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Variety in web spheres between research fields: content and function[1]

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Abstract:
In this paper we investigate the different ways the Internet and the WWW are used in different research fields. The question we address is: is the variation in use related to the type of research field – especially with the difference between basic research and more application oriented research? We compare fields from sciences, life sciences, social sciences and humanities, and among these some are more application oriented than others. The results indicate that the observed differences between the disciplinary websites are not systematically related to application orientation. We discuss other differences between research fields that may explain the use and nature of the websites.

Keywords
Webometrics; indicators; differences between research fields.

Introduction: background and research questions

Scientific change is often based on the availability of new tools and techniques, which enable researchers to explore new answers for existing questions, and to explore new questions that were not easily researched without these new *instrumentalities* (Price 1986). Information and communication technologies typically are such an innovation in research tools and data, on different levels (Van den Besselaar 2007). First of all, it changes the nature of research data: increasingly electronic data become available about everything – research becomes data intensive ever more than before. Secondly, the access to scientific data changes. The online data repositories and internet *archives* provide new ways of doing research. This type of sharing is not only restricted to data. Also repositories for papers, and other collaboration technologies become increasingly available. Thirdly, new tools for analyzing these data become available. These new research practices are increasingly based on *monitoring*, *modeling* and *mapping* (De Jong and Rip 1997; Nentwich 2003). Fourthly – and related – contemporary research focuses more on the properties and behavior of artifacts (such as computers) and artificial systems rather than on natural phenomena in the real world (Gibbons et al. 1994). These developments are not a finished project; and they are subject of science policies (ESFRI 2006). Of course the level of use of ICTs differs between fields, as some were much earlier taking it up than others (Nentwich 2003).

Parallel to this changing nature of research, also the contract between science and society has changed (Rip 2002), and the emphasis of research – in an increasing number of research fields – is increasingly use oriented. A variety of concepts have been suggested for this, such as *Pasteur's quadrant* (Stokes 1997), *mode-2 knowledge production* (Gibbons et al), or the *triple helix* (Etzkowitz & Leydesdorff 1997). In these more use oriented fields, the relation with the non-academic environment is also supported with electronic media – something that is visible in the content of the websites as in the hyperlink networks (Van den Besselaar & Heimeriks, forthcoming). In other words, the internet and

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the WWW are used in the internal academic communication and collaboration, as well as in the communication with the external network.

We do not focus on the motives for establishing hyperlinks (e.g., Wilkinson et al. 2003) but on the way hyperlinks can be used to map the communication networks within research fields and between research fields and their academic and non-academic environments (Heimeriks, Hoerlesberger, Van den Besselaar 2003; Heimeriks & Van den Besselaar 2006; Vasileiadou & Van den Besselaar 2006; Van den Besselaar & Heimeriks, forthcoming. See also Harries et al, 2004).

In this perspective, the following research questions arise: Do we find empirical evidence for the existence of distinct online communication patterns across fields? What do these differences relate to? Are the web based communications related to field specific use of the Web or can we identify more general patterns? In particular, is the level of 'use orientation' of research fields important to understanding the use of the web by research fields? Our main hypotheses are:

1 use oriented ('mode-2') sciences make more extensive use of internet and Web than the fields that are only aiming at fundamental understanding without any considerations of use ('mode-1' fields);
2 use oriented sciences are characterized by a greater variety of outputs disseminated through the web;
3 use oriented sciences address a greater variety of audiences through the web.

Data and Methods

The study is based on web data about the size, content, and outlinks of the websites of universities and departments from fifteen ('old') EU member states.[3] Once web sites were identified and selected, some basic information was collected using software tools called 'mappers': the name of the department, the institution they belong to, and the URL that identifies them. These tools simply 'crawl' the web starting from a certain site and following the trace of its embedded links and registering the objects found in this process.[4] The software program used to construct the database of European universities is Microsoft Site Analyst[5]. All URLs were classified in three ways: an institutional code that classifies the type of entity based on a survey of the higher education systems in the European Union; a geographical code using the NUTS classification (Nomenclature of Territorial Units for Statistics) of EUROSTAT; and a thematic code according to the UNESCO classification of science and technology domains. The UNESCO codes have a 3-level structure. The first two digits refer to the discipline, the third and fourth digits refer to fields, and the last two digits refer to subfields. In this study, the first 4 digits are used for the delineation of the fields.

Table 1. The distribution of the departments over the 15 EU countries

Field	AU	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK	TOTAL
Comp	68	41	383	14	205	70	108	17	39	55	0	95	26	34	334	1489
Astro	3	1	2	0	7	1	1	0	1	1	0	4	4	1	15	41
Bio	3	3	19	5	17	4	10	1	1	4	0	9	1	5	21	103
Gen	7	5	34	2	18	2	5	0	4	7	0	10	2	9	39	144
Hep	0	2	3	0	1	1	0	1	0	1	0	6	0	0	1	16
Info	11	8	43	6	32	8	11	3	4	21	1	7	4	7	51	217
Lit	3	8	11	5	16	12	7	0	0	16	1	17	0	3	37	136
Psy	1	3	14	0	16	1	0	0	2	3	0	6	0	0	7	53
Total	96	71	509	32	312	99	142	22	51	108	2	154	37	59	505	2199

Astro = Astrophysics; Bio = biotechnology; Comp = computer science; Gen = genetics;
Hep = High energy physics; Inf = information science; Lit = literature studies; Psy = psychology

[3] Data were collected in 2003.
[4] Details about the data collection and the further processing of the data can be found in Arroyo et al. (2003).
[5] Shareware (Back Office Pack) developed from Webmapper.

The data consists of website characteristics and outlinks that enable us to construct disciplinary hyperlink networks between departments. The fields differ in terms of the relevant dimensions of knowledge production: we selected fields with more and with less use orientation (mode-2 versus mode-1) and we included fields from the humanities, the social sciences, and the natural sciences: High Energy Physics, Astrophysics, Genetics, Biotechnology, Computer Science, Information Science, Literature Studies and Psychology. Table 1 shows the distribution of the departments over the 15 countries. The distribution over countries is reasonable (but we do not claim representativity).[6]
This study consists of several steps. We will start (section 4) by analyzing the outlink patterns of the websites, and focus on shared outlinks in the fields, using only unique outlinks.[7]. We analyze the composition of the outlink network, and compare the international and domestic networks. Then (section 5) we analyze the content of the websites. Finally (6) we analyze the relation between the size and content of a website, and the number of inlinks a website receives from other departments in the field: the academic impact of websites. Do the websites indicate the nature of knowledge production, the context of application, and the importance of web based communications to relevant audiences? Can we establish general patterns in web-based communications of scholarly departments or are field-specific patterns visible?[8]

Disciplinary outlink patterns

For each field, the 100 most frequently hyperlinked organizations are classified in the categories university, *publishers and journals*, *governmental organizations*, *companies*, *professional organizations*, *research organizations*, *data repositories* and *archives*. Differences exist in the frequency distributions, but it is also clear that the different types of organization are visible in all fields. It can therefore be argued that the internet maintains similar *networks* in all fields, albeit with rather *different compositions*, as large differences in the share of the different groups are visible (table 2).

Table 2. The distribution of different types of linked organizations

% outlinks to (by field)	Comp	Astro	Bio	Gen	Hep	Info	Lit	Psy
Companies	42	15	33	21	25	30	27	34
Publishers	10	13	14	24	15	18	8	13
Universities	29	36	29	28	23	28	46	43
Research organizations	2	5	0	5	11	1	0	0
Professional organizations	8	9	9	4	9	7	2	3
Governmental organizations	4	16	13	3	7	13	10	4
Archives, Data repositories	3	4	2	13	5	3	4	3
Other	2	2	0	2	5	0	3	0

Cells: percentage of the links

Not unexpectedly, in most of the mode-1 fields, universities are largest category in the outlink environment, whereas in most of the mode-2 fields companies are the largest category. In all fields we find links to software companies and to internet providers, but links to companies are most visible within Computer Science and Biotechnology. Publishers and journals are especially well represented in Genetics and Information Science and under-represented in Computer Science and – unexpectedly – in Literature Studies. Governmental organizations are most occurring in Astrophysics, Information Science and Biotechnology, while data-repositories are most important in Genetics. Archives only occur in Computer Science, Genetics, Astrophysics and High Energy Physics. Data repositories occur in all fields, but in Genetics they are a rather large category. Also the intensity of the hyperlink

[6] Because of lack of space we do not describe the different fields in detail.

[7] Also if a department has more links to an organization, this only counts for one relation. In this way, links represent (unvalued) relations between organizations

[8] The dataset contains *all outlinks* from, but only the *academic inlinks* to the departments. We therefore cannot analyze non-academic audiences, nor whether size and content relate to visibility for non-academic audiences.

relations differs considerably between the fields (Table 3). The intensity of outlinks is largest in Astrophysics and High Energy Physics. If we look in the other direction, we find that link relations are the strongest with universities, companies, and publishers.

Table 3. Average number of outlinks per department by different types of organizations

Links per department to:	Comp	Astro	Bio	Gen	Hep	Info	Lit	Psy
Companies	4,6	3,6	1,5	1,5	5,0	2,6	2,4	2,6
Publishers	1,0	3,5	0,7	1,9	3,3	1,7	0,6	0,8
Universities	2,3	8,8	1,1	1,7	4,3	2,1	3,5	2,5
Research organizations	0,1	1,1	0,0	0,3	2,8	0,1	0,0	0,0
Professional organizations	1,1	2,4	0,4	0,3	1,9	0,6	0,2	0,2
Governmental organizations	0,5	4,0	0,6	0,2	1,5	1,0	0,9	0,4
Archives, Data repositories	0,2	1,0	0,1	1.0	0.6	0,2	0,5	0,2
Average	1.2	3.1	0.6	0.9	2.4	1.1	1.0	0.8

The next question is whether *individual organizations* are prominent in disciplinary hyperlink environments ('preferential attachment' or 'codification')? Despite the lack of clear mechanisms structuring hyperlink behavior, differences exist. Links to internet-related companies such as Google are excluded in order to focus on field-specific outlinks. Figure 1 shows the distribution of the share of the departments in a field (on the y-axis) linking to the same organization (on the x-axis). Astrophysics shows the highest level of 'preferential attachment': Ten organizations in the environment of the field receive links from more than 30% of the European departments in Astrophysics included in this study. On the other side of the spectrum we find Information Science, Literature Studies, Genetics, Psychology and Biotechnology where no organization exists that receives links from more than 15% of the departments.

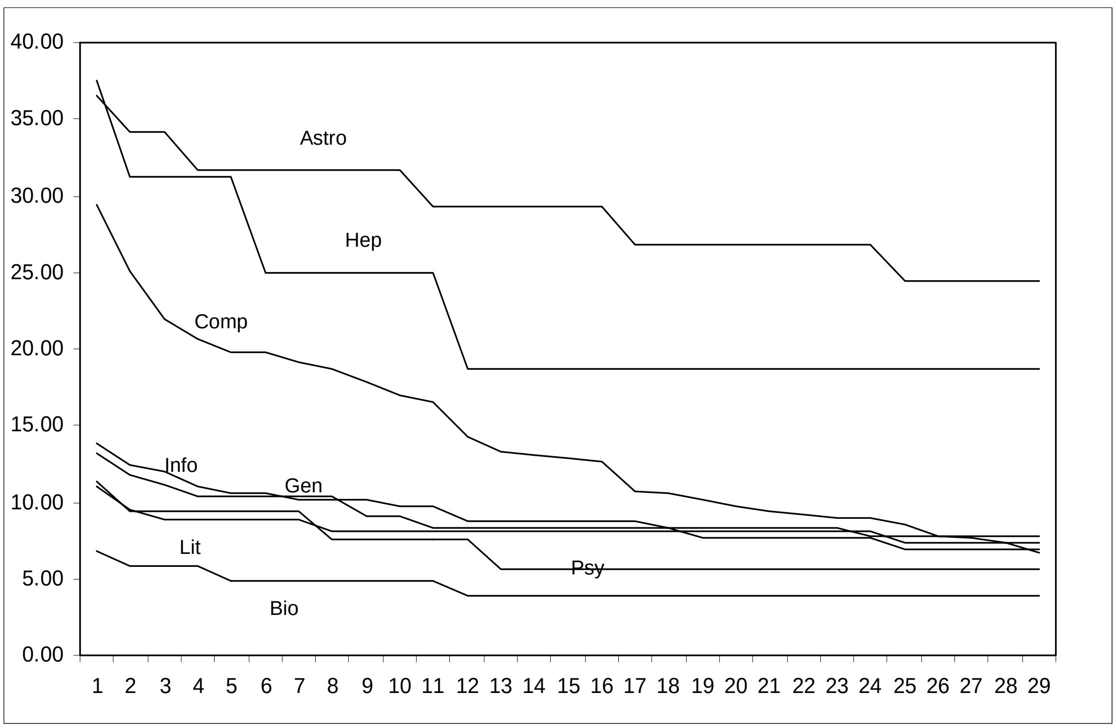

Figure 1. The distribution of most frequently linked websites in selected fields.

What kinds of websites receive many links? The 'codification' seems to depend on data sharing, on the role of governmental and professional organizations and of scientific publishers in the environment, and in some fields on links to important university departments. More specifically, we find that links to peer departments are important within Computer Science, Astrophysics, and High Energy Physics. In the latter two, and also in Genetics, global data repositories receive links from a large number of departments, and important global information repositories (NCBI, NASA and CERN respectively) clearly are the most frequently linked organizations. Shared links to companies are relatively important in Computer Science, in Information Science and in Biotechnology. Publishers (Springer) and journals (Nature and Science) are relatively important in Genetics.

Table 4. The outlink pattern of the random samples compared to the top-100*

Relative in random sample:	Comp	Astro	Bio	Gen	Hep	Info	Lit	Psy
Companies	1,2	2,1	1,5	1,5	1,2	1,4	1,6	1,2
Publishers	1,1	0,8	0,8	1,2	1,1	0,8	0,7	0,9
Universities	0,6	0,8	0,7	0,6	0,9	0,8	0,8	0,8
Research organizations	1,6	1,0	1,2	1,3	1,4	1,5	1,1	1,3
Professional organizations	2,8	1,5	-	1,2	0,8	8,0	-	-
Governmental organizations	0,5	0,6	0,5	1,0	0,7	0,2	1,8	2.0
Data repositories	2,1	0,6	0,6	0,8	1,5	0,8	0,8	0,5
Archive	1,0	0,4	-	-	0,6	-	-	-

* Index: the top 100 links = 1

Is the the top 100 outlinks different from outlinks in general? We randomly selected some 100 unique outlinks per field, and compared these with the top 100 lists (table 4). Generally, we find in the tail a higher share of links to universities and companies, but a lower to publishers, professional organizations, and data repositories. Interestingly, in Literature and Psychology we find a higher share of (national) professional organizations in the tail. Possibly in these fields, the focus of research is more local in orientation, which may be reflected by the presence of local professional organizations in the outlink environment.

Does local orientation differ between the fields? The more a field is oriented on a national and local context, the more it relies on local resources and dissemination outlets. We analyzed this for the Netherlands. Computer Science and Information Science have the lowest share national outlinks (19% and 20%) and Astrophysics and High Energy Physics slightly more (22% and 26%). Psychology and Literature are more locally oriented (28% and 34%) and in Biotechnology 56% of the outlinks are domestic organizations, whereas this much lower in the related field of Genetics (28%).[9]

On the country level, the ‘preferential attachment’ of the departmental outlinks is much stronger than on the European level. This is true for all fields, and ranges from 45% in Literature Studies to 100% in Astrophysics and Information Science. In all fields, the most occurring links are generally domestic. And, the links indicate the relevant local audiences and local resources. In addition to the national research council (funding) and the academy of science (policy), local universities are well represented in all fields.

Differences in website characteristics

Since the target audiences and types of output vary across fields, we expect that the field differences in We operationalize this in terms of the number of webpages, outlinks, images, video-files, audio files, web-maps, applications (java, docs, pdf, etc.) and total number of objects (Table 5)

The average size of the sites show enormous differences (in the year of observation) ranging from 76 pages per site in the field of Psychology to 1665 pages per site in Computer Science. In some fields departmental websites are obviously a less important medium for communication of data and output (Genetics, Biotechnology, Psychology and Literature Studies). At the same time, Astrophysics and

[9] Netherlands’ figures. National orientation correlates with size of countries: organizations in large countries have more local linking opportunities.

Computer Science research groups use their websites to a great extent, and Information Science and High Energy Physics in between[10]. Not surprisingly, the large websites have the most outlinks (r = 0.84), and the size of websites is also positively related to the level of codification.
Very pronounced differences between the fields are visible in the number of images and video files that the websites contain. The websites in the fields of Astrophysics and High Energy Physics contain a large amount of digital visualizations, which indeed are important in these fields (OECD 1998; Gooding 2002). It also shows that the web is used for data sharing. Computer Science websites also contain relatively large numbers of images and videos. Audio files were equally present in all fields.

Table 5. List of site characteristics in selected fields (averages per site by field).

Number of:		Web	Out	Images	Gate	Applica	Audio	Video	Text	Web
Fields	N	Pages	Links		ways	tions	Files	Files	Files	Maps
Comp	1489	1666	639	876	51	254	10	3,68	41	51
Astro	41	1321	1073	1082	29	183	7,7	14	41	4,4
Bio	103	413	147	371	10	47	0,2	0,7	0,4	0,2
Gen	144	313	261	273	11	37	0,4	0,9	2	0,1
Hep	16	519	445	1857	22	168	1,5	0,7	4,7	0,1
Info	217	678	290	482	25	268	8,8	1,2	14	34
Lit	136	350	279	220	18	27	4,2	0,2	0,8	0
Psy	53	76	47	63	2	17	0,17	0	0,1	0
Anova (sign)		,000	,004	,000	,118	,000	,865	,000	,038	,989

The number of applications (like *.doc and *.pdf files) and of text (*.txt) files indicates the digital content available on the sites. Two groups exist. Biotechnology, Genetics, Literature and Psychology have in average less than 47 application files on their websites, showing a low web use for information exchange. In contrast with this, the average site in Computer Science, Astrophysics, High Energy Physics and Information Science is much bigger, and contains more than 168 files.[11] Also here, the size of the websites is decisive, also for the number of files and applications. This distribution is not unexpected. Only for Genetics is, as in this field large online databases play a crucial role – which was also visible in the analysis of the outlink pattern. Obviously, this function is not necessarily reflected in a rich content of websites. Finally, the size of the website is the main determining factor for the content, as the variation of *content per webpage* is relatively low between fields (Table 6)

Table 6. List of average page characteristics in selected fields

Field	Out links	Images	Gate ways	Appli-cations	Audio files	Video Files	Text Files	Web maps
Comp	0.38	0.53	0.03	0.15			0.02	0.03
Astro	0.81	0.82	0.02	0.14	0.01	0.01	0.03	
Bio	0.36	0.90	0.02	0.11				
Gen	0.83	0.87	0.04	0.12			0.01	
Hep	0.86	3.58	0.04	0.32			0.01	
Info	0.43	0.71	0.04	0.40	0.01		0.02	0.05
Lit	0.80	0.63	0.05	0.08	0.01			
Psy	0.62	0.83	0.03	0.22				
Coeff of variation	0.34	0.91	0.31	0.59			0.46	0.35

Empty cell: <0.01

[10] The differences in distribution between these groups are also significant in the pairwise analyses.
[11] Significant between the two groups - not between fields within the same group.

Academic impact of the websites

In the previous sections we showed that the characteristics of the websites differ largely, as did the hyperlink patterns. In the analysis in this section we investigate the relationship between the academic impact of a departmental website and the characteristics of its website. The academic impact (or importance) of a website is measured here in terms in the number of inlinks it receives from *other departments in the field*. The question to be answered is whether this academic web impact is based on (correlates with) characteristics of the website. We only use the important characteristics, such as numbers of pages, outlinks, images and content (documents, databases, programs, and so on). The analysis is done per research field, and the results are shown in Table 7.

Table 7. Correlation between academic inlinks and various website characteristics.

	Comp	Astro	Bio	Gen	Hep	Info	Lit	Psy
Size	0.47	0.67	0.78	0.61	*0.40*	0.20	0.63	0.20
Outlinks	0.34	0.43	0.66	0,51	*0.29*	0.46	0.31	0.46
Images	0.47	0.45	0.72	0.43	*0.28*	0.25	0.59	0.25
Content	0.51	0.81	0.45	0.44	0.69	0.35	0.44	0.35

Italic: not significant; Size = nr of pages; Content = nr applications (text, data, programs)

All correlations are positive, indicating that in general large websites with a lot of content (documents, databases, spreadsheets, etc) and outlinks are more popular and seem to have a larger academic impact than smaller sites with less outlinks and content. Inspecting the results in more detail, we do not find a systematic difference between the so-called mode-1 and mode-2 fields, nor between the fields with large, medium size and small websites. The only 'systematic' difference seems between the sciences and the social sciences and humanities: in the latter fields, the correlation between website characteristics and academic inlinks seems somewhat lower than in the sciences. Overall, the academic status of websites seems to be discipline specific – or even more department specific – and not so much related to mode-1 versus mode-2 fields.

Conclusion and discussion

The previous sections analyzed the web-spheres of eight scientific fields, specifically their 1) linked environments, 2) content, and 3) academic reputation. We now firstly summarize the most salient findings per research fields. Then we reflect on the differences and similarities, and answer questions whether the differences relate to differences between sciences and humanities, or between mode-1 and mode-2 research fields.

In ***Astrophysics*** ICTs play an important role, as found in the website characteristics: an exceptionally large number of video files, for example. The outlinks suggested a well-defined academic audience with a large set of shared outlinks, many to universities. Additionally, the high number of outlinks to governmental organizations indicate the role of government support.

High Energy Physics departments link almost all to CERN, and for the rest to other academic institutions. In term of content, the number of images on the websites is exceptionally large, but also for the rest, the sites have much content. In this discipline, the websites seem to be an important medium of communication content to a predominant academic audience.

Biotechnology, a clear example of mode-2 knowledge production, has a focus on applications, is subject to policy involvement and has a heterogeneity in producers and users of knowledge. The websites are small and have not much content, suggesting that the role of the web is small in this field. The (small number of) outlinks are local and have a strong commercial orientation. This latter orientation explains the low level of web use (Nentwich 2003).

In ***Genetics***, websites are small, as is the number of outlinks. However, within the outlinks, those to international data-repositories have a prominent role, as expected. For the rest, outlinks seem domestically oriented, apart from links to publishers and scientific journals. This confirms that in Genetics researchers typically circulate information only within smaller groups and broader access depends upon publication in journals (Kling and McKim 2000). Here the distinction between fields with a restricted flow of information (like Biotechnology and Genetics) and fields with an open flow of information (like Astrophysics and High Energy Physics) becomes relevant – and this relates of course to the economic potential of genetic and biotech data.

Computer Science websites show a relatively high number of shared outlinks ('codification') and contain a large number of files and outlinks. The number of applications (content) is among the highest of the fields studied here. Furthermore, the outlinks have a more commercial orientation than other fields, suggesting the relevance of non-academic audiences in the field of Computer Science.

Like in Computer Science, in ***Information Science*** the web plays an important role, suggesting that the field has an 'open information flow'. Sites have a bigger content (number of applications) than in any other field. The outlinks go to a variety of audiences (apart from other academic departments). A relatively large number of outlinks are directed to governmental organizations and companies, underlining a stronger application orientation than most other fields. Therefore, big websites are not necessarily full with academic output, and this explains the comparably low correlation of the number academic inlinks with website size and content.

The departmental websites in ***Literature Studies*** are generally very small, and contain small numbers of files. The few – and generally local oriented - outlinks indicate a mainly academic audience. In this example of a traditional mode-1 field, scholars have a strong tradition in book publishing, a factor that Nentwich (2003) identified as having a negative impact on the level of 'cyberness'. Our analyses confirms this: in the hyperlink environment we find relatively many book publishers.

Finally, ***Psychology*** represents a mode-1 field in the social sciences. Websites are very small and maintain a small number of outlinks, showing that the Web plays a minor role in the field (Barjak, 2004). Furthermore, there is little common orientation in the set of shared outlinks, and a big percentage of these outlinks were local.

The sample seems to group into two categories. In Astrophysics, High Energy Physics, Computer Science and Information Science the web is used intensively, the number of shared outlinks is relatively high, the outlinks show an international orientation, and the number of webpages, outlinks, and content on the websites are large. A difference is that in the two physics specialties data sharing is an important issue (NASA; CERN as the most linked organizations), whereas in the two other fields it is not. And in Computer Science and Information Science, the relation with the non-academic environment seems stronger.

On the other hand, in Biotechnology, Genetics, Literature Studies and Psychology, websites are in average small, have a modest content, hardly share outlinks which are more often local. In some of the latter fields this may indicate that the WWW is not very important yet, in others, such as Genetics, the size may be more a reflection of the restricted access to the data, and not that data are not shared – as they are through (NCBI).

In light of these results, we now turn to the three hypotheses formulated in the introduction about the relation between 'cyberscience' and changes in the knowledge production system:

(1) mode-2 sciences make more extensive use of Internet applications than mode-1 sciences.
(2) mode-2 sciences disseminate a greater variety of outputs through the web compared to mode-1 sciences.
(3) mode-2 science address a greater variety of audiences through the web compared to mode-1 sciences.

Firstly, the size of the websites is obviously not related to the difference between mode-2 and mode-1. Secondly, the same holds for the content of the websites, in terms of applications, of images, video and audio, and in numbers of outlinks[12]. In other words, *hypotheses 1 and 2 are not supported*. If there is a relationship, we find it more between open information fields (like physics, computer science and information science) and the fields with restricted information flows (like the life sciences). This relates more to the type of valorization of knowledge than to the question of whether application contexts play a role or not. The position of the social sciences and humanities in this context needs further exploration. Another finding is that the early adopters of ICTs have the bigger sites (physics, computer/information science). The question is whether this is an issue of being behind (social sciences, humanities) or of variation, of heterogeneous developments.

[12] If we compare the *content per webpage* between the fields, differences disappear.

Thirdly, outlink patterns were rather different, in terms of the codification, the type of linked organizations, and in terms of the shares of international links. Codification differed, and was mainly related to the size of the websites, and not to the mode-2/mode-1 distinction. The linked environments differed between the disciplines, and could sometimes be related to specific mode-2 characteristics of the field – but certainly not always. For example, disciplines like computer science, biotechnology and information science have many commercial outlinks, as one would expect given the economic role of these fields, but why this also is the case for High Energy Physics is less clear. Astrophysics and Literature had significantly more academic outlinks. On the other hand, it was not clear why one would expect more governmental outlinks in fields like Astrophysics, Biotechnology, Information science or Literature. Also the size of the outlink environment, its diversity, and its (inter)national orientation does differ, but not related to 'mode-2-ness'. In other words, outlink patterns were different between disciplines, but not systematically related to the mode-1 versus mode-2 distinction. Summarizing, also *hypothesis 3 is not supported*.
Finally, in all fields we found that the size of sites (in terms of pages, content and outlinks) correlates relatively strong with the academic impact of the site, but also here the strength of the correlations did not systematically differ between mode-1 and mode-2 fields.

As a *general conclusion*, the web does play an important role in facilitating the mode-2 characteristics of knowledge production: in sharing data and information, in showing the network of the research organization, in supporting the interaction with non-academic partners, and in the dissemination of output. However, these characteristics of mode-2 can be observed in each of the fields to a different extent. The distinction between mode-1 and mode-2 sciences therefore seems less a dichotomy. Rather, it is better to speak of mode-1 aspects and mode-2 aspects of knowledge production, with each scientific field being characterized by a mix of both types of aspects. If such nuances are forgotten, terminologies quickly start to live a life on their own, and such lives tend to replicate extremely fast in academic and policy circles alike.
May be we need more subtle differences, in more dimensions. For example, low levels of codification, and related, high shares of local outlinks, may reflect heterogeneity of research fields, reflecting uncertainty (Whitley 2000) and diverging search regimes (Bonacorssi 2005), or low levels of dependency between researchers in the field (Whitley, 2000). And, as already suggested, the use of the public web for sharing networks, knowledge, data and information may depend on the way the (economic) value of science is appropriated (Nelson 2004; Dasgupta & David 2004, David & Foray 2002). This of course, needs further exploration.

References

Arroyo, N., V. M. Pareja, et al. (2003). *Description of web data*. Eicstes deliverable D3.2. Madrid, CINDOC.

Barjak, F. (2004). *On the integration of the Internet into informal science communication*. Solothurn, University of Applied Sciences, Northwestern Switzerland.

Bonaccorsi, Andrea (2005). *Better policies versus better institutions in European science*. Paper presented at the PRIME conference, Manchester, January 2005.

Dasgupta, P. & P.A. David (1994). Toward a new economics of science. In: *Research Policy* **23**, pp. 487-521.

David, P.A. & D. Foray (2002). An introduction to economy of the knowledge society.' In: *International Social Science Journal* (March), pp. 9-23.

Etzkowitz, H. & L.A. Leydesdorff (eds.) (1997). *Universities and the global knowledge economy. Science, technology and the international political economy*. London/New York, Continuum.

De Jong, H. and A. Rip (1997). The computer revolution in science: steps towards the realization of computer-supported discovery environments. In: *Artificial Intelligence* **91**, 225-256.

ESFRI (2006), *First european roadmap for new, large-scale research infrastructures*. Luxembourg, EC.

Gibbons, M. C., H. Limoges, et al. (1994). *The new production of knowledge*. London, Sage.

Gooding, D. C. (2002). Narrowing the cognitive span: experimentation, visualization and digitalization. In: H. Radder, *Scientific experimentation and its philosophical significance*. Pittsburg, University of Pittsburgh Press.

Harries, G., D. Wilkinson, L. Prize, R. Fairclough, M. Thelwall (2004). Hyperlinks as data source for science mapping. In: *Journal of Information Science* **30**, 436-447.

Heimeriks, G., M. Hoörlesberger, P. Van den Besselaar (2003). Mapping communication and collaboration in heterogeneous research networks. In: *Scientometrics* **58**, 391-413.

Heimeriks, G. & P. Van den Besselaar (2006). Analyzing hyperlink networks: the meaning of hyperlink-based indicators of knowledge production. In: *Cybermetrics* **10**. Accessible at: www.cindoc.csis.es/cybermetrics

Kling, R. and G. McKim (2000). Not just a matter of time: Field differences and the shaping of electronic media in supporting scientific communication. In: *Journal of the American Society for Information Science* **51** (14): 1306-1320.

Nelson R.R. (2004). The market economy, and the scientific commons. In: *Research Policy* 33, pp. 455-471.

Nentwich, M. (2003). *Cyberscience, research in the age of the internet,* Austrian Academy of Sciences.

OECD (1998). *The global research village: how information and communication technologies affect the science system*. Paris, OECD.

Price, D., de Solla (1984). The science-technology relationship. In: *Research Policy* 13, pp. 3-20.

Rip, A. (2002). Science for the 21st century. In: P. Tindemans, A. Verrijn-Stuart and R. Visser, *The future of the sciences and humanities*. Amsterdam, Amsterdam University Press.

Stokes, D. (1997). *Pasteurs quadrant. Basic science and technological innovation.* Washington: Brookings Institution Press**.**

Van den Besselaar, P. (2007). *Knowledge networks.* Inaugural lecture University of Amsterdam, December 8, 2005. Amsterdam, Vossius Pers.

Van den Besselaar, P., and Heimeriks, G. (forthcoming). New media and communication networks in knowledge production: A case study.

Vasileiadou & Van den Besselaar (2006). Linking shallow, linking deep; how scientific intermediaries use the web for their network of collaborators. In: *Cybermetrics* **10**. Accessible at www.cindoc.csis.es/cybermetrics

Whitley, R. (2000). *The intellectual and social organization of the sciences*. Oxford, Oxford University Press.

Wilkinson, D., G. Harries, M. Thelwall, L. Price (2003). Motivations for academic website interlinking: evidence for the web as a novel source of information on informal scholarly communication. In: *Journal of Information Science* **29**, 49-56.