Principles for Cultivating Scientific Communities of Practice

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Abstract. Scientific communities can be seen as a specific type of Communities of Practice (CoP). In this paper we analyze scientific communities from the CoP point of view. We show how models and design principles from CoP can be interpreted and adapted for scientific communities. Taking the CSCL (Computer-Supported Collaborative Learning) community as an example, we instantiate the adapted design principles and trace the development of this community based on an analysis of its first decade of existence (1995-2005). This analysis includes an analysis of CSCL conference proceedings and an analysis of the lists of participants and program committee members of CSCL conferences.

Introduction

The term "*Communities of Practice (CoP)*", coined by Lave and Wenger (1991), has been further developed over recent years and is now widely accepted. It has been defined as "*groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis*" (Wenger et al. 2002: 4).

A number of design principles have been proposed to cultivate CoPs (Wenger et al. 2002). These principles don't aim to design in the sense of specification and implementation of a process, but reveal the thinking behind a design. A design based on these principles and taking into consideration the current situation in the CoP is able to foster the liveliness of the CoP. While there exists substantial research to discuss the CoP approach in various domains (e.g. Allatta 2003 for the corporate context), discussing scientific communities as CoPs is less advanced.

The goal of this paper is to analyze scientific communities from the CoP point of view. Are scientific communities also CoPs? If so, then they can be cultivated as well, i.e. designed in order to foster their liveliness. Models and design principles for CoPs can be interpreted from the scientific community point of view and adapted to the specific characteristics of scientific communities.

The structure of this paper is as follows. After this introduction, we describe the characteristics of scientific communities and how practice in scientific communities changed in recent years (section 2). As an example of a scientific community we selected the international and multidisciplinary CSCL (Computer-Supported Collaborative Learning) community, which is characterized in section 3. We describe the CSCL community using an analysis of CSCL conference proceedings and an analysis of the lists of participants and program committee members of the CSCL conferences. Based on this we are able to discuss and adapt basic CoP models to describe scientific communities (section 4). Similarly, design principles for cultivating scientific communities are derived from generic CoP design principles and explained using data and observations from the CSCL community (section 5). Finally, we conclude the paper and point to some open research questions.

The Nature of Scientific Communities

A scientific community consists of people, usually working in groups of knowledge workers. Each group member is working on a particular aspect of the same overall problem or topic belonging to one or more research fields. In comparison to communities in the corporate context, scientific communities are more heterogeneous and the groups operate relatively independently (Doerry et al. 1997). A scientific community consists of various researchers who have different specialties. Also in each group members have various backgrounds and participate in various scientific communities. These characteristics indicate that scientific communities are Communities of Practice (CoP) in the sense of Wenger's definition mentioned in the introduction section above.

Given the heterogeneous nature of scientific communities in general as well as on the group level, deepening of knowledge and expertise (=learning) doesn't happen as participating in one specific scientific community only, e.g. as a straight path from a novice to an expert. Rather learning involves participating in different communities and switching the role of novice and expert depending on the current situation.

The groups building a scientific community are distributed over a certain region, nation or even world-wide depending on the nature of their research field. For interaction between the community members there are face-to-face meetings (especially conferences and workshops), research findings are distributed in printed form (e.g., as books and journals), and they engage in virtual activities like discussion forums, databases, websites, and mailinglists in order to communicate, cooperate or distribute findings in the community. The definition of the term "practice" for CoPs according to Wenger et al. (2002) focuses on these communal resources that form the basis of communication within a community: "*It (practice) denotes a set of socially defined ways of doing things in a specific domain: a set of common approaches and shared standards that create a basis for action, communication, problem solving, performance and accountability. […]The practice includes the books, articles, knowledge bases, websites, and other repositories that members share*" (Wenger et al 2002: 38).

In addition to the geographical distribution, community members belong to different organizations and cultures; have a different native language etc. This complicates meetings as well as the distribution of findings. On the other hand, the existence of advanced technical communication and cooperation infrastructures allows increasingly global involvement of institutions and researchers in scientific communities (Birnholtz & Bietz 2003). This is visible in the composition of editorial boards, in the attendance at conferences and workshops, in multinational projects and joint publications.

An important change in the nature of scientific communities is caused by rethinking the traditional distinction between basic and applied research, between theory and practice (Stokes 1997). There is an emerging paradigm of what Stokes called use-inspired research, which combines the goals of understanding and use, insight and creation. This points to an additional heterogeneity which characterizes (at least some) scientific communities.

To sum up, a scientific community is a community of practice with

- members working in a common field of research,
- members being distributed across disciplines, organizations, cultures and geographical regions,
- methods from a variety of disciplines and scientific cultures,
- members using a combination of face-to-face interaction and increasingly technology-mediated interaction, and
- at least for some disciplines – members following or even combining practice of basic and applied research.

The CSCL Community as an Example - Data, Analysis, Methods

One example for a scientific community like described in the previous section is the CSCL community. Since a first workshop in 1989 a growing number of researchers participate in this community. An international conference series started in 1995, which includes six passed and one upcoming conference in 2005. Because of the growing interest on the work of this community an international journal of CSCL (ijCSCL) in printed and online (www.ijCSCL.org) form was founded in 2004.[1]

The common research interest of this community is the design and evaluation of computer support for collaborative learning. This interest attracts and builds on the expertise of participants from various disciplines (e.g. computer science, psychology, education science, cognitive science) which also come from different countries and continents (mostly North America, Europe and Asia).

In a retrospect on the first decade of this scientific community our aim here is to analyse the development of a scientific community in order to derive design principles for cultivating scientific communities. For the analysis of the CSCL community we combine several analysis methods.

In order to analyse the international distribution of authors, their continuity and their relationships we used a citation analysis of the CSCL conference proceedings. "*Citation analysis is the formal quantitative analysis of the literature produced by a field and the relationships among people as evidenced by whom they cite in their published articles. Especially in academic disciplines where the importance of publication and citation are high, the bibliographic references used in research documents can be an important mirror of how people in a field construe it. Citation analysis can be used for many purposes. For instance, it is used as a tool for journal evaluation (Garfield, 1972), identification of subgroups or invisible colleges (Crane, 1972; Sachs, 1984), identifying the shared knowledge of a community (Small & Greenlee, 1980), or characterizing disciplines or communities (Chubin, Porter, & Rossini, 1984).*" (Kirby et al., in press).

Citation analysis is used here as a social network approach. Social network approaches (Scott 1991) to scientific communities are based on the members of a community and focus on networks of people linked for example by co-authorship. It utilizes measures such as connectedness, diameter, centralization and density of a community. This has been applied to a number of research fields, too (see Newmann 2004 for an overview). Social network analysis has been applied also in the CSCL community in order to measure the cohesion in collaborative learning teams (Nurmela et al., 1999; Woodruff, 1999; Cho et al., 2002; Nurmela et al., 2003; Reffay & Chanier, 2003).

Furthermore we included the lists of participants and program committee members concerning their international distribution and continuity in order to get a closer look at different groups, each on different degrees of participation , of the CSCL community. Thereby we also analysed the relations between the lists of authors, participants and program committee members.

Data for our citation analysis was mainly gathered by analysing the proceedings of the six CSCL conferences in 1995 1997 1999, 2001, 2002 and 2003

[1] CSCL = Computer Support for Collaborative Learning

(Schnase et al. 1995; Hall et al. 1997; Hoadley & Roschelle 1999; Dillenbourg et al. 2001; Stahl 2002; Wasson et al. 2003). Additionally all available participants' lists were analyzed (CSCL 1999, 2001, 2002 and 2003). All together we included 692 artifacts (e.g. poster, papers), 125 program committee members (PCM), 1187 authors and 1462 conference participants (575 active and 887 passive participants) in our analysis.

For all persons involved in the community we recorded the following data

- **Name**
- **Country and continent**. This data enables us to analyze the distribution of the community.
- **Discipline**. This data enables us to analyze the multidisciplinary character of the community.
- **Conference** in which she/he participated as member of the program committee, as author, or as conference participant. On basis of this data we analyzed the continuity of the community and transitions between the different degrees of participation.

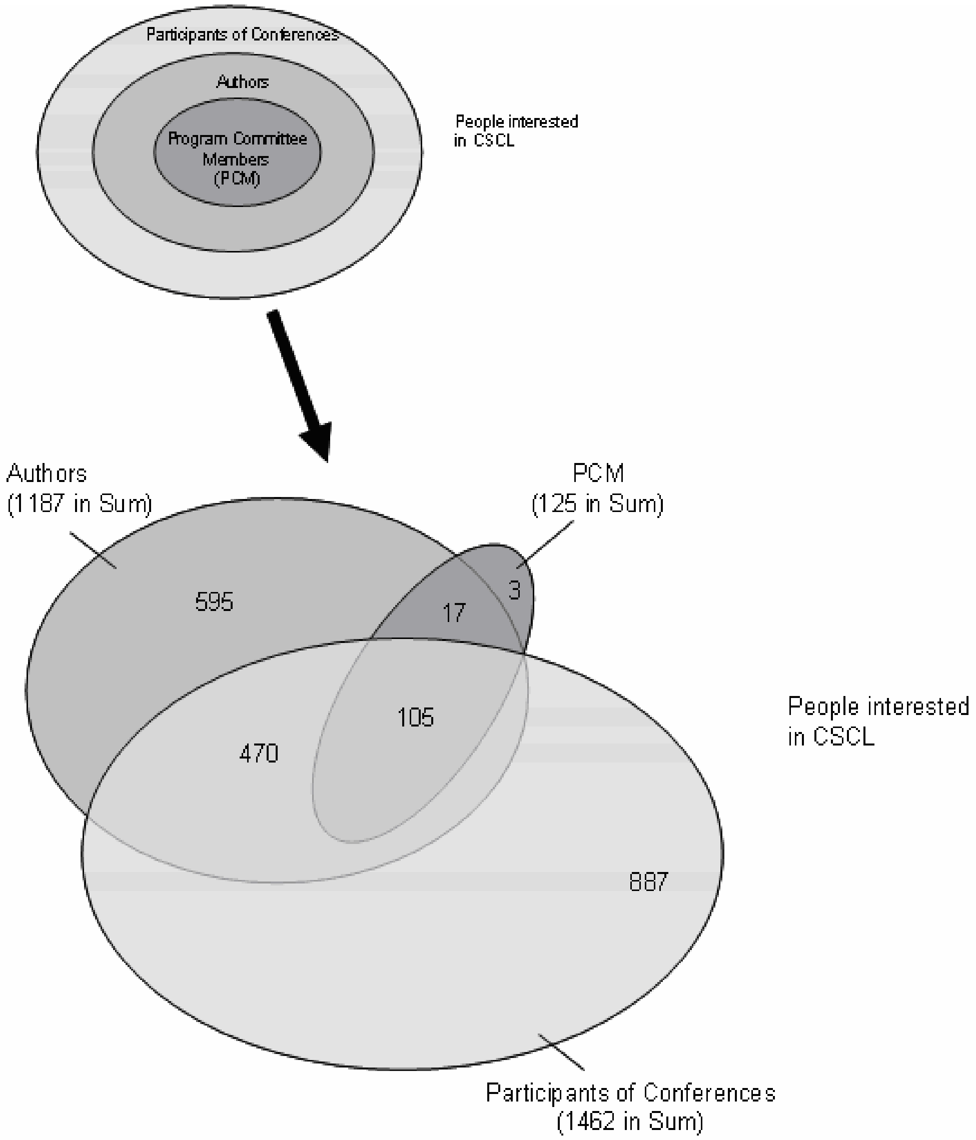
For a further analysis of the active participants – authors –we recorded for each author:

- **Co-authors** for the analysis of (strong) interaction between the participants of the community
- **Referenced authors** for the analysis of (weak) interaction between the participants. From the citations of each artifact we picked those people who participated at least once at an author.

Scientific communities can be analyzed in a number of ways and wrt. different aspects. In this paper we focus on the continuity in order to analyze how stable the CSCL community is and international distribution of the CSCL community members in order to explore how global the community is. An extensive analysis of the development of the CSCL community is ongoing work (see also Kienle & Wessner 2005) and should include for example the interdisciplinarity of the community.

Modeling the Participation in Scientific Communities

Wenger et al. (2002) promote a model for CoPs which classifies community members according to their degree of participation in the community. They differentiate between a core group (including a coordinator), active and peripheral participants and outsiders. Similar degrees of participation also exist in scientific communities. Here, we differentiate between the following groups: organizers, mostly program committee members (= core group), authors of papers (= active participants) and passive participants of conferences (= peripheral participants). Outsiders are people who are somewhat interested in CSCL, e.g. read single papers in conference proceedings, communicate with authors etc. but who are not members of the community.



Different degrees of participation

However, by analyzing the data we found that these groups are not in a “part of” relation like the figure of Wenger et al. suggests and what is shown in the adapted figure 1 at the top. In the CSCL community these groups overlap only partly, e.g. the groups of authors and participants overlap only by 50%. To give consideration to this finding, we rearranged the figure (see fig. 1 at the bottom). This can be explained by a number of reasons. Many institutions enable their researchers only to participate in conferences where they have an accepted paper; and in some cases only one member of the group of co-authors is allowed to go there. Also budget restrictions and teaching load influence the ability to attend international conferences, especially if they are abroad. Further (qualitative) analysis is needed to explain and assess this finding.

In the various groups identified above we found also different degrees of participation. The groups of program committee members, authors and participants are quite heterogeneous wrt. the number of conferences they were involved. For example, from 1462 participants in the last four CSCL conferences 1216 (83.5%) attended only one conference (see table 1 for more details).

No. of confer-ences	No. of participants (data available only for 4 out of 6 con-ferences)	No. of authors (data for all 6 con-ferences)	No. of PCM (data includes the upcoming 7th con-ference)
1	1221 (83.5%)	949 (79.9%)	65 (52.0%)
2	183 (12.5%)	150 (12.6%)	32 (25.6%)
3	43 (2.9%))	61 (5.1%)	15 (12.0%)
4	15 (1.0%)	19 (1.6%)	5 (4.0%)
5		5 (0.4%)	5 (4.0%)
6		3 (0.3%)	1 (0.8%)
7			2 (1.6%)
Sum	1462 (100%)	1187 (100%)	125 (100%)

Table 1: Distribution of participation in three groups

For a further analysis of the group of authors, we divided them into two subgroups according to the intensity of authorship: authors who published at three (half of all) or more conferences vs. authors who published at one or two conferences (see table 2). First, it can be observed that the group of authors at three or more conferences, which denotes the more or less continuous active members of the community, is relatively small (7.4% of all authors). Nevertheless this small group has a great influence on the community. The analysis of the group of authors who are referenced by other authors in the community shows that 18.6% of referenced authors are those who published at 3 ore more conferences. This means that 93.2% of these group members are referenced. The large group of authors who contributed only to one or two conferences (92.6%) has a much lower impact on the community wrt. citations. Roughly one third (32.8%) of these authors are referenced by other authors in the community.

A model to characterize global CoPs is proposed by McDermott & Jackson (presented in Wenger et al. 2002: 127). In this model, various local or regional groups are connected via local coordinators to each other and a global coordinator. In scientific communities program committee members, principal researcher and other engaged locally or regionally in the community's field of research take a role similar to local coordinators.

	Authors at 1 or 2 conferences	Authors at 3 and more conferences	Sum
All	1099	88	1187
	92.6%	**7.4%**	100%
Referenced authors	360	82	442
	81.4%	**18.6%**	100%
Quotient Referenced/All	32.8%	**93.2%**	

Table 2: Authors in detail

International connections

To characterize the latest development in the CSCL community towards an internationally connected community, figure 2a and 2b show the international connections based on the references between different countries for the last two conferences, CSCL 2002 and 2003. For simplicity, only relations greater than 20 are shown and countries having less than 20 incoming or outgoing references are not included. The upper row denotes the origin of references (nationality of the referencing authors), the lower row the target of references (nationality of the referenced author). The thickness of the lines corresponds to the number of references. From these coarse-grained representations one can already see that the international connections grow; e.g. in 2003 Norway is also connected to Finland and the relation between Germany and USA gets stronger from 2002 to 2003. However, any new or increasing relations from 2002 to 2003 are not visible in these figures as they are below the threshold of 20 references.

A more detailed analysis (not presented here) identifies the individual persons with the highest impact inside local groups (Kienle & Wessner 2005). To determine the impact of a person we looked at the number of references from papers of local group members to a specific person as well as the number of co-authorships with a specific person. Persons with the highest impact may be regarded as a kind of local coordinators in the sense of CoP.

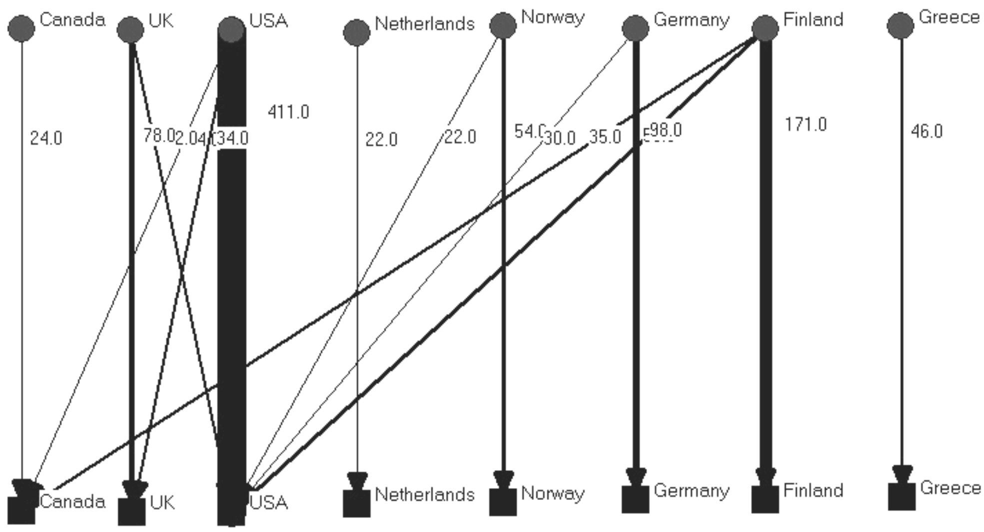


Figure 2a: References in the CSCL 2002 proceedings grouped by country

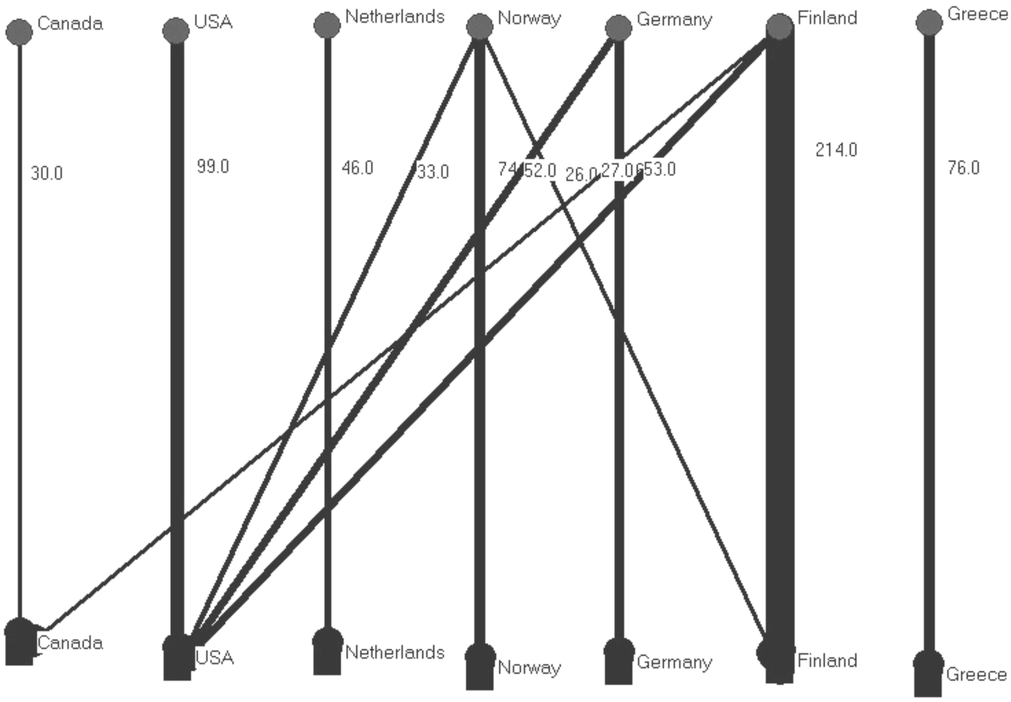


Figure 2b: References in the CSCL 2003 proceedings grouped by country

Design Principles for Cultivating Scientific Communities

Cultivating of a CoP can be achieved by "*valuing the learning they do, making time and other resources available for their work, encouraging participation, and removing barriers*" (Wenger et al 2002: 13). To make this more concrete a list of design principles to cultivate CoPs has been proposed (Wenger et al 2002).

In the following we look at one of these possibilities to cultivate a CoP, at encouraging participation. Especially, we focus on encouraging participation from different countries in scientific communities in order to increase the connectivity of the community members. For this we build on the models of scientific communities in the previous section. Design principles which aim at encouraging international participation are adapted to the specific characteristics of scientific communities. Using and presenting data and observations from our extensive analysis of the CSCL community (Kienle & Wessner 2005) which are relevant for this paper we trace these principles in this particular community.

These principles include smooth transitions between different degrees of participation (1), networking of local coordinators (2), rotation of meeting locations (3) and international program committees (4). Our principles are derived from Wenger et al.`s principles for cultivating distributed communities (see Wenger et al. (2002), pp. 119-137). More concretely, the first two of our principles are related to Wenger et al.`s second principle (for building up a structure), our third and forth principles to the third principle of Wenger et al. (for building a rhythm).

Smooth transitions between different levels of participation: horizontal and vertical paths

Wenger et al. (2002) point out that a "*good community architecture invites many different levels of participation*" (p. 55). These different levels allow a lively and also continuous community: new people with new ideas should be able to join the community as easy as possible; already existing members should be able to participate over a period of time and on different levels.

In scientific communities new people can join the community e.g. by a passive or active participation in conferences. In our data we analyse in which way people change between different levels of participation. While participation probably can be seen as a continuum, we can coarsely differentiate between the three levels participation at conferences, authorship and PC-membership (see the model of participation in scientific communities above). We compared for example the years of the first authorship or PC-membership (PCM; see table 3).

	Authors at 1 or 2 conferences (1099)	Authors at 3 and more conferences (88)	Sum (1187)
1. Only author	1017	52	1069
	92.6%	59.1%	90.1%
2. First author, then PCM	39	24	63
	3.5%	27.3%	5.3%
3. Same start: PCM and author	20	11	31
	1.8%	12.5%	2.6 %
4. First PCM, then author	23	1	24
	2.1%	1.1%	2.0%
5. Only PCM	--	--	97

Table 3: Different degrees of participation (transitions are in bold face)

Although the majority of authors are authors only and do not become PCMs, the data brought evidence for the existence of transitions between different degrees of participation:

- Most of the transitions occur from author to PCM (5.3% of all authors). This means that authors at one conference became PCM in subsequent years. As described above, we split up the group of authors in two groups according to the intensity of authorship. In the group of authors who contributed to three or more conferences (which are 88 authors; the "Top-88") the number of transitions is significantly higher. 27.3% of the "Top-88" authors became PCM in subsequent years. This transition may be seen as what Lave & Wenger (1991) call the way "from peripheral to full participation". We name this way **vertical path through a scientific community**: the participants do actively contribute to the community and are invited afterwards to join the core group.
- Other people start as author and PCM in the same year (2.6% of all). We assume that these people, after being asked for serving as a PCM, feel a high commitment for self contributing with an artifact.
- A third group started as PCM (2% of all PCMs became also author). Most of these PCMs are already experts in other scientific communities. They follow the **horizontal path into the community**: they do not start with the less active part as conference participant or author. This possibility offers new people to join the community in the most active role. This means that new ideas from and connections to other scientific communities are brought to this community on a high level.

As we have seen above there are new people joining the community each conference and existing members which participate over a period of time in the community. This combined with the existence of all possible transitions between different levels of participation is expected to lead to a lively and also continuous CSCL-Community. We sum up with the first principle. *Principle 1: Provide smooth transitions between different degrees of participation, e.g. vertical and horizontal paths*

Networking of Local Coordinators

As Wenger et al. (2002) point out, it is important to connect people in the community, especially to connect the local coordinators (p. 126). As mentioned above, in scientific communities such a role is taken by principle researchers or others engaged locally or regionally in this research field. These local coordinators influence by their publications, lectures and advice what other work is perceived by their fellows. In order to make available what has been done world-wide in the community and thereby to increase the internationality and advance the scientific progress, local coordinators play an important role. Fellows are likely to follow the model of the local coordinators.

Our analysis of the CSCL community shows the increasing international perception in the increasing degree of international references as well as in the increasing (but still low) amount of international co-authorships. It can be seen that the Top-88 authors (contributing to three or more conferences) are indeed more connected than the authors contributing to only one or two conferences. We expect from a further detailed analysis to be able to show also that newcomers are increasingly referencing international authors following the model of their local coordinators.

From this we derive the following principle. *Principle 2: In order to increase international participation in a scientific community the local coordinators should be connected among each other.*

Rotation of meeting locations

This principle is based on the Wenger et al.´s hint: “Rotate the location of face-to-face meetings” (Wenger et al. 2002, p. 131). While for Wenger et al. this aims to get members a better feeling for other members’ particular issues and situations, in scientific communities this plays a different role. It provides a low barrier for new people living near the meeting (conference, workshop) location to enter the community. Data for the CSCL community clearly shows that for example the majority of authors at a CSCL conference come from the continent where the conference takes place.

The conferences 1995, 1997, 1999 and 2002 took place in North America; the conferences 2001 and 2003 took place in Europe. In figure 3 we see the composition of authors at the six CSCL conferences. Participation of European authors was strongest in those years where the conference took place in Europe; participation of North American authors was strongest in the other years where the conference took place in North America. But following the first conference in Europe (2001) the share of European authors increased also in the following conference (2002) in North America. From an analysis of the lists of participants and authors we see that a small but substantial percentage of the authors not only enter the community when the conference is located nearby but stay (at least for a while) in the community, i.e. continue to participate in following conferences.

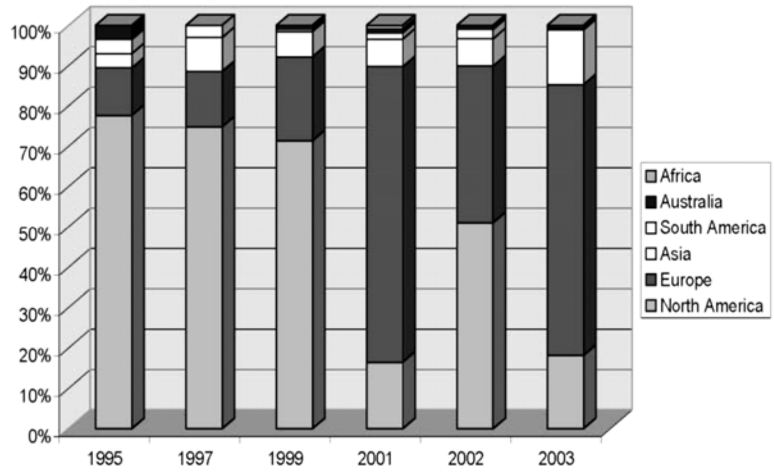


Figure 3: Distribution of authors by continents

From these findings we derive the following principle. *Principle 3: In order to increase international participation in a scientific community the conference location should rotate between different continents.*

International Program Committees

Wenger et al. (2002) recommend not only the mix of locations for face-to-face meetings, but also mixed preparation teams: "*Form meeting design teams of members from different locations*". (Wenger et al. 2002: 131). For a scientific community this topic is related to the program (and organizing) committee: its members can be seen as multipliers who distribute information about the conference locally and encourage people from their local network to submit papers or posters to the conference. Therefore we expect that an international formation of the program committee leads to an international group of authors.

This correlation can indeed be seen in our data. Figure 4 shows the geographical distribution of the program committee members which is quite similar to the distribution of authors in figure 3. A citation analysis concerning the International Conference of the Learning Sciences (ICLS) showed the same relation in a different direction: a program committee of members from one country only corresponds with a low degree of internationality in the group of authors (Kirby et al., in press).

From these findings we derive the following principle. *Principle 4: In order to increase international participation in a scientific community the program committees should be composed internationally.*

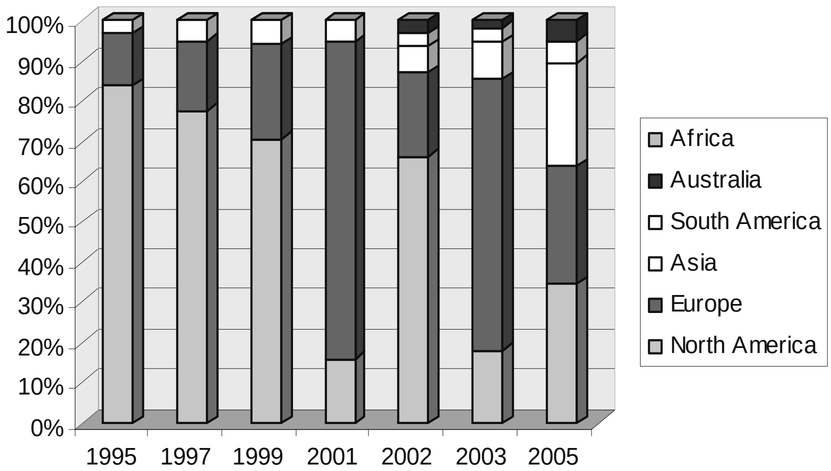


Figure 4: Distribution of PC members by continents

Conclusions and Further Work

This paper seeks to contribute to the understanding of scientific communities as Communities of Practice (CoP). Scientific communities can be seen as CoPs as they share a set of problems and a passion about a research field and aim to deepen their knowledge by interacting on an ongoing basis. On the other hand, models developed to characterize CoPs don't exactly match the situation in scientific communities. This was shown with the model of different degrees of community participation (Wenger et al. 2002).

We adapted the design principles for cultivating CoPs as introduced by Wenger et al. (2002) to the characteristics of scientific communities. It was shown how smooth transitions between different degrees of participation, networking of local coordinators, rotation of meeting locations, and international program committees help to cultivate the community wrt. its internationality.

As an example of a scientific community we characterized the international and multidisciplinary CSCL (Computer Supported Collaborative Learning) community. Based on data and observations from the CSCL community in its first decade of existence (1995-2005), basic models and adapted design principles have been instantiated.

There are a number of directions for extending the research presented in this paper. First of all, the quantitative approach taken so far should be complemented with a qualitative analysis. Thus important aspects like motivation and norms can be taken into account in order to further explain the effects described here. It seems promising to develop similar design principles for cultivating a scientific community which aim at other aspects of scientific communities like multidisciplinary or intercultural composition. The principles should be discussed also using data from other scientific communities in order to demonstrate their general applicability. Further research is needed to tackle other problems of (distributed) scientific communities, for example how to cultivate scientific communities depending on their current size. It has been argued that a community cannot grow infinitely (Shirky 2002). Above a certain threshold, an engaged community might turn into a passive audience, a group of people who mostly receive information rather than interact with each other.

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