Available online at www.sciencedirect.com
SCIENCE DIRECT®
Information Processing and Management 41 (2005) 1481–1494
INFORMATION PROCESSING & MANAGEMENT
www.elsevier.com/locate/infoproman

New indicators for gender studies in Web networks

Hildrun Kretschmer [a,b,c,*], Isidro F. Aguillo [d]

[a] *Nerdi, The Royal Netherlands Academy of Arts and Sciences, P.O. Box 95110, 1090 HC Amsterdam, The Netherlands*
[b] *The School of Humanities and Social Sciences, Dalian University of Technology, Dalian 116023, China*
[c] *COLLNET Center, Borgsdorfer Str. 5, D-16540 Hohen Neuendorf, Germany*
[d] *CINDOC, Calle Joaquin Costa, 22, 28002 Madrid, Spain*

Received 27 September 2004; accepted 3 March 2005
Available online 20 April 2005

Abstract

New indicators for gender studies are introduced using the multi-authored publications of a set of 64 members of the COLLNET network. Considering the sample of 223 papers and their visibility on the Web, analyses were performed on the sets comprised of publications on the one hand and the authors (social network analysis) on the other.

The indicators developed include: Gender co-operation; Web visibility rates and Gender centrality in networks.

The co-operation among COLLNET members results in a publication set with a different pattern to other gender studies in science, which show low contribution rates of women in collaboration activities. In the sample the collaboration patterns of female COLLNET members are almost the same as their male counterparts. However, when considering only the arrangement of gender in the by-line of publications, this is in favour of men.

Regarding average Web visibility rates, there are no differences dependent upon the arrangement of gender in publications with both male and female co-authors. However, the results also show strong gender differences in favour of publications with only male co-authors.

The centrality of female actors in the networks is correlated with the central positions of women in the International Society for Scientometrics and Informetrics (ISSI), where they are leading either as presidents or organisers of its international conferences.

It may well be that, with webometric methods and new indicators for gender studies, there is a real continuation of gender equality in COLLNET over time.

Keywords: Bibliometrics; Webometrics; Web; Collaboration; Gender studies; Social network analysis (SNA)

* Corresponding author.
E-mail addresses: kretschmer.h@onlinehome.de (H. Kretschmer), isidro@cindoc.csic.es (I.F. Aguillo).
URL: http://www.h-kretschmer.de/ (H. Kretschmer).

0306-4573/$ - see front matter © 2005 Published by Elsevier Ltd.
doi:10.1016/j.ipm.2005.03.009

1. Introduction

Although the participation of women in science is increasing in some countries and fields, the low participation rate of women in research activities indicates that it is worthwhile studying the background and problems faced by women in science and engineering (Leta & Lewison, 2003; Moore, 1987; Vetter, 1981). In recent years, increasing attention has been drawn to gender issues in science (Bordons, Morillo, Fernandéz, & Goméz, 2003).

In the mid 90s, the European Commission started a process with the objective of better reflecting gender within research policy. In 1999 the ''Women and Science'' sector was set up. Gender Impact Assessment studies were carried out in order to introduce a critical dimension in the way that gender issues are treated throughout the 5th European Framework Programme for Research, Technology Development and Demonstration (Schultz et al., 2001).

One part of the gender studies funded by the European Commission is related to bibliometric and patent indicators used for measuring the productivity and collaboration of women in the area of science and technology (Hullmann, 2002; Naldi, Luzi, Valente, & Parenti, 2004; Naldi & Parenti, 2002). According to these authors, questions can be asked about the publication indicator: do women publish more than men, in which disciplines and technology fields are they most active, and do they publish papers of a higher quality?

However, science is also turning to e-science. So, the question arises whether the position of women in science is changing with this new technology? Can we get more information from the new Web indicators than was previously possible with the bibliometric indicators alone?

An increasing part of online scientific communication and research is not (or only partially) visible in traditional S&T indicators. The EU has recently financed a new project run by a consortium from England, The Netherlands and Spain to further investigate the potential of creating new indicators of the Web for use in science and technology policy making. The WISER project started in November 2002, and runs for three years. Its objective is to explore the possibilities and problems inherent in developing a new generation of Web based S&T indicators (www.webindicators.org).

The study of gender relations in e-science is one focus of this project. One of the questions examined is whether the increased usage of the new information and communication technologies (ICT) in general, and the Internet in particular, help decrease existing differences in access to research resources, information and collaboration networks between people of different gender, or are existing differences in resources made more unequal? The results of these studies will be discussed in a forthcoming paper.

Another focus, on gender studies, will investigate whether there are differences in the way that male and female scientists and technologists are perceived on the Web. The first results are shown in this paper.

Bordons et al. (2003, p. 160), have referred to the results of a working group on women and science, science policy in the European Union:

> ''Although women constitute half the undergraduate population, their proposition decreases from graduation onwards. The more senior the academic post, the lower the representation of women. A continuous drop in the numbers of women at each level of the academic system has been described and many highly trained women are lost to science. Women face barriers not only against entry but also against promotion in their scientific career (ETAN, 2000).''

However, if we look at the development of the International Society for Scientometrics and Informetrics (ISSI) founded in 1993, we are surprised to see that four of the nine international ISSI Conferences were organised by women and, in this connection, three of the five ISSI Presidents were women!

ISSI, is an association of professionals active in the emerging interdisciplinary fields of informetrics, bibliometrics/scientometrics, technometrics and webometrics. Among its membership are scientists from over 30 countries representing all five continents (more details of ISSI, see website: www.issi-society.info/).

Is there a continuation of gender equality in the global interdisciplinary research group COLLNET? We ask this question because a high percentage of the 64 COLLNET members from 20 countries of all continents are also ISSI members.

The COLLNET members intended to co-operate on both theoretical and applied aspects on the topic "Collaboration in Science and in Technology" (Kretschmer, Liang, & Kundra, 2001). The focus of this group is to examine the phenomena of collaboration in science, its effect on productivity, innovation and quality, and the benefits and outcomes accruing to individuals, institutions and nations of collaborative work and co-authorship in science as well as collaboration in e-science (more details of COLLNET, see website: www.collnet.de).

Some new indicators of gender studies and the first results of investigations into the visibility of gender in the bibliographic and Web collaboration networks of COLLNET are presented here. This study is a continuation of another of the research network COLLNET (Kretschmer & Aguillo, 2004). The former research question posed was to which extent collaboration structures on the Web follow the same rules as collaboration networks measured by traditional bibliometric data. However the focus on gender is a new approach in the present paper.

2. Data

The same data are used as in Kretschmer and Aguillo (2004). Here in brief:

Both bibliographic and Web co-authorship networks of the 64 COLLNET members from 20 countries were examined. COLLNET is comprised of:

- 13 female EU members,
- 13 female non-EU members,
- 17 male EU members,
- 21 male non-EU members.

In total: 26 female members and 38 male counterparts.

Assuming that the reflection of collaboration in the Web is not limited to articles in SCI—or other data bases, a request was made to all the 64 COLLNET members for their complete bibliographies, independently of the type of the publications and independently from the date of appearance of these publications.

From these bibliographies all publications were selected that appeared in co-authorship between at least two COLLNET members. Thus, it concerns 223 bibliographic multi-authored publications. From this, the respective number of common publications between two members was determined as the basis for the analysis of the co-authorship network. The co-authorship network developed according to this method covers the entire lifetime collaboration between the COLLNET members. The last COLLNET data are from June 2003 and the Web searches took place in July 2003.

3. Methodology

Gender studies in science can be done under various conditions. For example, on one hand we can focus on a special set of multi-authored publications and study the percentages of male and female authors in this set of publications (Hullmann, 2002; Naldi et al., 2004; Naldi & Parenti, 2002). On the other we can focus on a special set of authors and study the links between these authors from multi-authored publications data, called network analysis (Otte & Rousseau, 2002).

Indicators for gender studies under both conditions are introduced here:

- Bibliometric and Web indicators of gender co-operation,
- Web visibility rates and
- indicators of gender centrality in bibliographic and in Web networks.

3.1. Bibliometric indicators of gender co-operation

Naldi and Parenti (2002 and also in Naldi et al., 2004) introduced three bibliometric indicators in order to evaluate patents and publications produced by co-operation among inventors/authors of different gender:

Participation	counts the number of publications with at least one author of a given gender
Contribution	measures the involvement of each gender in the production of a publication assuming that each author contributed the same amount
Number of authors (called *Presence* in Naldi et al., 2004)	total count of the authors of a given gender in each publication

Table 1 shows the calculation of the three indicators in the case of a publication produced by four authors (Table 1 according to Naldi and Parenti). These three bibliometric indicators are used for the investigation of collaboration in COLLNET. Beyond Naldi and Parenti an additional bibliometric indicator of gender co-operation is introduced here:

Arrangement in the by-line counts the number of publications with first authors of a given gender in the by-line of publications with both male and female co-authors.

3.2. Web indicators of gender co-operation

In addition to the bibliometric indicators of co-operation, the four new corresponding Web indicators:

- *Web Visibility of Participation*,
- *Web Visibility of Contribution*,
- *Web Visibility of Number of authors*,
- *Web Visibility of Arrangement in the by-line*

are used in a similar fashion to the four bibliometric indicators *but here in order to process multi-authored publications visible on the Web*.

Table 1
Calculation of female participation, contribution and total count (according to Naldi and Parenti, 2002)

Gender				Female participation	Female contribution	Female total count
F	M	M	M	1	1/4	1
F	F	M	M	1	2/4	2
F	F	F	M	1	3/4	3
F	F	F	F	1	4/4	4

Multi-authored publications are visible on the Web under the condition that bibliographic publications are mentioned after entering the full title of the co-authored publication into Google or Alltheweb on one website at least, i.e. $WVP_i > 0$ (explanation see below).

3.3. Web visibility rates

Whereas the Web indicators of gender co-operation are related to the corresponding indicators of gender co-operation by Naldi and Parenti, the indicators of Web visibility rates take into account the frequencies of the different websites on which bibliographic publications are mentioned (Kretschmer & Aguillo, 2004).

A high percentage (78%) of all bibliographic multi-authored publications of the COLLNET members became visible through the use of search engines in the Web (Kretschmer & Aguillo, 2004). Vaughan and Shaw's (2003) method of searching article quotations in the Web (*Web citations*) was used successfully, albeit in a slightly modified form (information about modification see in brackets below), to measure the visibility of the collaboration in the Web with the following definitions of the indicators already introduced in Kretschmer and Aguillo (2004):

- The *Web visibility rate of a multi-authored publication, i, from bibliographic data* (WVP_i) is measured as a frequency of the different websites on which the title (or more) of this bibliographic publication is mentioned after entering the full title of the co-authored publication into Google or Alltheweb [Modification means: Whereas Vaughan and Shaw are counting all of the pages of the websites on which this bibliographic publication is mentioned after entering the full title of a publication into Google here only the different websites are counted. The discussion about using the original or modified methods can be found in Kretschmer and Aguillo (2004, p. 409)].
  A multi-authored publication from bibliographic data is visible on the Web if the following is valid: $WVP_i > 0$.
  The *average Web visibility rate* (WVP′) *of n multi-authored publications* is equal to the total sum of WVP_i divided by the total number of multi-authored publications (n):

$$WVP' = \left(\sum_i WVP_i\right) \Big/ n$$

- The *Web visibility rate of a pair of collaborators* A and B (WVC_{AB}) is equal to the sum of Web visibility rates of all of their co-authored publications:

$$WVC_{AB} = \sum_i WVP_{ABi}$$

  A pair of collaborators is visible on the Web if the following is valid: $WVC_{AB} > 0$.
  The *average Web visibility rate* (WVC′) *of k pairs of collaborators* is equal to the total sum of WVC'_{AB} divided by the total number of pairs of collaborators (k):

$$WVC' = \left(\sum_{AB} WVC_{AB}\right) \Big/ k$$

These indicators of Web visibility rates are used for the study of gender differences on the Web.

3.4. Indicators of gender centrality in bibliographic and in Web networks

A social network analysis was performed (Wasserman & Faust, 1994). Some selected indicators of centrality describing the role played by particular COLLNET members were already used in Kretschmer and Aguillo (2004). Here in brief:

- Degree Centrality and
- Betweenness Centrality.

Explanations: Between two COLLNET members (node A and node B), there exists an edge if both have published at least one publication in co-authorship. The members A and B are called "*pair of collaborators*" (A, B). These pairs will be studied related to gender aspects.

A path from node X to node Y is a sequence of distinct edges between pairs of collaborators:

$$(X, A_1), (A_1, A_2), \ldots, (A_j, Y)$$

The length of the path is equal to the number of distinct edges. The shortest path from X to Y is called *distance* d_{XY}. The betweenness centrality refers to the shortest paths in the network, see below.

Degree centrality of a node A is equal to the number of nodes (or edges) that are adjacent to A:

$$DC_A = E_A$$

In other words the degree centrality of a node A is equal to the number of his/her collaborators or co-authors. An actor (node) with a high degree centrality is active in collaboration. He/she has collaborated with many scientists.

Betweenness centrality BC_A is the number of shortest paths (distance d_{XY}) that pass through A. Otte and Rousseau (2002) mention that actors (nodes) with a high betweenness play the role of connecting different groups or are 'middlemen'. Wasserman and Faust (1994, p. 188), mention: 'Interactions between two non-adjacent actors might depend on the other actors in the set of actors who lie on the paths between the two. These "other" actors potentially might have some control over the interactions between the two nonadjacent actors.' A particular "other" actor in the middle, the one *between* the others, has some control over paths in the network.

$$BC_A = \sum_{X,Y} G_{XAY}/G_{XY}$$

G_{XAY} is the number of shortest paths from node X to node Y passing through node A. G_{XY} is the number of shortest paths from node X to node Y ($X,Y \neq A$).

We are using these centrality indicators to describe the role played by particular COLLNET members. We compare female and male scientists in relation to their central role in the network.

4. Results

4.1. Bibliometric and Web indicators of gender co-operation

4.1.1. Study with focus on the set of multi-authored publications

The bibliometric results of Naldi and Parenti are compared with both the bibliometric and Web results of the COLLNET study. The bibliometric study of Naldi and Parenti is based on a data sample of about 10,000 items published during the year 1995 in scientific journals of international relevance and written by 35,000 authors from six European countries. The publications produced by co-operation are from several areas of science (mainly medicine and life sciences).

Whereas the COLLNET members are a small specific group of researchers in the area of scientometrics–bibliometrics–informetrics, the large sample of authors studied by Naldi et al. are working in various scientific disciplines. The differences between the results of these studies below may also be influenced by the above mentioned differences. Thus also studies of small groups have to be continued in order to allow for comparison with the current pilot study.

The *Participation* of women could only be found in 45.8% of all items as opposed to the *Participation* of men in 94.7% (Naldi et al., 2004; Naldi & Parenti, 2002). The *Contribution* of women resulted in 19.5% and the *Number of female authors* (*Presence*) in 22.2% of all authors (Naldi et al., 2004; Naldi & Parenti, 2002). Moreover in the publications with single authors the female *Contribution* is less, i.e. only 10.8% (Naldi et al., 2004).

Although the differences in these results are related to disciplines and countries, in general the low position of women in co-operation is striking. The results of the analysis of the co-operation of COLLNET members oppose the above mentioned study by Naldi and Parenti. As mentioned above, the bibliometric study of the 64 COLLNET members is based on a data sample of 223 multi-authored publications between at least two COLLNET members.

The *Participation* of women could be found in 65.3% of all items and the *Participation* of men in 76%. Although the difference between the participation of women and the participation of men is statistically significant (Chi-square test, $p < 0.01$) it is less clear than in the Naldi and Parenti study. The *Contribution* of women resulted in 45% and the *Number of Female Authors* in 47.9% of all authors. In total: co-operation between Female and Male COLLNET members is rather equally distributed.

After using the multi-authored publications from bibliographic data in the following, multi-authored publications visible on the Web ($WVP_i > 0$) are considered.

The *Web Visibility of Participation* of women has only slightly changed from the bibliometric value of 65.3% (*Participation*) to 67% on the Web and similar *Web Visibility of Participation* of men from the bibliometric value of 76% to the Web value of 73.9%. However both slight changes lead to the result that the difference between gender on the Web is not statistically significant, neither on the 1% level nor the 5% level.

The *Web Visibility of Female Contribution* has changed from 45% (female contribution) to 46.2% and *Web Visibility of Number of Female Authors* from 47.9% (Number of Female Authors) to 47.7%. Both indicators have only very slightly changed on the Web.

An overview about the results is presented in Table 2. The results of the analysis in co-operation of COLLNET members oppose the above mentioned study by Naldi and Parenti. Collaboration patterns between male and female members of COLLNET are almost equally distributed. Whereas very slight differences could be found between values of bibliometric and Web indicators of gender co-operation in favour of women in Web networks, as described above, strong gender differences can be shown in favour of men in the study of average Web visibility rates presented in the next section.

Results regarding the *Arrangement in the by-line* and *Web Visibility of Arrangement in the by-line* are shown below.

4.2. Average Web visibility rate of multi-authored publications (*WVP′*) and average Web visibility rate of pairs of collaborators (*WVC′*)

Studies are presented on the one hand focusing on the set of multi-authored publications and on the other focusing on the set of authors.

Table 2
Bibliometric and Web indicators of gender co-operation

	Participation of women in %	Participation of men in %	Contribution of women in %	Number of female authors in %
Naldi and Parenti	45.8	94.7	19.5	22.2
COLLNET bibliometric	65.3	76	45	47.9
COLLNET Web visibility	67	73.9	46.2	47.7

4.2.1. Study with focus on the set of multi-authored publications

The average Web visibility rate of the 223 multi-authored publications (WVP′) of the COLLNET members is studied depending upon the bibliometric indicator of gender co-operation called "contribution" by Naldi and Parenti. The bibliographic publications are classified according to three types of contribution. There are:

- 78 publications with only male co-authors and $\sum_i \mathrm{WVP}_i = 320/78$ resulting in $\mathrm{WVP}' = 4.1$,
- 54 publications with only female co-authors and $\sum_i \mathrm{WVP}_i = 113/54$ resulting in $\mathrm{WVP}' = 2.09$,
- 91 publications with both male and female co-authors and $\sum_i \mathrm{WVP}_i = 192/91$ resulting in $\mathrm{WVP}' = 2.11$.

The average Web visibility rate of multi-authored publications (WVP′) co-authored only by men is higher than the corresponding values for the other types of publications.

A Chi-square test was performed on the data (number of publications and $\sum_i \mathrm{WVP}_i$) and the result shows a significant ($p < 0.01$) difference of both distributions.

Moreover the 91 publications with both male and female co-authors are classified according to two types. There are:

- 33 publications with female co-authors as first authors in the by-line and $\sum_i \mathrm{WVP}_i = 69/33$ resulting in $\mathrm{WVP}' = 2.09$,
- 58 publications with male co-authors as first authors in the by-line and $\sum_i \mathrm{WVP}_i = 123/58$ resulting in $\mathrm{WVP}' = 2.12$.

Whereas female co-authors are arranged as first authors in the by-line in 37% of the 91 publications only there are rather no differences in the average Web visibility rates depending on the arrangement of the gender in the by-line.

4.2.2. Study with focus on the set of authors

Kretschmer and Aguillo could find that (2004) 48 of the 64 COLLNET members (=75%) have published in co-authorship at least once with at least one of the other COLLNET members (bibliometric data). The COLLNET members A and B are called "*pair of collaborators*" (A, B) if both have published at least one publication in co-authorship. It is independent from possible other additional co-authors in the same publication. However, in continuation triples or quadruples, etc., could be considered as well.

All of the 63 pairs of COLLLNET members are studied. There is the question who is collaborating with whom with regards to gender. Forty four of these 48 members (92%) are visible as co-authors in the co-authorship network obtained from the Web. There are 56 pairs of collaborators in the Web network, i.e. 89% of the 63 edges obtained from bibliographies.

Some gender differences, in particular those found between European Union and non-European Union countries, are presented. Differences in collaboration patterns between male (m) and female (f) COLLNET members and between EU (E) and non-EU (N) members are studied as well as combinations.

The values of *average Web visibility rates of pairs of collaborators* (WVC′) are presented in Table 3 and the values of the *average Web visibility rates of co-authored publications* (WVP′) in Table 4. In both tables the column is related to the collaboration between countries. For example, "EN" means one of the collaborators is an EU member and the other one is coming from a non-EU country. The row is related to gender collaboration. For example, "ff" means both collaborators are female.

Therefore, data in the cell EN/ff are collected from those collaborator pairs in which one of the collaborators is a female EU member and the other one a female non-EU member.

Table 3
Average Web visibility rate of pairs of collaborators (WVC′)

	ff	mm	fm	Total
EE	16.2	55.6	9.2	21.3
NN	7.3	5.3	8.9	7.2
EN	4.0	7.0	6.0	5.7
Total	9.4	19.7	8.5	12.07
FP	4.6	4.9	4.2	

FP—frequencies of publications per pair of collaborators.

Table 4
Average Web visibility rate of co-authored publications (WVP′)

	ff	mm	fm	Total average
EE	2.6	6.5	2.0	3.8
NN	1.5	2.0	2.4	2.0
EN	1.2	2.0	1.4	1.5
Total average	1.9	4.3	2.0	2.7

Results in brief: Trends of gender differences can be found, especially in average Web visibility rates (both WVC′ and also WVP′), but the gender differences are less marked in the *frequency of publications per pair of collaborators* (F_P) shown by bibliometric data.

Results in detail: On average there is no, or only a slight, gender difference between the different values of F_P (4.6 for female collaborator pairs, 4.9 for male collaborator pairs, 4.2 for male/female collaborator pairs).

However, there is one special case: The frequency of publications per pair of collaborators between males of the EU countries (EE/mm) is striking: $F_P = 8.6$.

Contrary to the bibliometric data above, gender trends can be found in the average Web visibility rates. Both WVP′ and WVC′ are highest between males. In particular, the average Web visibility rate of males from the European countries is striking (EE/mm).

Both WVP′ and WVC′ are in general higher between male pairs (row: total average; column: mm) than between other pairs of collaborators; the same pattern is valid in row: EE and in row: EN. It differs in row: NN. Both WVP′ and WVC′ are in general highest between members from the European Union and lowest between European and non-European members (column: total average; the same one is valid in column: ff and in column: mm. In Table 4 it differs in column: fm). It may well be that the reason for this result is the higher frequency of university websites in the EU than in non-European countries except North America. In particular, the WVC′ and WVP′ between males of the EU countries are striking (EE/mm). It corresponds with the frequency of publications per pair of collaborators (F_P).

Leo Egghe and Ronald Rousseau from Belgium are very highly outstanding collaborators. However the average Web visibility of male collaborators and the frequency of publications per pair of collaborators is also striking even when excluding the collaboration data of Egghe and Rousseau.

The pattern of WVP′ is similar to the table of WVC′ but not equal. The gender differences and the country differences are more pronounced in the pattern of the WVC′.

In summary, although in general there is almost no gender difference between the frequencies of publications per pair of collaborators obtained from bibliographies (F_P), the average visibility rates of pairs of collaborators on the Web are strongly gender oriented in the data of WVP′, and even more pronounced in WVC′. Questions arise, and should be studied, as to whether the quality of co-authored papers of male

scientists could be one of the causes of the higher Web visibility rate, or whether a special attitude against female scientists could be the cause of this pattern of Web visibility rates.

Although we have used different methods: on the one hand focusing on the set of publications (bibliometric and Web indicators of gender co-operation) and on the other focusing on the set of authors, the trends of the results do correspond.

4.3. Gender centrality in bibliographic and in Web networks

We shall focus on the role played by particular COLLNET members along the four stages of the studied time period.

We are starting with the three steps of the COLLNET development following the explanation of the corresponding four stages of the studied time period. Overview in brief (more details, see in Kretschmer & Aguillo, 2004):

First step of the development of COLLNET (1998–1999). An important trigger in the creation of COLLNET was the first Berlin Workshop on Scientometrics and Informetrics/Collaboration in Science, Berlin 1998.

Second step (2000–2001). In conjunction with the Second Berlin Workshop on Scientometrics and Informetrics/Collaboration in Science and in Technology, the first COLLNET meeting was held in Berlin 2002 (a special issue of the journal *Scientometrics* is published in 2001 about selected papers). A second COLLNET meeting took place in February 2001 in New Delhi, India and a third meeting in July 2001 in Sydney (Australia) in conjunction with the 8th International ISSI Conference on Scientometrics and Informetrics.

Third step (2002–2003). From here, COLLNET meetings have been held regularly.

Thus these three steps, along with the additional inclusion of the preliminary stage, will be incorporated to show the development of both the bibliographic COLLNET co-authorship network and the Web network in four stages:

- **First or preliminary stage**: Collaboration of the future COLLNET members until 1997, i.e. before 1998Number of co-authored papers from 1.1.1979 to 31.12.1997: 71.
- **Second stage**: Collaboration until 1999 (cumulative, including collaboration until 1997, i.e. preliminary stage and first step of COLLNET development)
  Number of co-authored papers from 1.1.1979 to 31.12. 1999: 97.
- **Third stage**: Collaboration until 2001 (cumulative, including collaboration until 1997, first and second steps)
  Number of co-authored papers from 1.1.1979 to 31.12.2001: 159.
- **Fourth stage**: Collaboration until June 2003 (cumulative, including collaboration until 1997, first, second and third steps)
  Number of co-authored papers from 1.1.1979 to 31.6.2003: 223.

For each stage on the one hand the five members with the highest degree centrality and on the other the five members with the highest betweenness were selected, both in the bibliographic and in the Web networks, resulting altogether in 12 members. These 12 members are ordered alphabetically in Table 5. The female members are marked in bold type. Five of these 12 members are part of the 26 most productive authors in the journal *Scientometrics* from 1978 to 2002 (Schubert, 2002), in alphabetical order:

- L. Egghe,
- **I. Gomez**,
- B.M. Gupta,

Table 5
Role played by particular COLLNET members

Name (map number)	Degree centrality				Betweenness				1997–1999 ∑B + W	2001–2003 ∑B + W
	1997	1999	2001	2003	1997	1999	2001	2003		
M. Davis (10)				B, W			B, W	W		5
L. Egghe (11)	B, W								2	
I. Gomez (12)	B, W				B, W				4	
B.M. Gupta (14)	B, W	B, W	B, W	B, W	B	B, W	B, W	B, W	7	8
C.R. Karisiddappa (19)	B				B	B			3	
H. Kretschmer (22)		B	B, W	B, W		B	B, W	B, W	2	8
R. Kundra (23)	B, W	B, W	B, W	B	B, W	B, W	B, W		8	5
L. Liang (25)			B, W	B, W			B	B, W		7
M. Meyer (29)								B		1
I.K. Ravichandra Rao (33)	B, W	B, W			B, W	W			7	
R. Rousseau (34)	B, W	B, W	B, W	B, W		B, W		B, W	6	6
C.S. Wilson (45)	B, W	B, W			B, W	W			7	

Note: B means he/she is one of the five members with the highest degree centrality (or betweenness respectively) in the bibliographic network related to the corresponding stage. W means he/she is one of the five members with the highest degree centrality (or betweenness respectively) in the Web network. In case there are several members with the same value on the 5th rank all of these members are included. Following there are some columns with more than five members. The female members are marked with fat letters.

- **H. Kretschmer**,
- R. Rousseau.

Two of these five are women (marked in bold letters).

For additional information: The COLLNET members L. Leydesdorff and R. Wagner-Döbler are also part of the above named 26 most productive authors. L. Egghe and R. Rousseau and D.deB. Beaver have published books or articles which are part of the most cited publications in *Scientometrics* (Schubert, 2002). All of these five members are men.

Let us come back to Table 5. When he/she is one of the five members with highest degree centrality (or betweenness respectively) related to a special stage in the bibliographic network, the letter B is entered in the corresponding cell, or W related to the Web network.

The results for degree centrality and betweenness are only slightly different from one another. The same is valid for bibliographic and Web networks. Therefore, a rough overview about the data per member was made by the sum of B and W for comparison of the two time periods before foundation of COLLNET in 2000 (first time period: stage 1 and stage 2, i.e. 1997–1999) and afterwards (second time period: stage 3 and stage 4, i.e. 2001–2003).

There is a change of the most central members in the networks from the first time period to the second.

However, we shall first look at the whole time period, i.e. the two time periods together. B.M. Gupta, R. Kundra and R. Rousseau (three men) are the most central actors followed by H. Kretschmer (woman). There is no difference between degree centrality and betweenness.

There is a difference related to bibliographic and Web networks for H. Kretschmer during the first time period. She is indeed a central actor during this period in the bibliographic network but not in the Web network. The role as central actor in the Web network started during the second time period, after founding of COLLNET.

Whereas L. Egghe, **I. Gomez**, C.R. Karisiddappa, I.K. Ravichandra Rao and **C.S. Wilson** (two women and three men) played a central role in the first time period (1997–1999), **M. Davis**, **L. Liang** and M. Meyer (two women and one man) are newcomers in the second time period (2001–2003).

L. Egghe's role as central actor is focused on the degree centrality only and C.R. Karisiddappa is a central actor only in the bibliographic network. M. Meyer is a newcomer starting with the bibliographic network. (All of these three members are men.)

The following three members (in alphabetical order): **H. Kretschmer** (female), R. Kundra (male) and **L. Liang** (female) are the founding members of COLLNET with **H. Kretschmer** as co-ordinator.

Five of the 12 central actors are coming from the EU countries.

It is interesting to mention that five of the 12 central actors (high degree centrality and high betweenness) are female members as well as two of the three founding members of COLLNET. It may well be that this kind of phenomenon is unusual in science. Therefore, a similar study should be done in several other scientific networks.

5. Conclusion

Science is turning to e-science. The question arises whether the position of women in science is changing with this new technology?

Some initial results of investigations into the visibility of gender in collaboration networks on the Web are presented here. It is interesting to recognize that about half of the central actors are female members, i.e. we could find out that, with other methods and new indicators for gender studies, there is a real continuation of gender equality in COLLNET in comparison with the central positions of women in ISSI related to the leading female positions in organization of international conferences and position of ISSI Presidents.

However, the question should be studied as to why these results of the social network analysis, including the high central positions of female scientists equal to the men, although corresponding with the bibliometric and Web indicators of gender co-operation do not correspond with the Web visibility rates.

The results of the pilot study have shown that maybe the newly created indicators of gender visibility in Web networks could be usefully applied in future as methods of investigating gender differences in the Web. However, the pilot study should be continued both with other small samples and with larger samples of scientists and with the application of the presented methods in different science disciplines and countries, because here the differences in the use of the Internet and the Web are to be expected.

In the same way, a relevant long-term study is to be recommended, because of the dynamic nature in which the Internet develops. However, there is also another kind of data collection for the study of collaboration in e-science in the literature, i.e. Web hyperlinks between homepages of scientists.

Terveen and Hill (1998) report on an empirical investigation into emergent collaboration: "Links between websites can be seen as evidence of a type of emergent collaboration among website authors". The authors have used SNA for analysis of the link structures.

It was intended to use the same method for the analysis of hyperlink structures between the homepages of the COLLNET members.

In July 2003 we could find homepages of 17 COLLNET members in the Web. However, contrary to the bibliographic and Web collaboration networks, there were not any links between the homepages!

From the 17 COLLNET members who had placed homepages on the Internet, are:

- 7 female (=27% of the 26 female members) and 10 male (=26% of the 38 males),
- 12 members from European Union countries (= 40% of the 30 European Union members) and five members from N countries (=15% of the 34 members from the non-EU countries).

While there appeared to be no difference between the female and male members, a tendency is apparent in favour of the EU when compared to the non-EU countries. A Chi-square test was performed on the

EU/N data and the result shows a significant ($p < 0.01$) difference between EU and N countries. It would be interesting to perform a similar investigation on a larger sample in the future to establish both gender and country differences in creation of homepages.

Acknowledgement

This work was supported by a grant from the Common Basis for Science, Technology and Innovation Indicators part of the Improving Human Research Potential specific programme of the Fifth Framework for Research and Technological Development of the European Commission. It is part of the WISER project (Web indicators for scientific, technological and innovation research) (Contract HPV2-CT-2002-00015) (www.webindicators.org). The authors thank Mike Thelwall for his helpful comments. Editorial discussions with Colin Reddy are acknowledged. Furthermore the authors thank Liwen Vaughan for her comments.

References

Bordons, M., Morillo, F., Fernandéz, M. T., & Goméz, I. (2003). One step further in the production of bibliometric indicators at the micro-level: differences by gender and professional category of scientists. *Scientometrics, 57*(2), 159–173.

ETAN expert working group on women and science (2000). Science policy in the European Union. Promotion excellence through mainstreaming gender equality European Commission, Directorate General for Research, Brussels <http://www.cordis.lu/improving/women/documents.htm>.

Hullmann (2002). Bibliometric and patent indicators by gender: Is it feasible? <http://wwwcordis.lu/indicators/publications.htm>.

Kretschmer, H., & Aguillo, I. F. (2004). Visibility of collaboration on the Web. *Scientometrics, 61*(3), 405–426.

Kretschmer, H., Liang, L., & Kundra, R. (2001). Foundation of a global interdisciplinary research network (COLLNET) with Berlin as the virtual centre. *Scientometrics, 52*(3), 531–537.

Leta, J., & Lewison, G. (2003). The contribution of women in Brazilian science. A case study in astronomy, immunology and oceanography. *Scientometrics, 57*(3), 339–353.

Moore, K. M. (1987). Women's access and opportunity in higher education: toward the twenty-first century. *Comparative Education, 23*, 23–33.

Naldi, F., Luzi, D., Valente, A., & Parenti, I. V. (2004). Scientific and technological performance by gender. In H. F. Moed, et al. (Eds.), *Handbook of quantitative science and technology research* (pp. 299–314). Netherlands: Kluwer Academic Publishers.

Naldi, F., & Parenti, I. V. (2002). Biosoft sas: bibliometric and patent indicators by gender: two feasibility studies (November 2002). *Vol. 1. Statistics; Vol. 2. Methodology*. <http://www.cordis.lu/indicators/publications.htm>.

Otte, E., & Rousseau, R. (2002). Social network analysis: a powerful strategy, also for the information sciences. *Journal of Information Science, 28*(6), 443–455.

Schubert, A. (2002). The Web of Scientometrics. A statistical overview of the first 50 volumes of the journal. *Scientometrics, 53*(1), 3–20.

Schultz, I. et al. (2001). Research on gender, the environment and sustainable development <http://dbs.cordis.lu/fep-cgi/srchidadb?ACTION=D&SESSION=&RCN=EN_RCN:2086005&CALLER=DOCS_PUBL>.

Terveen, L. G., & Hill, W. C. (1998). Evaluating emergent collaboration on the Web. In H. Naga (Ed.), *Proceedings of CSCW 1998* (pp. 355–362). Seattle, WA: ACM Press.

Vaughan, L., & Shaw, D. (2003). Bibliographic and Web citations: What is the difference? *Journal of the American Society for Information Science and Technology, 54*(14), 1313–1322.

Vetter, B. M. (1981). Women scientists and engineers: trends in participation. *Science, 214*, 1313–1321.

Wasserman, S., & Faust, K. (1994). *Social network analysis. Methods and applications*. Cambridge: Cambridge University Press.

Hildrun Kretschmer is associate researcher in the group "Networked Research and Digital Information" at the Royal Netherlands Academy of Arts and Sciences, Visiting Professor at the Dalian University of Technology, Dalian, China, Honorary Professor at the Henan Normal University, Xinxiang, China and private lecturer at the Free University Berlin, Germany. She has studied psychology and received both her doctorate Dr.oec. and her doctorate Dr.sc.phil. Her work deals with collaboration processes in science from the viewpoints of bibliometrics and socio-psychology, modelling of collaboration systems and theory, development and change of dynamic social structures in science. She is currently a member of the EU funded WISER project on Web indicators for science, technology and

innovation research. She is appointed as Associate Editor of both the international journal Scientometrics and the Journal of Information Management and Scientometrics. Currently, she is co-ordinating the Global Interdisciplinary Research Network COLLNET: ''Collaboration in Science and in Technology'', website: http://www.collnet.de. She is editor of 10 conference proceedings and she has published more than 70 peer reviewed articles or contributions in national and international journals or monographs, several non-peer reviewed publications. She was working as organiser or program chair of eight international conferences or workshops in the area of scientometrics and informetrics, collaboration in science and in technology.

Isidro F. Aguillo is the head of the Internet Lab in the Centre of Scientific and Technical Documentation (CINDOC) of the Spanish National Research Council (CSIC). His research topics include Information Society indicators and the quantitative description of the processes of scientific communication through Internet. He is the publisher of the electronic journal ''Cybermetrics''.