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Case Studies of e-Infrastructure Adoption

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Abstract

We report results from a study of e-Infrastructure adoption in the social sciences and humanities. We find that bridging barriers between computer and domain scientists is of key importance. In particular, SSH communities have to be accepted as being distinct and not suited to a “one size fits all” strategy of e-Infrastructure diffusion. Sustainability was also a core issue, whereas barriers to resource sharing could mostly be resolved with technological solutions, and skills and training activities are a reflection of the general “user dilemma”. Our recommendations to EU policy-makers point the way to promoting e-Infrastructure development and application in the social sciences and humanities.

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1 Introduction

By and large, social sciences and humanities (SSH) in Europe and United States have yet to widely adopt e-Infrastructure for their research (c.f. Catlett, 2006; Vanneschi, 2005). Little is known of what influences adoption, as Woolgar summarizes:

"Despite the enormous unfolding investment in eg grid technologies, it seems we know almost nothing about how and why (and by whom) these new technologies will be taken up, nor what will be the likely effects on the nature and conduct of e-Science and e-Social Science research." (Woolgar, 2003, 1)

Several reports predict enormous scientific payoffs from a large-scale adoption of e-Infrastructure in the SSH (e.g. ACLS, 2006; Berman & Brady, 2005; ESRC, 2004) because of the potential to collect, link, access and analyze data on a scale transcending what has been possible in the past. However, adoption of ICTs in science is clearly "not just a matter of time" (Kling & McKim, 2000). e-Infrastructure is usually not included among the core concerns and questions of SSH fields, but an activity of a few researchers with a particular technical inclination or computationally demanding research interests. Looking at e-Infrastructure from this perspective, it seems more appropriate to consider adoption as the result of localized negotiation processes under influences of a social, technological, scientific, cultural, economic and political nature. The present paper tries to shed some light on these influences and investigates the factors that support or hamper the uptake of e-Infrastructure among SSH researchers. It investigates why e-Infrastructure projects in SSH succeed or fail. It draws on exploratory data collected for the European Commission by the "Accelerating Transition to Virtual Research Organization in Social Science (AVROSS)" study.[1]

For AVROSS we adopted the e-Infrastructure definition promoted by the e-Infrastructure Reflection Group (e-IRG) which defined e-infrastructure as *integrated ICT-based research infrastructure* (Leenaars, Heikkurinen, Louridas, & Karayannis, 2005). Key elements include networking infrastructure, middleware and organization and various types of resources (such as supercomputers, sensors, data and storage facilities).

[1] See http://plattformen.fhnw.ch/avross.

2 Social shaping of e-Infrastructure

Opposing deterministic conceptions of the relationship between technology and society and replacing linear models of innovation by evolutionary perspectives, a set of models has been developed that can be summarised under the notion of “social shaping of technology” (SST). The overriding strength of these approaches is that they ask how “technology” comes to be “technology”. Common characteristics are that they do not conceive of technology as exogenous, or fixed by “nature” alone, but shaped also by non-technical factors (MacKenzie & Wajcman, 1999; Williams & Edge, 1996). Relationships between social groups, material objects, and other components of the socio-technical networks are crucial in the development of new technology (Edwards et al., 2007; Fleck, 1994; Fleck, Webster, & Williams, 1990; Molina, 1997). Social shaping describes this process as an alternation of variation and selection, replacing the linear order of invention, innovation and diffusion. An innovation is not considered as a fixed product, process or organisational configuration that is diffused if it matches the requirements of the potential adopters as in diffusion studies (Rogers, 1995). Rather, SST highlights that a new technology will still be shaped and reconfigured during innovation and diffusion, what has been called “innofusion” (Fleck, 1988) or “situated innovation” (Dittrich, Eriksén, & Wessels, 2003). We distinguish in this study between the following influences on this process of shaping e-Infrastructure:

1) Links between technology developers and users
2) Technical skills and training
3) Communities
4) Barriers to sharing resources
5) Funding

1) Links between technology developers and users: A major contribution of SST approaches is that it brought the users back into the picture. There are several aspects to this relationship. The features that developers bestow on and users expect in e-Infrastructure are influenced by what they perceive as feasible and desirable. These perceptions depend not least on the capacities of previous technologies which are used for the same or similar purposes. A “technological frame” or “technological paradigm” determines what the involved social groups perceive. It is a combination of current theories, tacit knowledge, engineering practice, specialized testing procedures, goals, and handling and using practice that determines problem perception and acceptable solution strategies (Bijker, 1987). Any new technological solution needs to be communicated and negotiated among developers and users on the grounds of their (often differing) technological paradigms.

Insufficient linking between technology developers and users has been a particular problem of IT development and e-Infrastructure has been no exception (Berman & Brady, 2005; Voss et al., 2007). Though the involvement of committed users has been standard practice in e-Infrastructure development, this is not, in itself, sufficient to ensure that prototypes are ready for deployment more widely. First, requirements identified by early users may not be representative of the requirements of the wider user community. Second, they may be more tolerant of limitations in new tools and services, being prepared, for example, to work around ‘bugs’, or to cope with poor usability. Third, agendas of computer scientists and researchers from the user domains are difficult to reconcile. Computer scientists wish to push the state of the art in their field, whereas domain researchers wish to see progress in delivering solutions

(Lawrence, 2006). We expect that the more profoundly e-Infrastructure projects manage to connect with their user constituencies, the better will be their uptake.

2) Technical skills and training: e-Infrastructure users cannot realize their ideas without mastering the technology. Among SSH researchers, the ability to formalize ideas and convert them into code is not common. e-Infrastructure projects in the SSH thrive and have a better chance to make an impact if they either have a "support infrastructure" of technology developers or widespread training measures or – ideally – both.

Educating and training developers to engage with users from the SSH and training the latter to work with e-Infrastructures contributes to the "intellectual sustainability" (ACLS, 2006, p. 28) of e-Infrastructure. The necessity to increase grid and other e-Infrastructure related training has been stressed for all scientific domains and by different organizations.[2]

3) Communities: One of the key arguments of SST is that a new technology is not a black box, but is shaped by the demands of the community (Kling & McKim, 2000). The use of whatever application and technology will often not depend on individual interests, but institutional and community requirements and practices (Voss et al., 2007). e-Infrastructure might be functional for some activities which are realized collaboratively in a community, e.g., the building of a joint on-line database, the distribution of new findings in a repository, whereas others are typically done non-collaboratively, like the use and analysis of data (Anderson & Carlson, 2006). Some scholarly communities still attach little value to collaboration and rely on single author work or simply do not need technological tools for collaborating (ACLS, 2006).

It has been argued that the difference between fields in the soft sciences and the hard sciences has not been taken into account sufficiently in the building of e-Infrastructure. Wouters and Beaulieu (2006, 2007) find a misalignment between the emerging e-Science community and SSH communities in regard to the culture, habits, customs and organizational setting. Field-specific practices, conventions and standards have developed over decades and scientists tend to be sceptical and unwilling if somebody tells them that they have to change, in particular, if that somebody is considered to be an outsider without expert knowledge in the field. A different turn to e-Science should be considered: one that changes the focus from "electronic science" to "enhanced research" (Wouters & Beaulieu, 2007), starting with analysis of different research fields, research practices, communication and collaboration relations, and social organization, to find out how differing needs can be supported (Hodgson & Clark, 2007; Woolgar, 2003; Wouters & Beaulieu, 2006, 2007). Being supported by communities of domain scientists is not only necessary for defining requirements but also for acquiring funds and making infrastructure sustainable in the long term (Avery, 2007).

4) Barriers to sharing resources: Another important and systemic aspect is the multiple barriers to sharing resources, such as data and software. Data in the SSH is often complex, tacit, fuzzy, discursive, inconsistent, and subject to privacy and ownership concerns (Carlson & Anderson, 2007). All this leads to large costs for preparing data for shared use. At the same time, virtually no scientific credit is allocated for sharing datasets. In addition, ownership rights in data generated in a collaborative project might be difficult to assign, yet the data themselves may have substantial financial value. Another problematic issue lies in the systemic dependence of

[2] Training is an issue in e-Science in general and substantial concerns about sufficient numbers of trained individuals for the full exploitation and maintenance of e-Social Science investments have been frequently expressed (e.g., e-IRG in Leenaars, et al., 2005; OGF at http://www.ogf.org/gf/group_info/view.php? group=et-cg).

new applications on their development context and the problems of re-embedding and interoperability which accrue in transfers (Voss et al., 2007).

5) Funding: The role of (future) costs and benefits certainly exerts an important influence on the shape and success of an innovation in market economies (MacKenzie & Wajcman, 1999). Costs of development, market introduction, and production, return on investment and competing solutions are economic categories which influence the decision of groups involved in an innovation project. Moreover, in order for social scientists to invest time and energy in e-Social Science, they need to be convinced that the tools will not become rapidly obsolete. Hardening and sustaining research products is difficult because products are heterogeneous, the process is costly, and researchers are trained to break new ground, rather than sustain existing projects. Standardization could solve the concern by (potential) users about the sustainability of new tools and the resulting interoperability (Kahin, 2007). This is, of course, a fundamental issue in e-Science more broadly.

3 Data and methods

One of the main empirical contributions of AVROSS was based on an analysis of eight case studies identified as promising SSH e-Infrastructure projects. For the selection of the interviewees from the cases, a snowball sampling was used aiming at the following groups: PI(s), researchers, developers, users and (if it made sense and was applicable) involved stakeholders like National Grid Service (UK), JISC, TeraGrid, D-Grid or similar related e-Infrastructure projects or service/technology groups. For each case study, several face-to-face or telephone interviews with the main initiators, providers and managers of the projects were conducted.

A semi-structured interview approach was followed which permitted exploring the conceptual linkages among the sources of influence on the shaping of technology, as well as potentially identifying new ones. Regarding influences on e-Infrastructure development, the interview guidelines took SST perspectives into account, namely technological frames and user requirements, scientific shaping of technology, economic factors, and political influences Additionally, the following points had to be considered:

- Challenges and difficulties projects had to master in their different phases from the invention to the introduction and dissemination among the user community
- Modifications to the initial objectives, key current applications and benefits to users and possible future developments which might further increase the usability and benefits
- Possibilities of, or experiences with, transferring the project from the initial work environment and community for which it was made to other environments

Archival materials complemented interviews in order to enable a comprehensive analysis of the case studies. Both published and internal project material was obtained from different sources such as the interview partners and project websites.

The case studies were documented and compared along the main dimensions of the analysis.

Selected cases

Three of the eight cases were taken from the UK and two from the US. Another three cases were from other EU countries (see Tab. 3-1).

Five case studies have a focus on data repositories, including tools and applications for regulating access as well as managing and processing the data (ComDAT, DReSS, DoBeS, TextGrid, and FinGrid). Of these, four were in the development phase and one (FinGrid) had ended. Two projects (SPORT and MoSeS) use data for modeling and simulating socio-economic events and processes. The eighth project, AGSC, was a support service for users of the AccessGrid (AG), a conferencing and collaboration application.

Tab. 3-1: Overview of the AVROSS case studies

Project	Country	Domain	Technology
Access Grid Support Centre – AGSC	UK	Multi	conferencing and collaboration tool
Modelling and Simulation for e-Social Science – MoSeS	UK	SS	simulation portal
Communication Data ComDAT (pseudonym)	US	SS	data repository
Simulation Portal – SPORT (pseudonym)	US	SS	simulation portal
Understanding New Forms of Digital Records for e-Social Science – DReSS	UK	SS	data repository
Documentation of Endangered Languages – DOBES	NL	Hum	data repository
TextGrid	DE	Hum	data repository
FinGrid (pseudonym)	EU country	SS	data repository

Source: AVROSS.

4 Influences on e-Infrastructure adoption

4.1 Links between technology developers and users

The case studies either address a broad user community from several SSH fields and beyond (AGSC) or focus on one specific field for which the applications are being or have been developed. Projects in early stages (SPORT, ComDAT, MoSeS, DReSS, and TextGrid) rely on pilot users and work with prototypes and testbeds. Only two projects had large user communities at the time of data collection: AGSC is a special case as it offers free services to users of a proprietary technology and DoBeS has a large user community among the language researchers. For the other projects, the establishment of a user community was still an open and critical issue for success.

The strategies for recruiting users were in nearly all cases rather weak and under developed: projects tended to rely on what was offered by their funding or institutional environment, e.g., DReSS relying mainly on NCeSS activities. In some cases, developers and PIs expected that word-of-mouth advertising at conferences or other events would do the trick. However, the FinGrid project, which has been discontinued (not least for failing to attract a user community), shows that this is not enough. Another weakness seems to be that user-developer interaction is the main focus of user-related activities. However, this is not enough for making the merits of e-Infrastructure visible to potential users. In addition to user-developer interaction, more user-user interaction would be required, for instance, pilot users presenting showcases to potential users or PIs disseminating their results in the user domains.

In several cases, the often negative experiences of (pilot) users led project leaders and developers to delay large-scale roll-out (AGSC, SPORT, TextGrid, and FinGrid). These negative experiences resulted, for instance, from complex user interfaces, low stability of the applications, and difficulties in integrating existing applications into new environments. Solutions to these problems were often sought in the technical sphere, e.g., re-designing user interfaces, adding and re-launching applications, quality testing programmes etc.

In sum, the case studies mostly seem to be driven by the traditional conception of a linear sequence of invention, innovation and diffusion. Users were perceived as such and not as co-developers with different backgrounds and perspectives.

4.2 Technical skills and training

Skills and training issues are relevant in the case studies from two different perspectives: 1) projects need technical developers who are also able to link with the particular communities; 2) users need sufficient skills to use the e-Infrastructure.

Availability of technical developers for e-Infrastructure projects in SSH. FinGrid was the sole project with difficulties in finding staff (developers). DoBeS was the only project with reported regular training courses for staff, while three projects (AGSC, MoSeS, FinGrid) mentioned training taking place more informally on the job. Also, post-graduate education was of little importance: MoSeS and SPORT were the only two projects to have graduate students included in development.

User-oriented training. In several case studies (AGSC, DReSS, DoBeS, and FinGrid), developers and providers also engaged in training events with the users. In FinGrid they conceded, however, that training of SSH users needed to take into account of their lower computing skills and less structured and formalised problems. The project also developed a training tool to help users with Grid installation. Training activities for staff and users were piecemeal and designed ad hoc to solve upcoming problems. A comprehensive and long-term strategy could not be discerned in any of the case studies.

4.3 Communities

Cross-disciplinary communication and collaboration. Several case studies struggled with communication barriers between social scientists or humanities researchers and computer scientists. These barriers place a burden on project development: specialized languages, “ping-pong” communication and differing work styles translate into differing expectations on what a project can and should achieve.

This lack of mutual understanding of domain and computer scientists goes on beyond the development phase, as SPORT interviewees highlighted: a “Throwing your research over the wall and see if anybody picked it up” attitude usually results in nobody picking it up. Domain differences were often ignored by computer scientists and developers for whom there is little difference between processing astronomical or socio-economic data (ComDAT). Nearly all of the projects stressed close ties and involvement with the global Grid community, but not their contribution to the development of their social science or humanities “home base”.

Some examples on how to deal with these communication barriers also surfaced:

- TextGrid successfully reduced communication barriers by involving both domain and computer scientists early on in the projects, letting them discuss critical issues and establish a joint basis for further work.
- In DReSS, the user-developer collaboration was institutionalised in the structure of the project through so-called “driver projects” intended to make sure that developments were triggered by and linked-back to user needs.
- Another solution, implemented to some extent in ComDAT, may be to engage “translators”, individuals trained in both fields who understand the language, problems and work styles of each group and can bridge communication between the domains.
- In MoSeS, the collaboration between computer scientists and geographers worked well, as both sides had a hand in development and being co-located helped the daily exchange of information. Users were represented by three co-PIs (one in each application domain), who successfully collaborated with developers to transfer user requirements.

Involving leading domain scientists in the diffusion of an e-Infrastructure and building of a user community might be a good strategy – peers and researchers in the field are the main information source on e-Infrastructure (Barjak et al., 2007). This should be a worthwhile but not necessarily easy undertaking: First, it should not be neglected that it still takes considerable time, as interviewees from ComDAT and SPORT pointed out, to learn and master new e-Infrastructure technologies. The necessary effort depends on the development status of the technology and the technological level of the learner. Second, researchers also may owe their position in part to current infrastructural arrangements, e.g., their access to particular resources or technology (Edwards et al., 2007, pp. 26-27). Hence, they might not be willing to put their position at stake through supporting the diffusion of a new technology.

4.4 Barriers to sharing resources

Problems with sharing resources appeared in some of the social science projects. Interviewees in two projects (SPORT, ComDAT) stated that, because of the confidential nature of the data and disciplinary practices, sharing is not accepted. FinGrid had to find ways around existing restrictive policies of data providers.

These projects encountered the issue of data protection as a major challenge. The necessity to protect data may originate in legally binding constraints of data providers (FinGrid), from institutional regulations on (ComDAT) or from national law in case of census data which has to be handled under strict regulations (MoSeS). Projects had to solve this issue by developing tools and applications that implemented data rights and access management. Technological solutions were possible when it came to regular numerical or textual data, though they might have required devising new applications that were not (yet) common in the broader e-Infrastructure environment. However, when it comes to new types of data, like audio or video recordings (ComDAT), technological solutions for masking the identity of individuals without invalidating the recordings are not yet established.

The situation regarding data protection and sharing is somewhat different in the case studies mainly led by the humanities: in aiming to build libraries/archives for languages and text data, both DoBeS and TextGrid naturally tend to support data sharing in order to benefit from such a practice.

4.5 Funding

Six projects were been funded through public R&D grants from different research programmes. The SPORT project was funded through institutional seed money and DoBeS through a non-profit foundation. Sustainability was an issue in all cases. The AGSC will probably be funded for at least eight years, whereas there is currently no more funding for the FinGrid project leaving a developed e-Infrastructure unsupported. The MoSeS project emerged from two pilot demonstrator projects giving the previous work some continuity.

Service-oriented business models. The success story of the AGSC confirms the value of “robust, resilient services” to academia, in particular, when it comes to supporting collaboration. An ingredient for success seems to be that the service is offered free to users, as we also saw in the ComDAT example. TextGrid interviewees also pointed in this direction, as they considered the requirement of charging individual projects and users for the service to be a major barrier to future adoption.

If the users themselves do not pay, alternative funding schemes need to be found that provide long-term funding to secure continuity and improvement of the service. The case studies do not provide any guidance on possible solutions as they are still mainly funded through public research (and development) grants. As historical studies of other infrastructures have shown, it was often public investment or funding arrangements that coupled private investment with public regulation that led to the establishment of a network (Edwards et al., 2007, p. 29). At the same time, users will have to commit themselves to long-term solutions and accept the service idea that comes with the technology. They will have to provide funds that cover more than the initial set-up and include support and maintenance.

All projects developed applications or tools but, with the exception of FinGrid, are all still in a rather early stage. Therefore, procedures for a larger rollout of the software were not mentioned (for FinGrid the infrastructure is in place but with no further funding future support cannot be provided). Only MoSeS explicitly referred to using open source and free software whenever possible and also developing as open source (this was a funding requirement). Similar to the free provision of services, the free use of software under an open license could be a model to foster sustainable use – if models for the necessary further support can be found and established.

4.6 Success

We can distinguish the success and impact of the case studies with respect to the three main missions of science, 1) research, 2) teaching and 3) technology transfer.

Research. The biggest gain was generally seen in addressing issues in new ways beneficial for research questions, methods and data in SSH. This was especially true for simulation and modelling (MoSeS, SPORT), replaying and analysing new forms of digital data (DReSS) and linguistics (DoBeS). Different categories of impact have been identified.

- The AGSC can point to the uptake and use of AG and its own support services by various scientific communities. Projects connected to the AGSC have been funded and improvements made to AG and related services.
- MoSeS and SPORT have not seen impact beyond pilot systems so far, but have generated significant interest in various communities, leading to new funding opportunities or concrete scenarios for future use envisioned by researchers from other domains.
- DReSS, DoBeS and TextGrid in different ways have fostered the use of digital data and repositories through new means of integration using e-Infrastructure.
- The ComDAT project has had limited impact on research due to inappropriate means for "utilizing social and behavioural data on e-Infrastructure", but reported reduction in research time and re-use of successful models for other domains.
- In the completed FinGrid project the impact on the original user community was modest and shifted to creating benefits for the European Grid development community.

Teaching. Most of the projects so far have no connection to teaching or formal learning activities, but the need for e-Infrastructure "to be integrated in future curricula" (DReSS) and to address this in a future work-package (TextGrid) are recognised.

Technology transfer. None of the case studies had meaningful linkages to the private sector, public administration or non-profit organizations. The AGSC had only one non-academic user; DReSS and MoSeS maintained some informal links to local public administrations who might become users; the FinGrid project managed to engage an enterprise software firm very active in financial services in an unsuccessful follow-up research proposal. In the other projects (ComDAT, SPORT, TextGrid, DoBeS) there was no mention of technology transfer.

5 Evaluation of the cases

The challenges in achieving project goals are particularly seen in making use as well as funding sustainable and enlarging the user base (AGSC, ComDAT, DoBeS, TextGrid, FinGrid), followed by solving confidential and security data issues (MoSeS, SPORT) and bridging the gap between creating new prototypes for SSH and having an application which is considered to be helpful in research and will de facto be used (DReSS). Impact is rather low, as most projects are in an early phase and still have significant challenges to solve. Relating this to the other dimensions, three groups of projects can be distinguished:

- AGSC, DoBeS, and MoSeS are projects that fit rather neatly into the communities in which they are integrated. They also have a (growing) user community and functioning user-developer interaction. They have either already shown that they can have an impact (AGSC) or puts them in a good position to make an impact as they develop.
- TextGrid and DReSS are weaker in regard to integration into the field and its practices and they have not yet advanced as far in regard to users. They also have not yet achieved an impact and they are in a weaker position for achieving this in the future.
- FinGrid, SPORT, and ComDAT are in a worse position when it comes to user-developer interaction and their user communities are restricted to people involved in the project, they have no discernible strategies for recruiting users and significant problems in linking up with potential user communities. Sharing resources seems to be also rather problematic. The projects are weak when it comes to the realised impact on research or teaching.

Of course, this is a very much ad hoc evaluation of the case studies that does not take into account the different development stages of the projects. Therefore, the results should not be considered as conclusive, i.e., projects like SPORT and ComDAT might become accepted in their fields, and others might still fail, though the current conditions seem to be promising. However, we think that the overview is a satisfactory representation of the projects that might help to focus the activities and further development on key preconditions for success.

6 Policy recommendations

Although not scientific in nature (see Barjak et al., 2007) and inherently illustrative rather than definitive in scope, the AVROSS study identified several key issues relevant for policy purposes. Social sciences and humanities can play a more active role in e-Infrastructure development if a virtuous circle at the level of e-Infrastructure initiatives as well as at the level of individual projects can be generated. This virtuous circle rests on four pillars:

1) Capacity building for e-Infrastructures: the base of motivated researchers and skilled technicians trained on e-Infrastructures needs to be broadened through education and training and funding needs both, to take the specific demands of SSH into account and to move on to sustainable funding schemes.

2) Developing appropriate tools: tool development must be done in close, permanent and effective interaction with users. Use barriers are lower if users are familiar with tools which "only" have been ported on the grid environment; standardisation raises the confidence in sustainability.

3) Fostering adoption by domain scientists: incentives need to be given and barriers to need to be reduced. Such incentives should be instituted in funding schemes – e.g., to reuse existing data and make new data available through repositories – and become part of SSH research and academic practice, for instance, in publishing, evaluation, and promotion. Barriers often require organizational as well as technical solutions, for instance, when it comes to reducing language barriers between developers and domain researchers.

4) Making domain scientists aware of e-Infrastructures: Awareness needs to be raised above all by demonstrating benefits. This is most effectively done through field-specific information channels and between peers. Institutional environments, of course, need also be responsive to the pay-offs of e-Infrastructure. Last but not least, knowledge of what type of infrastructure and support SSH researchers actually need and where they stand in the adoption process needs to be broadened (raising awareness in the process).

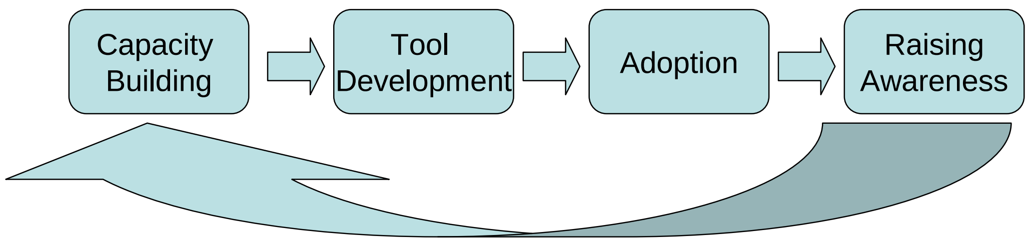

Fig. 6-1: A virtuous cycle of e-Infrastructure in the social sciences and humanities.

Previous research has also made it clear that successful infrastructures are a combination of 'top down' and 'bottom up' processes, implying they cannot be planned in any complete sense (e.g., Edwards et al., 2007). However, we believe that the following measures will improve the chances for success at each step of the process described in the previous Figure.

Tab. 6-1: Overview of policy measures

Capacity Building	Tool development	Adoption	Raising awareness
1. Develop dedicated training events for SSH 2. Step up the role of e-Infrastructure in graduate education 3. Increase the use of CSCL environments 4. Support small-scale initiatives 5. Design effective funding and programme coordination structures 6. Fund field-specific flanking measures in general, multi-disciplinary e-Infrastructure programmes 7. Support the development of service-oriented business models	8. Involve users at all stages 9. Mandate user-centred design 10. Port existing SSH tools to e-Infrastructures 11. Target vertical areas to ensure tool adoption across sub-fields 12. Support standardisation	13. Institute activities to promote the reuse of SSH data 14. Assign scientific credit and ownership rights 15. Reduce technical barriers through providing organizational solutions 16. Promote understanding of SSH among IT specialists 17. Improve cross-disciplinary communication and collaboration	18. Create supportive institutional environments 19. Increase user-user interaction 20. Increase the information exchange across projects 21. Involve lead users in community-building 22. Institute a research programme on e-Infrastructures in SSH

Source: AVROSS.

Most of these measures need further analyses and discussions in the process of operationalisation and integration into existing or new policy measures. Doing this would have gone beyond the scope of the AVROSS project.

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