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Co-Authorship Networks of Scientific Collaboration

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***Abstract*—**This study analyzes collaborative and networked academic authorship in higher education. The literature review shows evidence that single authorship has made a gradual paradigm shift to joint authorship. The empirical evidence from the Turku University of Applied Sciences indicates that collaborative authorship has notably increased in the last few years. Co-authorship has extended outside the institution to other domestic and international academic organizations. Co-authorship not only increase the merits of academic scholars but builds and maintains networks of research and development. The results of this study help the authors, editors and partners of research and development projects to have a more concrete understanding of how co-authorship has developed and spread beyond higher education institutions.

***Keywords*—**Co-authorship, social networking, higher education, research and development.

I. Introduction

SCOLARS in many fields of higher education have paid increasing attention to the collaborative aspects of the development of knowledge. There is growing interest in distributed intelligence which concerns the creation of expertise in networks, rather than individual researchers. Academic scholars are also interested in the circumstances under which the most productive authors create and publish their work. Co-authorship can be thought as a collaboration between two or more authors in a network.

Publications in peer-reviewed journals are a major criterion for assessing scientists for promotion, tenure or funding [1], [2]. As bibliometric data can be easily obtained and quantified, they have an important role in decision making, especially for academic promotion committees [3]. The academic community is facing the challenge of how to build networks of co-authorship and how to improve the productivity of publications. This study addresses the trends of internal co-authorship within the higher education institutions and extramural co-authorship with other domestic and international academic communities.

Library science has a long history of citation networks [4], [5]. These networks are formed by the citations between publications which are the nodes of networks. These networks are quite distinct from co-authorship networks, where the nodes are also publications but networks are based on collaboration among individuals. The co-authorship network is a network depicting an academic society and the structure of its knowledge. Co-authorship networks have received less scholarly attention than the citation networks. Therefore the co-authorship networks can shed new light on the development of knowledge.

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Both literature and empirical studies witnessed a notable change in scientific collaboration in the last decades. Glänzel [6] reported that all areas of science are characterized by intensifying collaboration associated with the increase of the share of multi-authored papers during the 1980s and 1990s. The medical fields, the biosciences and chemistry have seen notable deceases in single-authored papers. Single-authorship has decreased also in mathematics, traditionally a domain of individual scientists rather than teams. A similar development has been observed in the social sciences especially in psychology, while philosophy has been less affected [7]. Similar results have been seen in humanities from 2000 to 2010 [8].

The purpose of this study is to analyze the collaborative and networked co-authorship in higher education and how the patterns of collaboration varied during the years 2012-2014. The study also investigates the changes in extramural and international co-authorship which took place at that time. The intramural collaboration takes place in a research group, department or institution. In extramural collaboration, co-authors are sought from other domestic organizations and abroad.

This study uses the official publication data of the Turku University of Applied Sciences. The data describe scientific networking where the nodes are publications and the scientists are connected, if they have co-authored a publication. The publication data are reliable because they have been collected for the Finnish Ministry of Education and Culture and the number of publications is part of the performance-based funding scheme, which is accustomed to allocating government funding to higher education institutions. The data includes information on the number of internal, domestic and international publications. The results of the study show that the number of joint publications with domestic and international co-authors has increased during the last few years.

The remainder of this study is set up as follows. Section II presents the literature review, which discusses collaborative and networked co-authorship in higher education. Section III describes the publication data obtained from the Turku University of Applied Sciences. The results and discussion in Section IV describe the practices of scholars at the universities of applied sciences to write publications with their students. The final section concludes the study.

II. Literature Review

There are two types of doctoral dissertations including monographs and a collection of articles. A monograph is a typical case where a single researcher works alone and in

many cases the supervision is distant compared with the applied research and development in project teams [9]. Many researchers who have defended their doctoral dissertation do not learn to write internationally published articles without the support of collaborative and networked practices [10]. The lack of publication skills may become obstacles to an academic career.

Writing a paper for an academic journal requires a great deal of tacit knowledge that is difficult to transfer to another person orally or in writing. Co-authorship turns tacit knowledge to explicit knowledge and helps less experienced researchers to write high-quality papers. Laband and Tollison [11] found a 23 % higher acceptance rate for co-authored articles than for single-authored articles for the *Journal of Political Economy*. That indicates a quality improvement by co-authorship. The quantity of published articles is likewise clearly related to the co-authorship.

Academic writing is moving towards a culture, in which more publications are written in collaboration with other scholars [12]. Many universities have adopted the new collective model of doctoral education which supports the student in the learning process towards the doctoral degree [13]-[15]. The socialization of doctoral students introduces the student as a member of the research community where he or she learns its culture, values, attitudes and expectations.

The prevalence of collaboration suggests that academic scholars must have good epistemic reasons for working together. DeB Beaver [16] gave a list of the most important purposes for which people collaborate. The list includes the access to funding and equipment, access to expertise, speeding up progress, enhancing productivity and reducing isolation. The increasing mobility of scientists and changing communication patterns have also made collaboration easier. Social scientists are rarely as dependent on laboratories and equipment as natural scientists. However, the research findings of increasing collaboration in social sciences support the argument that the team production model produces the benefits of collaboration [17], [18].

Collaborative authorship in applied research and development projects is often related to sources of external funding. There are typically several partners in these projects. A larger share of the partners come from other countries because the European Union presumes partners from several countries in its research and development programs. Many of the funding bodies assume that innovations are created based on collaborative and international innovation ecosystems. For example, the Erasmus+ Programme Guide of the European Commission specifies the number of partners from different countries.

There are also pedagogical reasons for collaborative authorship. The Turku University of Applied Sciences developed innovation pedagogy, which has extended the individual learning to collaborative and networked learning [19]-[21]. The institution responds to the regional development needs and applies project funding for research and development. The development needs and projects are usually multidisciplinary. The projects are integrated into education so that students can participate in the projects and acquire development skills. Innovations promote entrepreneurship and often they are based on international ideas.

Multidisciplinary fields are the obvious places to look for collaboration among scholars with very different backgrounds. There are huge gains to be made in the number and rate of theoretical results. These gains emerge because multidisciplinary collaboration brings together previously isolated theoretical ideas that can produce fruitful combinations [12]. The gains of multidisciplinary projects are not immediate, because much time and effort is usually required for people from different backgrounds to understand each other. The shared customer requirements help researchers to work productively.

The joint topics and subject matters of research and development projects enable students to settle in the middle of the process in which new knowledge and innovations are created [22]. Students are able to participate in collaboration which develops processes, services and products. They are able to write their thesis and attain capabilities to participate in research and development after graduation. The process also socializes students to generate new scientific knowledge [23].

The supervision of academic writing in joint research and development projects is not only between the supervisor of the institution and the researcher. The research staff adopts practices of the customers and external partners involved in the projects. Novices are able to learn from experienced members of the project and adopt practices from the other members of the academic community [24]. In addition, all members of the research community are able to learn from the networked knowledge which is based on social networks and information and communication technology.

Prior research has demonstrated that scientific collaboration through co-authorship has increased, despite important disciplinary differences. Persson et al. [25] reported a growing number of publications and a sharp increase in the number of active authors. Between 1980 and 1998, the number of papers rose by 36 % and the number of authors by 64 %. These figures indicate the change in the patters of documented scientific communication and the tendency of inflatory features. The number of authors per paper is growing and this is an increasing trend in many research fields, largely owing to the greater pressure to publish [8].

Ossenblok, Verleysen and Engels [8] studied the international co-authorship of Flemish multi-authored articles in social sciences and humanities. The share of internationally co-authored papers increased slightly, especially in the social sciences. The trend towards more international co-authorship results from the spread of the international collaboration. For most disciplines, this trend does not result in the involvement of more international contributors per article. More internationally co-authored articles are being published, but this does not imply that the average contribution of international authors to these articles is significantly growing.

Durden and Perri [26] examined the relationship between the number of published articles and the number of co-

authored articles and found that co-authorship was associated with productivity. The relation of cooperativeness with publication activity was analyzed also by Braun et al. [27] and Glänzel [6]. When average productivity is plotted against mean cooperativeness, the field specific patterns of productivity can be observed. Productivity increases with cooperativeness until a specific number of co-authors is reached; beyond this point the productivity turns negative. The optimum number of co-authors is one-two in mathematics, three-four in chemistry and five-six in neurosciences and biomedical research. Some researchers find it easier to develop new ideas in collaboration than in solitary thinking or writing.

Cronin [28] studied hyper-authorship of a single paper that has an extraordinary large number of authors. These are found especially in biomedical research and high-energy physics. The publications with hundreds of co-authors affiliated with one large institute or dozens of institutes in 10 and more countries are no longer the exception to the rule. Cronin questioned the possibility of fixing the degree of each co-author's contribution to the paper because not all researchers could have made an equal contribution to the work. In addition, in hyper-authorship an author is not necessarily a writer. It becomes difficult to know whom to reward or blame for the errors in the final paper.

In considering the merits of collaboration in authorship, the occurrence of losses can be assessed. The results of Rutledge and Karim [29] and Leff [30] indicate that prolific authors become more productive and produce longer articles by working with others, but they appear to decrease the number of co-authors in their higher-quality publications, possibly to improve their reputation. It is also expected that with a large number of writers the time spent on communication and coordination would reduce the time spent on actual writing.

Wren et al. [3] conducted a survey on the way in which authors are listed in medical journal and noted that the first and last authors are generally perceived as the most important; there is no consensus on the value of other positions. They noted that a larger number of authors dilutes the amount of credit awarded to each contributor. The respondents of the survey thought that the first author in a three-person byline had made the greatest contribution to the work and that the last author deserved the most credit for both the initial conception and supervision of the project. In contrast, radiology articles, authors that are listed first in the byline are assumed to deserve more credit than those who appear later [31].

Laudel [32] interviewed a sample of scientists and found that a major part of collaboration is not recognized either through a proper acknowledgement or co-authorship. Even though many people are involved in the preparation of a scientific paper, these people are not mentioned as co-authors or as sub-authors of the publication. According to Glänzel and Schubert [33] sub-authors are people whose contribution is acknowledged by the authors of the publication as substantial. Acknowledgements could increase the value of the paper because of the increased credibility in the opinions of readers, reviewers and editors of the article.

III. Data and Methodology

The empirical data of this study was obtained from the Turku University of Applied Sciences. The Finnish higher education institutions annually compile publication data for the Ministry of Education, because the Finnish performance-based funding scheme of higher education institutions is based on publications, among other indicators [34]. Each researcher saves his or her publication data in the information system, Publikaattori, located in the website of the institution. The publication data are also available to the public.

The access to official publication data is an advantage of this study. The data are reliable, because the Ministry carefully defines the criteria of publications, the publication data are collected for official purposes and they are the basis of the funding of the institution. The data are not comparable before 2012, but thereafter the data have been collected in a similar way in all the universities of applied sciences in Finland. The sector of universities also has a performance-based funding scheme, but the publication data is not comparable with that of the universities of applied sciences.

Fig. 1 depicts the frequencies of the co-authorships during 2012-2014. The share of single authors clearly decreased and the share of two writers increased that time. Clearly most publications are written by no more than three or four authors but there are some outliers. These frequencies support the argument that most publications are still written by a single author but collaborative authorship has notably increased.

The co-authorship of this study will focus on three levels: 1) internal co-authorship where the collaboration is intramural, 2) domestic co-authorship where the co-author comes from another domestic organization, and 3) international co-authorship where the co-authors is affiliated with an institution in another country. The study gives an overview of the development of co-authorship on these levels of aggregation.

TABLE I
The Descriptive Statistics of the Publications at the Turku University of Applied Sciences 2012-2014

	2015	2013	2014
Internal co-authorship, %	73.4	64.7	64.4
Domestic co-authorship, %	21.7	30.9	29.4
International co-authorship, %	4.9	4.5	6.1
The share of international publications, %	13.8	20.1	22.7
The share of open access publications, %	72.4	63.8	68.5

Table I indicates the descriptive statistics of the authorship data of internal, domestic and international co-authorship from 2012-2014. The share of internal co-authors from the same higher education institution decreased but the share of domestic co-authorship notably increased. The share of international co-authorship increased but remained rather low. The international publication refers to an international publisher whose share has notably increased. The share of open access publications was on high level and showed variation without a clear trend.

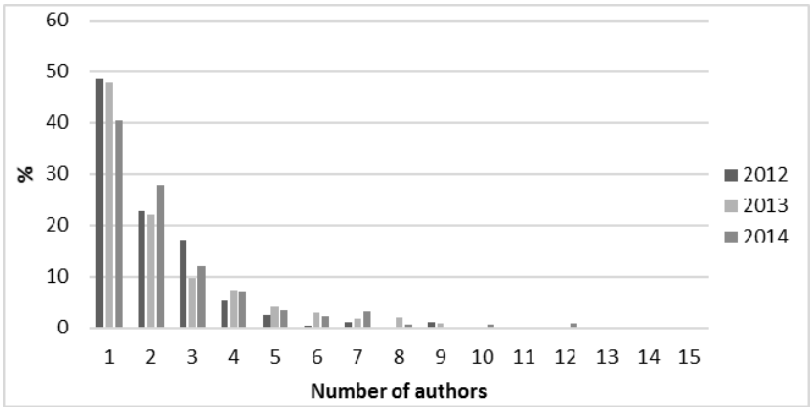

Fig. 1 The frequencies of the number of co-authors 2012-2014

The statistical relationship of the number of co-authors and the extramural co-authorship is examined in this study using the method of ordinary least squares regression. The estimated models are used to study the relationships of the number of co-authors and domestic and international co-authorship. The regression model is defined as follows

$$N_i = \beta_0 + \beta_1 D_i + \beta_2 F_i + \varepsilon_i \quad (1)$$

where Ni is the number of authors, Di is the dummy variable for domestic authorship and Fi is a dummy variable of the foreign authorship for a publication i. The coefficients β0, β1 and β2 are the constants to be estimated and εi is the residual term. The dummy variables indicate the domestic and international authorship by one and otherwise these variables are zero.

Table II depicts the estimated coefficients of the regression models. The results indicate that both the domestic and international co-authors have a positive relationship with the number of authors. The results support the finding that intramural authorships are not usually carried out in teams but by single scholars. Research is much more collaborative in extramural networks than in intramural ones. The domestic and especially the international authorship have a positive relationship with the number of authors. The results are statistically significant at the 1 % level. The international co-authors clearly have a stronger relationship with the number of co-authors than domestic co-authors do.

TABLE II
THE REGRESSION RESULTS OF ORDINARY LEAST SQUARES

	2015	2013	2014
Coefficient	1.50	1.41	1.61
	(0.11)	(0.15)	(0.12)
Domestic co-authorship, %	2.44	2.71	2.24
	(0.24)	(0.27)	(0.22)
International co-authorship, %	4.33	6.53	4.34
	(0.46)	(0.61)	(0.42)
R^2	0.56	0.60	0.59

IV. DISCUSSION

The co-authorship with doctoral students is obvious from the viewpoint of a supervisor, but co-authorship with undergraduate students comes with special challenges. These and other publications written by students are not counted in the Finnish performance-based funding scheme, although co-authorship with the teacher is, and increases the funding from the Ministry of Education and Culture. The research topics given to undergraduate students must be selected carefully so that students can learn from the thesis within a designated time span. At the Turku University of Applied Sciences, bachelor's thesis is 15-25 European Credit Transfer System (ECTS) credits and the master's thesis is 30 credits. One credit is 26.7 hours of study, which sets a time limit for the student participation in the project.

An applied research and development project is a possible thesis topic. Undergraduate students are not eligible to plan research and development projects and apply for funding. The teachers and the other personnel of the institution must plan the projects so that students can be involved in them. The development need of a customer organisation does not necessarily fit the skills, knowledge and interests of all students. Therefore the institution has to match the projects with the students who are most capable and interested. The projects are presented for the students and interested students can apply for the projects to perform their tasks and write the thesis.

The reports on the integration of projects into education are encouraging. Students are pleased that they are able to participate in applied research and development projects, gain the capabilities for development work and build networks for employment. Students write their thesis as a single-author or in collaboration with another student. Co-authorship with a teacher can take the form of articles based on the thesis and other information. The dissemination of practical information is valuable along with the more demanding journal articles.

Another possibility to write a thesis and produce a co-authored publication is to participate in domestic or international internships (practical training) and collect the data from the enterprises or other organisations. The tasks designed for student interns must also fit their studies, capabilities and interests. The documentation and dissemination of the practices and development work of a customer organisation is important for the other students,

teachers and a wider audience, because they improve the networking of higher education institutions with the world of work.

V. Conclusions

This study analyzed the trend of collaborative and networked authorship in higher education institutions. The literature review introduced recent studies about changes in co-authorship. The empirical part of the study was based on the official data on publications at the Turku University of Applied Sciences. The data are annually used to report the publications and other outputs to the Ministry of Education and Culture to allocate funding from the central government to the institutions using the performance-based funding scheme. Access to the official data improves the reliability of the data.

The literature has witnessed a dramatic quantitative and structural change in the number of co-authored publications. The empirical data of Turku University of Applied Sciences also indicate that collaborative authorship has increased. The share of single-authored publications was 49 % in 2012, but it was only 41 % in 2014. The number of studies by two or three co-authors has notably increased. At the same time, collaborative and networked learning and international research and development projects have improved incentives for joint authorship. In addition, the share of international joint publications has increased, but their share is still rather small.

The empirical data supports the finding that co-authorship decreases with the distance between the collaborative partners. Intramural co-authorship is the most common, but it has dropped from 73 % to 64 %. The share of domestic co-authorship has increased from 22 % to 29 % and the share of international co-authorship has risen from 14 % to 23 %. The results from the regression analysis indicate a statistically significant relationship between the number of co-authors and the domestic and international co-authorship. These results support the finding that intramural authorship is carried out mainly by single authors, not by teams.

The limitation of the empirical results is based on the fact that the data are only from the Turku University of Applied Sciences and they are not necessarily applicable to other higher education institutions despite empirical evidence about similar institutions. One interesting topic of future study is to extend this study to other institutions and countries. Another interesting undertaking would be to analyze the differences across fields of education and science. Co-authorship is related to the research productivity, so it would be important to study the optimum number of co-authors.

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