. Süreç modelleme yetkinliğinizi nasıl değerlendirirsiniz?

- Çok iyi
- İyi
- Orta
- Kötü
- Çok kötü

15. Daha önce bilgisayar destekli işbirlikçi ortamda süreç modelleme deneyiminiz oldu mu?

- Evet
- Hayır

16. Aşağıdaki süreç modelleme yöntemlerinden (dillerinden) hangilerini duydunuz?

- UML Aktivite Diyagramı (UML Activity Diagram)
- Veri Akış Diyagramı (Data Flow Diagram)
- Genişletilmiş olay güdümlü süreç zinciri (Extended Event-Driven Process Chain)
- İş Süreci Model ve Notasyonu (Business Process Model and Notation)
- Petri Ağı (Petri Nets)

17. Aşağıdaki süreç modelleme yöntemlerinden hangilerini kullandınız?

- UML Aktivite Diyagramı (UML Activity Diagram)
- Veri Akış Diyagramı (Data Flow Diagram-DFD)
- Genişletilmiş olay güdümlü süreç zinciri (Extended Event-Driven Process Chain)
- İş Süreci Model ve Notasyonu (Business Process Model and Notation)
- Petri Ağı (Petri Nets)

18. Aşağıdaki süreç modelleme araçlarından hangilerini duydunuz ?

- Microsoft Office Visio
- ARIS Business Architect
- ARISalign
- Enterprise Architect
- iGrafx Process Modeler 2011
- CA Erwin Process Modeler
- Business Modeler Advanced 7
- Signavio Process Editor
- BONAPART Collaborative
- AdorisSavvion
- Process Manager
- Innovater for Business Analysts
- SILVERRUN BPM

19. Aşağıdaki süreç modelleme araçlarından hangilerini kullandınız ?

- Microsoft Office Visio
- ARIS Business Architect
- ARISalign
- Enterprise Architect
- iGrafx Process Modeler 2011
- CA Erwin Process Modeler
- Business Modeler Advanced 7
- Signavio Process Editor
- BONAPART Collaborative
- Adoris
- Savvion Process Manager
- Innovater for Business Analysts
- SILVERRUN BPM

20. Takım arkadaşınızı tanıyor musunuz?

- Evet
- Hayır

21. Takımızı arkadaşlarınızla olan sosyal iletişimizini nasıl değerlendirirsiniz? (20. Sorudaki cevabınız Evet ise)

- Hiçbir iletişimimiz yok
- Sınırlı iletişimimiz var
- Orta dereceli iletişimimiz var
- İyi bir iletişimimiz var
- Son derece açık bir iletşimimiz var

22. Daha önce bilgisayar ortamında eşzamanlı grup çalışması yaptınız mı?

- Evet
- Hayır

23. Grup çalışmalarına olan yatkınlığınızı nasıl değerlendirirsiniz?

- Çok iyi
- İyi
- Orta
- Kötü
- Çok kötü

Appendix D –Semi-Structured Interview Questions

1. Bu deney kapsamında modelleme yapacağınız platform (VMT Chat) hakkında verilen eğitim yeterli miydi?
2. Bu deney kapsamında modelleme yapacağınız platform (ARISalign) hakkında verilen eğitim yeterli miydi?
3. Geleneksel yöntemlerle süreç modelleme aktivitelerinde yaşadığınız problemler nelerdir? Yaşadıysanız bu problemleri eşzamanlı olarak bilgisayar destekli işbirlikçi süreç modelleme uygulamalarıyla aşabileceğinizi düşünüyor musunuz?
4. Eş zamanlı, bilgisayar destekli işbirlikçi süreç modelleme uygulamasında hoşunuza giden ya da olumlu bulduğunuz unsurlar nelerdi? Neden hoşunuza gittiğini ya da olumlu bulduğunuzu lütfen açıklayınız.
5. Eş zamanlı, bilgisayar destekli işbirlikçi süreç modelleme uygulamasında hoşunuza gitmeyen ya da olumsuz bulduğunuz unsurlar nelerdi? Neden hoşunuza gitmediğini ya da olumsuz bulduğunuzu lütfen açıklayınız.
6. Görevlerinizi yaparken sistemde karşılaştığınız zorluklar nelerdir?
7. Chat ortamında süreç sahibi ile yapılan tartışma sonrasında süreci anlayabildiniz mi?
8. Verilen süreci eşzamanlı olarak bilgisayar destekli işbirlikçi ortamda modellemek için harcanan işgücü hakkında ne düşünüyorsunuz?
9. Verilen süreci eşzamanlı olarak bilgisayar destekli işbirlikçi ortamda modellemek için harcanan zaman hakkındaki düşünceleriniz nedir?
10. Eşzamanlı bilgisayar destekli işbirlikçi süreç modelleme ile geleneksel süreç modelleme yöntemlerini harcanan süre açısından kıyaslar mısınız.
11. Deneyimlediğiniz kadarıyla, eşzamanlı bilgisayar destekli işbirlikçi süreç modellemenin avantajları nelerdir?
12. Deneyimlediğiniz kadarıyla, eşzamanlı bilgisayar destekli işbirlikçi süreç modellemenin dezavantajları nelerdir?

Appendix E - Business Process Descriptions Used in Main Study

Askerlik Nedeniyle Kayıt Dondurma Süreci

Öğrenci askerlik nedeniyle kayıt dondurmak için Kayıt Dondurma Başvuru Formu'nu doldurur ve ABD Başkanına iletir. ABD Başkanı onaylar veya reddeder. Eğer onayladıysa öğrenci kayıt dondurma dilekçesi yazar ve Asker Alma Dairesi Başkanlığı'ndan Askere Sevk Belgesi alır. Öğrenci Kayıt Dondurma Başvuru Formu'nu, Kayıt Dondurma Dilkçesi'ni ve Askere Sevk Belgesi'ni Enstitü Yönetim Kurulu'na iletir. Enstitü Yönetim Kurulu kayıt dondurma talebini değerlendirir. Değerlendirmesi olumluysa kayıt dondurma uygunluğunu resmi bir yazı ile öğrenci işleri daire başkanlığına gönderir.

Ders Saydırma Süreci

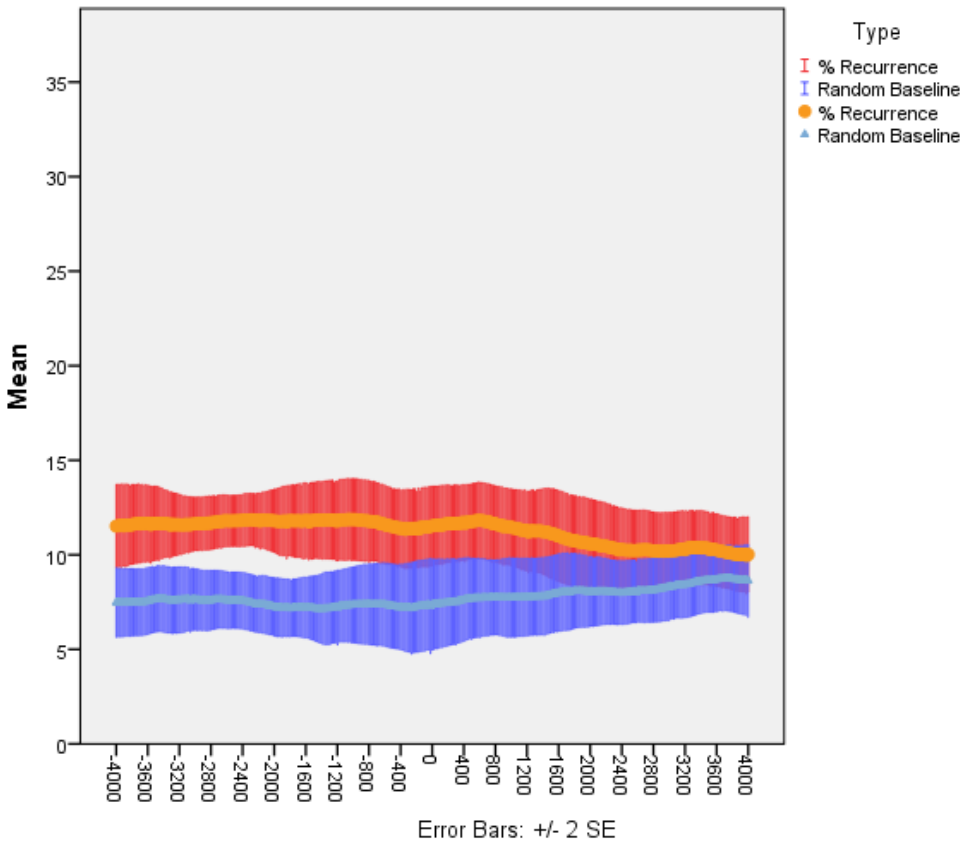
Öğrenci ders saydırma formunu Öğrenci Ders Danışmanına ilgili dersin saydırılması için iletir. Danışman ders saydırma talebini değerlendirir ve Kabul veya ABD Başkanı'na danışma gereği duyuldu kararlarından birini verir. Öğrenci Ders Danışmanı kabul kararı verdiyse ders saydırma formunu onaylar. Dersin denkliğinden emin olamayıp, ABD başkanına danışma kararı verdiyse, ABD başkanı ilgili dersi, Ders Denkliği Formunu kullanarak değerlendirir. Değerlendirme sonunda Ders denkliği geçerli veya Ders denkliği geçersiz kararlarından birini verir. ABD Başkanı ders denkliği geçerli kararı verdiyse Ders Saydırma Formunu Onaylar.

Appendix F - Krippendorf's Alpha Score of all Interaction Quality Factors

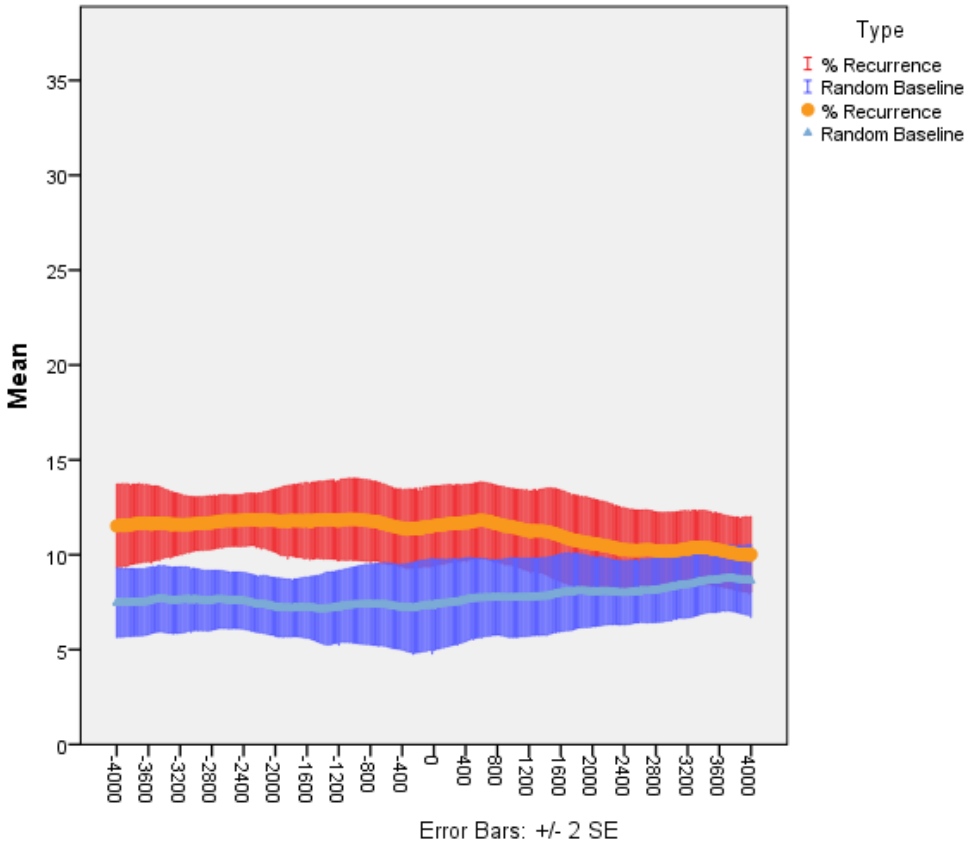
Interaction Quality Factors	Krippendorf's Alpha Score
SMU	0.726
CF	0.827
SMP	0.721
CO	0.717
KE	0.780
RC	0.714
V&V	0.798
AW	0.775
GM	0.719
MC	0.806
TS	0.820

Appendix G – Overall Reccurence Graph of the Groups

Group2_1



Group 2_2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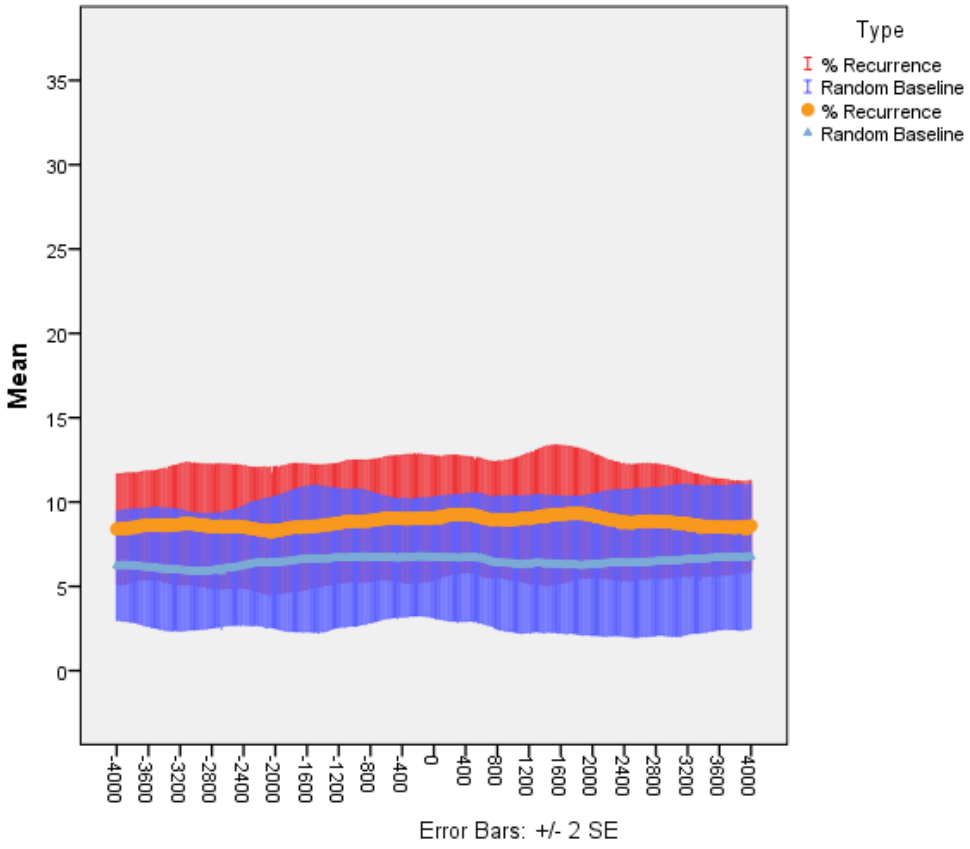
Error Bars: +/- 2 SE

Group3_1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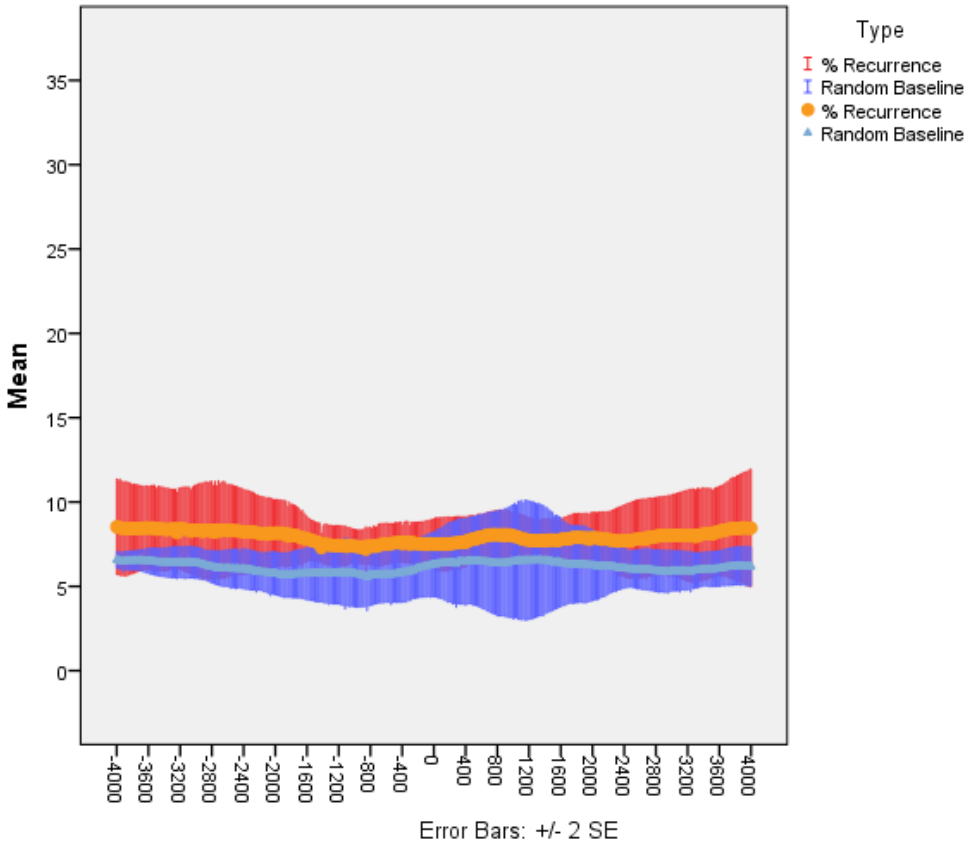
Group3_2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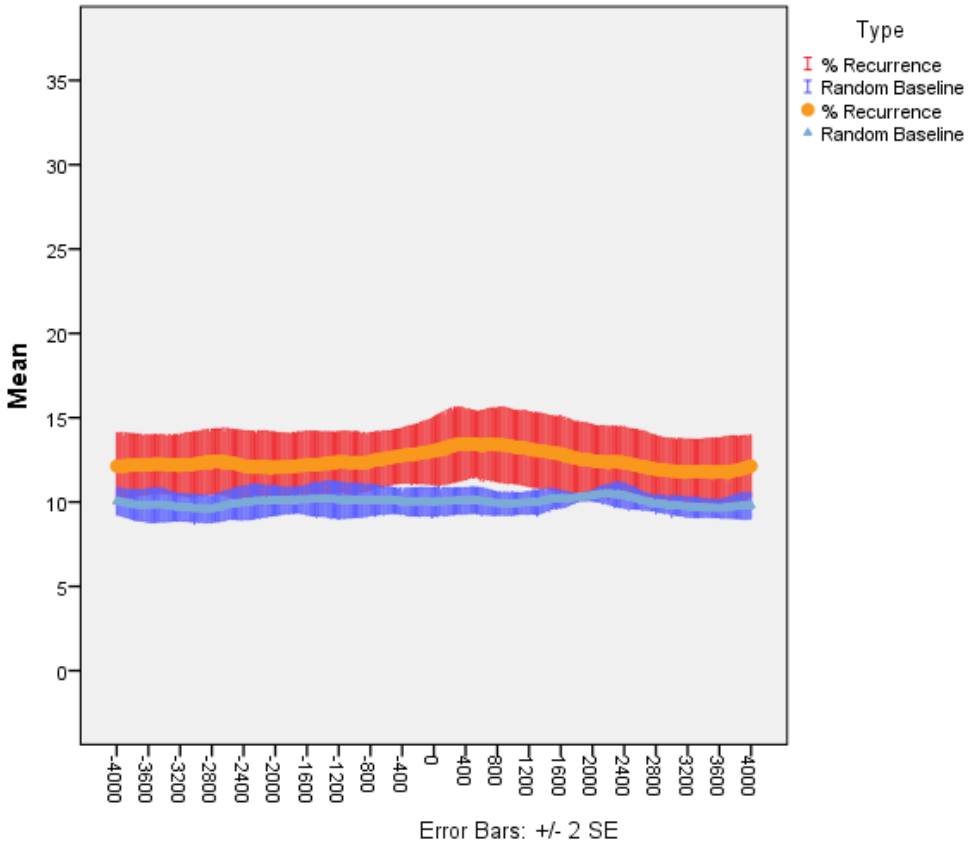
Group 4_1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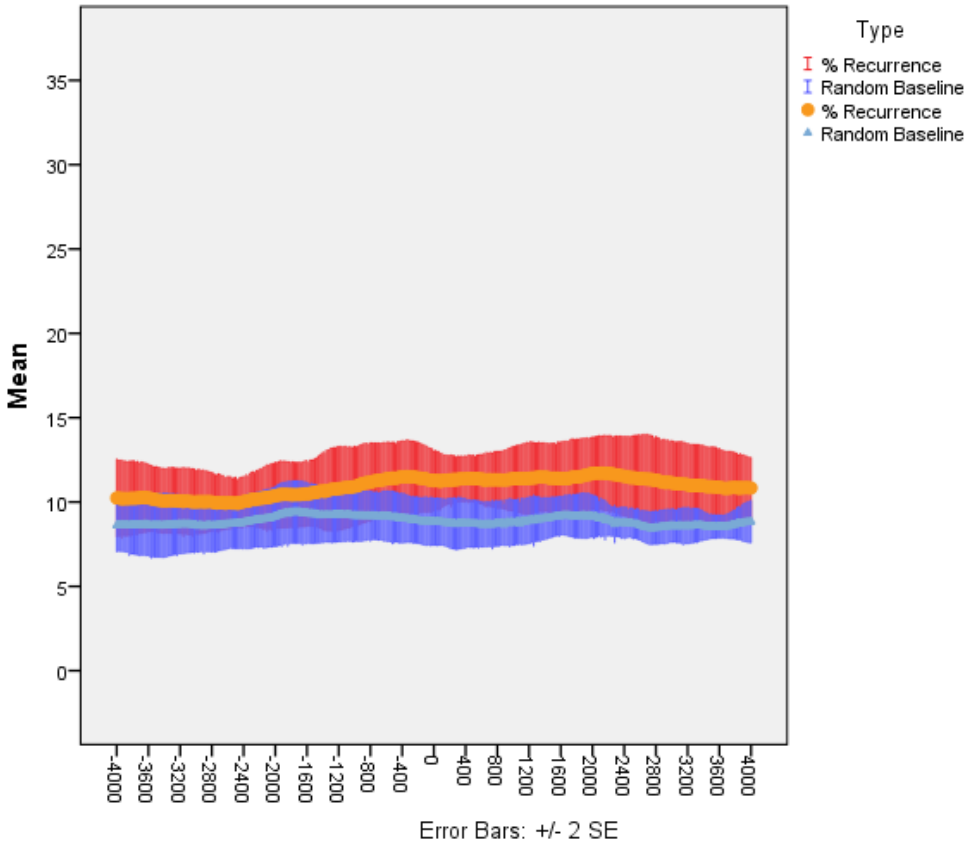
Group 4_2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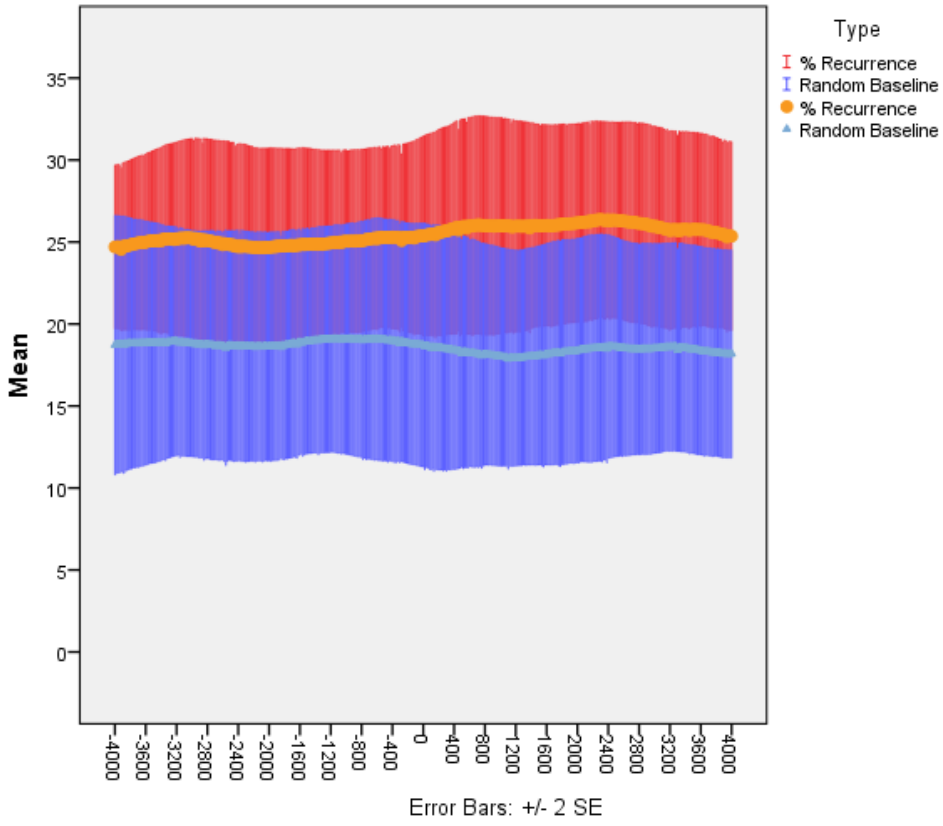
Group 5_1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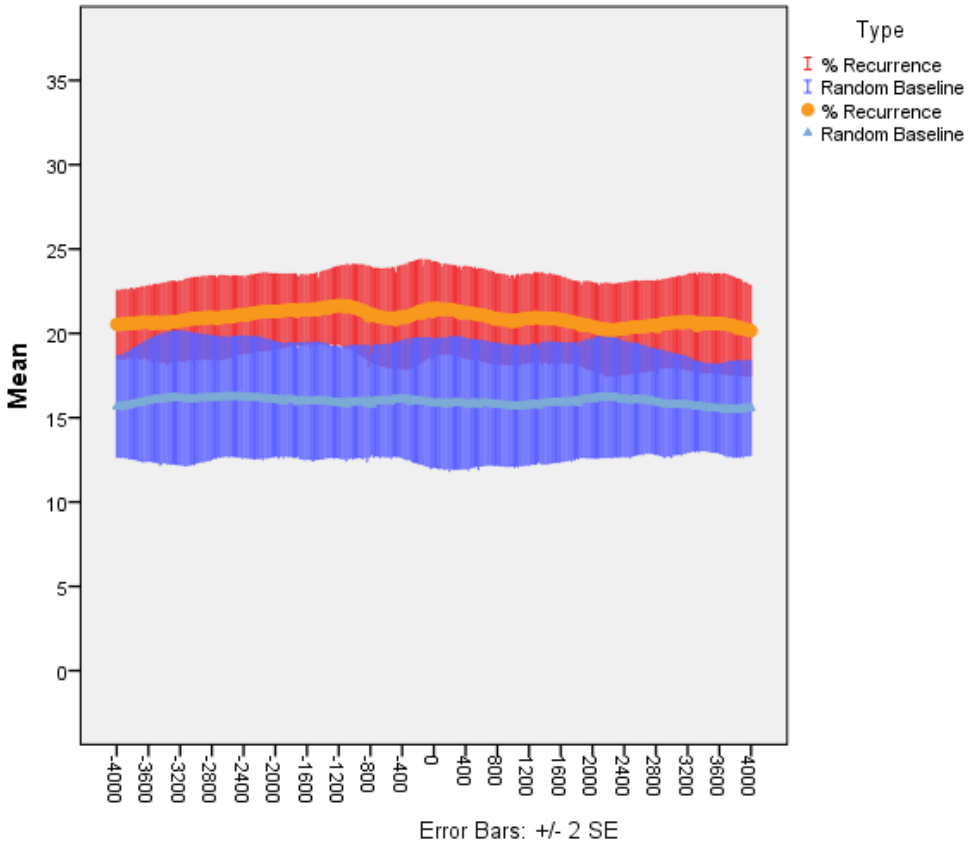
Group 6_1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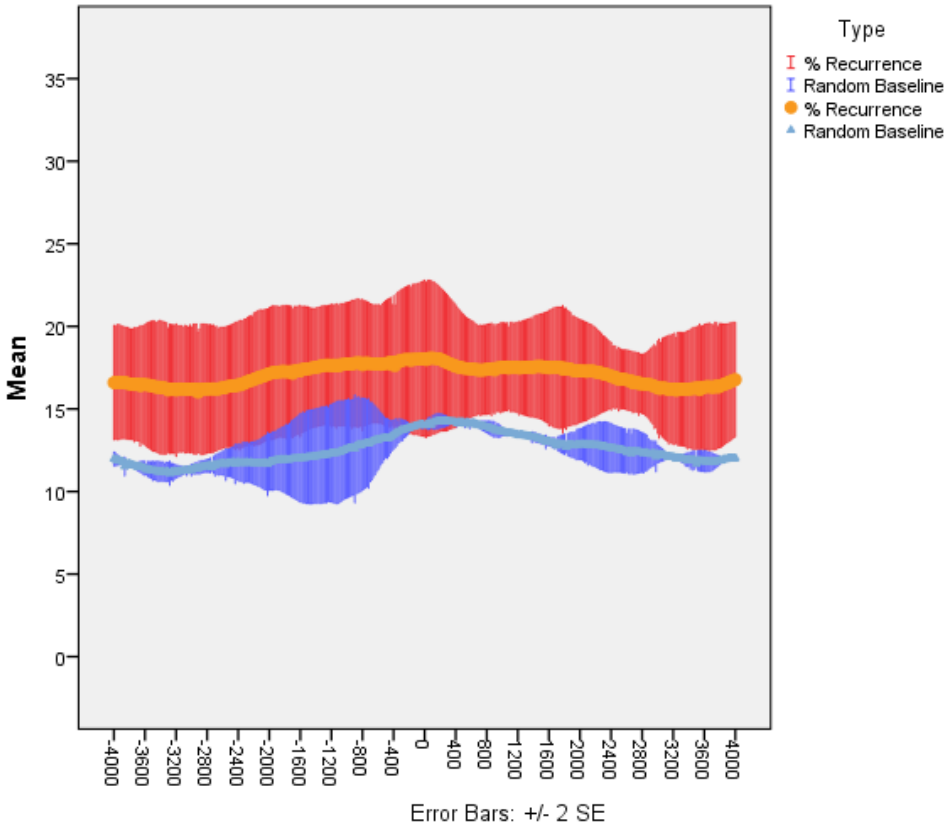
Group 6_2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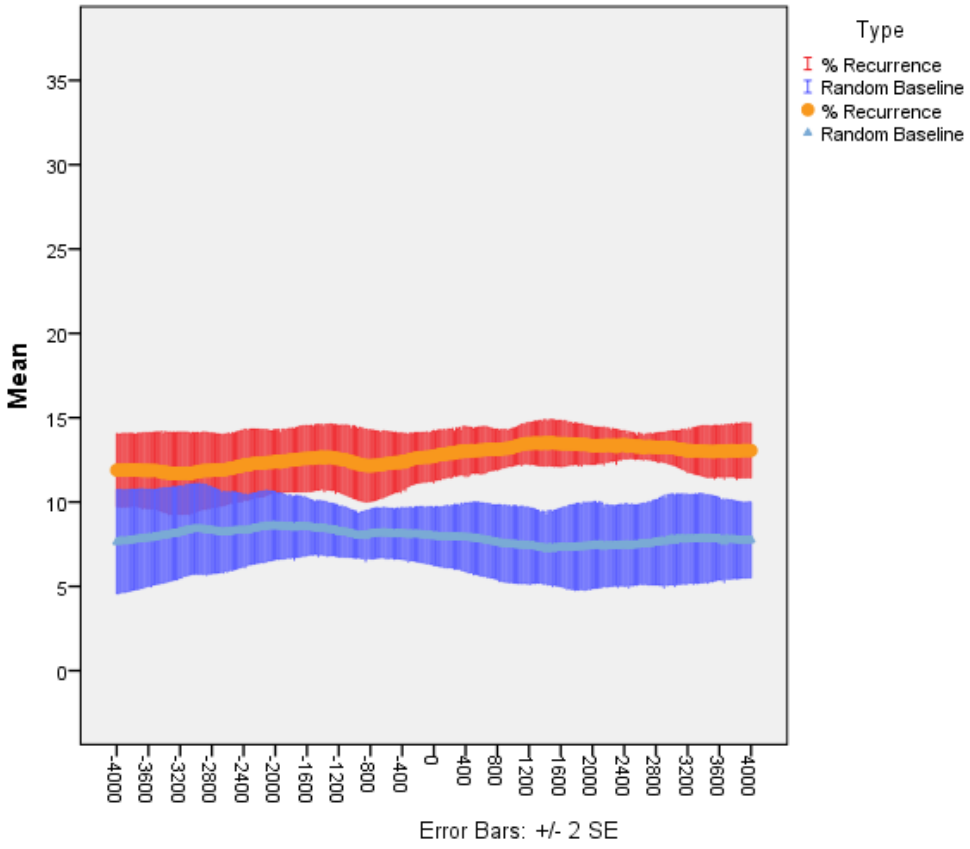
Group 7_1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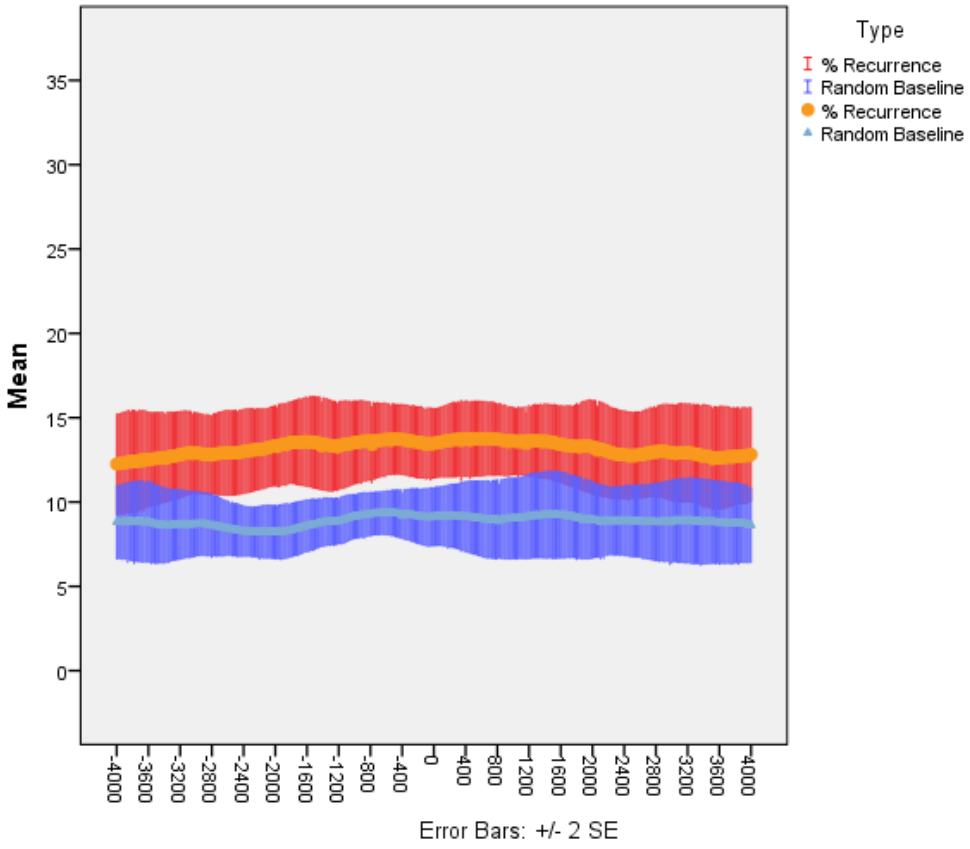
Group 7_2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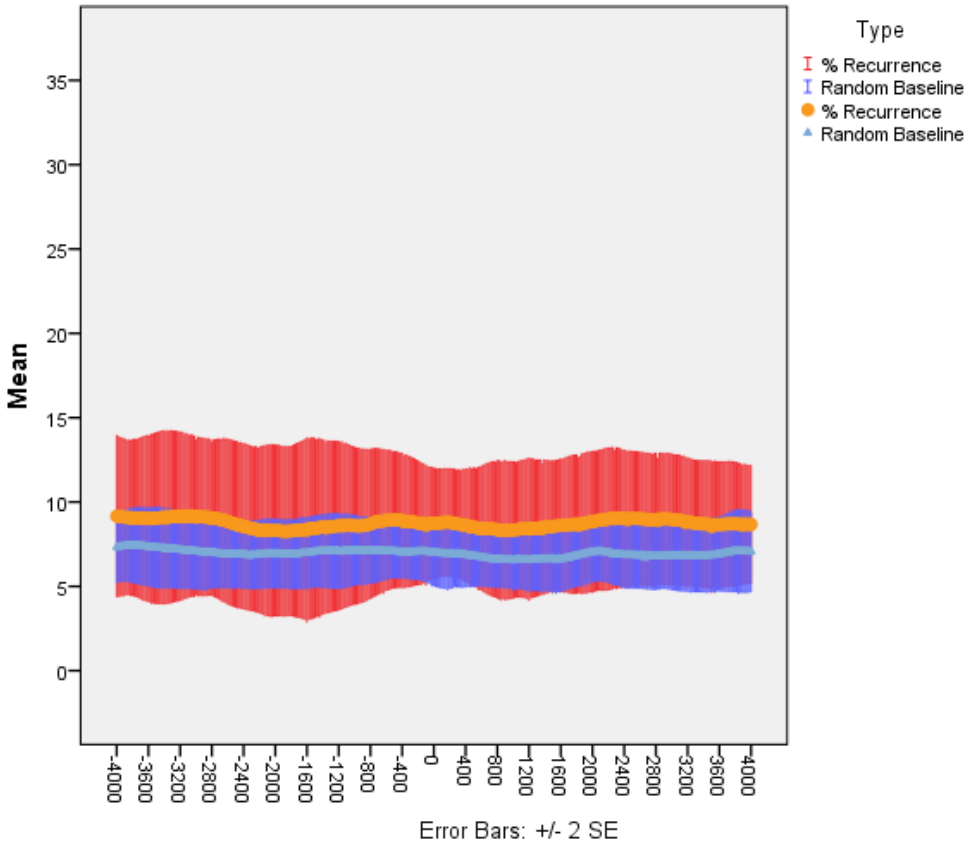
Group 8_1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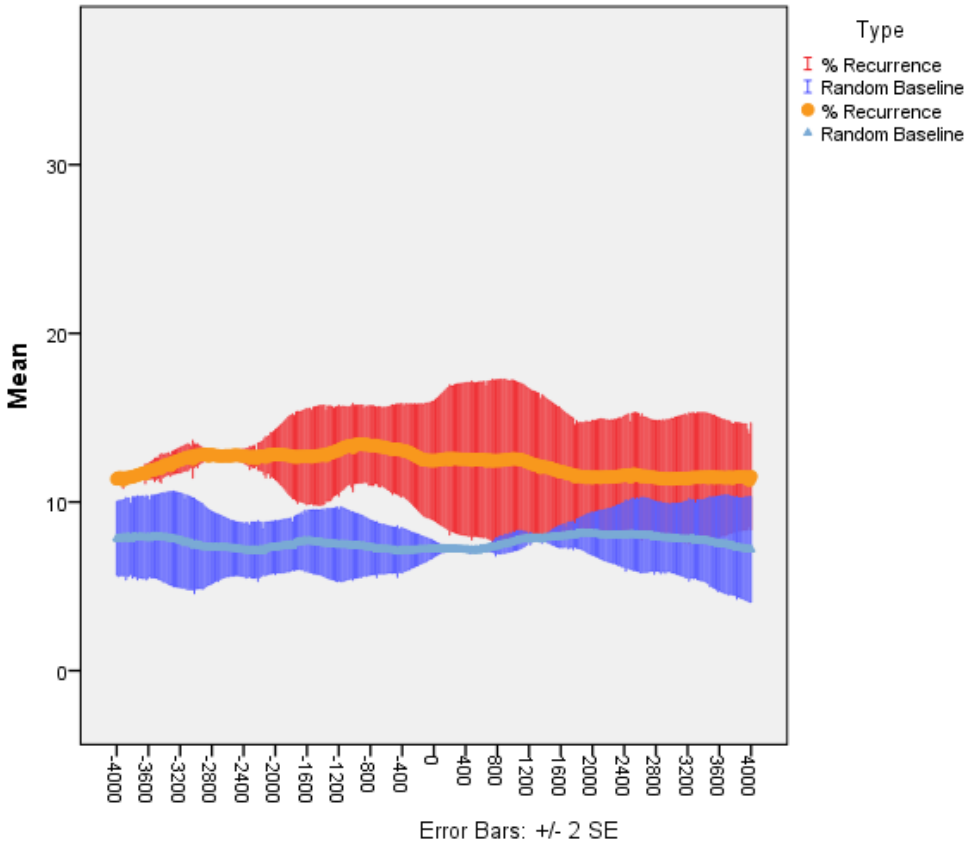
Group 8_2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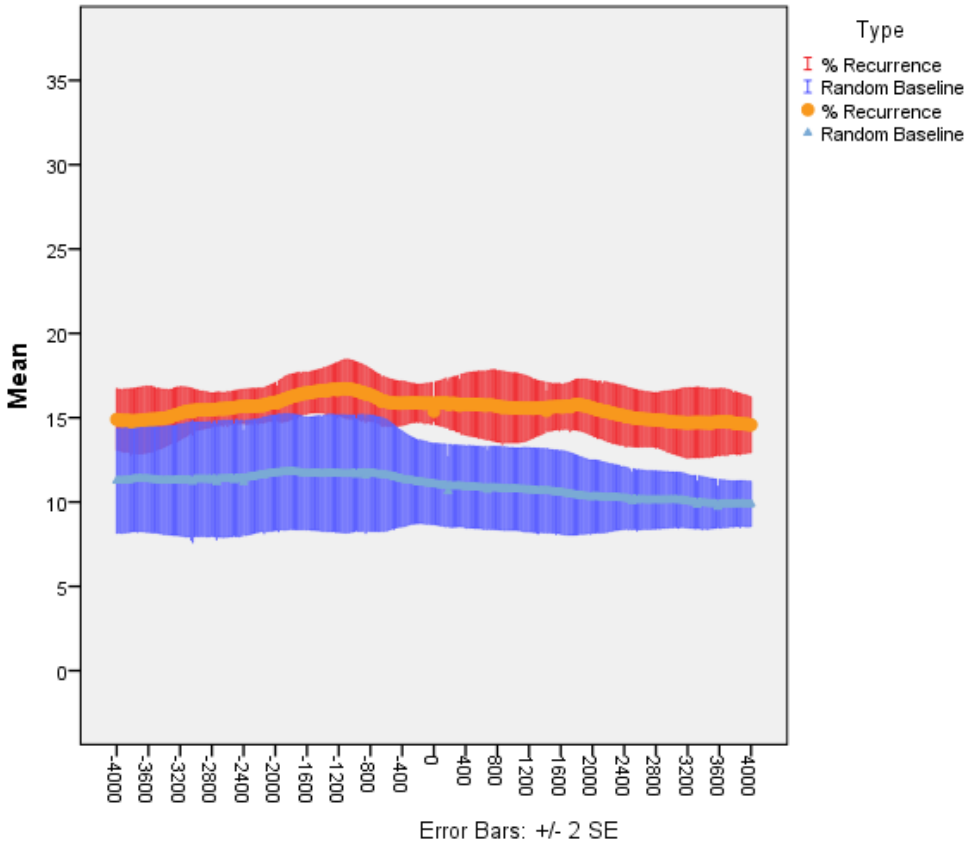
Group 9_1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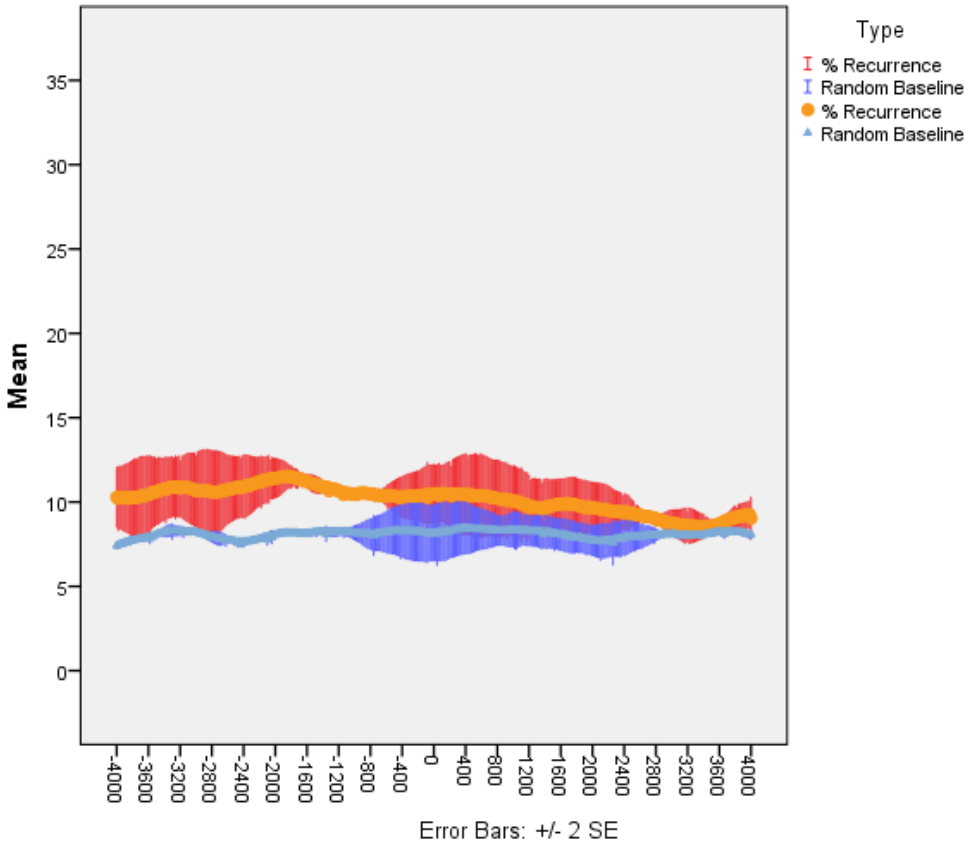
Group 9_2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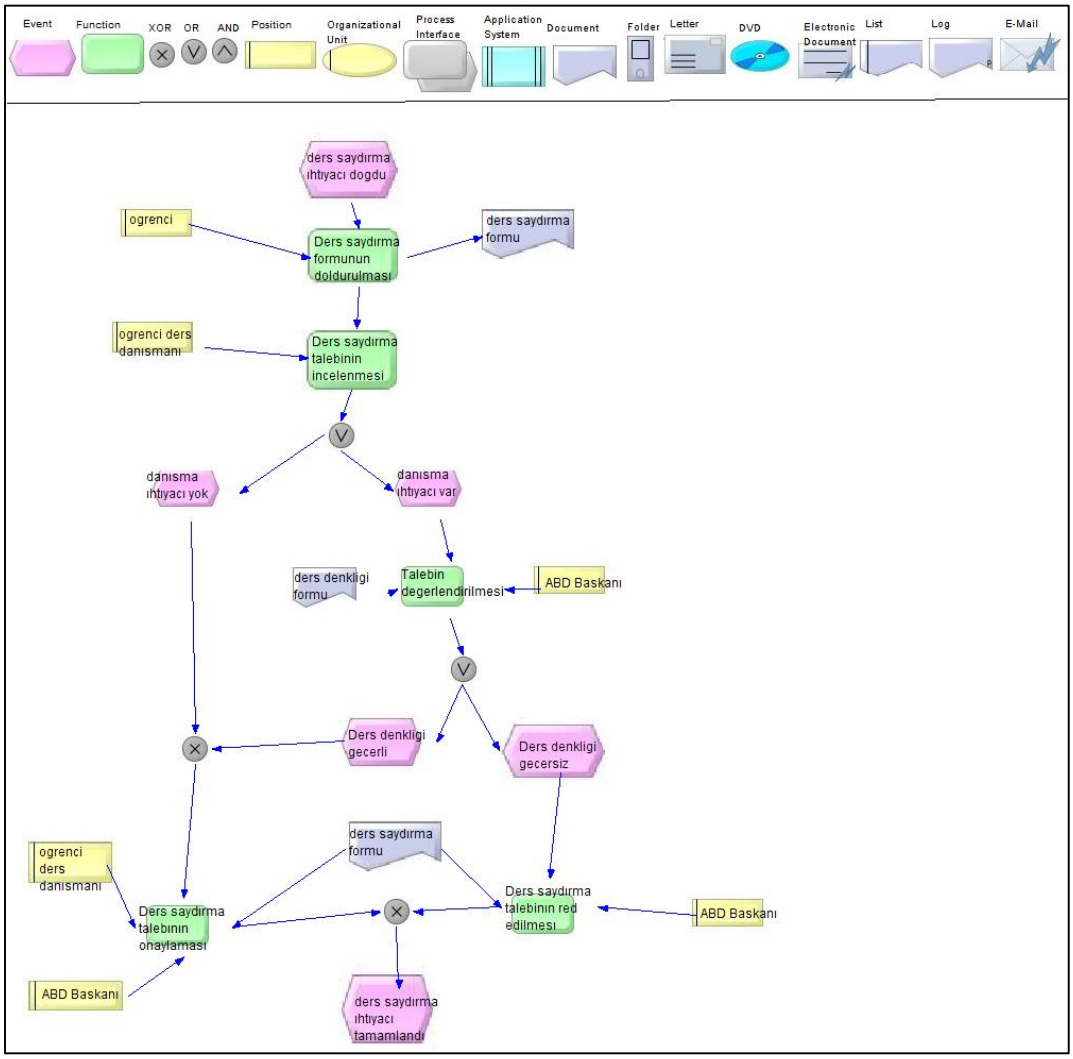
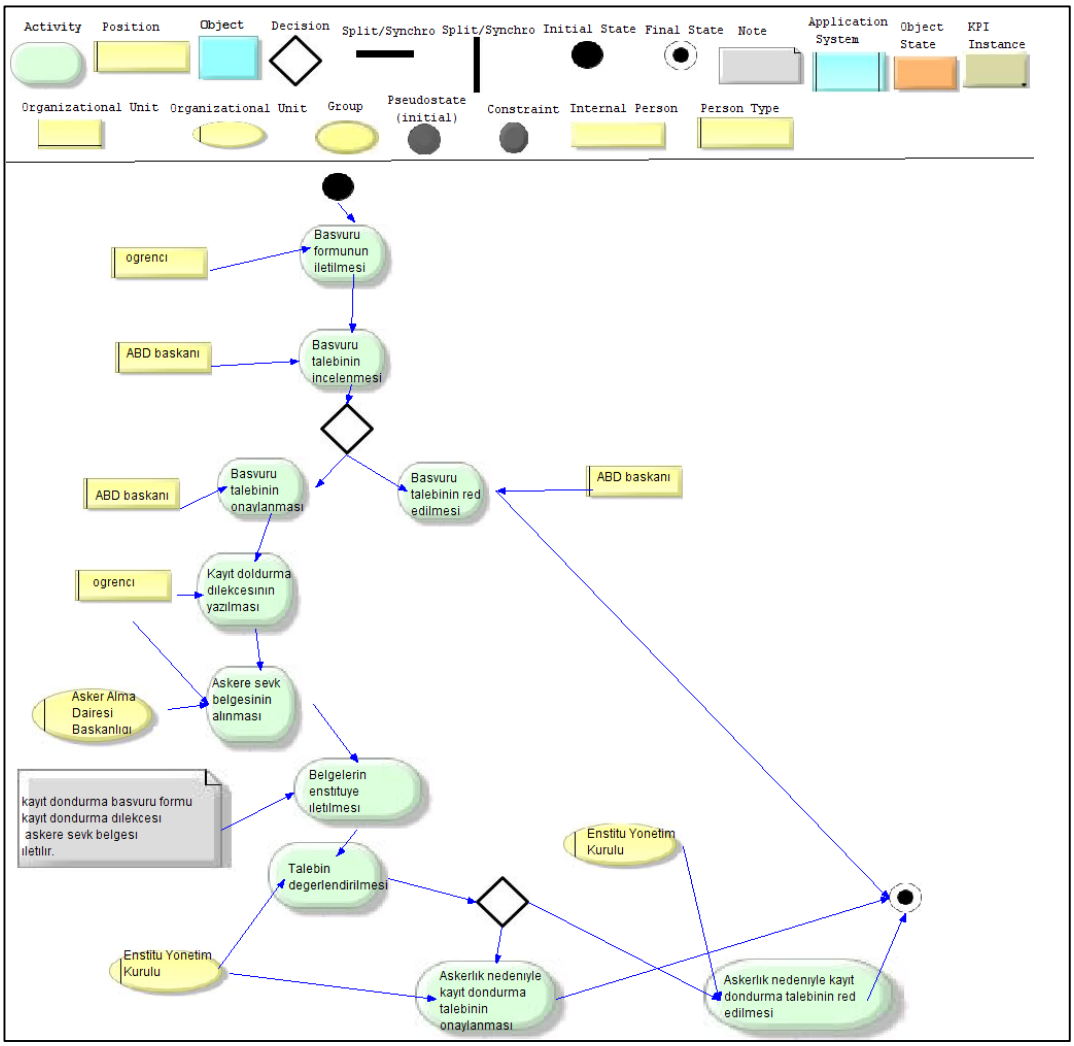
Appendix H – Final Models

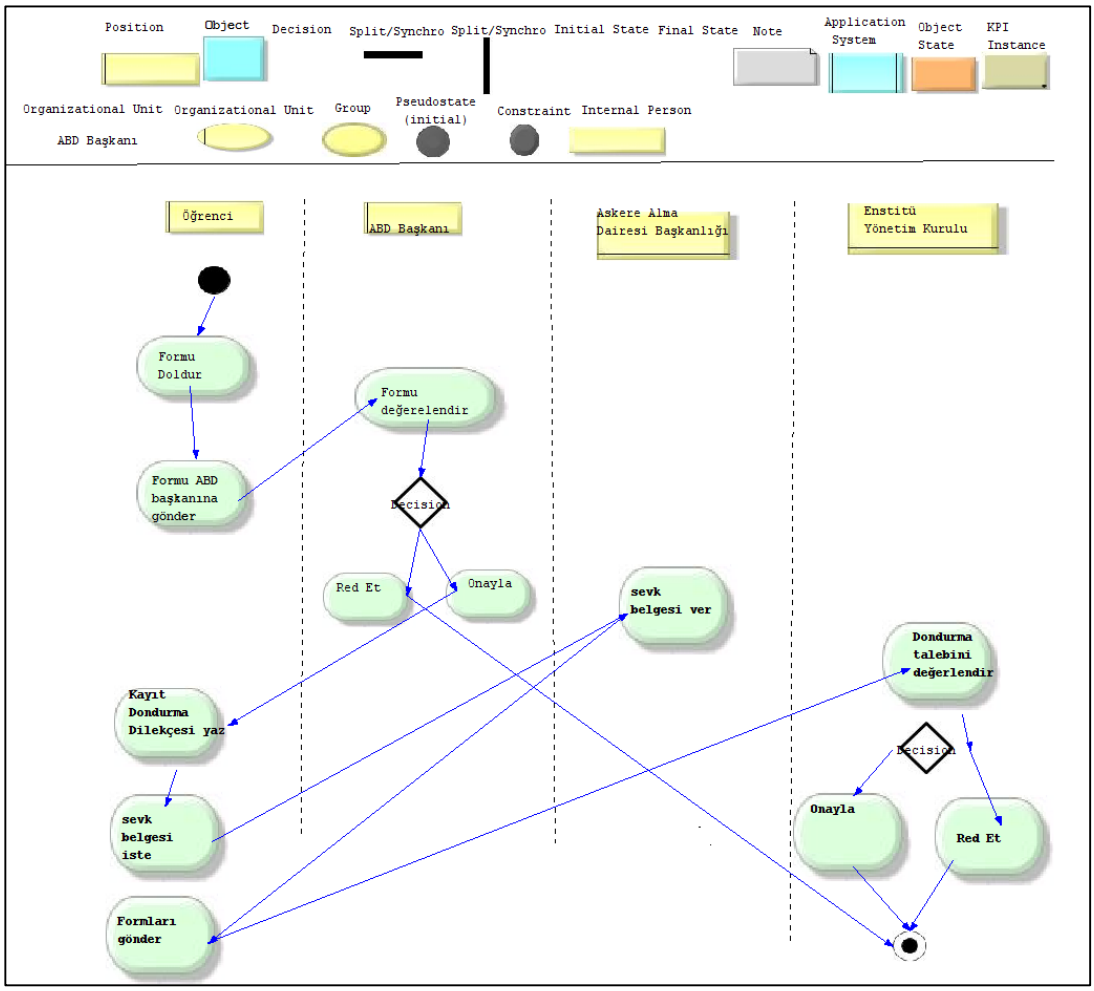
Group1_1



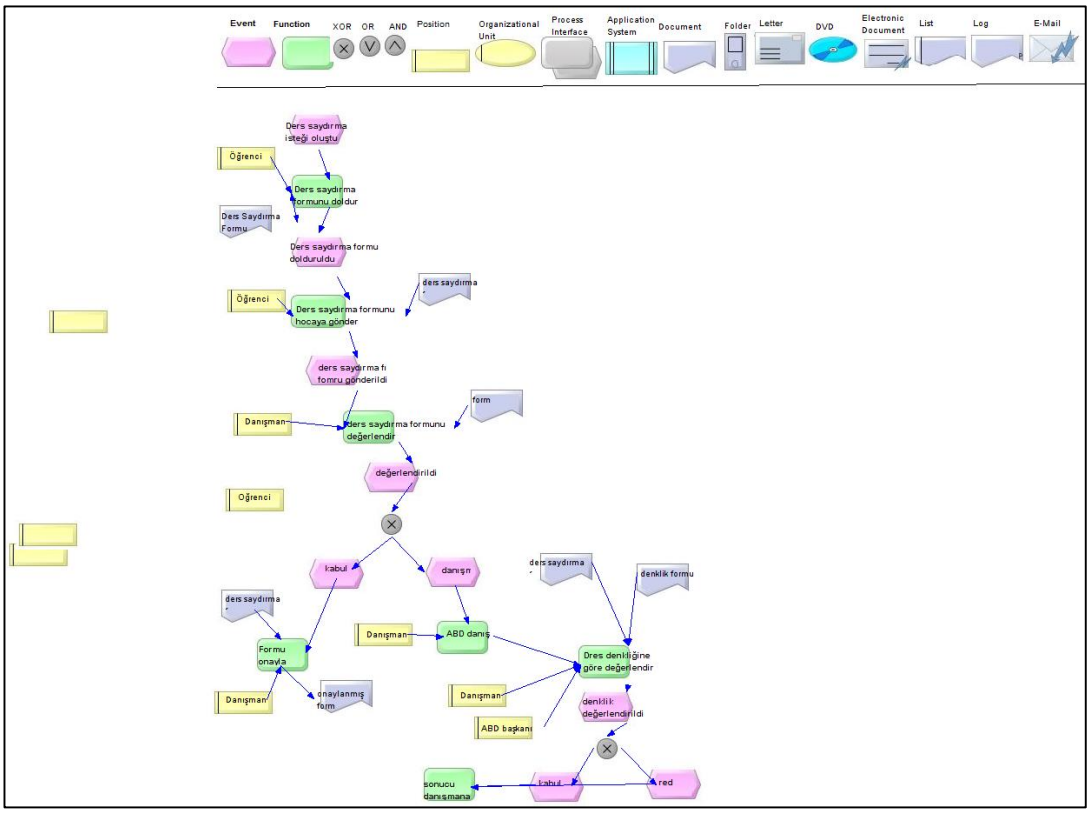
Group 1_2


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Person Type
ogrenci
Basvuru formunun iletilmesi
ABD baskanı
Basvuru talebinin incelenmesi
ABD baskanı
Basvuru talebinin onaylanması
Basvuru talebinin red edilmesi
ABD baskanı
ogrenci
Kayıt doldurma dilekcesinin yazılması
Asker Alma Dairesi Baskanlıgı
Askere sevk belgesinin alınması
kayıt dondurma basvuru formu
kayıt dondurma dilekcesi
askere sevk belgesi
iletilir.
Belgelerin enstituye iletilmesi
Enstitu Yonetim Kurulu
Talebin degerlendirilmesi
Enstitu Yonetim Kurulu
Askerlik nedeniyle kayıt dondurma talebinin onaylanması
Askerlik nedeniyle kayıt dondurma talebinin red edilmesi

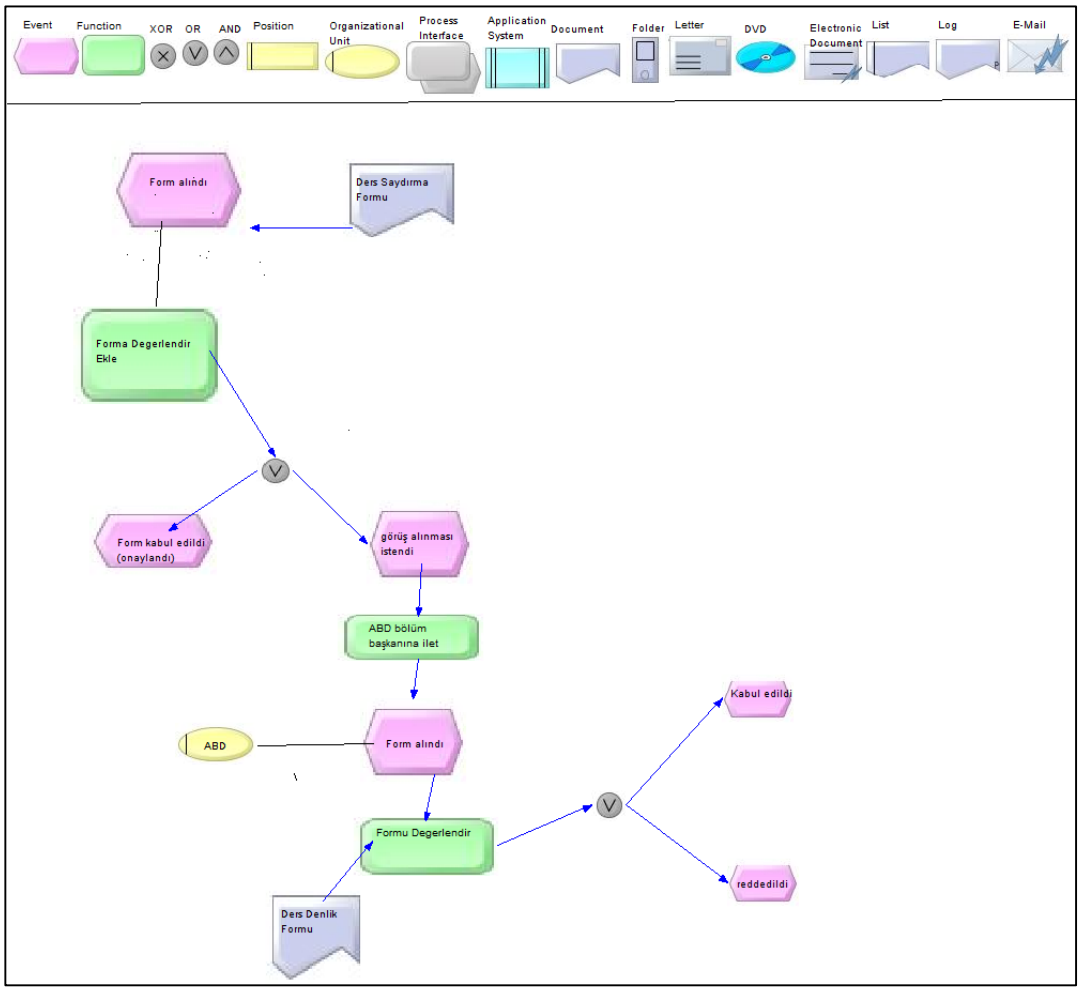
Group2_1


Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
ABD Başkanı
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Öğrenci
ABD Başkanı
Askere Alma Dairesi Başkanlığı
Enstitü Yönetim Kurulu
Formu Doldur
Formu değerelendir
Formu ABD başkanına gönder
Decision
Red Et
Onayla
sevk belgesi ver
Dondurma talebini değerlendir
Kayıt Dondurma Dilekçesi yaz
Decision
sevk belgesi iste
Onayla
Red Et
Formları gönder

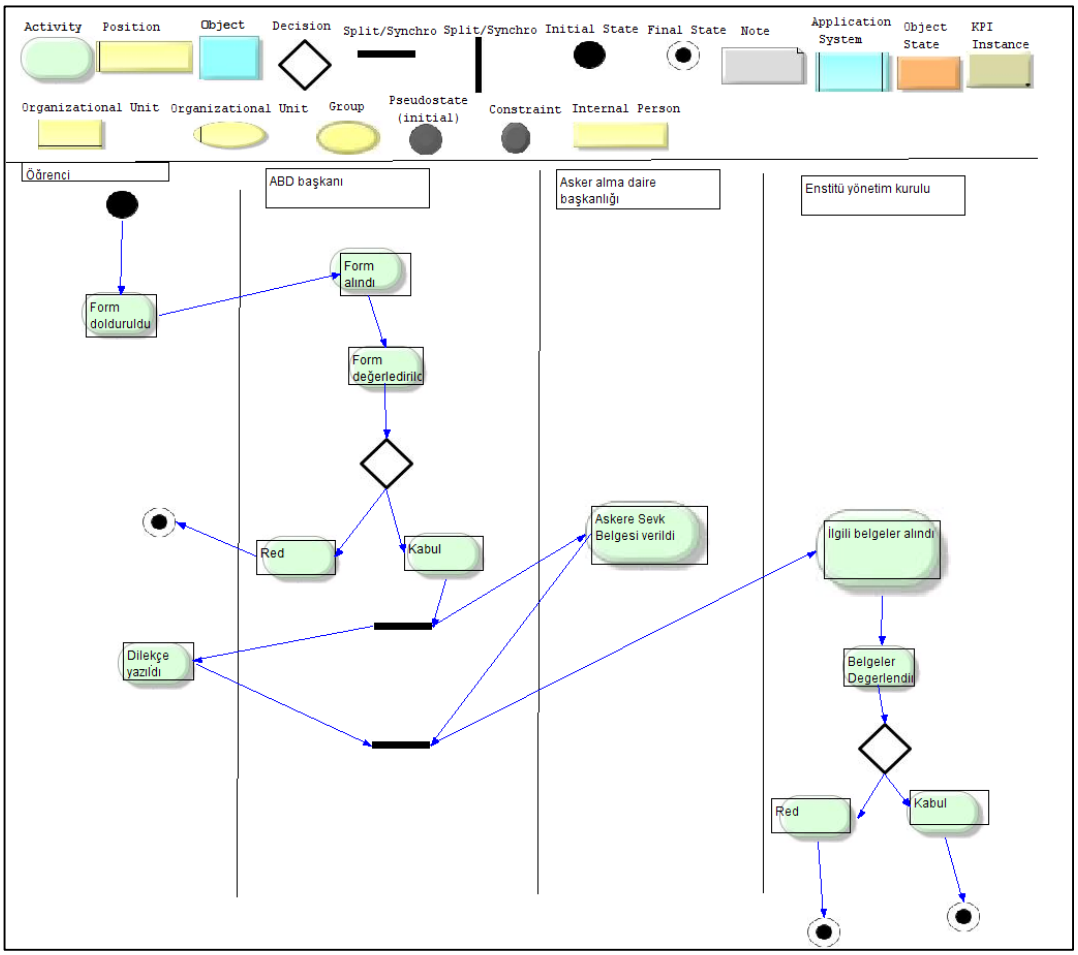
Group 2_2


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
Ders saydırma isteği olustu
Öğrenci
Ders saydırma formunu doldur
Ders Saydırma Formu
Ders saydırma formu dolduruldu
Öğrenci
Ders saydırma formunu hocaya gönder
ders saydırma
ders saydırma fı formu gönderildi
Danışman
ders saydırma formunu değerlendir
form
değerlendirildi
Öğrenci
kabul
danışn
ders saydırma
denklik formu
ders saydırma
Danışman
ABD danış
Formu onayla
Dres denkliğine göre değerlendir
Danışman
onaylanmış form
Danışman
denklik değerlendirildi
ABD başkanı
sonucu danışmana
kabul
red

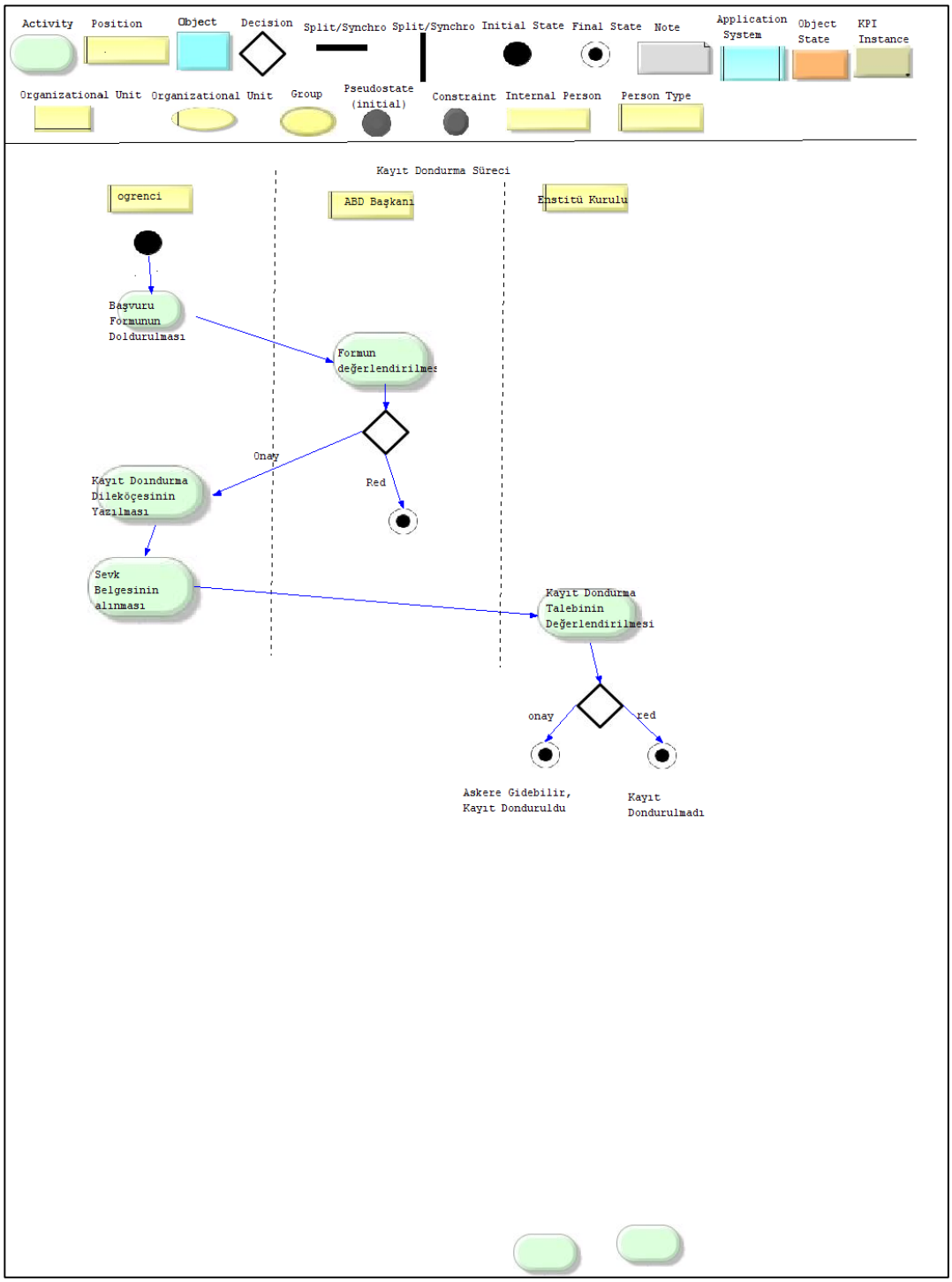
Group 3_1


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
Form alındı
Ders Saydırma Formu
Forma Degerlendir Ekle
Form kabul edildi (onaylandı)
görüş alınması istendi
ABD bölüm başkanına ilet
ABD
Form alındı
Kabul edildi
Formu Degerlendir
reddedildi
Ders Denlik Formu

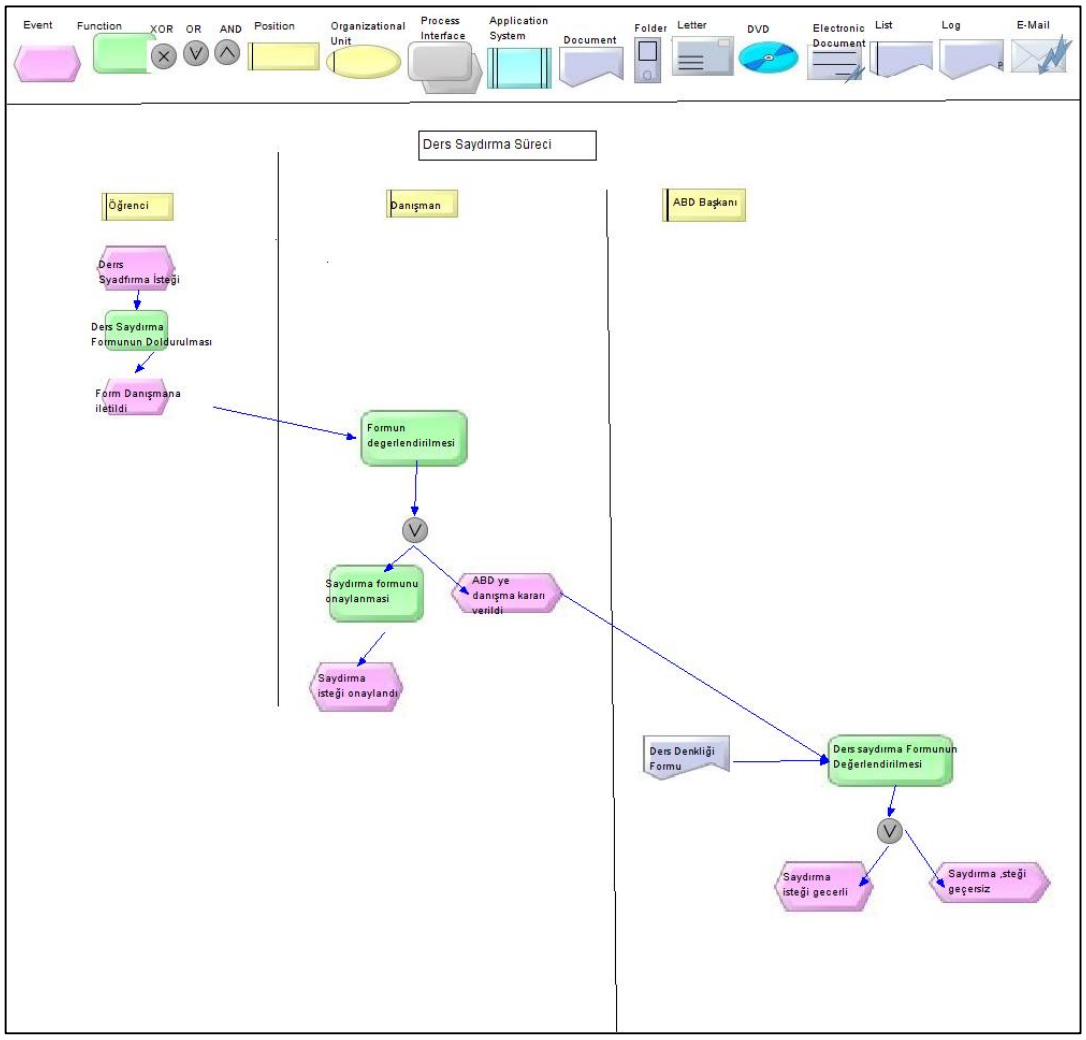
Group 3_2


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Öğrenci
ABD başkanı
Asker alma daire başkanlığı
Enstitü yönetim kurulu
Form alındı
Form dolduruldu
Form değerlendirilc
Red
Kabul
Askere Sevk Belgesi verildi
İlgili belgeler alındı
Dilekçe yazıldı
Belgeler Degerlendir
Red
Kabul

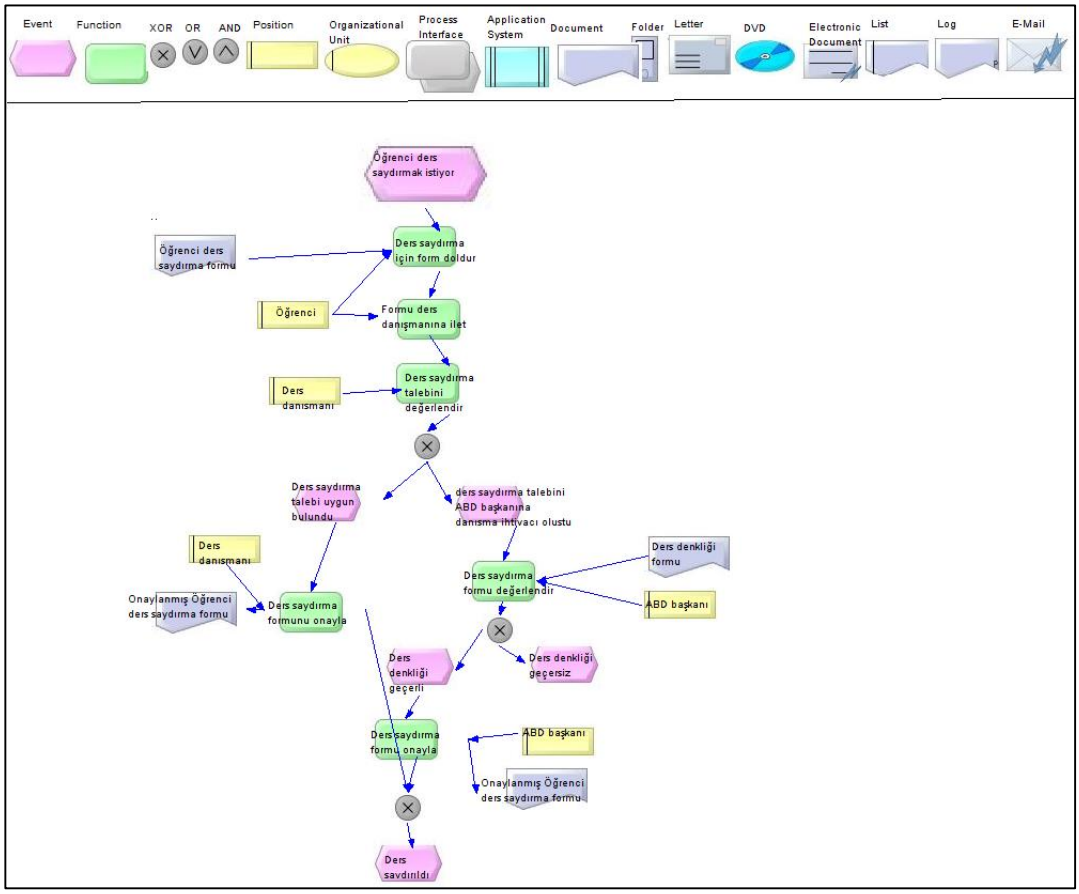
Group 4_1


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Person Type
Kayıt Dondurma Süreci
ogrenci
ABD Başkanı
Enstitü Kurulu
Başvuru Formunun Doldurulması
Formun değerlendirilmes
Onay
Red
Kayıt Doındurma Dileköçesinin Yazılması
Sevk Belgesinin alınması
Kayıt Dondurma Talebinin Değerlendirilmesi
onay
red
Askere Gidebilir, Kayıt Dondurulduu
Kayıt Dondurulmadı

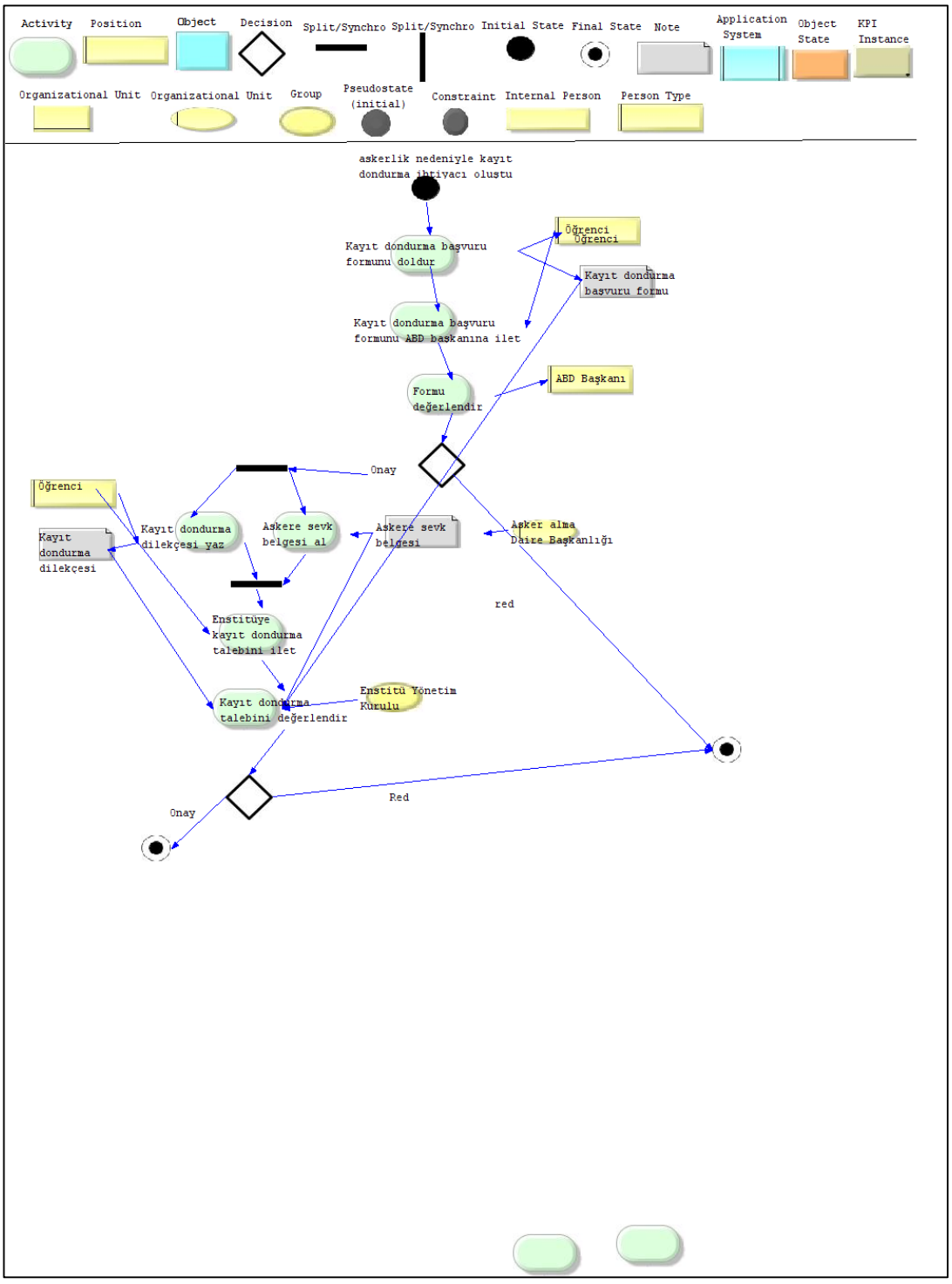
Group 4_2


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
Ders Saydırma Süreci
Öğrenci
Danışman
ABD Başkanı
Ders Syadfırma İsteği
Ders Saydırma Formunun Doldurulması
Form Danışmana iletildi
Formun degerlendirilmesi
Saydırma formunu onaylanmasi
ABD ye danışma kararı verildi
Saydırma isteği onaylandı
Ders Denkliği Formu
Ders saydırma Formunun Değerlendirilmesi
Saydırma isteği gecerli
Saydırma ,steği geçersiz

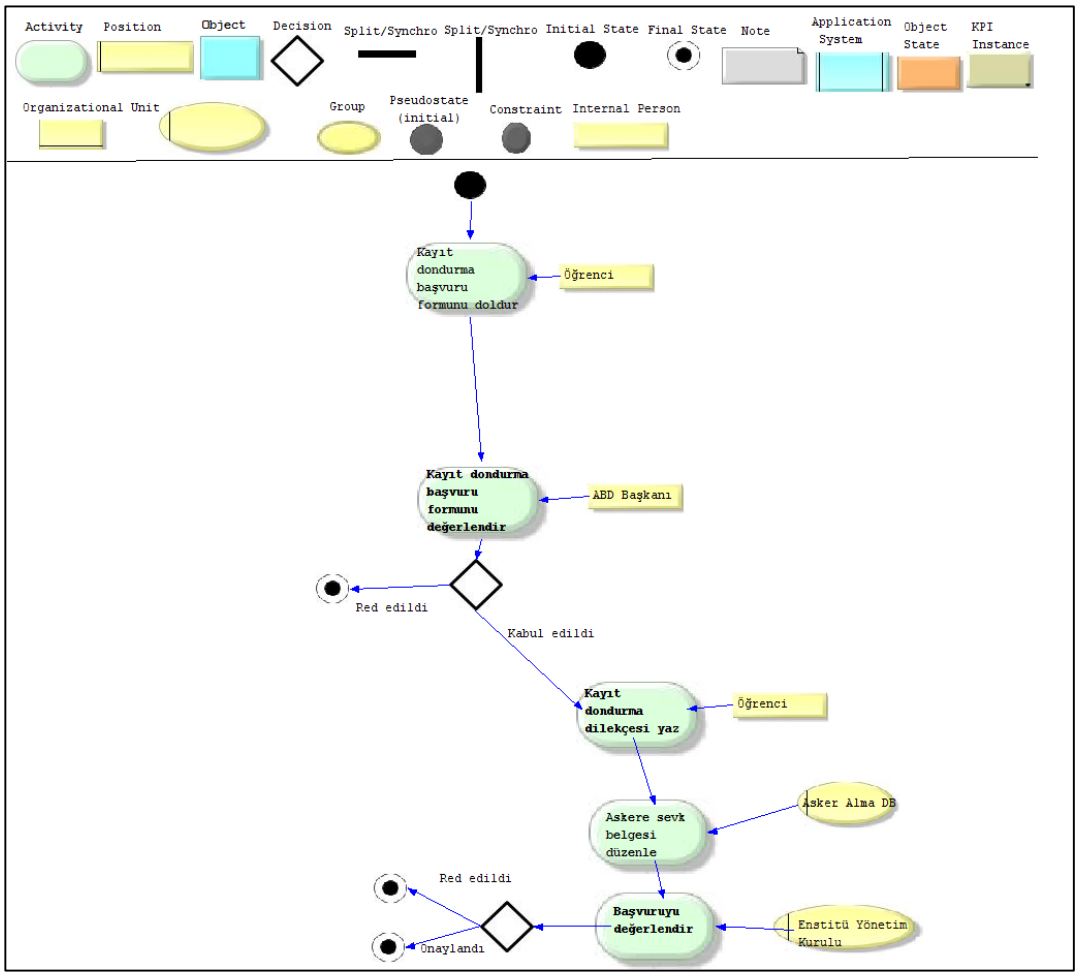
Group 5_1


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
Öğrenci ders saydırmak istiyor
Ders saydırma için form doldur
Öğrenci ders saydırma formu
Öğrenci
Formu ders danışmanına ilet
Ders danışmanı
Ders saydırma talebini değerlendir
Ders saydırma talebi uygun bulundu
ders saydırma talebini ABD başkanına danışma ihtiyacı olustu
Ders danışmanı
Ders saydırma formu değerlendir
Ders denkliği formu
ABD başkanı
Onaylanmış Öğrenci ders saydırma formu
Ders saydırma formunu onayla
Ders denkliği geçerli
Ders denkliği geçersiz
Ders saydırma formu onayla
ABD başkanı
Onaylanmış Öğrenci ders saydırma formu
Ders saydırıldı

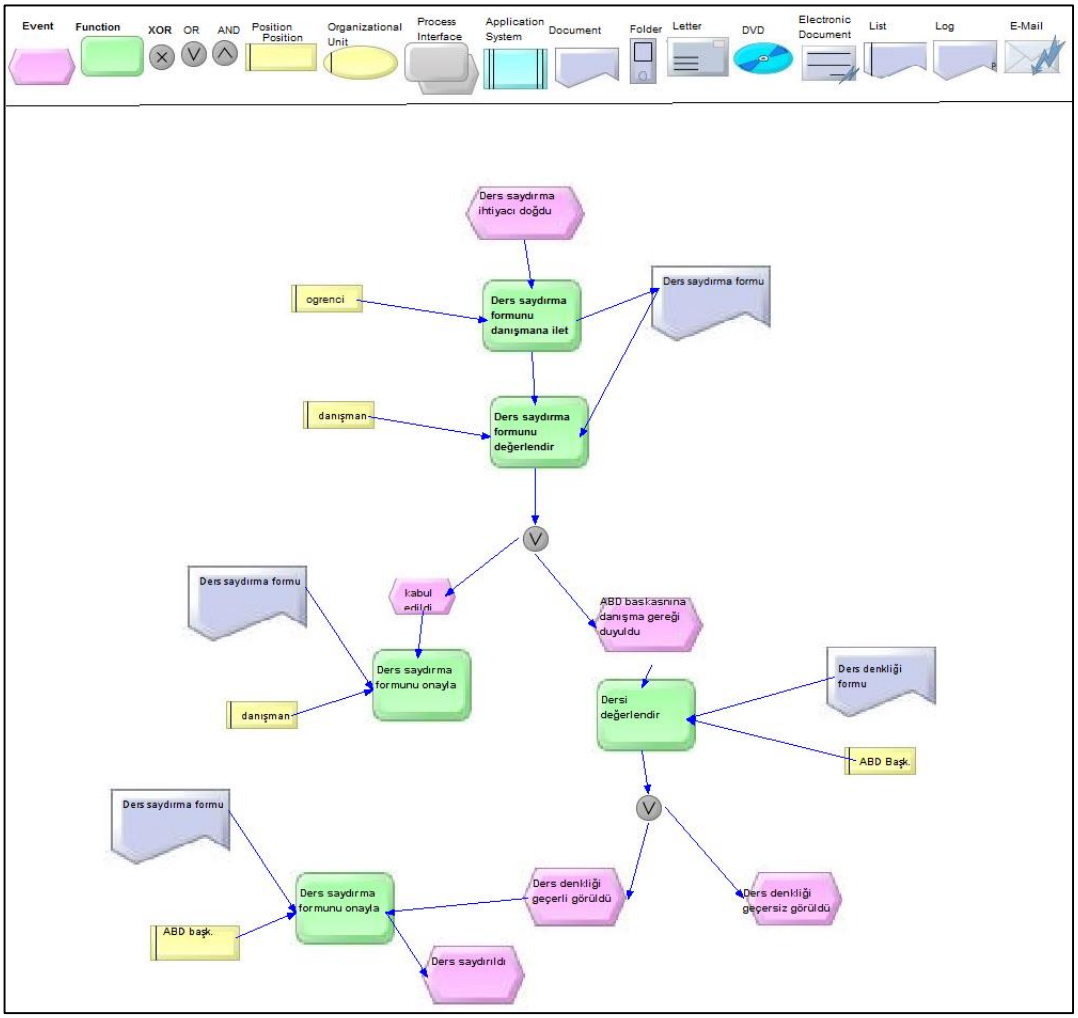
Group 5_2


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Person Type
askerlik nedeniyle kayıt dondurma ihtiyacı oluştu
Kayıt dondurma başvuru formunu doldur
Öğrenci
Kayıt dondurma başvuru formu
Kayıt dondurma başvuru formunu ABD başkanına ilet
ABD Başkanı
Formu değerlendir
Onay
Öğrenci
Kayıt dondurma dilekçesi
Kayıt dondurma dilekçesi yaz
Askere sevk belgesi al
Askere sevk belgesi
Asker alma Daire Başkanlığı
red
Enstitüye kayıt dondurma talebini ilet
Kayıt dondurma talebini değerlendir
Enstitü Yönetim Kurulu
Onay
Red

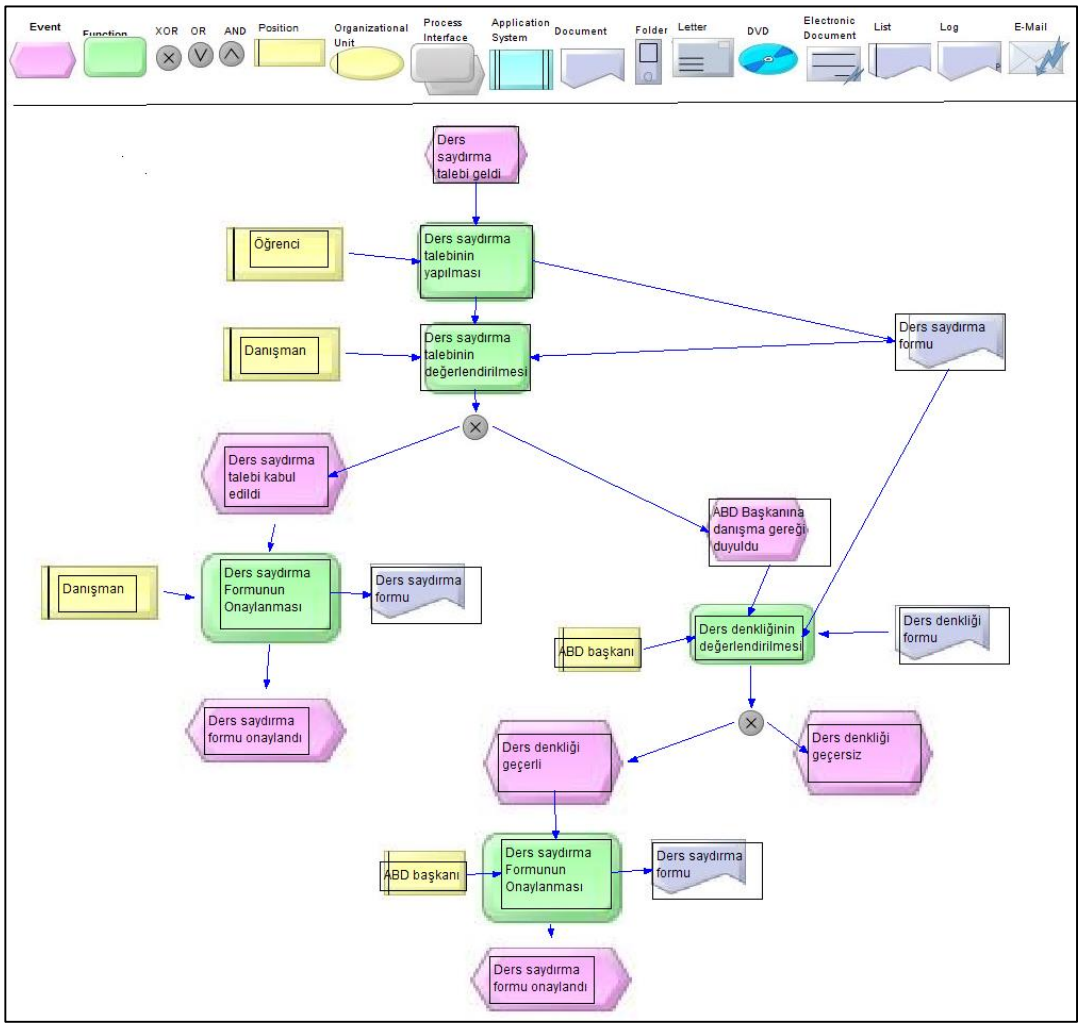
Group 6_1


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Kayıt dondurma başvuru formunu doldur
Öğrenci
Kayıt dondurma başvuru formunu değerlendir
ABD Başkanı
Red edildi
Kabul edildi
Kayıt dondurma dilekçesi yaz
Öğrenci
Askere sevk belgesi düzenle
Asker Alma DB
Red edildi
Başvuruyu değerlendir
Enstitü Yönetim Kurulu
Onaylandı

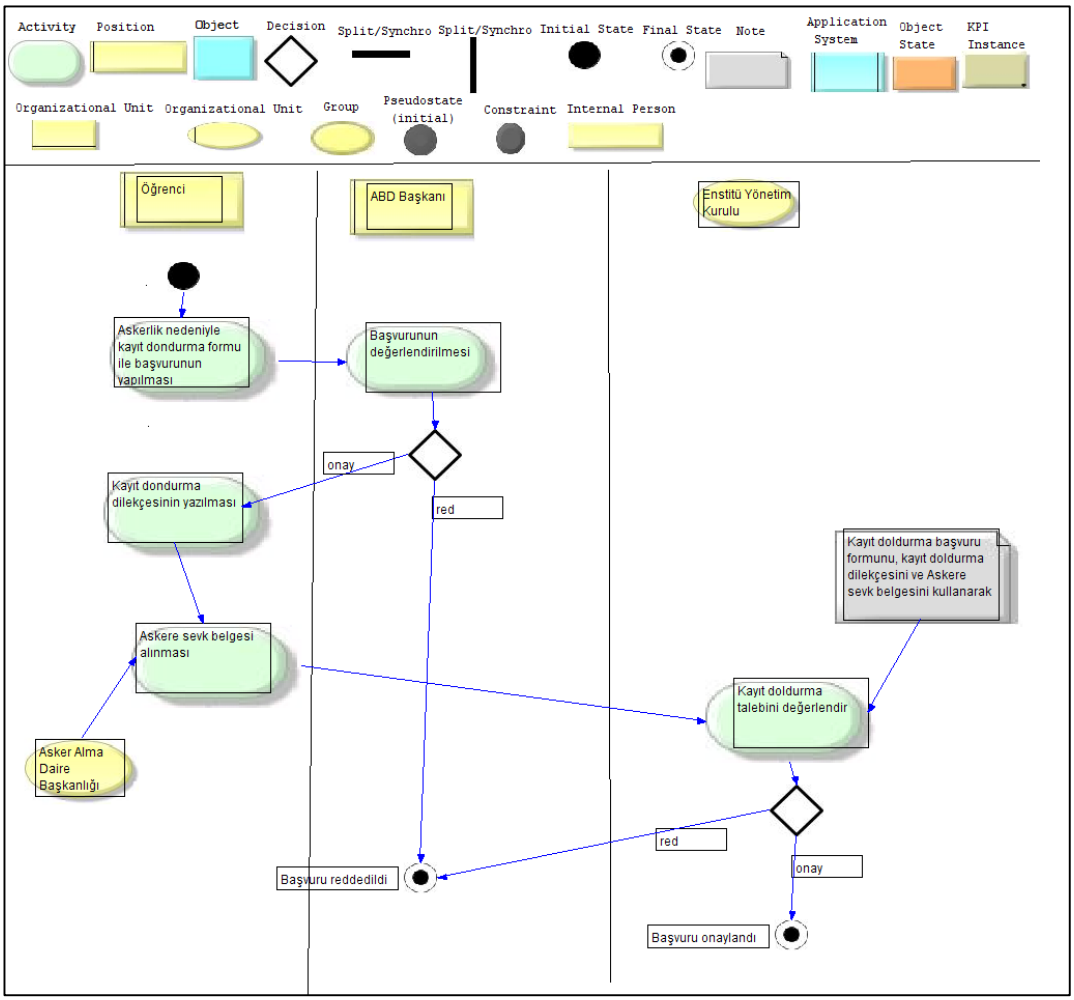
Group 6_2


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
Ders saydırma ihtiyacı doğdu
ogrenci
Ders saydırma formunu danışmana ilet
Ders saydırma formu
danışman
Ders saydırma formunu değerlendir
Ders saydırma formu
kabul edildi
ABD baskasına danışma gereği duyuldu
Ders saydırma formunu onayla
danışman
Dersi değerlendir
Ders denkliği formu
ABD Başk.
Ders saydırma formu
Ders saydırma formunu onayla
ABD başk.
Ders denkliği geçerli görüldü
Ders denkliği geçersiz görüldü
Ders saydırıldı

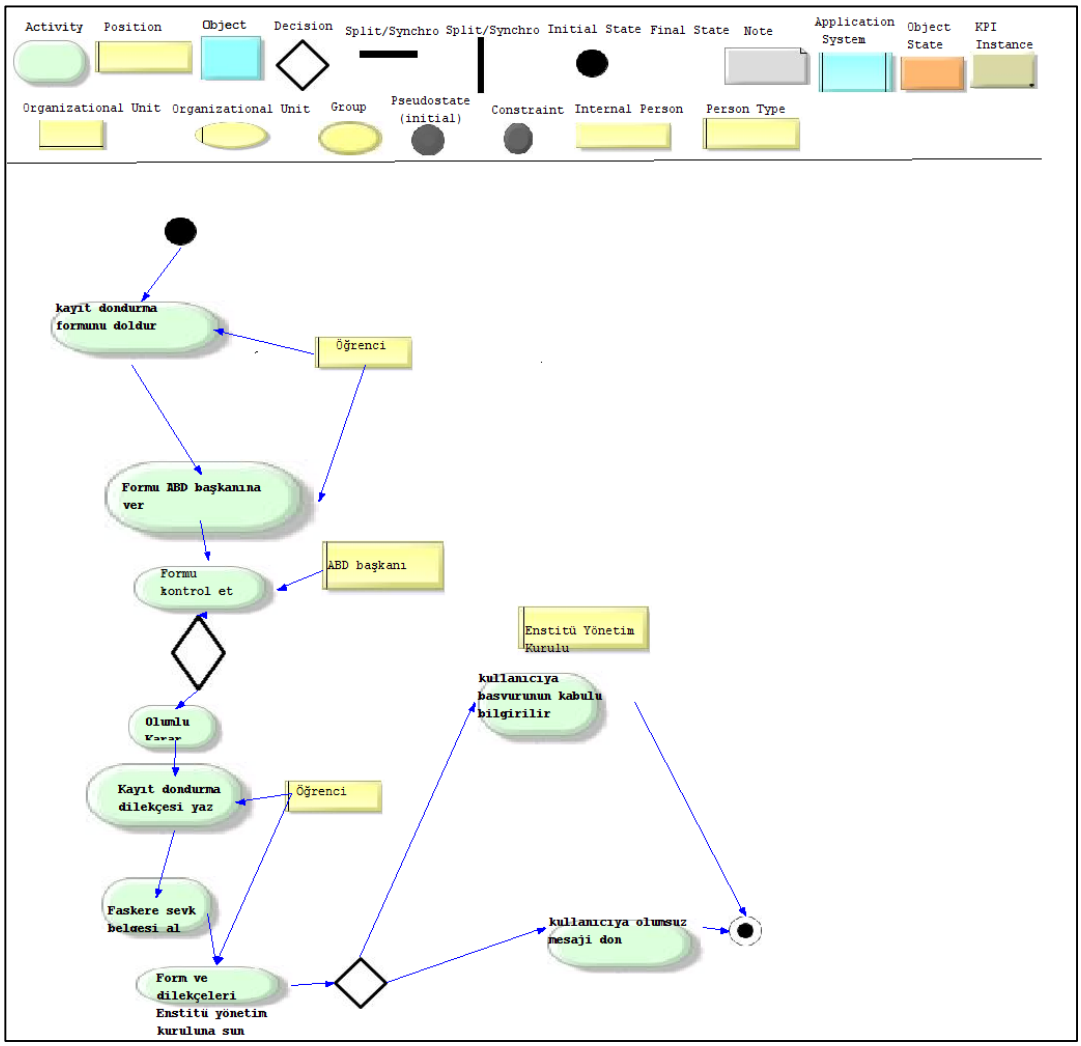
Group 7_1


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
Ders saydırma talebi geldi
Öğrenci
Ders saydırma talebinin yapılması
Danışman
Ders saydırma talebinin değerlendirilmesi
Ders saydırma formu
Ders saydırma talebi kabul edildi
ABD Başkanına danışma gereği duyuldu
Danışman
Ders saydırma Formunun Onaylanması
Ders saydırma formu
ABD başkanı
Ders denkliğinin değerlendirilmesi
Ders denkliği formu
Ders saydırma formu onaylandı
Ders denkliği geçerli
Ders denkliği geçersiz
ABD başkanı
Ders saydırma Formunun Onaylanması
Ders saydırma formu
Ders saydırma formu onaylandı

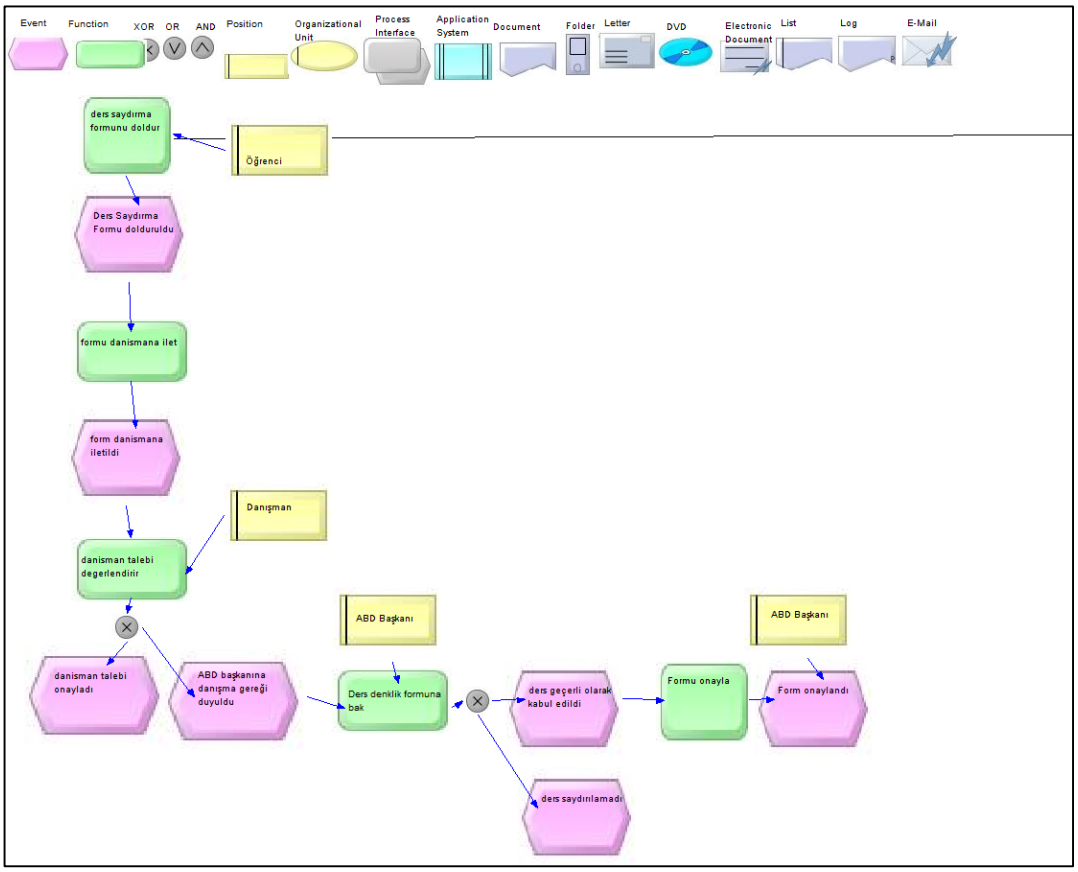
Group 7_2


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Öğrenci
ABD Başkanı
Enstitü Yönetim Kurulu
Askerlik nedeniyle kayıt dondurma formu ile başvurunun yapılması
Başvurunun değerlendirilmesi
onay
red
Kayıt dondurma dilekçesinin yazılması
Kayıt doldurma başvuru formunu, kayıt doldurma dilekçesini ve Askere sevk belgesini kullanarak
Askere sevk belgesi alınması
Kayıt doldurma talebini değerlendir
Asker Alma Daire Başkanlığı
red
onay
Başvuru reddedildi
Başvuru onaylandı

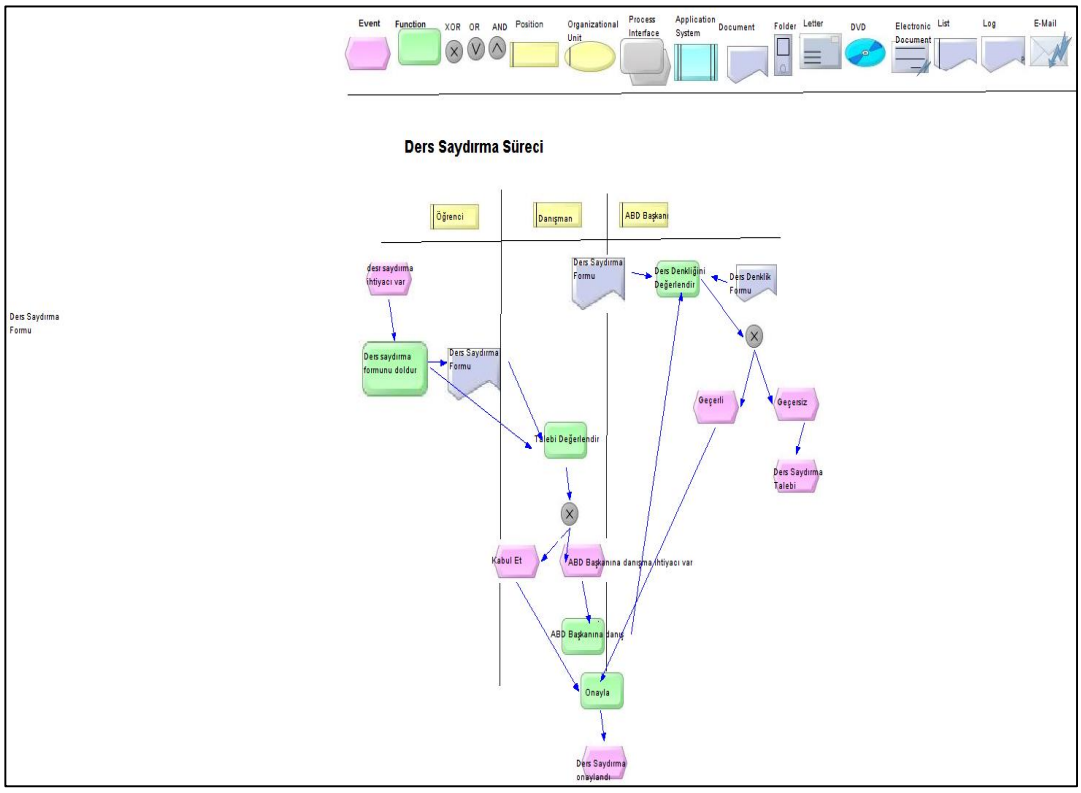
Group 8_1


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Person Type
kayıt dondurma formunu doldur
Öğrenci
Formu ABD başkanına ver
Formu kontrol et
ABD başkanı
Enstitü Yönetim Kurulu
kullanıcıya basvurunun kabulu bilgirilir
Olumlu Karar
Kayıt dondurma dilekçesi yaz
Öğrenci
Faskere sevk belgesi al
kullanıcıya olumsuz mesaji don
Form ve dilekçeleri Enstitü yönetim kuruluna sun

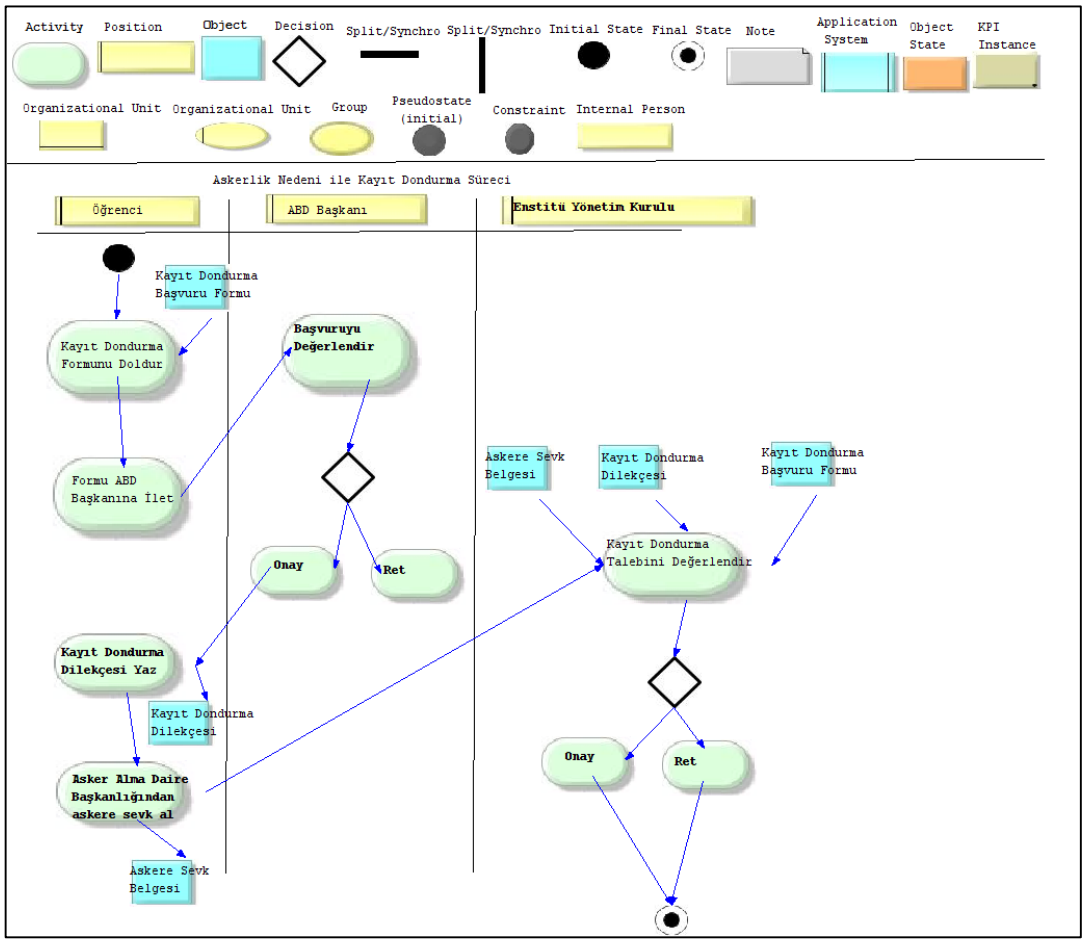
Group 8_2


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
ders saydırma formunu doldur
Öğrenci
Ders Saydırma Formu dolduruldu
formu danismana ilet
form danismana iletildi
Danışman
danisman talebi degerlendirir
ABD Başkanı
ABD Başkanı
danisman talebi onayladı
ABD başkanına danışma gereği duyuldu
Ders denklik formuna bak
ders geçerli olarak kabul edildi
Formu onayla
Form onaylandı
ders saydırılamadı

Group 9_1


Event
Function
XOR
OR
AND
Position
Organizational Unit
Process Interface
Application System
Document
Folder
Letter
DVD
Electronic Document
List
Log
E-Mail
Ders Saydırma Süreci
Öğrenci
Danışman
ABD Başkanı
desr saydırma ihtiyacı var
Ders Saydırma Formu
Ders Denkliğini Değerlendir
Ders Denklik Formu
Ders Saydırma Formu
Ders saydırma formunu doldur
Ders Saydırma Formu
Geçerli
Geçersiz
Talebi Değerlendir
Ders Saydırma Talebi
Kabul Et
ABD Başkanına danışma ihtiyacı var
ABD Başkanına Danış
Onayla
Ders Saydırma onaylandı

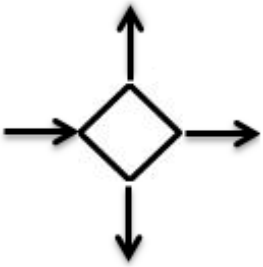
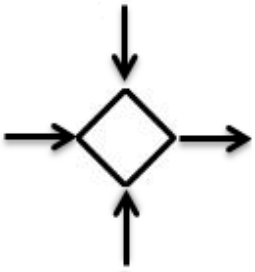
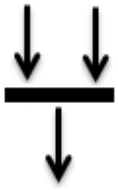
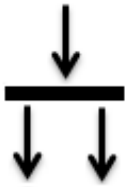
Group 9_2


Activity
Position
Object
Decision
Split/Synchro
Split/Synchro
Initial State
Final State
Note
Application System
Object State
KPI Instance
Organizational Unit
Organizational Unit
Group
Pseudostate (initial)
Constraint
Internal Person
Askerlik Nedeni ile Kayıt Dondurma Süreci
Öğrenci
ABD Başkanı
Enstitü Yönetim Kurulu
Kayıt Dondurma Başvuru Formu
Kayıt Dondurma Formunu Doldur
Başvuruyu Değerlendir
Formu ABD Başkanına İlet
Onay
Ret
Askere Sevk Belgesi
Kayıt Dondurma Dilekçesi
Kayıt Dondurma Başvuru Formu
Kayıt Dondurma Talebini Değerlendir
Kayıt Dondurma Dilekçesi Yaz
Kayıt Dondurma Dilekçesi
Asker Alma Daire Başkanlığından askere sevk al
Askere Sevk Belgesi
Onay
Ret

Appendix I - Syntactical Rules for UML Activity Diagram and eEPC

UML activity diagrams are used to demonstrate the logic of "a complex operation", "a complex business rule", "a single use case", "several use cases", "a business process", "concurrent processes" and "software processes" (Ambler, 2005; Ambler, 2004). Basic elements of activity diagrams (Hamilton & Miles, 2006) are shown in Table 21.

Table 21 UML Activity Diagram Notations

Initial State		An activity is started by the Initial State node.
Final State		Final State node marks the end of the activity.
Action		Action node refers an active step within an activity and which can be a performed behavior, a computation or any key step in the process.
Decision		Decision node is similar to the if-else statement in code. After incoming edge is executed, only one edge is followed out of the decision node.
Merge		Merge node includes several incoming edges and one outgoing edge. Merge node is used to accept one incoming edge among several alternate flows.
Join		A black bar with several incoming edges and one outgoing edge. All flows going into the join must reach it before processing may continue. Join node denotes the end of parallel processing.
Fork		A black bar with one incoming edge and several outgoing edges. This denotes the beginning of parallel activity.

Object		Object nodes are used to show data flowing through an activity. This node represents an object which is used, created or modified by any of its surrounding actions.
Note		This node is used to enter comment which is useful for a modeler.

In order to ensure structural correctness of UML activity diagram, the following syntactical guidelines (Ambler, 2005) were considered for the evaluation of created process models;

General Guidelines;

- Activity diagram should start with Initial State node
- Activity diagram should state ending points.
- Complex operations should be refactored.
- Action node should be named with Verb + Noun convention.

Activity Guidelines;

- Black-hole activities should be revealed and cleaned. Black-hole activity refers to an activity which has incoming edge but no outgoing edge.
- Miracle activities should be handled. Miracle activity refers to an activity which has outgoing edge but no incoming edge.

Decision point and Guard Guidelines;

- If the decision model element represented with diamond has no label to define decision point, the guards (which are the conditions that must be true in order for an activity edge to be traversed) should be depicted with [description] format. The labels on the guards help to describe decision point.
- The labels of the guards can be simplified by indicating the decision within the diamonds
- Superfluous decision points should be eliminated.
- Each activity edge leaving a decision point should has a guard; which ensures that you have thought through all possibilities for that decision point.
- The guards should not overlap. For instance, the guards like x<0, x=0 and x>0 are consistent; however, x<=0 and x>=0 is not consistent due to the overlap of the conditions.
- The guards on the decision point should be complete. For instance, x<0 and x>0 condition is not complete because it does not explain the x=0 condition.
- The guard should be modeled only if it adds value.

Parallel Flow Guidelines;

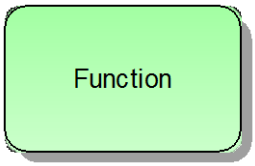
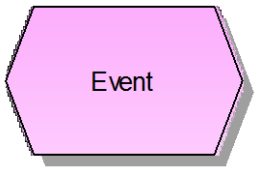
- Every fork should have a corresponding join.
- Fork should have only one entry.
- Join should have only one exit.
- Superfluous forks should be eliminated.

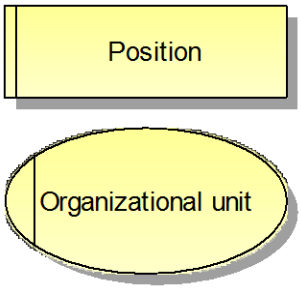
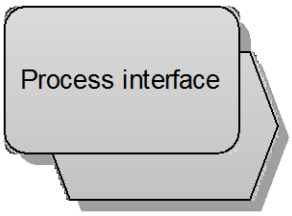
Swim Lane Guidelines;

- Swimlane is used for activity partitions which means grouping activities performed by the same actor or grouping activities in a single thread (Ambler, 2005). This guideline is relaxed with linking activities and actors with position and organizational unit model elements.
- Swimlanes should be ordered in a logical manner and the number of swimlanes should be less than 5 to reduce the size of the diagram.

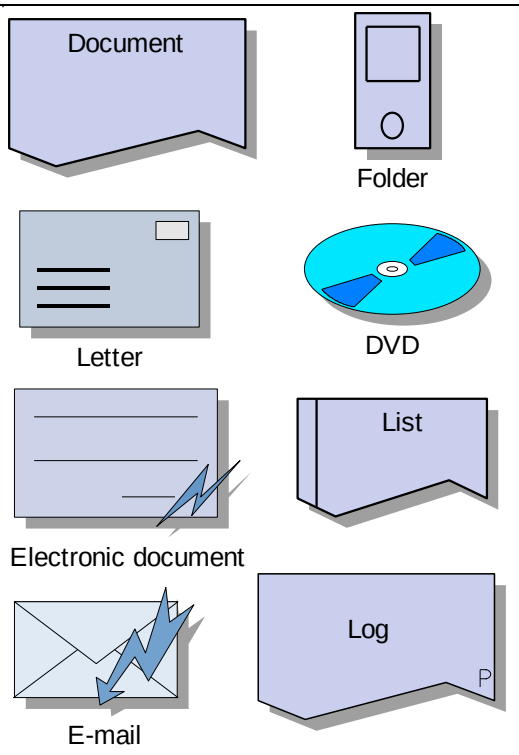
The Event-driven Process Chain (EPC) is a business process modeling language that is used for the representation of temporal and logical dependencies between activities in business processes (Mendling, 2008; Scheer & Schneider, 2006). The basic model elements of this language (Davis & Brabander, 2007; Mendling, 2008) are shown in the Table 22.

Table 22 eEPC Model Notations

Function		Function model element is used to define activities of a process.
Event		Event model element is used to define pre-condition and post-condition of a function.
XOR, OR, AND	**Connectors**	Connectors could be either join connectors or split connectors. Split connectors have one incoming and multiple outgoing arcs. Join connectors have multiple incoming and one outgoing arc.
		XOR-split model element represents a choice

		between one of several alternative branches. XOR-join model element merges alternative branches.
		OR-split model element triggers one, two or up to all of multiple branches based on conditions. OR-join model element synchronizes all active incoming branches.
		AND-split model element activates all subsequent branches in concurrency. AND-join model element waits for all incoming branches to complete and then propagates control of coming EPC element.
Position and Organizational Unit		Position and organizational unit model elements are responsible to perform the activities (Scheer & Schneider, 2006).
Process Interface		Process interface model element is used to link two consecutive EPCs; in other words, the process interface links the model continues with another business process.

Information Carrier



Information carriers which are represented with different symbols that show the data types used as input and output of the functions in the process model (Davis & Brabander, 2007).

In order to ensure structural correctness of eEPC, the following syntactical guidelines (Davis & Brabander, 2007) were considered for the evaluation of created process models;

- The model must have at least one start event and one end event. We relaxed this guideline by accepting the models which have more than one end event.
- In the model functions and events always alternate which means functions should not connect to other functions and events should not connect to the other events. We relaxed this guideline by accepting the models which have function to function connection.
- The event model elements should be named with Noun + Verb convention; such as “Order Entered”.
- The function model elements should be named with Verb + Noun convention; such as “Enter Order”.
- Functions and events model elements have a single incoming and outgoing connection.
- The resources that are inputs and outputs must be connected to the functions.
- Operator Rules;
    - OR – Decision: “One or many possible paths will be followed as a result of the decision”
    - OR – Trigger: “Any one event, or combination of events, will trigger the Function”

    - XOR – Decision: “One, but only one, of the possible paths will be followed”
    - XOR – Trigger: “One, but only one, of the possible events will be the trigger”
    - AND – Parallel Path: “Process flow splits into two or more parallel paths”
    - AND – Trigger: “All events must occur in order to trigger the following Function”
- The split and join combination should be considered; which means, the join should be made with the same rule that is used to make split after the decision.
- Rules that are OR, XOR and AND cannot have multiple input and multiple outputs; in other words, the rules should have only one incoming connection and multiple outgoing connections or the rules should have multiple incoming connections and one outgoing connection.
- The following layout in the Figure 26 shows functions, events and rule combinations.

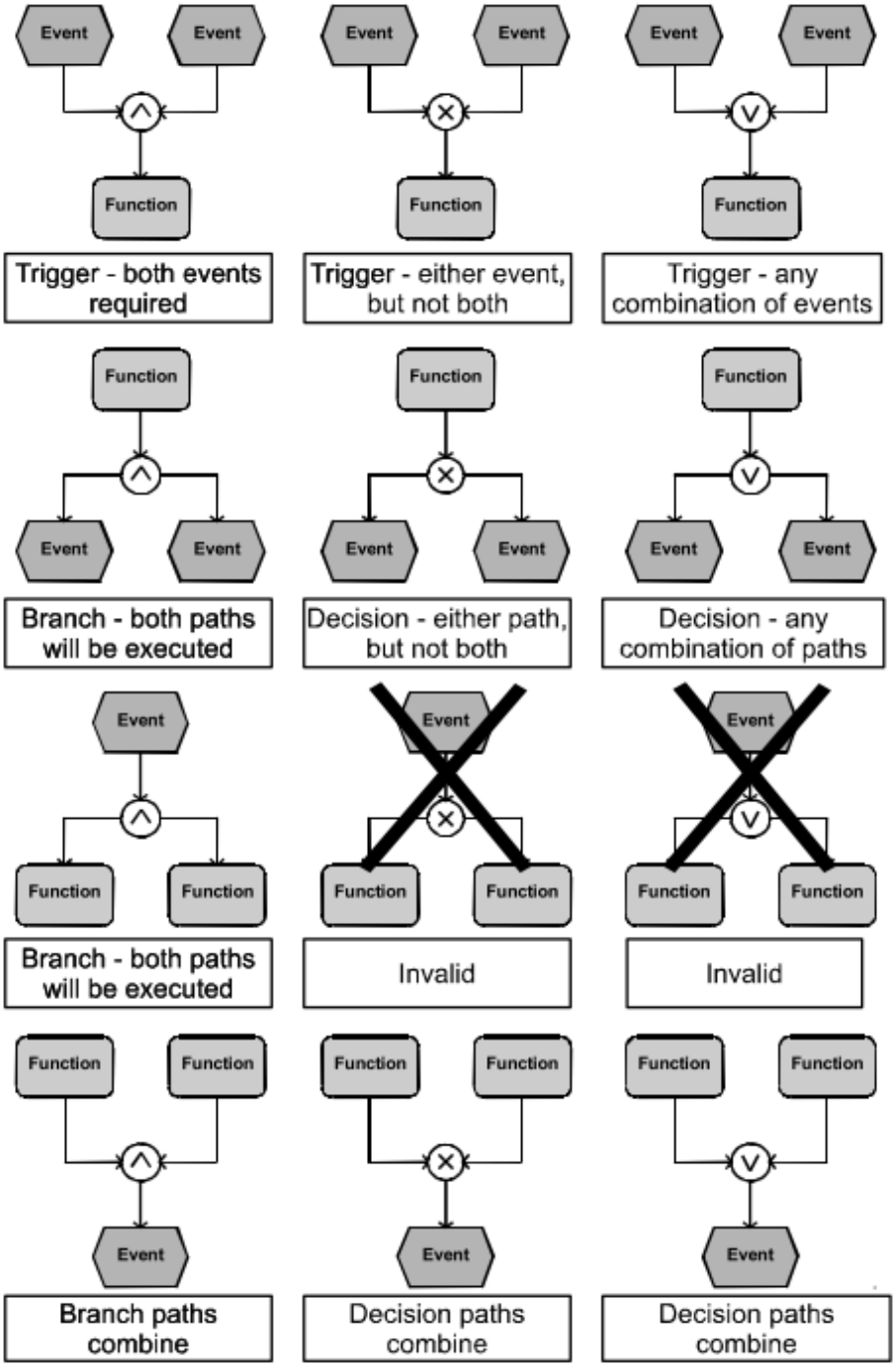


Figure 26 Function, Event and Rule Combinations (Davis & Brabander, 2007; pg.123)

Appendix J – A Sample Cross Connectivity Measure Calculation

To illustrate the use of the CC measure, the following example is presented for Group1_1. Figure 27 shows Group1_1's last model with eleven tasks (i.e. *T = {A, B, C, D, E, F, G, H, I, J, K}),* four connectors (i.e. *C = {OR1, OR2, XOR1, XOR2}),* and sixteen directed arcs (i.e. *A = {a1, a2, a3, a4, a5, a6, a7, a8, a9, a10, a11, a12, a13, a14, a15, a16}).*

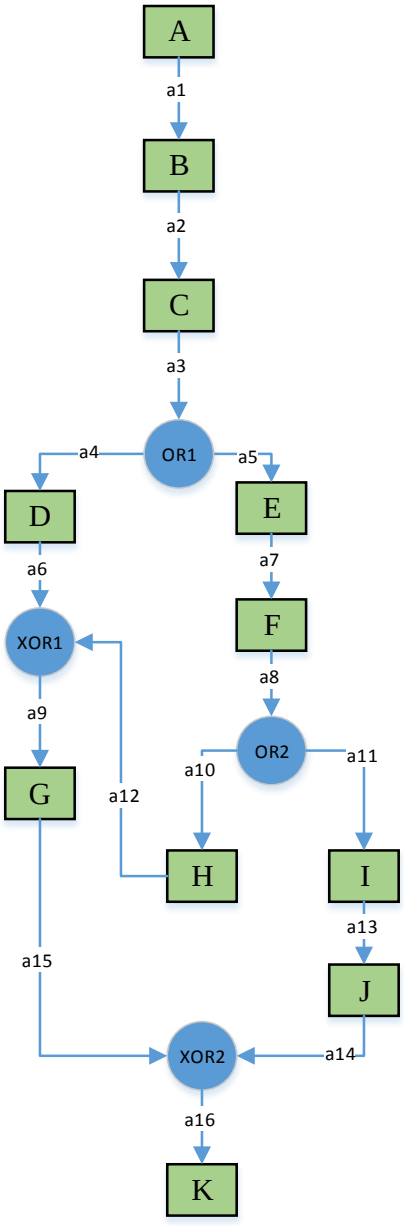


Figure 27 Group1_1's model tasks and connectors.

Firstly, the weight for each node is calculated with the following formula (in Table 23) (Vanderfeesten et al., 2008, p.4);

> *"Let a process model be given as a graph consisting of a set of nodes (n_1, n_2, ... $\in N$) and a set of directed arcs (a_1, a_2, ... $\in A$). A node can be one of two types: (i) task, e.g. t_1, $t_2 \in T$, and (ii) connector, e.g. c_1, $c_2 \in C$. Thus, $N = T \cup C$. The weight of a node n, w(n), is defined as follows:*

$$w(n) = \begin{cases} 1 & , \quad if\ n \in C \wedge n\ is\ of\ type\ AND \\ \frac{1}{d} & , \quad if\ n \in C \wedge n\ is\ of\ type\ XOR \\ \frac{1}{2^d-1} + \frac{2^d-2}{2^d-1} \cdot \frac{1}{d} & , \quad if\ n \in C \wedge n\ is\ of\ type\ OR \\ 1 & , \quad if\ n \in T \end{cases}$$

> *with d the degree of the node (i.e. the total number of ingoing and ongoing arcs of the node)."*

Table 23 The degrees and weights for the nodes in the process model of Figure 27

Node (*n*)	**Degree (*m*)**	**Weight (*w(n)*)**
A	1	1
B	2	1
C	2	1
D	2	1
E	2	1
F	2	1
G	2	1
H	2	1
I	2	1
J	2	1
K	1	1
OR1	3	$\frac{1}{2^3-1} + \frac{2^3-2}{2^3-1} \cdot \frac{1}{3} = \frac{3}{7}$
XOR1	3	$\frac{1}{3}$
OR2	3	$\frac{1}{2^3-1} + \frac{2^3-2}{2^3-1} \cdot \frac{1}{3} = \frac{3}{7}$
XOR2	3	$\frac{1}{3}$

Secondly, the weight for each arc is calculated with the following formula (Vanderfeesten et al., 2008, p.5);

> *"Let a process model be given by a set of nodes (N) and a set of directed arcs (A). Each directed arc (a) has a source node (denoted by src (a) and a destination node (denoted by dest (a)).*
> *The weight of arc a, W (a) is defined as follows:*

W(a) = w(src(a) . w(dest(a)))"

The weight for each arc:

W(a1) = w(A) . w(B) = 1.1 =1
W(a2) = w(B) . w(C) = 1.1 =1
W(a3) = w(C) . w(OR1) = 1.3/7 =3/7
W(a4) = w(OR1) . w(D) = 3/7.1 =3/7
W(a5) = w(OR1) . w(E) = 3/7.1 =3/7
W(a6) = w(D) . w(XOR1) = 1.1/3 =1/3
W(a7) = w(E) . w(F) = 1.1 =1
W(a8) = w(F) . w(OR2) = 1.3/7 =3/7
W(a9) = w(XOR1) . w(G) = 1/3.1 =1/3
W(a10) = w(OR2) . w(H) = 3/7.1 =3/7
W(a11) = w(OR2) . w(I) = 3/7.1 =3/7
W(a12) = w(H) . w(XOR1) = 1.1/3 =1/3
W(a13) = w(I) . w(J) = 1.1 =1
W(a14) = w(J) . w(XOR2) = 1.1/3 =1/3
W(a15) = w(G) . w(XOR2) = 1.1/3 =1/3
W(a16) = w(XOR2) . w(K) = 1/3.1 =1/3

Thirdly, the value of a path is calculated with the following formula (Vanderfeesten et al., 2008, p.5);

> *"Let a process model be given by a set of nodes (N) and a set of directed arcs (A). A path p from node n_1 to n_2 is given by the sequence of directed arcs that should be followed from n_1 to n_2 : p =<a_1, a_2,…, a_x>. The value for a path p, v(p), is the product of the weights of all arcs in the path:*
>
> *$v(p) = W(a_1) . W(a_2) . \ldots W(a_x)$"*

Fourthly, value of a connection is examined with the following formula (Vanderfeesten et al., 2008, p.5);

> *"Let a process model be given by a set of nodes (N) and a set of directed arcs (A) and let Pn_1,n_2 be the set of paths from node n_1 to n_2. The value of the connection from n_1 to n_2, V (n_1, n_2), is the maximum value of all paths connecting n_1 and n_2:*
>
> $$V(n_1, n_2) = \max_{p \in Pn1,n2} v(p)$$
>
> *If no path exists between node n_1 and n_2, then V (n_1; n_2) = 0. Also note that loops in a path should not be considered more than once, since the value*

of the connection will not be higher if the loop is followed more than once in the particular path."

The all values are in Table 24. Finally, the CC value is defined with the following formula (Vanderfeesten et al., 2008, p.5).

"*Let a process model be given by a set of nodes (N) and a set of directed arcs (A). The Cross-Connectivity metric is then defined as follows:"*

$$CC = \frac{\sum_{n1,n2 \epsilon N} V(n1, n2)}{|N|.(|N| - 1)}$$

$$\text{CC} = \frac{1+1+\frac{39}{49}+\frac{4}{9}+1+\frac{39}{49}+\frac{4}{9}+\frac{4}{9}+1+\frac{4}{9}+0+\frac{6}{7}+\frac{1}{3}+\frac{6}{7}+\frac{1}{3}}{15*14} = 0{,}046$$

Table 24 Connections between all pairs of nodes

	A	B	C	D	E	F	G	H	I	J	K	OR1	XOR1	OR2	XOR2	TOTAL
A	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
B	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
C	0	0	0	9/49	9/49	0	0	0	0	0	0	3/7	0	0	0	39/49
D	0	0	0	0	0	0	1/9	0	0	0	0	0	1/3	0	0	4/9
E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
F	0	0	0	0	0	0	0	9/49	9/49	0	0	0	0	3/7	0	39/49
G	0	0	0	0	0	0	0	0	0	0	1/9	0	0	0	1/3	4/9
H	0	0	0	0	0	0	1/9	0	0	0	0	0	1/3	0	0	4/9
I	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
J	0	0	0	0	0	0	0	0	0	0	1/9	0	0	0	1/3	4/9
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OR1	0	0	0	3/7	3/7	0	0	0	0	0	0	0	0	0	0	6/7
XOR1	0	0	0	0	0	0	1/3	0	0	0	0	0	0	0	0	1/3
OR2	0	0	0	0	0	0	0	3/7	3/7	0	0	0	0	0	0	6/7
XOR2	0	0	0	0	0	0	0	0	0	0	1/3	0	0	0	0	1/3

Appendix K - Ethics Clearance

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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Danışmanlığını yapmış olduğunuz Bilişim Sistemleri Bölümü öğrencisi Duygu Fındık Coşkunçay'ın "An Emprical Examination For Collaborative Nature of Business Process Modeling – İş Süreci Modellemenin İşbirlikçi Doğası Üzerine Bir Ampirik İnceleme" isimli araştırması "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

04/11/2013

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FOREIGN LANGUAGE

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PUBLICATIONS

1. Fındık Coşkunçay, D., Çakır, M. P. (2016). Factors Affecting Interaction and Product Quality in Collaborative Business Process Modeling: A Dual Eye Tracking Study. *International Journal of Human Computer Studies*, (Submitted).Fındık Coşkunçay, D., Çakır, M. P. (2016). A Comparision of Different Computer Supported Collaborative Work Design Methodologies for Business Process Modeling. *Software Quality Journal.* (Submitted).
2. Fındık Coşkunçay, D., Özkan, S. (2013). A Model for Instructors' Adoption of Learning Management Systems: Empirical Validation in Higher Education Context. TOJET. 12(2), p.13-25.
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11. Fındık Coşkunçay D., Alkış N., Özkan Yıldırım S. (2015). Öğrenme Yönetim Sistemlerininin Kullanmasını Etkileyen Faktörlerin Belirlenmesi: Teknoloji Kabul Modeli Yaklaşımı. YAEM 2015: 35. Ulusal Yöneylem Arastirmasi ve Endustri Mühendisligi Kongresi, Ankara.
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