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Review Article

Models of Research and the Dissemination of Research Results: the Influences of E-Science, Open Access and Social Networking

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Abstract: In contrast with practice in recent times past, computational and data intensive processes are increasingly driving collaborative research in science and technology. Large amounts of data are being generated in experiments or simulations and these require real-time, or near real-time, analysis and visualisation. The results of these evaluations need to be validated and then published quickly and openly in order to facilitate the overall progress of research on a national and international basis. Research is increasingly undertaken in large teams and is also increasingly interdisciplinary as many of the major research challenges lie at the boundaries between existing disciplines. The move to open access for peer reviewed publications is rapidly becoming a required option in the sector. At the same time, communication and dissemination procedures are also utilising non-traditional forms facilitated by burgeoning developments in social networking. It is proposed that these elements, when combined, constitute a paradigm shift in the model of research and the dissemination of research results.

Keywords: ***academic social networking; collaboratories; grand challenges; big data; analytics; visualisation; paradigm shift***

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1. E-Science

The E-Science initiative was started in the UK in 1999 to utilise the capabilities of distributed network environments to give researchers direct access to computationally-intensive facilities to process large amounts of data, such as those generated by experiments, sensors, modelling, or simulation. This can be termed a "collaboratory" and may be defined as an environment where participants make use of computing and communication technologies to access shared instruments and data, as well as to communicate with others. Typical research areas are engineering simulations,

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climate prediction, molecular modelling, particle physics, medical analysis, and astrophysics; however, collaborations in the emerging research field of digital media have also been significant drivers of the scale of this methodology. Research projects with multidisciplinary research teams across institutions that required the processing of massive data sets, often in real-time, were able to exploit this provision. Collaborations started on a local geographic basis, but rapidly expanded to an international basis (e.g. the Large Hadron Collidor), since Web- or Cloud-based collaboration with colleagues on the other side of the World is almost indistinguishable from collaboration with someone in the next room. These initiatives have been demonstrated to improve productivity and capability in research [1]. The trend of focussing resources on large groups of researchers has continued with the emphasis in EU funding schemes and national research councils on the awarding of large collaborative grants on a trans-institution basis.

Initial experiments on a trans-European basis demonstrated that a wide variety of application areas benefited from collaboration across networks in the research and development process, particularly where teams of researchers needed to collaborate on shared data, or where interdisciplinary work was concerned. In addition, industries associated with the outcomes were able to benefit by the reduction of research and development times (e.g. from prototype to final design), the sharing of information across the network, and also the sharing of access to specialist facilities over the network [2].

A further project funded by the European Union (MAID [3]) designed, tested and demonstrated a range of high-level information services for the industrial design sector, aimed at improving the competitiveness of the design-based industries and professions. It addressed a wide range of information engineering problems and demonstrated effective systems of multimedia data exchange and asset trading involving existing technologies and offering scaleable solutions. The project developed and demonstrated systems which allowed designers and industry to access multimedia databases interactively and integrate data into their own design computing environment. However, very significantly, it also demonstrated participation in distant work groups, enabling users to receive on-line design tools and services: this demonstrated the viability of implementing complex projects at a distance.

The combination of visual tools with supercomputers has enabled the interactive exploration of massive datasets in real-time. Visual analytics combines scientific and information visualization with technologies from other disciplines, including statistical analysis, cognitive science, knowledge management and decision science [4,5], which is by definition an interdisciplinary research environment.

In 1999 the National Science Foundation and the European Commission set up a joint initiative to define the areas of research that would benefit most from greater international collaboration. These included human-centred computing, online communities and virtual environments [6]. This implicitly acknowledged the interdependence of these areas in research investigations in any one of them.

It has been argued that these developments constitute a paradigm shift as they increase the scale and complexity of the problems that can be addressed [7].

Muggleton [8] summarised this as follows -

> "During the twenty-first century, it is clear that computers will continue to play an increasingly central role in supporting the testing, and even formulation, of scientific hypotheses. This traditionally human activity has already become unsustainable in many sciences without the aid of computers. This is not only because of the scale of the data involved but also because scientists are unable to conceptualize the breadth and depth of the relationships between relevant data-bases without computational support. The potential benefits to science of such computerization are high — knowledge derived from large-scale scientific data could well pave the way to new technologies, ranging from personalized medicines to methods for dealing with and avoiding climate change. Meanwhile, machine-learning techniques from computer science (including neural nets and genetic algorithms) are being used to automate the generation of scientific hypotheses from

> data. Some of the more advanced forms of machine learning enable new hypotheses, in the form of logical rules and principles, to be extracted relative to predefined background knowledge. One exciting development that we might expect in the next ten years is the construction of the first microfluidic robot scientist, which would combine active learning and autonomous experimentation with microfluidic technology"

The computational approach to problem solving involves the deterministic processing of data, so is in principle reproducible. At the same time, interactive steering of a computation can lead the investigation in new directions not originally envisaged. Thus an element of creativity can be involved in reaching a solution. It has become recognised that the data involved in the computation is just as important as the results, so the datasets should also be made available, typically by being held in an open repository where they can be accessed. If traditional science has both deductive and empirical approaches, it can be argued that the computational approach represents a shift in a new direction.

2. Interdisciplinarity

Large research teams seeking to solve problems requiring large data sets often involve specialists from a number of disciplines in order to gain maximum value from, and insight into, the data. In particular, the use of various types of computer interface has been shown to influence the choice of analytical options. Also, the choice of the method for information display can influence what is viewed and perceived. Modelling and simulation also requires expertise in the various methods of analysis, and may often involve specialists from more than one discipline. Further, it has become apparent that computer architecture has an influence on the choice of algorithm and even the mathematical-physical formulation used in large-scale simulations: this has become apparent in fields where there is a choice of radically different approaches, e.g. between integral-equation and differential-equation formulations [9].

Moti [10] provides a definition of interdisciplinarity as "bringing together in some fashion distinctive components of two or more disciplines" and suggests that there are four 'realms' of interdisciplinarity:

1. "interdisciplinary knowledge – familiarity with distinctive knowledge of two or more disciplines;
2. interdisciplinary research – combining approaches from two or more disciplines while searching or creating new knowledge;
3. interdisciplinary education – merging knowledge from two or more disciplines in a single programme of instruction; and
4. interdisciplinary theory – takes interdisciplinary knowledge, research or education as its main objects of study"

Weller [11] notes that many of the current grand challenges may not be solvable by a single disciplinary approach. Such challenges include including climate change, dwindling resources, global health epidemics and the impact of global information networks. Indeed the globalisation of many issues, often driven by the Internet, can be seen as an impetus for interdisciplinarity. Kockelmans [12] states that there is an "inexorable logic that the real problems of society do not come in discipline-shaped blocks".

Differences between the disciplines can be both technical and cultural. In addition, the broad division between arts and sciences, as set out by Snow [13], is no longer a sufficient or accurate statement of the situation. As research accumulates knowledge in greater detail, the differences can be increasingly fine-grained. As well as the technical components of the research, they also include how research is performed, what constitutes valuable knowledge in the field(s), conventions for collaboration, and what form dissemination should take.

Bauer [14] suggests that "interdisciplinary work is intractable because the search for knowledge in different fields entails different interests, and thereby different values; and the different possibilities of knowledge about different subjects also lead to different epistemologies. Thus differences among practitioners of the various disciplines are pervasive and aptly described as cultural ones, and interdisciplinary work requires transcending unconscious habits of thought". In some circumstances social and cultural issues and differences can have a greater negative impact on the overall project than any technical issues or roadblocks [15]. This however is very much dependent on individual personalities and diversity can enhance creativity and problem-solving capability, due to different kinds of information and different perspectives

It is possible that technology can play a positive role in ameliorating these difficulties and supporting interdisciplinary investigations. Bainbridge [16] proposed that there is a convergence occurring in science based on three developments - scientific knowledge now being applicable from the macro- to the nano-scale, developments in technology, and the choice of methodology. However, Hendler [17] proposed that the study of the technology itself should be an interdisciplinary field – an example in computing would be Web science. The Web Science Institute describes Web science as focusing "the analytical power of researchers from disciplines as diverse as mathematics, sociology, economics, psychology, law and computer science to understand and explain the Web. It is necessarily interdisciplinary and is as much about social and organisational behaviour as about the underpinning technology" [18]. As the Web cannot exist without its technological infrastructure, then this component underlies all the experiments and investigations associated with it. However, this is no guarantee of an interdisciplinary approach, since many aspects of studying the Web can proceed independently. For example, its social and economic implications can be studied in isolation from other aspects, and where the Internet is regarded solely as a transport service.

The way data is viewed also needs to be carefully considered, whether for further investigation or public presentation and dissemination. Visual representations are prone to misrepresent and mislead [19] and are often used in advertising to support pre-conceived notions rather than to display the true facts about a situation. In the future it could be important to consider how such visual representations could be certified, so that those who use them as a basis for decision-making can have the assurance that they have been correctly and accurately formulated, and they are not open to misinterpretation or misuse.

3. Open Access Publishing

3.1. Discipline-specific research

Open access is defined as unrestricted online access to peer-reviewed research publications. It can be either completely free, or free with some additional usage constraints. The latter can be provided by a creative commons license. Authors can provide open access by self-archiving their journal publications in an open access repository (known as green open access) such as their institutional repository, or by publishing in an open access journal (known as gold open access). Hybrid open access journals are subscription journals that provide gold open access only for those individual articles for which their authors (or their author's institution or funder) pay an open access publishing fee.

The Budapest statement [20] defined open access as follows:

> "There are many degrees and kinds of wider and easier access to this literature. By 'open access' to this literature, we mean its free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. The only constraint on reproduction and distribution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited"

From 2016, the UK funding councils have required that journal articles and conference proceedings will only be eligible for inclusion in future Research Excellence Framework submissions if they have been made open access [21]. Further, in a recently published article [22], 11 national funding organizations in Europe, which jointly spend about €7.6 billion on research annually, will require from 2020 that every publication they fund is to be freely available from the moment of publication. Hybrid open access publishing will not be allowed. This will have important repercussions for professional society publications such as IEEE Transactions, conferences and magazines, which either follow the hybrid OA model or lack any OA provisions. Policy adjustments will have to be made at the professional society level, but this development will need to be addressed at Executive level when considering initiatives, such as the IEEE Digital Library. Thus the open approach to the dissemination of research publications is moving mainstream.

3.2. Interdisciplinary research

Discipline-specific research outcomes can be published in the standard journals and conferences that are well established in their respective fields. However, interdisciplinary research outcomes have no specific avenue for publication. When refereed using the standard procedures it is possible that a research paper at the boundary between two disciplines could be regarded by a reviewer in each of the disciplines as not sufficiently central to the discipline area. However, there is now the option of utilising the more open environment of the Web for publication and also the option of exploiting the associated networking tools and facilities. Many blogs and networking sites are being used to disseminate research ideas and to gather views. Aemeur, Brassard and Paquet [23] suggest blogs act as a form of personal knowledge publishing which fosters interdisciplinary knowledge sharing.

Shaohui and Lihua [24] suggest the following three characteristics of blog culture -

1. "Thought share – if the first generation of websites were characterised by information sharing, then blogs mark a move to sharing thoughts.
2. Nonlinearity and concentricity – through linking, embedding, within blogs and then aggregation of blogs, there is a nonlinear construction of knowledge.
3. Criticalness and multivariate collision – specifically this arises from a personal, subjective standpoint that attracts varied comments and views".

Le Meur [25] suggested a number of aspects of a blog community, including -

- "a willingness to share thoughts and experiences with others at an early stage;
- the importance of getting input from others on an idea or opinion;
- launching collaborative projects that would be very difficult or impossible to achieve alone;
- gathering information from a high number of sources every day;
- control over the sources and aggregation of their news;
- the existence of a 'common code': a vocabulary, a way to write posts and behaviour codes such as quoting other sources when you use them, linking into them, commenting on other posts and so on;
- a culture of speed and currency, with a preference to post or react instantaneously; and
- a need for recognition – bloggers want to express themselves and get credit for it"

Thus interdisciplinary knowledge may arise in the following ways in blogs, as noted by Weller [11]:

1. "as the formal communication platform of a department, project or individual with a specific interdisciplinary remit;
2. through the historical context of the individual, who may have specialised in a different domain previously and can reference this in a personal blog;
3. informal interests which overlap with the more substantive content of the blog, such as the examples above; and
4. through comments and links from the blogs' wider readership

Each of these routes for interdisciplinary publication would be difficult to realise through the more formal mechanisms of journals or conferences. What is potentially significant for interdisciplinarity is not so much the technology itself but the practices that are associated with it. This is particularly relevant with regard to openness".

3.3. Academic social networks

Some early attempts to set up a social network for science and technology were generally not successful, at least in research collaborations (e.g. Scientist Solutions, SciLinks, Epernicus and 2collab). However, more recent initiatives have attracted substantial interest. Table I shows the current activity on academic social networking –

Table 1. Academic Social Networking

	ResearchGate	Academia.edu	Mendeley	Google Scholar
No of users	4.5 million	11 million	3.1 million	~ 160 million documents
Investment	US$35 million	US$17.7 million	Bought by Elsevier for US$76 million	Owned by Google
No of papers	14 million	3 million		

ResearchGate enables users to create profile pages, share papers, track views and downloads, and discuss research and make contacts. Its objective is to advance research by means of sharing, collaboration, global links to other researchers, and open science [26]. Academia.edu supports the sharing of papers, viewing of analytics on the papers, and tracking of other people in the field. Mendeley is a free reference manager and academic social network which allows users to read and annotate PDFs and create a fully searchable library. Google Scholar is a freely accessible Web search engine that indexes scholarly publication. It includes most peer-reviewed online journals of Europe and the USA, other non-peer reviewed journals, and scholarly books. LinkedIn, Twitter, and other channels are also being increasingly used to generate online presence and contact those with cognate interests [27,28].

It is possible that publishing using the social networking may increase in importance as there are signs of changing models of publication, dissemination, and exhibition, such as: the sharing of "raw science" such as datasets, code, and experimental designs; semantic publishing or "nanopublication," where the citeable unit is an argument or passage rather than the entire work; self-publishing via blogging, microblogging, and comments or annotations on existing work; online simulations. However, the recent rise of the previously-unexpected phenomenon of "fake news" raises serious questions of the way such publishing can be validated – the traditional function of the publisher.

7. Conclusion

E-Science provided an initial infrastructure to support computational and data intensive processes of the kind often essential to address major scientific challenges. It also provided a model for collaboration across institutions and disciplines. Interdisciplinary research and development is growing but is still not able to realise its full potential due to "discipline silos" associated with traditional university conventions regarding funding and publication. In part, this "silo mentality" is underpinned by the (generally) narrow discipline coverage of "established" journals: this has possibly driven the growth in the range of journals on offer, although there are still difficulties in raising a significant impact factor for a new journal. However, the move to open access, and the trend to sharing of data and results via social networking platforms, is breaking down traditional barriers and will yield significant potential for the future of research and the open discussion and dissemination of results. This clearly represents a challenge to publishing models – an issue that arguably first appeared in the Physics community due to outlets like ArXiv [29] and experience there deserves to be monitored to deduce lessons for the future.

Note

This paper is an edited and expanded version of one originally presented at the Conference on Internet Technologies and Applications, Wrexham, UK, in 2015 [30].

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