

# The communication infrastructure during the learning process in web based collaborative learning systems

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## ABSTRACT

As people adopt *lifelong learning* as a key strategy to succeed in the modern knowledge society and conventional teaching styles of classroom lecturing are supplemented by computer-supported collaborative distance learning opportunities, traditional roles of learners and educators may change. The identification and meaning of actor roles and their embeddedness in social systems have a long tradition in social sciences [Freeman 2004; Simmel 1984]. In education sciences, learning is traditionally conceptualized as an adaptive knowledge construction process [Bruner and Piaget 2009]. This view has started to be extended by also taking the network structure and group dynamics during the interaction process of teachers and learners into account [Gergen 1985]. Based on this theoretical background, in this research teachers and students are examined by their embeddedness in different communication networks in macro and micro perspective in remote e-learning communities. By performing structural analysis on the relational data we identified the role structure of actors with three common communication roles, and five emergent network roles of actors as well as the relationship between network structure and learning processes. The results of the study put us in a position to describe the impact of actor positions for the communication behavior in the digital knowledge process in collaborative learning communities.

## Categories and Subject Descriptors

H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – *Collaborative computing, Computer-supported cooperative work, Web-based interaction.*

## General Terms

Human Factors

## Keywords

Learning networks, Role analysis, Emerging roles, Communication roles, Network position, Social learning, Social Network Analysis (SNA), Web-based collaborative learning,

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Relational content analysis, Computer-supported collaborative learning (CSCL), Communities of Practice (CoP).

## 1. INTRODUCTION

Every person as a social actor adopts different social roles [Linton 1936] with varied “identities” in diverse “stories” [White 1992] in his everyday life. However, only a few actors having more specific function [Lewin et al. 1936] and gaining greater influence in their social context than others. Among other factors, this depends priority on their special property of embeddedness into their surrounding [Granovetter 1985; Luhmann 1984]. Therefore, the systematic characterization of actor roles and social structures has been a key topic in various approaches to learning sciences, including those influenced by sociology [Luhmann 1984; Simmel 1890; Tönnies 1887/2005 (2.Aufl.)], social anthropology [Linton 1936], socio-psychology [Lewin 1947; Mead and Morris 1934; Moreno 1934], learning theory [Foucault 1973; Latour and Woolgar 1986; Piaget 1959], and communication science [Lazarsfeld 1940/ 1944]. This study aims to describe the status quo of a web-based collaborative distance learning environment with the view of distribution patterns from a social network perspective. We emphasize the question about the way of information in remote e-learning communities based on Lasswell’s formula about mass communication “Who says what in which channel to whom with what effect?” [Schenk 2002; Schulz 2009] in order to get an overview about the infrastructure in this e-learning environment. In order to describe social actors and their communication structure in learning discussion boards we use the methods and theories from social network analysis (SNA) [Wasserman and Faust 1994; Wellman 1997; Wellman and Berkowitz 1988]. The data were collected from the most popular 120 discussion boards with 834 users and 11030 articles in the distance learning system, called OPAL, that are actively used by eleven universities located in the state of Saxony, Germany. In the case study we use social network analysis (SNA) to investigate network structures and the impact of emergent network roles of actors during the learning process. We analyze the communication infrastructure of participants in learning discussion boards based on the identification of actor roles in the given e-learning environment. We present the social network data in combination with semantic network data as communication networks which denote the collaboration between individuals. We use the relational analysis tool ORA to examine the role structure of actors and the flow of information through the network of learners and educators. We aim to discover the collaboration

between actors by classifying communication roles and examining the infrastructure via structural and positional analysis in order to describe the relationship between social networks and e-learning processes. In general, by performing structural analysis on the relational data we classify the role structure of actors in three typical communication roles and five emergent network roles of actors in the given e-learning environment. In addition with this research we ultimately aim to contribute to a better understanding of the relationship between theories about socio-technical networks, communication, and learning in humans.

## 2. BACKGROUND

One of the first sociological discussions about the role concept has delivered the sociologist Ferdinand Tönnies [Tönnies 1887/2005 (2.Aufl.)]. He classified the social actor as carrier of different social roles and highlighted the distinction between the role of “community” and the role of “society” as an essential feature during the role construction process. Furthermore, sociological discourses about actor roles were provided by e.g. the sociologists Ralph Linton with his first concept of the social role [Linton 1936], Talcott Parsons with the transfer of terms of evolution processes in social systems [Parsons 1951], and Robert K. Merton with the introduction of role models and the Matthew effect [Merton 1957]. Later, with his concept of “Homo sociologicus” [Dahrendorf 1969] the sociologist Ralf Dahrendorf has introduced theories about social roles in the German sociology. From sociological perspective social actors construct their different social roles depending on their social environment. The social psychological view of social roles was strongly influenced by the psychologist George H. Mead. Mead’s theory of socialization is based on the “Self” as a social construction process, a product of society and social interaction (Mead 1934; S. 364 f.). Furthermore, the classification of the social role from micro sociological view are shown by the cognitions of the social psychologists Jakob L. Moreno [Moreno 1934], Kurt Lewin [Lewin 1947], and Fritz Heider [Heider 1946]. Beside Simmel, they are considered to be the most important pioneers of constructivist learning models and precursors of the social network theory. Since the mid-20th century, particularly communication scientists have looked for a systematic description of actor roles in the communication process. The sociologist Paul F. Lazarsfeld is regarded as the most essential pioneer in the communication science. Lazarsfeld and his lackey Elihu Katz discovered the model of the *Two-Step-Flow*<sup>1</sup> of communication in their studies during the U.S. election campaign in the year 1944. They have detected in their media studies the different concepts of roles by “leaders“ and “followers“ [Lazarsfeld 1940/ 1944]. Lazarsfeld and Katz have manifested the model as “opinion leader”<sup>2</sup> concept in the communication sciences. This and further studies of Lazarsfeld and Katz about the personal influence [Katz

et al. 1955] are considered as milestones in the communication theory [Schenk 2002]. Due to the rapid technological development of the last 35 years has been clear a increasingly rethinking of the education culture [Lattemann and Köhler 2005]. In particular, the demand for new advanced learning theories which explain the digital knowledge transfer process<sup>3</sup> moving to the foreground of modern education sciences. The importance of online communities and the increasing need for improved digital-oriented knowledge management were first centered in education science by the social scientists Jean Lave and Etienne Wenger. They assigned this as *situated learning* in the context of academic research [Lave and Wenger 1991]. With their *Communities of Practice* (CoP) approach they discussed the phenomenon of group dynamics in digital knowledge networks. They defined CoP as “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly” [Lave and Wenger 1998]. With the rise of the computer as multidirectional communication staff, the understanding for the process of knowledge creation and knowledge management has changed fundamentally and the term collective learning was introduced as new paradigm in the context of education sciences [De Laat 2001; Dillenbourg 1999]. Since that time, the scientific discussions about learner roles changed increasingly. The current frontend research in this area focus on the interdisciplinary cooperation of findings about computer science, education science and psychology [Engeström 1999; Fischer 2007]. Above all, content analysis studies determine the current role research in the area of educational technologies (e.g. in [Bruhn 2000; Hammond 1999; Hara et al. 2000; Strijbos and Weinberger 2010; Weinberger 2005]). A learning theoretical study approach about *Computer-supported collaborative learning* (CSCL) has introduced the learning theoretic Georg Siemens in the year 2004 in: “Connectivism: A Learning Theory for the Digital Age” [Siemens 2004]. He highlighted, that the implementation of new learning theories in the age of web 2.0 is associated with social live, social communication and informal learning. Thereby, learning is understood as process between actors and their embeddedness in a social environment and it was introduced as *Connectivism theory* [Siemens 2004] in the context of research in education sciences. Even, the Canadian Stephen Downes emphasized in his scientific article about *E-Learning 2.0* in 2006 the popular position of the social integration of actors in social networks during the knowledge transfer process [Downes 2006]. In this context the network-analytical studies [de Laat et al. 2007; Marcos et al. 2008; Strijbos and De Laat 2010] gaining in importance increasingly [de Laat, Lally, Lipponen and Simons 2007]. Based on this theoretical background, in this study social actors shall be examined by looking for characteristics of participants through social embeddedness in the different communication networks in macro and micro perspective.

## 3. DATA

The relational data were collected from discussion boards of the e-learning system OPAL. This learning management system is currently the most popular e-learning system in higher education in the state Saxony, Germany. OPAL combines currently

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<sup>1</sup> Although their study “The People’s Choice” (Lazarsfeld et al 1944) originally was not designed to test the hypothesis of a two-step-flow of communication (Katz 1957: 62), they discovered the different communication roles.

<sup>2</sup> In the 1960s, Troidahl developed further the Lazarsfeld opinion leader concept and added to the theoretical model, the balance theoretical concept of Heider (Troidahl 1966, 611f.) in order to show the limits of the Two-Step-Flow model of social psychology view.

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<sup>3</sup> Not the technical implementation of new learning media present a problem for education researchers, but the didactic and conceptual treatment of the subject matter, the timing and motivation schemes for digital learning environments has gaps.

collaborative blended learning activities of 11 universities in the state Saxony, Germany, and is administered by the Educational Portal Saxony GmbH. The learning system itself supports the most popular forms of collaborative learning scenarios and is based on a core of modern AJAX technologies, such as forums, learning groups, wikis, ratings, tests, etc. The original data set includes 5808 participants (U) with 49863 posted articles (W) in 2567 different discussion boards (F). After an iterative selection process of highly frequented discussion boards and most popular users, we generate a selected data set with 834 participants (U) with 11030 posted articles (W) in 120 discussion boards (F) over a period ranging from 2005 to 2010 for further analysis of actor roles and structures. The selection process itself we have fully described in our previous research work with the working title "Identifying and Integrating Social and Structural Roles for the Case of Collaborative E-Learning Environments." [Stuetzer et al. 2010].

**Table 1. Selected learning network**

	Original	Selected
No. of Users (U)	5808	834
No. of Forums (F)	2567	120
No. of Articles (W)	49863	11030

The communication network data are defined as bipartite network which consists of two types of nodes. Our communication network consists of:

- Nodes representing participants in discussion boards (U) that have at least one post in a forum (label for node type: actor).
- Nodes representing the discussion boards (F) itself, which contain at least one article (label for node type: resources).

The participants, who did not post any contributions e.g. read-only participants, were not recorded. Thus, it could not be explored isolated individual actors (as known as "lurkers") in the multimodal communication network. Since, isolates were disregarded, the behavior, impact and roles of lurkers is not considered in this study. The connections or links between the nodes or actors are defined as posted contributions which were posted by at least one participant in at least one discussion board (Actor-Resources-Association (UxF matrix)).

## 4. METHOD

In order to describe emergent network roles structurally, we use SNA as exploration and analysis method. SNA is generally used as a scientific research tool to describe social actors and their relationships. It seeks primarily to provide an explanation of how social behavior and actions work by the influence of social embeddedness. SNA is a body of methods and theories that supports people in exploring, describing and reasoning about social actors and their relationships [Scott 1991]. "One of the primary uses of graph theory in social network analysis is the identification of the most important actors in a social network." [Wasserman and Faust 1994]. In general, social networks are represented as graphs  $G = (N, R)$ , which are characterized by nodes  $N$  and edges  $R$ . In our case, the nodes  $N$  represent users of

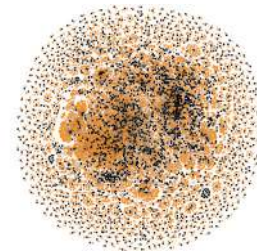
the learning network, and the edges  $R$  represent relations among these users. The advantage of this formal description is that it can be described various networks through the same methods and algorithms and can be integrated in the particular monitoring context [Jansen 2006; Wasserman and Faust 1994]. In this study, we used the SNA software tool ORA, which was developed under the direction of Kathleen M. Carley at the CASOS Center at CMU. The tool is publically available for research purposes ([www.casos.cmu.com](http://www.casos.cmu.com)).

## 5. RESULTS

Our dataset allows us to classify different role structures of learners and educators in the distance e-learning system from a macro and micro network perspective. We first deliver a description of the network structure and present our findings regarding the communication behavior as well as the positional power in the communication process. Next, we describe different types of actor roles of communication marked by their specific way of interaction in discussion boards. The actor roles are classified in two ways, first, by the way of posted contribution of users, and second by diversity of the user's interaction via positional analysis. With the view of the communication structure we describe the identification of three types of communication roles in macro level and five emergent network roles in micro level both via descriptive statistic and network analysis.

### 5.1 Network Analysis results

The selected learning network consists of 834 participants (U) in 120 discussion boards (F) and 11030 posted contributions (W). The network in one-mode-association features the total of 954 nodes, 1455 edges, and a density value of ( $D=0.04$ ). On average, each forum has seven users and 92 posts per forum. Users with 13 or more posts are considered as above-average activity users in the learning network. These users interact in a very heterogeneous way, e.g. they actively contribute to 10 or more different forums and post at least 35 articles within and across forums.



**Figure 1. Entire learning network**

After the iterative selection process<sup>4</sup> the network features just one single weakly high-connected component (Components=1; Isolates=0), which has a high efficiency value for local and global information transfer (Krackhardt efficiency=0.96).

<sup>4</sup> STUETZER, C.M., CARLEY, K.M., DIESNER, J., KOEHLER, T. AND THIEM, G. 2010. Identifying and Integrating Social and Structural Roles for the Case of Collaborative E-Learning Environments. Unpublished Paper. Presented on Sunbelt XXX., July 2010, Riva del Garda, Italy.

The average length of the path between any pair of message posters and receivers is 2.9. The longest shortest path (Diameter) through the whole network is on average 6.0 steps long per post. These results confirm Milgram's theorem of "Six Degrees of Separation" and Granovetter's concepts of "Strength of the Weak Ties" and "embeddedness" for the case of an e-learning system [Granovetter 1978; Milgram 1967].

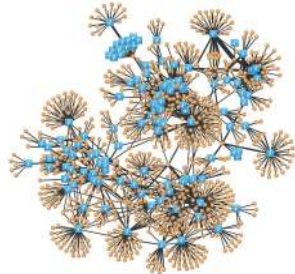


Figure 2. Selected learning network

Table 2. Statistics of the selected learning network

	Original	Selected
Nodes	8375	954
Edges (Single)	10843	1455
Isolate count	0	0
Density	0.00	0.04
Component count	618	1
Diameter	13	6
Avg. Path Length	4.5	2.9
Network fragmentation	0.55	0
Krackhardt connectedness	0.45	1
Krackhardt efficiency	0.99	0.96
Degree centraliz.(DC) <sup>5</sup>	0.05	0.25
Betweenness.centraliz.(BC) <sup>6</sup>	0.04	0.20

## 5.2 Structure of communication

The examination of the communication roles were inspired by Lazarsfeld's mass communication concept of "leaders" and "followers" [Lazarsfeld 1940/ 1944]. The user behavior was examined with the help of relational text data which were defined by their different ways of posted contributions during the communication process. Thereby, in the first step the articles of the participants were classified by starter and follower articles. The analysis of the network has result the following three types of communication roles, which were very noticeable in the 120 most attractive forums of the 834 participants:

- Initiator
- Follower
- Role Switcher.

<sup>5</sup> Degree centralization of the network is a measurement for communication activity for actor networks [Scott, 1991].

<sup>6</sup> Betweenness centralization of the network is a measurement for information flow control for actor networks [Freeman, 1979].

Table 3. Statistics of communication roles

	Initiator network	Follower network	Role Switcher network
No. of Forums (F)	37	83	120
No. of Users (U)	99	405	330
No. of Articles (W)	124	1279	9627
Degree centraliz. (DC)	0.75	0.92	0.95
Between. centraliz. (BC)	0.01	0.02	0.36
Network fragmentation	0.89	0.9	0
Krackhardt connectedness	0.11	0.12	1

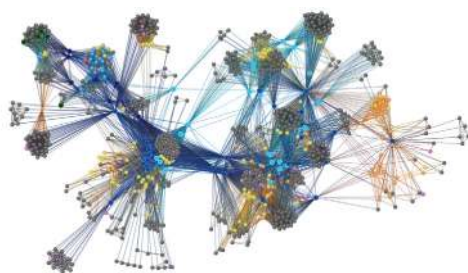
**(1) Initiator.** The participants, who were only identified through starter contributions, were assigned to the role of the *Initiator*. Initiators are forum users who are taking only the starter role of a discussion board. The Initiator network includes 99 participants (approx. 12% of all participants in the SubLearn network) in 31% of the forums with 2.7 participants per forum. The Initiator is regarded as the most inactive user ( $DC(U)=0.001$ ) in the learning network with average 1.3 articles and approx 1.7 posts per user per forum ( $WC(U)=0.0001$ ). By setting of only about 1.2 articles in different forums, the Initiator interacts very biased and is due to its low communication activity within its network ( $DC=0.75$  ( $U \times U$ )) comparably less communicative. The Initiator network is highly fragmented ( $Fragmentation=0.89$  ( $U \times U$ )) and is especially characterized by many individual players (15 isolates) which shows the low willingness of collaboration of the Initiator. The Initiator network has due to the low heterogeneity ( $BC=0.01$  ( $U \times U$ )) and low connectness (Krackhardt-connectivity = 0.11 ( $U \times U$ )) only a minor influence at the transfer of information process. Thereby, the examined learning network consists of approx. 78% instructed forums and about 2/3 (approx. 69%) of all the participants follow the formally instructed discussion forums. So, the Initiator can be identified as topic generator who specifically takes care to setting its instructed content.

**(2) Follower.** The Followers occupy with 405 participants (approx. 49% of participants) in 69% of the forums and 4.9 users per forum the quantitative largest proportion of the examined learning network. They are these participants who only respond to articles or follow other posted contributions. Thereby, the Follower is characterized by mainly so-called "reply of posts". A Follower is an active user of the learning portal and interacts on average with 3.2 articles with about 8.2 articles per user per forum ( $WC(U)=0.0003$ ). With approx. 1.4 different forums per each participant, the Follower is only less interactive ( $DC(U)=0.0012$ ) but he takes by its high level presence and mean activity among themselves a special role in the communication process ( $DC=0.92$  ( $U \times U$ )). With the user group of the Followers in the e-learning network, the influence of the critical mass (Watts & Dodds, 2007) can be shown. The Follower is identified as advice seeker in the initiated learning network, who helping the brokers and gatekeepers to their central position of power in the knowledge transfer process [Watts and Dodds 2007]. By the global decentralization ( $BC=0.02$  ( $U \times U$ )) and the high level fragmentation of its network ( $Frag=0.90$  ( $U \times U$ )) the Follower exercises less influence in the process of information transfer but he is considered as the essential fundament in the digital knowledge transfer process of the blended learning system.

**(3) Role Switcher.** All participants in the discussion boards, who have both follower and initiator articles, were characterized in this study as Role Switcher. They switch or change their communication role depending on the discussion board and the topic. In one discussion board they are regarded as Initiator, because they take the role of topic giver or starter of a contribution. In other forums they take the role of a Follower, where they can be identified by their really active scripting behavior. The Role Switcher has the special role of piers in the interaction process. The Role Switcher network consist of 330 participants (approx. 40% of all users in the SubLearn network) with 9627 articles in 120 discussion boards and approx. 2.8 users per forum. The Role Switcher network is characterized through by a single high-connected component (Frag=0,00 (UxU)) in which every actor is weakly connected to everyone else in a distance of approx. 35.2 steps. Through the highly connectivity in the participant network (Krackhardt-Connectivity=1.0 (UxU)) the efficiency for the information transfer process is really high (Krackhardt-Efficiency=0.92 (UxU)). While the Initiators are only active in approx. 1/3 forums (31 forums) and the Followers actively works on approx. 2/3 forums (69 forums) of all the forums, the Role Switcher using on average at least one time in every forum (120 forums). Role Switcher work with approx. 29.2 articles per user on average with 129.5 articles per user per forum extremely active (WC(U)=0.003). They interact with approx. 6.5 different forums per participant highly heterogeneous (DC(U)=0.003) and hold through their highly collaboration ability (DC=0.95 (UxU)) within the Role Switcher network a mightily central position (BC(U)=0.006) in the learning network. By the global centrality of its network (BC=0.36 (UxU)), they can also bring different information of the digital learning forums together and can distribute gained knowledge in transformed shape. Thus, they regarded as substantial element in the growing and diffusion process of information within the digital knowledge transfer process.

### 5.3 Positional analysis

In order to classify emergent network roles in micro perspective, existing measurements of positional analysis were applied with the help of the relational analysis tool ORA [Carley and Reminga 2004].



**Figure 3. Infrastructure of actor roles**

For identification of network roles were introduced and established standard network metrics for activity (Degree centrality (DC(U)<sup>7</sup>), global centrality (Betweenness centrality

<sup>7</sup> Degree centrality is a measurement for communication activity for a node [Freeman, 1979].

(BC(U)<sup>8</sup>), local centrality (Eigenvector centrality EC(U)<sup>9</sup>), and intensity (Weight centrality WC(U)<sup>10</sup>) for individual participants. The calculation of the values follows in general the definition from the relational statistics [Freeman et al. 1991; Freeman et al. 1989]. Were the values above-average high, we coded the nodes with 1 (+) otherwise with 0 (-). First, with the help of the introduced coding scheme we identify eleven different types of network positions of actors. Then, we summarized the following five emergent actor roles in micro perspective through local and global positional similarities of network positions.

**Table 4. Coding scheme of emergent roles**

Code	Emergent role	DC (U)	BC (U)	WC (U)	EC (U)
0 0 0 0	Sightseer	-	-	-	-
1 0 0 0	Cosmopolitan	+	-	-	-
1 0 1 0		+	-	+	-
1 0 0 1		+	-	-	+
1 1 1 0	Broker	+	+	+	-
1 0 1 1		+	-	+	+
1 1 0 0		+	+	-	-
1 1 1 1		+	+	+	+
0 0 1 0	Individualist	-	-	+	-
0 0 1 1	Alpha Dog	-	-	+	+
0 0 0 1		-	-	-	+

Via the positional analysis in micro view we assigned the following actor roles of:

- *Sightseer*
- *Cosmopolitan*
- *Broker*
- *Individualist*
- *Alpha Dog.*

**Table 5. Statistics of emergent roles**

	Users (U) [%]	Forums (F) [%]	Articles (W) [%]
<b>Sightseer</b>	68%	61%	13%
<b>Cosmopolitan</b>	17%	66%	21%
<b>Broker</b>	12%	100%	60%
<b>Individualist</b>	2%	10%	4%
<b>Alpha Dog</b>	1%	3%	1%
	<b>834</b>	<b>120</b>	<b>11030</b>

**(1) Sightseer.** The emergent role of the *Sightseer* corresponding with the common participant from the crowd, who are especially

<sup>8</sup> Betweenness centrality is a measurement for information flow control for a node [Freeman, 1979]

<sup>9</sup> Eigenvector Centrality is a measurement for group leader function for a node [Bonacich, 1972]

<sup>10</sup> Weight centrality is a measurement for the centralization of strength of ties for nodes [Granovetter, 1983]

characterized by their above-average presence and their low activity and centrality indices ( $DC(U)=0.001$ ;  $WC(U)=0$ ;  $BC(U)=0$ ;  $EC(U)=0$ ). The network of the Sightseer is characterized by highly fragmented clique building ( $Frag=0.96(UxU)$ ) and shows by the low connectedness with each other (Krackhardt connectivity= $0.04(UxU)$ ) extremely low efficiency values for the global transfer of information (Krackhardt-Efficiency= $0$ ) with comparatively high collaboration activity ( $DC=0.91(UxU)$ ) within the Sightseer cliques. The Sightseer exerts with its extremely low global and local centrality ( $DC=0.06(UxF)$ ,  $BC=0.001(UxF)$ ) with less impact on the diffusion and growing process in the learning network. The Sightseer can also be identified as a typical Follower. Its network consists of approximately 62% of Followers, about 21% of Role Switchers and approx. 16% of Initiators. The largest quantitative proportions of the Sightseers were found in *formally instructed* learning forums with approx. 77%.

**(2) Cosmopolitan.** The *Cosmopolitan* combines the typical characteristics of a active user who search, exchange and collect information in different forums with especially above-average high activity indices ( $DC(U)=0.003$ ). The Cosmopolitan takes approx. 17% ( $U=144$ ) of the whole network and is represented in about 66% of all forums with approx. 1.8 users per forum. He is characterized by its above-average heterogeneous activity with a total of 2281 articles, 15.8 articles per user and about 2.5 different forums per user ( $D(U)$ ). The network of the Cosmopolitan is marked by its high interactivity ( $DC=0.92(UxU)$ ;  $0.08(UxF)$ ). Thereby, it comes increasing to cross-group clique building, which has a significant impact on the group-wide transfer of knowledge in the learning network. The Cosmopolitan network has with its high activity a central position ( $BC=0.06(UxU)$ ,  $0.02(UxF)$ ) and is characterized by a mean network fragmentation (fragmentation= $0.77(UxU)$ ) and low connectedness (Krackhardt-connectivity= $0.23(UxU)$ ) in the whole network. Thereby, the interactivity of the Cosmopolitan acts primarily on its efficiency (Krackhardt-Efficiency= $0.72(UxU)$ ) in the diffusion process of information of the network. About 69% of Cosmopolitans can be assigned to the communication role of the Role Switcher, which favors the influence of the Cosmopolitans on the entire network in the knowledge transfer process. About 26% of participants belong to the Follower network, and 5% to the Initiator network. Thereby, the Cosmopolitan was found with about 70% in formal discussion networks, with approx. 22% in Group Switcher network and with 8% in informal discussion networks.

**(3) Broker.** The role of the *Broker* combines properties of diffusers, connectors, and gatekeepers. Thus, they concentrated the properties of the most influential's in the network with the attitudes of above-average activity ( $DC(U)=0.006$ ), connection strength ( $WC(U)=0.008$ ) and local ( $EC(U)=0.119$ ) and global centrality ( $BC(U)=0.021$ ). The Broker is regarded as an innovation giver, information distributor, and influential participant in the learning network. The Broker takes approx. 12% of the learning network ( $U=100$ ) with about 0.8 participants per forum and are characterized primarily by its high activity indices with 6666 articles, 66.7 articles per user and 171.4 articles per user per forum ( $W(U)$ ) in on average 8.5 different forums. The network of Brokers is extremely complex and highly connected ( $Frag=0$ ; Krackhardt connectivity= $1$ ). With the comparative highest value of Krackhardt efficiency of  $0.77(UxU)$  is the Broker network the most efficient user network in the information transfer process of this e-learning environment. Due to the high

communication activity ( $DC=0.92(UxU)$ ) and the central position ( $BC=0.68(UxU)$ ), the Broker network is considered as building bridge for growing and diffusion of information. At the search for information in the Broker network are the principles of the shortest paths, because everyone is connected to everyone on average path length with only 2.5 steps (path length= $2.43$ ) and a maximum distance of 5 (Diameter= $5$ ). The Broker is a typical Role Switcher with approx. 90% of the learning network. Thereby, there are only 10% of Followers and no Initiator in the Broker network. In addition, Brokers are also Group Switchers (approx. 55%), that means, they switching constantly in his interactions between initiated formal and informal discussion boards. Only 33% of Brokers are located exclusively in formal and 12% in informal discussion networks.

**(4) Individualist.** The *Individualist* corresponds to the role of experts. He is regarded as a owner of special knowledge and is characterized by its above-average connection strength ( $WC(U)=0.002$ ). The Individualist includes approx. 2% of all users and is represented in only 10% of the forums with approx. 1.5 users per forum. With a total of 445 articles and 24.7 articles per user and 29.4 articles per user per forum, he is considered to be as forum-specific user ( $DC(U)=0.001$ ) in the e-learning system. The Individualist network, similar to the Sightseer network, is highly fragmented ( $Frag=0.9(UxU)$ ) and is established clique-like (Isolates= $10$ ; Components= $12$ ). With its low connectedness (Krackhardt-connectivity= $0.10(UxU)$ ) and low centrality measurements ( $BC=0$ ) the Individualists network has little efficiency (Krackhardt-Efficiency= $0$ ) in the global information flow. The Individualist takes most often the role of the Role Switcher (approx. 89%) and is constantly changing its communication role between the Follower and the Initiator depending on the topic and the forum. He organized itself either in formal (approx. 50%) and informal discussion networks (approx. 39%), but he never changes its group role.

**(5) Alpha Dog.** The *Alpha Dog* combines the characteristics of high local centrality values ( $EC(U)=0.03$ ) of a topic giver and organisator of a discussion board. This "*leading wolf*" takes about 3% of the whole network and is with approx. 2.3 users per forum, a total of 161 articles, approx. 23 articles per user and about 32.3 articles per user per forum only less active. Alpha Dogs interact especially forum-specifically and depending on the topic and so they are low interactive ( $DC(U)=0.001$ ). The network of Alpha Dogs is established clique-like by their average fragmentation ( $Frag=0.67$ ). The Alpha Dog network has comparatively low activity ( $DC=0.74(UxU)$ ) and low connectedness (Krackhardt-connectivity= $0.33$ ) indices. It is characterized by only less global centrality values ( $BC=0.2$ ). In the global information transfer are the Alpha Dogs less efficient (Krackhardt-Efficiency= $0.00$ ). The Alpha Dog can be marked by the role of Role Switcher (approx. 71%) and to 29% to the Follower. The Alpha Dog can be found especially in informal discussion boards with about 86%.

## 6. SUMMARY AND CONCLUSION

The knowledge management in the modern society of the 21st century is characterized by innovation, distribution, and sustainability of information with the help of educational technologies. With this research we aimed for an improved understanding of the mechanisms of interaction between the theories of socio-technical and communication networks and the human impact on learning. We discuss and adapt elements from theories and models from socio-technical science, communication

science and learning theory for our SNA approach. In this study, we have detected the infrastructure of social roles in a digital learning system through SNA. We characterized the structure of communication roles, and emergent network roles of learners and educators in the given e-learning environment from micro and macro network perspective. This study discovered the structures which are characteristically for the diffusion processes of information and the growth of knowledge networks in this e-learning environment. The theoretical elaboration has shown that the impact of social roles and structures are widely used research fields with interdisciplinary characteristics. As limitations of the study we could explore, first, the manually handling with the complexity of the data set, second, the specifically data from the given instructed e-learning network, and thus the comparability of the results. Nevertheless, the research put us in a position to get sociological, communicational, learning theoretical and network analytical insights about the construction and behavior of social learning groups. The impact of social structures, that are evolving highly heterogeneous under the influence of educational technologies, is considered to be as most significant milestone in the development and transfer of learning management systems in the 21st century. The results of this study put us in a position to describe social behavior for the case of roles of actors in collaborative learning communities and the knowledge transfer processes they engage.

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