Adoption of e-Infrastructure Services: inhibitors, enablers and opportunities

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Abstract. Based on more than 100 interviews with respondents from the academic community and information services, we present findings from our study of inhibitors and enablers of adoption of e-Infrastructure services for research. We discuss issues raised and potential ways of addressing them.

Introduction

In order for the e-Research community to realise the full potential of e-Infrastructures for research, issues of uptake and of embedding these socio-technical configurations in day-to-day working practices need to be addressed and opportunities for widening the uptake need to be understood and exploited. Consequently, investments in the development of technologies and applications are now being complemented by active programmes of community engagement (Voss *et al*. 2007). The UK's Joint Information Systems Committee (JISC) has funded three complementary initiatives that work in close cooperation with each other. The e-Infrastructure Use Cases and Service Usage Models project (eIUS) focuses on uncovering and documenting existing usage of e-Infrastructures that may inspire further uptake. The ENGAGE initiative aims to uncover examples of e-Research projects that can benefit from a short-term injection of effort that help them overcome concrete obstacles they face.

The third project, on Widening Uptake of e-Infrastructure Services (e-Uptake), studies the inhibitors researchers face in taking up e-Infrastructures and possible enablers that may help to overcome them. The project has interviewed more than 50 researchers from a wide range of disciplines and institutions as well as more than 50 people working as intermediaries between service providers and researchers (for example, staff from information services and research computing services). We have described the approach we have taken for data collection and analysis in a previous paper (Voss *et al*. 2008) and will focus on the findings in this paper.

Representing Findings

The main output of the project is a corpus of detailed findings that provide evidence for the existence of inhibitors and enablers of e-Infrastructure services adoption. As the number of individual findings is large (counting in the hundreds) and as a resulting document would be

in excess of 300 pages long, we decided that the best way to represent this material is through an online resource. In this way, the detail can be preserved while making the material more accessible through the extensive use of hyperlinks and through a search function in addition to a hierarchical structure facilitating browsing.

After some initial investigations of this form of representing the data using custom built tools, we decided to adopt the Connexions service developed at Rice University[1], which provides support for authoring learning material and structuring it as a set of collections of re-usable modules. We found that the functionality provided by the service can model all the aspects of the data that we felt needed to be supported. The fact that the service supports OIA-PMH harvesting and OpenSearch means that we can integrate the data into other systems such as the ENGAGE portal[2].

At the same time, the system allows the integration with material produced by the other two community engagement projects, ENGAGE and eIUS as well as resources unrelated to the current efforts funded by JISC. As the individual findings are presented as self-contained modules, it is also possible to create new collections that combine a selection of these modules to represent a particular analysis of the data, for example, with a particular disciplinary perspective or from the point of view of particular stakeholders. In addition to the web-based view, the system also supports the production of a compiled PDF version that can be downloaded or printed using an on-demand printing service.

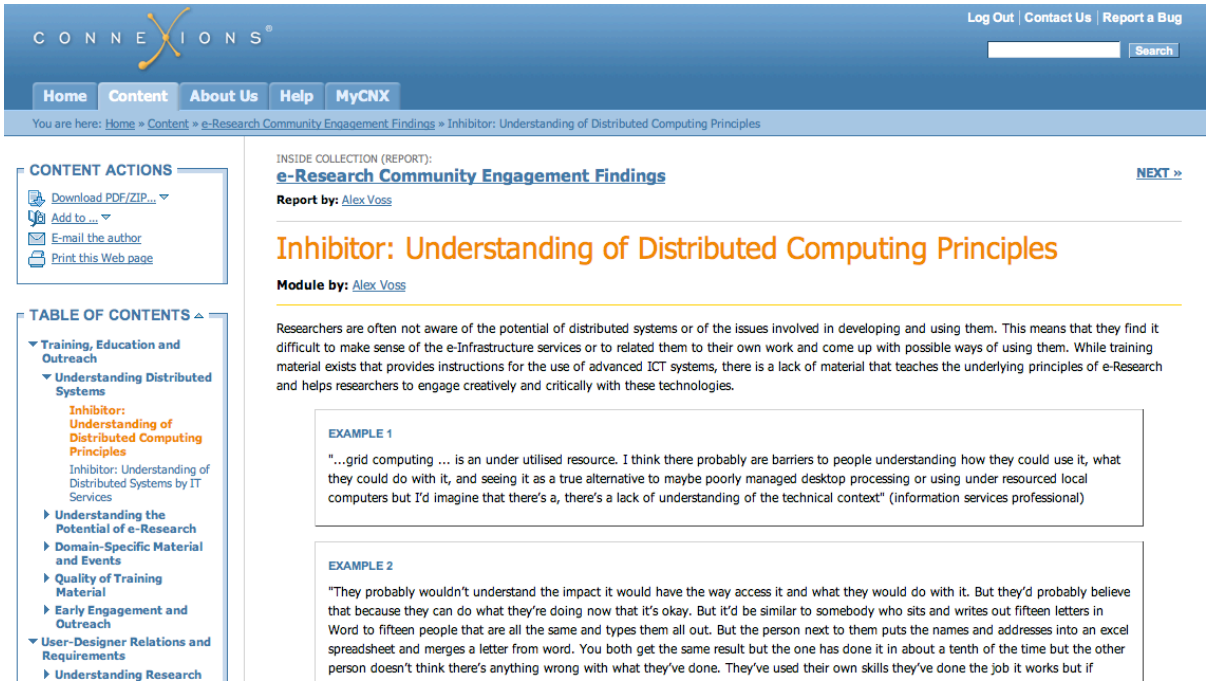

Figure 1: Findings in the Connexions System (output view)

The openness of the system will help to ensure the sustainability of the outputs. We envisage that other projects will revise the material and add to it. The role-based access control in the system will enable collaborations and a distribution of responsibilities after the end of the current projects. The fact that the data can be exported in a well-defined, XML-based format means that the collection of material is not dependent on the existence of the Connexions

[1] www.cnx.org

[2] www.engage.ac.uk

service but can be imported into another instance of the software the service is based on or that it can be converted to other formats for import into different systems.

Inhibitors, Enablers and Opportunities

In this paper, we give an overview of the findings we have derived from the interview material and discuss the implications for e-Research practice and the development of e-Infrastructures. We have completed an analysis of the two phases of interviews, with researchers and with intermediaries, and the material presented in this paper is based on an initial assessment of how the findings from the two phases relate to each other. We examine, in particular, patterns that are beginning to emerge that seem to indicate that certain issues are of wider relevance, for example, that they are of importance in more than one field. These may include, for example, user-service relations, data security and confidentiality, collaboration, and training, education and outreach.

In order to reduce the wealth of material down to a manageable list of findings of wider significance, we have made a number of analytical distinctions represented in a typology of inhibitors and enablers that we have used as a structuring device for our material. In the following sections we present a selection of our material under the following three main headings: 'social issues' relate primarily to the social and organisation arrangements of e-Research and technology usage; 'technical issues' relate to aspects of technologies and their importance in contexts of use; 'discovery, access and usage of digital resources' relates to (collections of) data and issues around their usage. The initial form of this typology of findings was based on a literature review conducted at the start of the project. It has been revised in the light of findings from the interviews where necessary.

Social Issues

A large number of issues raised can be classified as social rather than technical issues as they relate to social relations, the organisation of activities and human skills rather than to aspects of technologies. The following sub-categories were identified: training, education and outreach; user-designer relations and user requirements; understanding disciplines; collaboration; policy and funding; organisation of disciplines; individual issues; organisational issues; ethical and legal issues. In the following, we will focus on training, education and outreach as well as support mechanisms as an example, because of the fundamental importance of these issues.

Issues related to training, education and outreach seem to be major barriers, especially to early engagement of researchers and the connection between different stages of engagement. **Lack of awareness** of services is a main barrier to their use. In general, there seems to be a **lack of systematic introduction to the services and the training available,** which results in a lack of awareness as well as a lack of understanding of how services and methods can facilitate research and what different options exist. Some respondents from information services suggested that there is an emphasis on basic computing support caused by the wide uptake of desktop computing in institutions but that "maybe now [information services] need to get back and think about helping people with what it is they want to use computers for." Support and outreach activities varied significantly between different kinds of institutions and between different disciplines. Awareness of services provided within an institution is systematically reported to be higher than that of equivalent services provided elsewhere even if those have a national remit.

Researchers appear to find out about e-Infrastructure services through events such as the UK e-Science All Hands Meeting, through colleagues or workshops and it is often through their personal initiative that they acquire the skills on how to use these resources. Of importance are also the effects of boundary spanning, when people move from one discipline to another. We might conclude, then, that **social relations are key enablers of uptake**. People tend to be **resourceful in getting the support they need** once they have made a decision to engage and are becoming more self-reliant over time. Some may even actively **contribute** to the development of e-Infrastructure services and tools through reporting bugs and stating requirements. However, being able to engage in such a meaningful way depends on **the availability of support mechanisms** that are well advertised and dependable.

In areas where the use of e-Research tools is quite common, we can observe relatively **stable arrangements for the systematic training of young researchers**: "some of the OMII[3] people have been helping us run the little short courses, so two three days courses on e-Science or Life Sciences and these are actual workflows for Life Science and Medicine and that sort of stuff, and they're incredibly useful just to some people like PhD students and post-docs." Clearly, such routine arrangements would be of immense value in other areas but they rely on having a **critical mass** both on the demand and the supply side. A medical researcher was in no doubt that there is an urgent need for capacity building within their field: "Well, yes, biology is now data rich science in the same way as particle physics is because of its technological innovations but the personnel hasn't caught up at all, there is still a massive shortage of computational biologists people."

One researcher outlined the difficulties users face when engaging with grids for the first time. From their experience with cluster computing and grid applications, they commented on the **lack of support bridging the gap between initial interest and specific training** and a bias in the kind of training provided: "perhaps there's a general need for more training that's aimed at the domain experts rather than e-Science experts." Also, they expressed a **need for more hand-on consultancy style interaction**: "there is a need for more people to sit down with scientists and work with them on their specific applications […]". However, a member of an information services department raised the issue that departments like theirs **are not necessarily equipped to provide such hands-on support**: "within information services 20 or 30 years ago it was the case that people […] had the skills […]; information services I'd say has become more focused over the last few years on technical support, and I would say that application support has lost out."

A problem raised by a member of a research computing group services is that **researchers often do not get in touch with them prior to writing a research proposal** – the time when their input could be most fruitful. The consequence is that support for advanced computing is often not considered and costed: "The big problem we face is people write their proposals, run into problems, come to us, but in their proposal there was never anything mentioned about computing support or visualisation support." As a result of this, the scope for usage of e-Infrastructure is often limited. The cause is a lack of awareness of researchers of the importance to consider research computing at the proposal stage but this may be compounded by a corresponding **lack of awareness within information services**: "we should in theory be contacted via the University IT support. Unfortunately, at this time […] we have still the problem that faculty IT support doesn't necessarily know about [us]". On the other hand, we have found evidence of **very active and routine user engagement** in *some* institutions: "information services has […] academic liaison directors whose task it is to speak to the users and their colleges. [There are] monthly stakeholder meetings, and [liaison staff] go out and

[3] www.omii.ac.uk

meet with the research groups.“ Clearly, active user engagement by research computing services has the potential to overcome the lack of awareness discussed above.

The development of pathways to adoption and of support mechanisms calls for increased collaboration between service providers and institutional services. For example, while the call for more direct involvement of services is being met by the ENGAGE initiative and increased NGS user engagement activities, questions remain about how such initiatives can become more embedded in the normal practices and arrangements of HEIs. For example, an information services professional commented that they “it is important that JISC explain to the information community what facilities there are, so that we can share that with our users”. The problem being addressed here is one of a **lack of information flow from JISC and JISC services into institutions**.

Potential users often **lack the time to develop the necessary skills and insights on their own**. On respondent comments: “I can see that there are things there which we probably could be able to use in the future but first we’d have to work out how […] if we had the time to actually be able to get far enough into the technology to be able to actually utilise it properly.” This example underlines the importance of developing exemplars, not as demonstrations of technical feasibility but as ways to **explore possible use cases and technical configurations**. Examples of usage can also help to further uptake by communicating a vision or triggering competitiveness: “having stuff where you can show that people have done really new science using those tools […] it seems to be working quite well in terms of getting engagement and we're seeing that other communities just like these things - like the systems biology communities are beginning to be very keen to play and join in.” Clearly, it is important for the community to **formulate clearly where e-Infrastructure usage has made a significant difference to researchers and to disseminate these success stories** widely to inspire more researchers to start engaging.

An opportunity that has perhaps not been exploited to a large enough extent is to **link e-Research with existing ICT training programmes** in some disciplines: “we used to run a very successful digitisation summer school for cultural heritage professionals […] and now we run a preservation summer school.” Clearly, integrating e-Research training with events like this will serve to reach a wider audience of young researchers who would otherwise be difficult to reach. Another opportunity is the integration of appropriate content in the course structures of **doctoral training centres** and the inclusion in normal disciplinary curricula through the route of **teacher training**, making a baseline level of knowledge about e-Research practices a prerequisite for the acquisition of Learning and Teaching certificates. Another suggestion was that **service providers should visit institutions**, making use of staff development events and promote uptake of technology: “so I would suggest a sort of travelling roadshow […] give presentations, go round different universities, […] show them what’s available and show them how it can be useful.” Again, the **importance of adequate follow-up** was stressed, an issue that will need to be take into consideration in the development of roadshows and other outreach initiatives.

Technical Issues

Our interviews uncovered a number of technical issues experienced by researchers and intermediaries alike. Because they are experienced in a context of use rather than as attributes of technical artefacts *per se*, we often find them linked to practices and organisational arrangements. Comments were categorised under 5 different headings: infrastructure, security, rate of change, cost of adoption and scale. In the following discussion, we focus on

the example of security and access mechanisms, as we believe that these are of particular interest for uptake of e-Social Science.

Researchers commented negatively on the **procedure for acquiring a UK e-Science certificate**. They suggested that "there are many places where the security gets in your way and what it does it puts people off getting involved. It is easier to use a computer at your university that is free and easy to access." The process of acquiring a certificate and managing it is quite fundamentally different from the normal ways in which researchers gain access to resources within their institutions as well as in other contexts. The overall process gives rise to a number of inhibitors at different stages but our interviews indicate that the first step of acquiring a certificate is the main hurdle that many researchers do not pass. We found evidence that **practices for issuing certificates differed from one registration authority to another**, with institutions adding to the complexity of the process: "we will only issue certificates to members of the university […] we will only issue certificates to people who we have some reason to believe might possibly have some good reason to have a certificate […] if an undergraduate comes along and says I want an e-Science certificate, our first question would be 'why?' […] we need authorisation from your director of studies for that". Ironically, the **effort involved in obtaining a certificate leads to a security problem**: "you create an incentive for the users to behave badly and we've seen this, we've come across users sharing certificates and stuff like that."

On the other hand, researchers complained about the need of using **different passwords** for different services. Clearly, some unified form of authentication is required. Athens is a partial answer to the problem but the sign-up process and the need to remember and periodically renew passwords make it less than ideal. The **move towards Shibboleth-based authentication** will address many of these issues and efforts are underway to integrate Shibboleth and the UK Access Management Federation with traditional certificate-based security mechanisms. At the same time, the NGS is using the model of a 'roaming RA' to simplify the process of issuing certificates and signing up groups of researchers at the same time and in their normal work environment. Other models such as community gateways were mentioned but there are significant issues with authorisation and accounting where the resource provider does not know the identity of the requesting user.

While Shibboleth and the UK Access Management Federation offer a potential solution for many authentication scenarios, they are not without their problems. Respondents from information services raise issues about **scalability**: "at the moment, there is this huge XML file that has to be passed round which is here's everybody that the UK Access Federation knows about". The respondent also commented that there should be **drop-in plug-ins for commonly deployed systems**, for example, for "IIS, for Apache and for Tomcat. So that it's a simple drop in install for an ignorant webmaster, oh I run Apache, right, what do I do to get Shibboleth, well it should be double click on this."

Authorisation is another issue mentioned. The possession of a certificate does not normally equate to gaining access to a protected resource. The **division between authentication and authorisation** again is unusual as it differs from the familiar model of obtaining a password for a system. While in the long run mechanisms such as certificates or single sign-on systems provide benefits, they often require an initial effort that is not immediately rewarded by gaining access to a resource. There were several issues mentioned concerning **the need for registration** in order to access services, **the lack of standardised rules and systems** to access services and the **lack of group access to services** for teaching purposes. More specifically, one of the interviewees underlined that registration is a barrier not only for them but for many other users: "I know there has been a barrier for me and also for a lot of users

which is the requirement that you register before you can download anything from the [service] and […] a lot of people just give up before they download stuff."

The flipside of these practical issues with authentication and authorisation is the **lack of trust in the security of distributed computing systems** that is often observed: "other projects (not necessarily medical ones, but also engineering ones) where the organisations involved saw the Grid as [a] great looking solution but didn't want their data to leave their network […] it has happened before where companies involved didn't want to go beyond some toy examples, despite the project being able to solve a lot grid related problems." The lack of strong assurances about security and confidentiality in general e-Infrastructures for research means that research with sensitive data often has to be carried out in **secure environments ('data enclaves')**: "if we want to link individual level data and link things like census data and council registries then we need to have names and addresses." Practical arrangements can sometimes be made that allow some processing to be carried out outside these secure settings, e.g., through the use of artificial identifiers (or pseudonyms): "have you heard of pseudo-anonymisation where you create an ID from a name and address, for example, and then those pseudo-anonymised IDs can be […] kept in a very secretive file." However, to date there are **no generic mechanisms and organisational arrangements that make work with sensitive data possible** at a reasonable cost while complying with data protection legislation and relevant regulatory regimes.

Discovery, Access and Use of Digital Resources

Respondents raised a range of concerns about digital resources, most commonly in relation to research data but also concerning resources such as learning materials. Broadly speaking, these collectively point to a number of perceived gaps in digital resource infrastructure provision. The following six categories were the most prominent ones: discovery, storage and archival, sharing/re-use, curation and legal/ethical.

In the idealised research process, the data collection phase marks the beginning of the data lifecycle. For many researchers, however, data collection is complemented or even substituted by the discovery phase where a search is conducted to see if relevant datasets already exist. For example, repositories such as the UK Data Archive, Mimas and EDINA provide a vast range of datasets to the social science research community. Respondents confirmed that these services are perceived as being very valuable but that they also feel the **discovery process is not always effective or reliable**. In a number of cases, it was the quality of metadata that was a key concern: "it is quite difficult to find all the data that exist […] There is metadata there to be sure but you cannot query it in a way we want, that would facilitate the research, because it's a laborious part of the research which is not that exciting. So a better metadata and better ways of searching the metadata is what's needed there."

Part of the problem is seen by respondents as stemming from a **lack of agreement within research communities on data and metadata standards**: "people do not use controlled vocabularies, and ontology, that also causes difficulties sharing data, because meanings of the terms used […] are different from individual to individual or even the same individual on different trials, they may use the same word to mean different things. That was the biggest problem we identified." The existence of **heterogeneous data formats** can cause problems both for researchers and for service providers. A social scientist respondent remarked: "it's getting the stuff in a format that you actually know what to do with it." Another respondent lamented the lack of "common data formats so that you don't have to know a hundred data formats." This respondent continued: "there is a need for core data services which serve fairly raw data and also value added services [on] top of that, that package up the data in a way

which could be more valuable for certain clients [...] you just get the data that you need in a format that you expect it." A member of information services discussed the problems of providing support for researchers working with very different datasets: "I suppose the problem is that it's a complicated area, different people have data which is structured differently, and I suppose we're grappling with whether you can give generic advice or if it's got to be discipline specific or if it's got to be indeed project specific."

Most kinds of automated data manipulation and analysis require **data to be of good quality, regular, well-defined and well-described**. Very often, though, data in the Arts and Humanities, the Social Sciences and in Medicine (e.g., hospital records) is highly irregular, lacks adequate metadata and is of varying quality. Consequently, automated processing cannot be applied without further effort, workarounds or methodological compromises. For example, one researcher said: "[our project] kind of died a death because the data which was available wasn't good enough to use any of the tools that social scientists [use] to look at the data, to manipulate it because the nature of the data is that it is fuzzy, it is not scientific data. […] that is on hold until we can get better data." Another respondent, noting that curation must increasingly embrace outputs over the whole of the research lifecycle, commented on whether it is feasible to **capture sufficient provenance information**: "in terms of dealing with relatively complex data and relatively complex analytical techniques, at least complex to the perspective of social scientists, there is this basic tension between describing things clearly and from an introductory level and having enough space to go into the more details, detailed output."

A number of researchers commented on the **legal and ethical issues** in relation to conditions applied for the access and use data and on various ways in which these might inhibit the research process. In many fields, the sharing of data is subject to policies, which are designed to protect confidentiality and IPR (e.g., where commercial collaborators are involved). In some cases, these policies were seen as being **too restrictive**. One of the solutions suggested was to move the computation to the data: "you could use other people's data but not necessarily download it, its licence agreement kind of allowed it. And then you could run your model regardless […] you could just get the results from the model and that sort of thing so there was a lot of discussions on how to deal with that as well." In other cases raised by respondents, **licensing policies are still in their formative stages**, limiting the ability to share data. This posed a problem for medical researchers in particular: "We have spent endless hours, essentially one person full time on a big collaborative project negotiating these issues […] the fact that there is no national policy has cost us […]" Data that is made available for research is often anonymised, for example, by **removing, restricting or aggregating variables, which makes it less useful for research**. A social researcher remarked: "in my view some of the survey data is unnecessarily reduced in its detail, sometimes I can fully understand why […], sometimes I don't think it's necessary.''

Curation, i.e., the preservation, archiving and maintenance of digital resources for future use, is becoming an issue that researchers are increasingly expected to grapple with. For example, if new (or derived) datasets are to be discoverable, researchers must prepare them for deposit according to accepted standards. However, **curation of existing data** is not an activity that researchers would normally define as part of their role: "some researchers are a little concerned that putting either research papers or data in an institutional repository […] they're worried that that will increase their workload […] that will slow them down and take them away from actually […] conducting research which is what they see their role as." One respondent pointed to the problems that depositors face owing to **current repository practices not being 'user-centric'**: "Repositories tend to provide a view of the world which is very much the librarians' view […] it emphasises the description of an item rather than the

item itself […] we have tried to make the actual files or documents themselves […] much more at the heart of dissemination process, rather than the metadata, the title or the abstract, the authors, all those kind of things which are given much more priority in the librarian standard view of how a repository should operate."

The **funding** of institutional and discipline specific repositories and associated curation efforts has been flagged as an issue by a number of respondents. Perceptions of what level of support is needed differ quite widely, with some researchers suggesting that what they need is bulk archival storage while others point to the complexity of their data and discipline specific ways of managing and using it. One respondent commented that a service provided "fairly rapid access back again but that comes at a cost premium so we didn't go for it." Another respondent pointed to discipline specific needs to have not just bulk data storage but a service that forms the heart of **a community of users of data**: "the main need we hear of that we should be able to help with is storing large quantities of data and curating it for humanities researchers, and it's obviously a new problem since the end of the data service was announced […] it obviously provided a facility but it also built a community because the people sharing it would naturally get to know each other, be introduced to each other, which we can't really do, or only on a smaller scale." Another respondent commented on the **lack of adequate financial support**, which makes proper curation infeasible: "Another barrier is the long term support of databases […] research funding bodies are proved to be quite reluctant to do that, the US government and NIH has been the best by quite a long way, and the European Union does help through European Bioinformatics Institute, the other major funders want scientists to share data but they are not showing enough evidence to me that they are actually putting money into a resource in which it can be shared."

Discussion

The analysis of interview material from the two phases of fieldwork has helped us gain insights into current research practices, the state of adoption of e-Infrastructure and e-Research methods, and brought to light a great variety of issues, barriers and enablers across the research fields which influence their uptake. The majority of these issues were broadly in alignment with the typology of barriers, which resulted from our initial desk research, while others were added to the typology during the analysis of the data.

The typology of barriers and enablers has been useful in that it has provided a systematic way into the data collected. However, it should not seen as a way to produce a limited set of overall findings through aggregation but rather as a way into the wealth of material collected. In reality, factors implicated in the uptake of e-Research are interrelated and do not lend themselves readily to the simplifications imposed by hierarchical representation. In the case of e-Research, we might expect and, indeed, are beginning to discover, that there is a network of interrelated factors, some with complex or subtle interdependencies, embedded in a wide variety of situations or circumstances, which impact on the uptake of e-Research services and resources. Untangling these relationships will be part of our continuing data analysis efforts conducted in conjunction with stakeholders to tease out findings that can inform possible interventions they can make the foster the uptake of e-Infrastructure services.

Conclusions

e-Infrastructures promise those who adopt them access to an almost limitless range of resources for research. Their value as facilitators of larger-scale and more multi-disciplinary collaborations, as enablers of new kinds of research and for reducing 'time to discovery' is

unquestionable. However, our investigations reveal that e-Infrastructures are often seen as complex and challenging by their users (both current and potential). From our findings, it is clear that current users often experience frustrations, while potential users may be unaware of its benefits and of how to take the first steps towards exploiting them. In dealing with the former, there is clearly a need to continue to develop the technologies which constitute the technical basis of e-Infrastructures in order to create a more satisfying 'user experience': there is still much that needs to be done to deliver the vision of inter-operable services and resources, and to improve ease of discovery, access and use.

It is also clear that some of the frustrations of current users and many of the issues, which inhibit potential users, call for interventions of an altogether different kind. It is on the social layers of e-Infrastructures, by which we mean the support services and community knowledge networks (both formal and informal) through which awareness, advice and assistance are made available to researchers that attention must be focused if these are to be tackled. Just as the technical layers of e-Infrastructure often fail to shield the user from the complexities of accessing distributed, heterogeneous resources, so too it seems that the social layer often fails to provide the user with access to the right information and advice as and when they need it.

There is, then, a need for a greater degree of integration and inter-working between, for example, service providers who operate at the national level and the support available to researchers at the local, institutional level to ensure that the former are integrated effectively in the latter. Similarly, there is a need for closer collaboration between local support services and their users so that the former have a better understanding of the latter's requirements and the latter have a better grasp of the opportunities available to innovate their research methods and practices. Finally, there is a need for communities of practice to form that can articulate common needs and drive forward the development of established e-Research practices. Just as at the technical level, the e-Infrastructure community seeks to create an environment where location ceases to be a barrier to access to resources and to collaboration, it must also strive at the social level to create support arrangements that are coordinated nationally but grounded in a local presence that makes them pervasive and accessible.

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