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HOW DO COMMUNICATION STRUCTURES SHAPE THE PROCESS OF KNOWLEDGE TRANSFER? - AN AGENT-BASED MODEL

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Abstract. Knowledge diffusion is a complex process. Knowledge is intangible and therefore is not easy to capitalize within an organization, or share between a set of individuals. The aim of this paper is to study the impact of two different structures of communication on both processes of knowledge transfer and individual learning, in the context of a community of practice. We will specifically compare two types of communication structures (through face-to-face interactions and through a forum) by using agent-based models. Results show that each structure has a different impact on individual learning and knowledge transfer. Though, communication through face-to-face interactions seems to make individuals learn slower than on a web forum. Conclusions are widely discussed.

Keywords: knowledge; communication structure; communities of practice; agent-based models.

1 Introduction

The analysis of knowledge formation and diffusion became very important for organization research since knowledge based economy appeared. It has been recognized that it represents a crucial asset that every organization should take care of, just like every other asset and yet, in a quite different way [1]. Knowledge is intangible and therefore is not easy to capitalize within an organization, or share between a set of individuals. Some authors studied the economic features of knowledge, as well as its transfer and sharing among individuals [2, 3].
Knowledge is acquired through a learning process, and we can distinguish several levels of learning in the literature [4, 5, 6, 7, and 8]. This process is very important for the sharing and capitalization of knowledge within an organization. However, as stressed by [9], "*the traditional vision of learning does not fully account for what actually occur within firms. It fails to acknowledge the importance of the complex cognitive structure of the firm from which stems learning processes.*" The authors suggest considering a firm as a set of overlapping communities, and they studied the

role played by such entities in the process of organizational learning. Starting from this point, it seems important to study the process of learning *within* these communities. We will focus on communities of practice (CoPs).
There is a rich literature on CoPs in the knowledge management field. However, economic literature shows that no particular research was led about learning and knowledge transfer within a CoP. We consider that it is an important issue that we wish to address in this paper.
Indeed, we aim at answering the following question: *what impact do structures of communication have on knowledge transfer within a community of practice?*
In order to do so, we choose to compare two types of communication structures: communication through face-to-face interactions and communication through a web based forum. This paper will be structured in three parts: the first one gives a background literature on communities of practice and learning; then we will present the agent-based models in the second part. The third one is a presentation of the results, followed by discussion and concluding remarks.

2 Communities of Practice (CoP) and learning

This notion appeared for the first time in the early 1990's, in the work of [10]. A CoP is seen as one of the most efficient concepts to study the process of knowledge sharing in groups [11, 12, and 13]. A community of practice (CoP) is defined as an informal network composed of agents working together in the development of a common practice [12]. They interact and exchange knowledge and ideas and build a common repertoire of representations. According to [13], a CoP's definition is based on three major points:

- the practice that binds the members of the community together;
- the mutual and voluntary commitment of its members to the community's objectives;
- a repertoire of common representations built through repeated interactions.

According to this author, CoPs' success is essentially due to their informal and independent status, as well as to the voluntary engagement of their members and the knowledge created through their interactions.
In this paper, we will consider that individual learning occurs when an individual increases his/her competency. [8] state that, in reality, it is not possible to consider individual learning as an isolated process, as it is always related to a social context with social norms and influences. Learning is thus a socially constructed phenomenon [14]. In the specific context of a CoP, [10] highlight the role of the social participation in the process of learning. Indeed, according to these authors, new comers play an essential part in the diffusion of knowledge across the community, as stresses by the "Legitimate Peripheral Participation" theory (LPP). We will see to what extent this theory is relevant, according to the structures of communication used. The model we build will be described in the next section.

3 The model

As previously mentioned, the model we build aims at comparing two ways of communication through two types of simulations:
Simulations with communication though face-to-face interactions: here, the most competent agents in the community are explicitly identified to answer eventual questions. In this case, agents always ask these particular agents;
Simulations with communication through a forum: where agents simply post a question on a forum, and wait for an answer. Here, agents answer posted questions according to their knowledge and availability.

3.1 The agents

We have a population composed of 110 agents. Each agent is characterized by the following features:
Knowledge vector: this vector is composed of 100 knowledge concerning 100 different subjects.

Subjects →	1	2	…	99	100
Knowledge vector →	1	0	…	1	1

Fig. 1. Example 1: an agent has the knowledge concerning subjects 1, 99 and 100 but knows nothing about subject 2

Competency: defined as the number of subjects an agent knows about.
Memory: where an agent stocks information about past interactions.
Availability: defined by the number of questions that an agent is able to answer per time-step.
Tolerance threshold: defined as follows:
- In simulations with communication through face-to-face interactions: it is defined as the number of unanswered questions that an agent is willing to accept from another agent, before deciding not to ask it anymore.
- In simulations with communication through a forum: it is it is defined as the number of unanswered questions that an agent is willing before deciding to leave the community.

According to these features, every agent is potentially a knowledge-seeker or a knowledge-provider, or both, according to his competency.
In terms of answering questions and providing knowledge, we consider that the population of agents is divided in two parts: priority knowledge-providers (*pkp*) and secondary knowledge-providers (*skp*). The members of the former have knowledge about all the subjects of an agent's knowledge vector; they have a competency equal to 100. Whereas the latter's members have a competency greater than or equal to a

competency threshold (CompMin) defined as the minimal competency required in order to have the ability for answering questions. This threshold is equal to 75[1].
In terms of asking for knowledge, each agent that has a competency smaller than 100 is a knowledge-seeker. This includes *skp* as well.
The initial structure of the population is the following: 1 agent with an initial competency equal to 100; 9 agents with an initial competency equal to 75; 100 agents with an initial competency equal to 0.

3.2 Interaction rules

An interaction is defined according to the type of simulation used:
- *In simulations with communication through face-to-face interactions*: an interaction is defined by a question asked by agent *a* to agent *b*, and an answer given by agent *b* to agent *a*.
- *In simulations with communication through a forum*: an interaction is defined by a question posted by agent *a* on the forum, and an answer posted by agent *b* on the forum.

Each agent can only ask one question per time-step, about a subject it knows nothing about. And an agent answers a question if it has the specific knowledge asked for and if it is available; otherwise, it will ignore the question.

3.3 Learning process

Each time an agent gets an answer to a question; it raises its knowledge of that particular subject to 1, and won't ask questions about this subject anymore. Following example 1 (cf. Fig. 1), an agent increases her knowledge of subject 2, as shown in figure 2.

Subjects →	1	2	…	99	100
Knowledge vector →	1	**1**	…	1	1

Fig. 2. An agent learns and acquires knowledge about subject 2

3.4 Choosing a knowledge-provider:

- In simulations with communication through face-to-face interactions: agents always choose the most competent agent in the population.
- In simulation with communication through a forum: agents don't choose a particular agent, but post a question on a forum.

[1] We led simulations for several values for CompMin and 75 is the value where the highest number of agents are able to increase their individual competencies.

3.5 Parameters of simulation

Availability: we will make this parameter vary between 1 and 10 questions per time-step.
Tolerance threshold: will also vary between 1 and 10 unanswered questions per agent in simulations with communication through face-to-face interactions, and between 1 and 10 unanswered questions in simulations with communication through a forum.

3.6 Indicators

We will observe the coordination of agents to have access to knowledge. This coordination is captured by the required values of knowledge-providers' availability and knowledge-seekers' tolerance, in order for all agents to become *pkp*.
With the several variations of the simulation parameters, we have 100 different scenarios of simulation. We run each scenario 30 times, and the results presented are the mean results of the 30 iterations of each scenario.
The results can be divided in two parts according to the structures of communication: face-to-face interactions and communication through a forum.

4 Results of simulations:

4.1 Coordination in simulations with communication through face-to-face interactions

The figure below shows the values of availability and tolerance required, in order for all agents to become priority knowledge-providers. In this set of simulations, we can see that knowledge-providers need to be able to answer at least 3 questions per time step, and knowledge-seekers must have a tolerance threshold equal to 5 unanswered questions per agent, in order to reach an optimal level of learning (all agents become *pkp*). Before these values, optimal learning is impossible to reach.

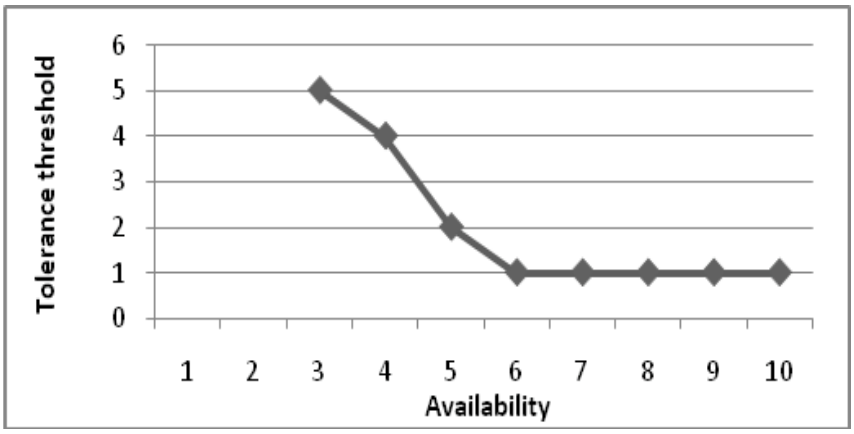

Fig. 3. Coordination of agents in simulations with communication through face-to-face interactions

4.2 Coordination of agents in simulations with communication through a forum

Things are a bit different in simulations with communication through a forum. All agents are able to become priority knowledge-providers as soon as the smallest value of availability, provided that knowledge-seekers accept 7 unanswered questions per agent, before leaving the community. Moreover, optimal learning is always reached when agents' availability is greater than or equal to 5, even when knowledge-seekers are not tolerant at all.

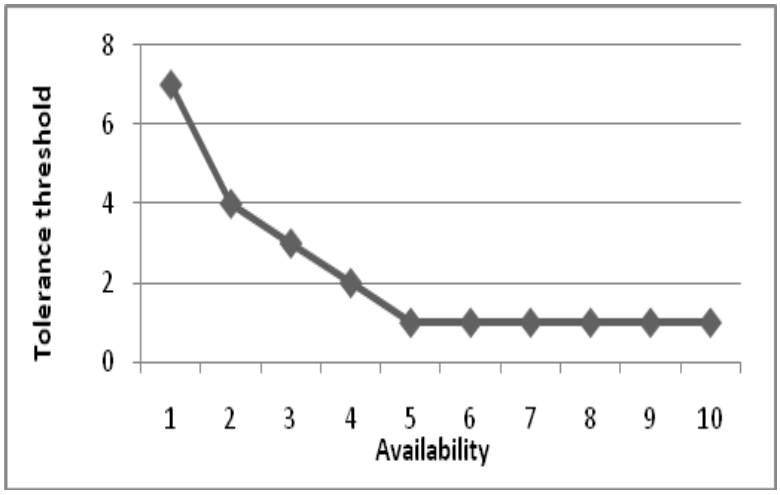

Fig. 4. Coordination of agents in simulations with communication through a forum

5 Discussion and concluding remarks

Results from simulations above stress that agents increase more easily their competencies when they use a forum to communicate, than when communication is based on face-to-face interactions. This can be explained by the strong congestion effect observed in the first set of simulations. In fact, because all agents always ask the most competent ones in the community, and because these knowledge-providers have limited availability, knowledge-seekers don't always get a chance to access knowledge. This congestion effect is obvious if we consider the figure below. This figure shows the graph of interactions within the community, based on "who asks who", at the end of a simulation with availability equals 1 and tolerance threshold equals 10. In this situation, the community has a star-shaped structure, with the priority knowledge-providers at the core of the network.

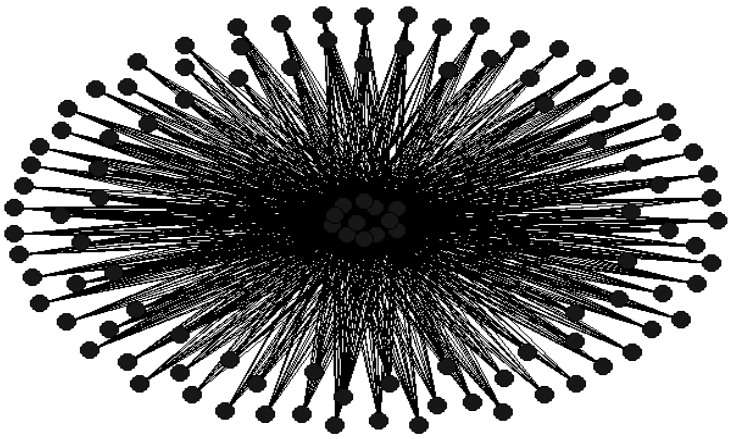

Fig. 5. In face-to-face interactions, the community presents a star-shaped structure (with availability equals 1 and tolerance threshold equals 10)

There is a kind of queuing effect observed here, and it really slows down the learning of knowledge-seekers, when using face-to-face interactions. However, we believe that this problem could be overcome if we follow the legitimate peripheral participation theory, emphasized by [10]. According to this theory, individuals situated at the periphery of a community play an essential part in the process of knowledge diffusion within this community. As a matter of fact, because of the tolerance threshold, it would not be very pertinent that new priority knowledge-providers are initial secondary knowledge-providers. If their availability is not high enough, these agents will soon be ignored by many other agents in the community. Consequently, they won't be asked anymore, and there will not be much new sources of knowledge in the community. Whereas, if new comers are favored in terms of access to knowledge, then the number of sources to knowledge would increase and hence, knowledge would be transferred in an easier way.

Things are different in the second set of simulations. Here, it makes no sense to talk about a congestion effect when communication happens through a forum. Indeed, agents don't ask particular agents, but post their questions on the forum, addressing the whole community rather than a particular set of agents.

To make sure of that, we build the graph of interactions based on "who answers who". As we can see from the figure below, the network structure is different from the previous one. We can see little stars emerging around initial knowledge-providers, and a much bigger one around the forum, where most agents find answers to their questions. This entity stores all the answers provided throughout the simulations, and as soon as the 15^{th} time-step on, when availability equals 1, all knowledge is available on the forum. Hence, all the agents that didn't leave the community so far

systematically get answers to their questions. This explains the large number of priority knowledge-providers at the end of most simulations.

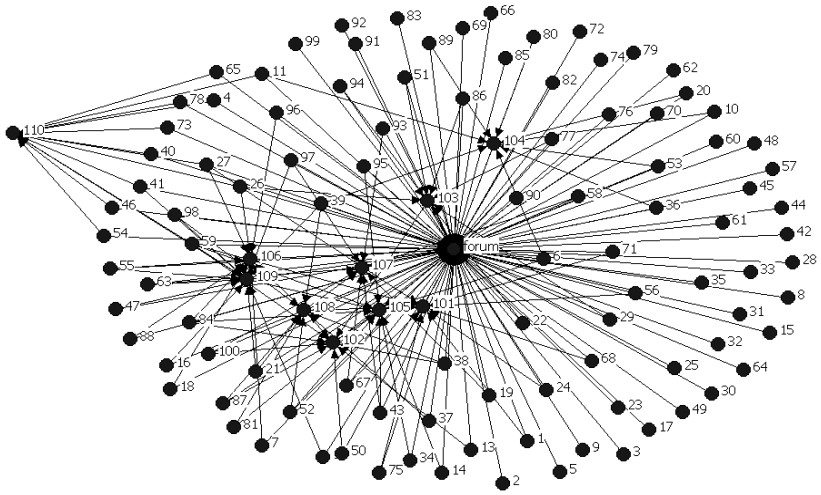

Fig. 6. In communication through a forum, the community presents a hybrid structure between a star-shaped one and a connected one (with availability equals 1 and tolerance threshold equals 10)

Moreover, learning is easier in the second set of simulations because knowledge is **stored** on the forum. It becomes available even when knowledge-providers are not. Hence, from a certain time-step on, all knowledge-seekers can learn and acquire all the knowledge required to become priority knowledge-providers themselves. In this perspective, knowledge can be considered as a public good which no longer depends on the availability of individuals, but on the forum where it can be stored.

Unlike in simulations where communication happens through face-to-face interactions, new comers do not play a central part in knowledge transfer, when a forum is used. Accordingly, the LPP theory is not really relevant in such a context. This theory stresses the importance of a high social participation, in order to enhance individuals' learning. However, this appears not to be essential when using a web-based forum. Though, we are not denying the importance of this theory when using face-to-face interactions as a means to diffuse knowledge.

These results need to be validated, by comparing them to real data. That will be our next step in our research. Another development would be to transpose our model to two different real contexts of learning in order to compare the two situations and stress significant differences. Enhancing knowledge transfer and learning through communication structures can be much more relevant in this perspective.

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