Purpose and aims

The purpose of this project is to contribute to our understanding of how digital technologies are transforming the production of scientific knowledge. In particular, we will examine how new technologies and practices are expanding the role of volunteer contributors in scientific research. Recently, scientists have begun to turn to crowds of online volunteers through open calls for help in the collection and analysis of very large sets of data. Although large data sets pose serious challenges for science, they also promise groundbreaking discoveries if and when resources for their analysis are available. Often the resources necessary include not only equipment, but also expensive human labour, especially if scientists are to be free to perform more demanding conceptual work than routine tasks (Olson et al. 2008). In the current climate of scarce financial resources, enlisting the help of crowds of volunteers is an attractive way for science to expand the workforce needed to work with large data sets.

The idea of science turning to untrained volunteers for help in classifying and standardizing large sets of data and, in some recent instances, even in shaping research questions is spreading throughout the research community (Rowland 2012). Well-established institutions such as Johns Hopkins University, NASA, Berkeley, Yale, Stanford, and Oxford have recently launched a number of crowdsourcing programs under the banner of Citizen Science Alliance (2013). As part of this initiative the project GalaxyZoo (2008) is often highlighted as an especially successful model for managing large data sets. GalaxyZoo has had 200.000 volunteers making 150 million classifications of galaxies from images provided by different telescope platforms (Nielsen 2012). In this case, as with other projects, volunteer contributors is a huge resource for science, supplying a "larger workforce than any academic department can provide" and Citizen Science Alliance now accept proposals globally from scientists interested in managing classifications of large data sets (2013). While crowdsourcing is a potentially significant resource for scientists, it also offers volunteer contributors the opportunity to expand their roles, sometimes beyond the expectation of scientists. This type of changing relationship has not been encountered on such a grand scale before and the current trend opens up the practices of science to the general public in ways not seen earlier (Bonney et al 2009a, 2009b).

In this project we focus on two issues: (1) how scientific work in crowdsourcing projects is accomplished, analysing the expanded role voluntary contributors play as their relationship to science is mediated through digital means and scientific practices are modified, and (2) the development of communities of engaged amateurs and their own epistemic practices. This transformation of scientific knowledge production will be addressed through studies of three different crowdsourcing projects: GalaxyZoo (astronomy), FoldIt (biochemistry), and AncientLives (papyrology).

Survey of the field

Over the past centuries, with the aid of new technologies, science has invited non-scientists to take part in both the production of knowledge and in managing data, until universities and governments gradually took financial stewardship of research in the mid 20th century and the sciences became increasingly professionalised (Star & Griesemer 1989, Goodchild 2007).

In the late 1990s with the development of the personal computer and the Internet a new way for non-scientists to participate in scientific projects emerged. Dubbed 'distributed computing', this new approach used the web to assemble the computing power of thousands of personal computers to create virtual supercomputers. Building on initiatives such as Rosetta@home

(2012), which used the power of thousands of Internet-connected personal computers to analyse the structure of proteins, distributed computing soon developed into something much more complex. Projects began to include new types of more active volunteer participation, using digital tools to support reconfigured communication patterns, expertise and skills among researchers, computer programmers and volunteer contributors. This development is linked to the idea that since it is very difficult to program computers to make serendipitous discoveries in large data sets, humans are still preferred as they have an "eye out for the weird and the odd, even while sorting most objects into more mundane categories" (Citizen Science Alliance 2012; see also Cooper et al. 2010). Opening up who could be involved in scientific classification tasks, the GalaxyZoo project used standardized protocols in an online software platform to involve volunteer contributors in classifying images of galaxies. Due to its success in attracting and maintaining the enrolment of volunteers, GalaxyZoo, now on its 5th year and 4th edition, has become a blueprint for this contemporary and quickly expanding form of crowdsourcing in scientific practice.

Currently, the number of active crowdsourcing projects is increasing and there are indications that the role of crowds is changing once again. Projects such as FoldIt aim to involve volunteers in shaping research questions and suggesting innovative solutions, not only in classifying or collecting data. New technologies, including mobile applications, are being designed to empower volunteers in the investigation and creation of large data sets and to play a part in setting agendas for future scientific research, policy and social action (Haklay 2010, Rowland 2012, Wiggins 2012, Citizen Cyberscience Centre 2012). Based on these current trends, it is reasonable to say that new forms of crowdsourcing in science are continuing to emerge and that participation in scientific research continues to be reconfigured in new ways.

By using the communication resources provided by the Internet, science has entered a remarkable digital phase that is the focus of our research project. This new phase generates possibilities for distributed cognition (Wiggins & Crowston 2011), allowing geographically separated volunteers to contribute to science through their unpaid efforts in front of a computer screen. While such possibilities are an essential benefit of crowdsourcing, its use in scientific projects also raises a number of issues. Contributions from a wider population into scientific knowledge production require arrangements to ensure quality raising key questions such as who or what creates scientific knowledge in crowdsourcing projects? How are digital technologies used to enable volunteers with limited knowledge about theory and method to contribute to science? How is agreement on scientific rigour and data quality achieved and maintained? To date, however, social studies on crowdsourcing in scientific practice have mainly focused on meaning (Mankowski et al. 2011) and the motivations of contributors, developing models of participation (Lawrence 2006, Raddick et al. 2010, Wiggins 2012). Studies on enrolling and maintaining participation of volunteers is important, but need to be connected to the intended scientific task at hand in understanding roles, interactions and practices of knowledge production. This is the focus of our project.

Each crowdsourcing project involves the collaboration of scientists, computer programmers and volunteer contributors. It is clear that the members of each of these groups have a role in producing scientific knowledge, but the details of what the division of labour looks like and how interactions between groups are performed are matters of great importance to the success of a project. For example, questions of how and under what conditions volunteers without formal scientific credentials can be regarded as contributors to science and whether or not computer programmers simply act as contractors or as something more central to the development of a

crowdsourcing project are particularly relevant. The particular contributions of volunteer contributors is also an important issue since they may be skilled, competent and mindful actors whom science depends on for progress, possibly changing the very content of what we take for granted as scientific knowledge (Nielsen 2012). Volunteers may introduce unanticipated elements to the work through different forms of personal engagement and/or participation in communities supported by social media outside official crowdsourcing project resources.

Shedding insight into the roles, interactions and practices of existing crowdsourcing projects will have implications for generating research policies that both recognize current developments and can support future research initiatives that take advantage of crowdsourcing as a form of collaboration.

Project description

Aims, research questions and selection of cases

The project aims to:

- Analyse the relationships and interdependences between scientists, programmers and volunteer contributors and how these are mediated and sustained through digital technologies.
- Analyse the kinds of participation and expertise such arrangements require among scientists, programmers and volunteer contributors (i.e. what they need to learn in order to participate in the new arrangements) and the consequences this may have for for scientific outcomes.

To realise these aims, the project will address these research questions:

- How is scientific 'work' co-produced by the actors and artefacts involved?
- How are tasks and responsibilities mediated through digital technologies?
- What kinds of concerns, problems or issues are/have been attended to and what do they imply in terms of required expertise and learning among the actors involved?
- What forms of participation are encouraged, maintained or emerge through the communication between and among the actors involved?
- What are the similarities and differences between actors and artefacts in three cases?

Case studies

Three cases have been selected, all of which rely on virtual modes of contribution through Internet mediated participation of volunteers (see Table 1). The case of GalaxyZoo represents one of the oldest sciences (astronomy) and a field in which collaboration with volunteers has been sustained over long periods of time. Such collaboration is currently being investigated from a historical perspective within our interdisciplinary research environment and this work will be a resource in the proposed project (see Kärnfeldt 2011). GalaxyZoo invites volunteers to classify digital images of galaxies. Today GalaxyZoo has yielded 25 scientific publications, many in journals with high impact factors.

The second case, AncientLives, represents the field of papyrology, established in the late 19th century. In this field, collaboration with volunteers has not been as prominent as in the case of astronomy, and while classification of digitalized original research material is a main task for volunteers in both these cases, the kind of efforts involved are very different. Volunteers in AncientLives are invited to transcribe and catalogue digital images of papyri fragments, creating

a database for research on Greco-Roman Egypt to be published in the Egypt Exploration Society's Greco-Roman Memoirs Series at Oxford University.

The third case, FoldIt, represents the scientific field of molecular biology, which is currently very dynamic in terms of scientific and technological innovation. In this project, scientists analyse the structural configurations produced by contributors in relation to existing proteins, moving from the virtual space of gaming to the biochemistry lab. FoldIT, as a competitive on-line game, is distinctly different from GalaxyZoo and AncientLives, which aim to provide a 'culture of learning' in understanding the past, the known and the unknown. To date, FoldIt has led to seven academic publications and results from the project may lead to developments in antibiotics, cancer treatment and bio fuels (Bohannan 2009).

Table 1: Comparison of cases

	Galaxy Zoo	**Ancient Lives**	**FoldIT**
Field	Astronomy	Classical archaeology / Papyrology	Molecular biology
Culture of crowdsourcing	Well established amateur role/emerging digital	Emerging amateur digital role	Emerging amateur digital role
Scientific need	Huge quantity of digital images not easily machine processed	Huge quantity of digital images not easily machine processed	Identification of promising protein structures from vast number of possibilities
Volunteer contribution to research	Classification of galaxy types	Transcription & cataloguing of ancient papyri texts	Creation of new virtual 'protein structures' to be synthtetized in the lab
Volunteer task	Identification of direction of rotation	Identification of symbols from available options	Compete in a three dimensional puzzle game

Representing a strategic and selective variation of research fields, cultures of crowdsourcing, scientific needs, and volunteer contributions and tasks, the analytical ambition is that commonalties and differences identified in these cases will be useful to explore in order to understand shared challenges and emergent possibilities for future virtual crowdsourcing projects.

Theoretical perspective and analytical approach

To analyse these virtual crowdsourcing projects, we will make use of theoretical and analytical insights from the field of Science and Technology Studies (STS), in particular Actor Network Theory (ANT). According to ANT, the complex sociotechnical phenomenon of scientific practice requires a range of actors and artefacts to be organized and assembled to create scientific knowledge. Our study will examine the processes of *translation* as actors and artefacts attain the necessary organization and sustainability of heterogeneous networks for the production of scientific knowledge in our three case studies (Latour & Woolgar 1986; Law & Lynch 1988; Latour, 2005; Latour et al. 2012; Nielsen 2012). The phases of *translation* are:

a) *Problematization*. Researchers and programmers form socio-material alliances and begin looking for further allies (volunteers) as a solution to scientific needs. In our case studies the question will be how researchers manage and exploit large datasets (LDS), how concerns of scientific 'work' is conceived and tasks and responsibilities are inscribed in and mediated by digital technologies.

b) *Interessement*. Researchers and programmers now enact new arrangements, inviting crowds of online volunteers via open calls for help in the analysis of LDS, creating forms of participation,

encouraging and maintaining them through the communication between and among the actors involved.

c) *Enrolment*. Identities and roles of actors in the socio-material arrangements are established and stabilized, making the entry of new contributors as easy as possible. This is manifest in protocols aligning dispersed volunteers for contribution to crowdsourcing projects following standard classificatory schemes. An important strategy of enrolment from scientific leaders of crowdsourcing projects is that the cognitive threshold for participating as a volunteer contributor is kept low (Nielsen 2012), implying the necessary attention to and technological mediation of concerns, problems or issues of required expertise and learning among the actors involved. However, from an ANT-perspective the language and practices around volunteer activity needs to recognize that the participation forms prescribed by the scientists and programmers in their efforts to enrol contributions also are translated and reconfigured by the volunteers, implying an enormously rich activity that goes on outside the constraints of the participation framework instantiated by scientists and programmers.

d) *Mobilization*. Researchers, programmers and volunteer contributors work to maintain social and material arrangements by mobilizing valid and new observations and innovations. As representatives of a large network of a new promising scientific practice they mobilize results into scientific publications and future discoveries as scientific 'work' is co-produced by the actors and artefacts, tasks and responsibilities mediated through digital technologies, constantly managed and requiring attention to the actors and technologies involved.

Methods and data

Methods will involve traditional ethnographic methods of ANT such as interviews and observation (Latour & Woolgar 1986; Lynch 2002), together with web-ethnography exploring digital traces of volunteer contributors and organizers (Latour et al. 2012). Together these methods will allow for the examination of online spaces in relation to the situated local practices of actors who participate in them, forming what has been characterised by Dirksen, Huizing and Smit (2010) as a connective-ethnography. This will include social network analysis (SNA) to map the connections and interactions between participants (Rogers 2012) and *scraping* of online content from social media forums so that it can be assembled in analysable forms (Marres & Weltevrede forthcoming). SNA will help us in rendering rigorous samples of actors that are relevant for our ethnographic studies. This way we are using SNA as an exploratory, qualitative method, rather than treating it as a quantitative method on its own terms.

One of the possibilities and methodological challenges of working with online activity is the volume of data that can be quickly collected (Rogers 2010; Kasperowski 2012). To address this concern, our analysis of online material will proceed by working both to find broad patterns within the large sets of data (e.g Markham & Lindgren forthcoming) and by using the accounts provided by participants during interviews and participatory observations to help identify particularly important instances (e.g. Weilenmann, Hillman & Jungselius 2013). By taking these instances as starting points, trajectories of activity within the online material will be identified and used to help unpack the patterns found when the data is examined at a broader level.

We will start by mapping the specific features of our cases as they are presented on their websites and in published materials, and then make a first visit to interview scientists and programmers involved in the projects. These interviews will be used to identify main concerns, issues, discoveries, anomalies, or problems, which have been critical for how work is currently conducted in a project, and scientific practices are developed. By following project members in

their interactions and collecting materials, we will define instances in all three cases where important translations have been necessary in order to proceed with scientific work. The competences of our research team will be drawn on when following scientists, programmers and volunteers respectively in each of the three cases. Contacts have been established with research and design teams for all three cases. Chris Lintott, chair of Citizen Science Alliance (GalaxyZoo, AncientLives) at the University of Oxford (cjl@astro.ox.ac.uk) and Zoran Popovic, principal investigator of FoldIt at the University of Washington (zoran@cs.washington.edu), have agreed to initial interviews and further collaboration.

Moreover, the research project will set up a blog where preliminary research findings are published. The purpose of the blog will be to discuss the phenomena of crowdsourcing with international scholars, but also with participants inside various crowdsourcing projects that have an interest in understanding their practice in a reflective way.

Table 2: Data collection process

	Scientists & programmers	**Volunteer contributors**
Collection of (web) documents	Project websites, project programming forums, scientific articles	Social media scraping of project forums and wider social media (e.g. Twitter, blogs, other forums)
	Actors identified↓	
Video-recorded interviews	Focus groups and interviews with scientists and programmers	Interviews with frequent, sporadic and one-time contributors (face-to-face or through video conferencing)
	Actors identified↓	
Video-recorded observation	Observation of project meetings and scientific work connected to crowdsourced results	Observation of volunteer contributors engaged in crowdsourcing activity and in meetups with other contributors

Time plan and execution of research

The proposed research project will start in January 2014 and end in December 2017. The execution of research will be as follow:

Table 3: Time plan

Activities	**2014**	**2015**	**2016**	**2017**
Examination of online material	X	X		
Interviews, transcriptions	X	X	X	
Mapping and identification of critical instances	X	X	X	
Video-recorded participant observation	X	X		
Analyses of actors across and within cases	X	X		
Workshops	X	X	X	X
Conferences		X	X	X
Publications		X	X	X

Research team

The issues addressed in this project require a multidisciplinary research effort that draws on

expertise from the following fields: STS (Kasperowski, Bowker, Kullenberg, Hagen), The Learning Sciences (Hillman, Mäkitalo), and Information Sciences/Applied IT (Ponti, Bowker). Kasperowski will function as coordinator, contribute to mapping and identification of critical instances in the cases, analysing volunteer contributor communities and participating in the collection and analysis of video-recorded observations. Kullenberg and Hagen will examine web-material, work toward identifying critical instances in the cases, contribute to interviewing, participant observation and to comparing actors within and across cases. Hillman will focus on volunteer contributor communities while collecting online material, conducting interviews, and participating in the collection and analysis of video-recorded observations. Ponti will do cross-project analysis with a focus on online material. Mäkitalo will together with scientific advisor Bowker mainly devote time in the project to workshops and conferences. All project members will participate in workshops, publications and conferences.

Significance

The primary theoretical contribution of this project will be to develop a tentative social epistemology of crowdsourcing in scientific practice. Providing a structure and context for volunteer-derived knowledge that more broadly makes it possible to articulate, formalize and validate this type of scientific projects. Special attention will be given to how Internet mediated participation creates new contexts of discovery, which include not only scientists, but also amateur volunteers. By using large databases and social functions enabled by Internet technologies, volunteers are able to compare observations, advance observational techniques and establish criteria for knowledge production that go beyond the frameworks of participant established by scientists. In this way, crowdsourcing enables a context of discovery outside of the established borders of science. The ways these new, amateur-driven, communities then interact with established scientific communities is an important tension that will be studied and theorized as part of this project.

These new contexts of discovery sometimes shape new cultures of discovery. For example, since 1905 amateur ornithologists have been participating in the Audubon Christmas Bird Count. These amateur ornithologists not only contribute to science with census data about bird populations, but have also developed their own competitions and high-score tables for number of observations conducted that blur the boundary between a recreational and a scientific activity. Examing the development of such phenomena in relation to current crowdsourcing projects, this study will investigate how these new cultures of discovery emerge and establish their own social epistemology, which may or may not unfold along the lines of established scientific epistemology. New contexts of discovery also challenge many of the assumptions in established theory used to understand scientifc practice such as ANT. Many ANT studies characterize the act of discovery as requiring that actors work together towards a common goal. In scientific practice, these goals are funnelled through various translations into obligatory passage points such as laboratories or leading scientists. In the case of crowdsourcing, however, we see how amateur communities are shaping their own “centres of calculation” that are not necessarily in tune with the scientific (see Latour 1987). This project will thus update and challenge the standard ANT-model by studying these new forms of distributed epistemology.

Crowdsourcing in itself is not new, but what is novel are the possibilities offered by digital technologies: the range of sciences involved and the huge numbers of volunteer contributors. In response, the scientific media has begun to take notice and since 2010 *Nature* and *Science* alone have published more than 50 articles on the subject. As crowdsourcing initiatives continue to

expand in both number and size, we hear calls by scientists for social science analysis of the processes involved (Wiggins & Crowston 2011; Cohn 2008). However, to date the phenomen has received little academic attention from the social science community (see Wiggins 2012). Given this, the proposed project will be particularly significant. Not only will the project offer novel empirical knowledge, but it will also provide theoretical and methodological resources that will be important for the future development of research on online scientific practice.

Equipment

The Linnaeus Centre for Research on Learning, Interaction and Mediated Communication (LinCS) at the University of Gothenburg directs a lab facility, serving as a platform for theoretical and methodological development. The lab will be a resource for the project and provide guidance for researchers to ensure the quality of the design, analysis and communication of research. The LinCS lab provides an infrastructure and constitutes a national and international centre of competence with regard to:

- Theoretical and methodological contributions aimed at developing the quality, scope and analytic rigour in using digital data.
- An up-to-date technological infrastructure serving projects at all stages of research. From video recordings to the latest digital resources for web-ethnographies.
- The LinCS lab contributes to clarifying and specifying standards, policies and regulations relevant for using digital material in research. Providing expertise for new central ethical issues that need to be resolved for each project.

International and national collaboration

This project will be conducted in close collaboration with the University of Gothenburg Learning and Media Technology Studio (LETstudio 2011a), where Mäkitalo is head and Kasperowski coordinates research on expert-lay participatory practices (LETstudio 2011b). The LETStudio is a strategic initiative connected to LinCS, where Mäkitalo is co-director, addressing issues of knowledge, learning, communication and expertise in society and their re-enactments through information and communication technologies. Throughout the project Professor Geoffrey Bowker, University of California, Irvine (http://www.ics.uci.edu/~gbowker/) will act as scientific advisor. He is a leading researcher on scientific cyber-infrastructure, classification and standardization and has been a visiting professor at the LETStudio. (e.g. 2000; Bowker 2001, 2005, 2012; Vann & Bowker 2005; Bowker et al 2009; Millerand & Bowker 2009).

Ethical considerations

This project will be conducted in accordance with guidelines established by the Swedish Research Council, The Association of Internet Researchers (Markham & Buchanan 2012) and The Norwegian National Committee for Research Ethics in the Social Sciences and the Humanities' Research Ethics Guidelines for Internet Research (2003, 2010). Since audio and video recordings, web ethnography, interviews and participant observation will be used, ethical issues concerning participants' integrity will be present in the project and all participants concerned will need to approve being recorded. Informed consent in written form will be asked for before any data is collected (whether web based or not). The identity of participants will be made confidential in the material when used outside the project team (i.e. in publications, at conferences and other forms of dissemination of project results). The material will be kept in

secure facilities at the University of Gothenburg and the regional ethical board will review the study before any fieldwork is conducted.

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