STIR: Socio-Technical Integration Research

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Introduction

Science and technology policies around the world are placing new pressures on laboratories to address broader societal dimensions of their work in ways that have the potential to influence the content of science and engineering activities themselves – presumably for the better. Despite longstanding calls for collaborations between natural and human scientists to achieve this goal, neither the capacity of laboratories to respond to such pressures nor the role that interdisciplinary collaborations may play in enhancing responsiveness is well understood or empirically supported. It is crucial to overcome these limitations in order to design, implement and assess effective programs aimed at responsible innovation.

To address these limitations, the Socio-Technical Integration Research (STIR) project conducts a coordinated set of 20 laboratory engagement studies to assess and compare the varying pressures on – and capacities for – laboratories to integrate broader societal considerations into their work. Ten doctoral students each conduct two paired laboratory studies that extend more traditional ethnographies by engaging researchers in semi-structured interactions designed to enhance reflection upon research decisions in light of broader considerations.

The objectives of the STIR project as a whole, as well as each paired study, are to:

- Identify and compare external expectations for laboratories to engage in responsible innovation;
- Assess and compare the current responsiveness of laboratory practices to these pressures;
- Investigate and compare how guided interdisciplinary collaborations may assist in elucidating, exercising or enhancing deliberate and responsive capacities.

Doctoral students base their studies on a protocol developed by PI Fisher during a previous 33-month "laboratory engagement study." This study provides preliminary

evidence that such activities enable laboratory work to become more sensitive to its potential societal implications, without compromising laboratory research, education or strategic goals. The STIR project investigates whether these results are applicable across a diverse and globally distributed range of labs and in a less time- and labor-intensive manner.

Project findings are in some cases strongly suggestive of the possibility and utility of broadening routine laboratory decision processes so as to more critically take into account social and ethical dimensions of the lab research that are typically not explicitly considered. Project participants have disseminated these findings in over 30 publications and 60 presentations.

Project participants

PI Fisher has planned, coordinated, and run all project events including four international workshops in the United States, Norway and Japan; regular lab meetings with project investigators; mentoring sessions and correspondence with all ten project investigators and with several more associated investigators; and site visits to research sites in six countries. Fisher has mentored and/or collaborated with project participants on the development of multi-authored publications involving the PI and of single- and multi-authored publications not involving the PI; on conference panels; and on numerous presentations. Fisher has worked with several project participants on their dissertation plans and/or served on their thesis committees; on several single and multi-authored publications involving non-investigator participants and non-project participants on work relevant to the project. Fisher and Co-PI Guston have been working with project participants both to produce an edited volume and to build an "international network for responsible innovation" that would increase and sustain STIR activities after the conclusion of the project's NSF funding period.

The core group of project investigators consists of 10 doctoral students from nine universities in six nations spread across three continents (Antonio Calleja-López, Shannon Conley, Paul Ellwood, Byongyoon Kim, Christine Luk, Robin Phelps, Daan Schuurbiers, Anthony Stavrianakis, François Thoreau, and Qin Zhu). These investigators ("STIRers") represent half a dozen disciplines in the social sciences and humanities. Each investigator conducts two paired, comparative and intervention-oriented "laboratory engagement studies." To do so, each investigator must become embedded within two comparable laboratories that conduct research in similar fields but that are situated in different national, regional (or in one case, municipal) locations.

In addition to this core group, seven more graduate students and three postdocs are associated with the project. These associated collaborators conduct STIR (Steven Filpse, Birgitte Hansen, Bastien Miorin) or STIR-inspired (Dorothy Dankel, Anna Delgado, Federica Lucivero) laboratory engagement studies, document and analyze STIR activities (Frank Theys, Brenda Trinidad) or conduct parallel research into socio-technical integration policies around the world (Hannot Rodriguez, Michiel van Oudheusden).

In addition to the participation of graduate student investigators, numerous others have participated in the project, including but not limited to investigators' dissertation advisors (Sebastien Brunet, Peter deLeon, Clark Miller, Krsto Pandza, Ramon Queraltó, Paul Rabinow, Ned Woodhouse), collaborators who have participated as hosts, speakers or observers at STIR workshops and meetings (Bruna De Marchi, Silvio Functowicz, Brice Laurent, Roop Mahajan, Farzad Mahootian, Carl Mitcham, Alison Mohr, Dave Rejeski, Arie Rip, Roger Strand), the laboratory directors who have hosted STIR studies (e.g., Simon Biggs, Robert Bowman, Stuart Lindsay, Neal Sullivan, Wim Vermass) and their graduate and postdoctoral researchers (e.g., Troy Benn, Sonja Billerbeck, Shreya Bhattacharryya, Courtney Hanna) located in over twenty participating laboratories in a dozen countries across three continents.

Project Findings

STIR laboratory engagement studies have produced strong indications of both the possibility and the utility of semi-structured collaborations between social and natural scientists. As stated, these studies require investigators to become embedded within their research contexts, in order to allow the investigator to (1) observe ongoing laboratory decision processes that unfold over time, (2) feed back their observations, descriptions and findings into the research context being studied, and (3) continue to observe, collaboratively participate, and document relevant changes in these same laboratory decision processes. Investigators are aided by regular employment of the STIR protocol, both in the form of a semi-structured interview protocol and in the form of a deliberative exercise, which helps facilitate collaborative descriptions of practitioner decision-making processes; and other forms of feedback into the research environment. Feedback is designed to highlight opportunities for laboratory practitioners to engage in reflexive thinking and behavior. In the language of the framework that underlies the protocol, the protocol helps to articulate, enhance or stimulate "reflexive midstream modulation." The following integrative, capacity-building outcomes have become somewhat typical of STIR studies:

Learning

Reflexive midstream modulation is a form of practitioner learning that involves recognition of one's own participation in ongoing processes of co-production, including one's broader roles and agency within socio-technical systems. STIR studies have documented laboratory practitioners' own implicit and explicit

accounts—as well as changes in discourse and behavior that unfold over time—that are indicative of such learning. Accounts and observations can indicate enhanced cognitive awareness of interrelations between institutional and other system elements and the practitioner's own behavior as well as changes in affective orientation. A typical pattern begins with the practitioner's statement that he or she does not make decisions during research and eventual acknowledgement that he or she does, in fact, make decisions. These changes may relate to decreased resistance or skepticism on the part of research participants and increased social capital.

For instance, Schuurbiers' paired studies in the Netherlands and the U.S. documented two different forms of reflective learning among biological and biotechnology researchers. Schuurbiers found evidence of both first- and second-order reflective learning. In particular, his second-order learning findings—in which underlying value systems become the object of reflection—are significant with respect to enhancing laboratory practitioners' capacities for social responsibility in laboratory research practices. Schuurbiers found that his STIR studies served to render the socio-ethical context of research visible to laboratory practitioners and, in turn, encouraged them to critically reflect on this broader context. Such reflections produced also "ripple effects." For instance, in some cases they led practitioners to recognize that there were inconsistencies in their stated views about the role of science in society.

As stated earlier, participants' descriptions of their work and of themselves often undergo alteration over time. For example, Conley was told by the lab director of her first study, "We don't really make decisions around here." This is a typical example of the "demarcation boundary work" that STIR investigators encounter early on in their studies. Conley, like Schuurbiers and others, however, have also documented changes over time, in both content and tone. For instance, one participant in Conley's first study came to a turning point at the end of a protocol exercise, evident in his statement: "I guess this really is a decision!" The theme of laboratory researchers as non-decision makers is one that STIRers generally encounter at the start of their studies; and somewhat consistently, STIRers document discursive shifts that appear to indicate shifts in the self-conceptualization of laboratory practitioners and the social processes in which they participate. Fisher describes these shifts as "undoing boundary work."

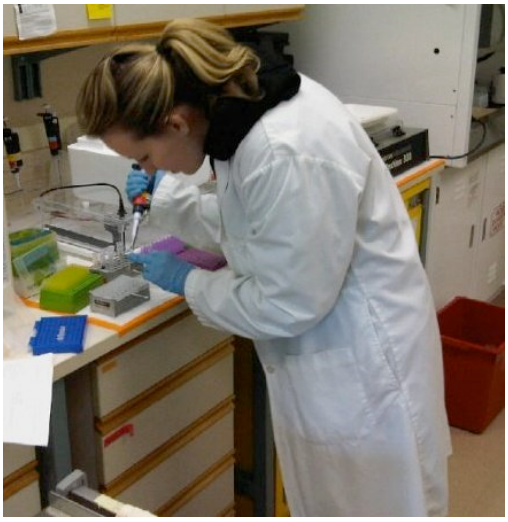
Philosophy doctoral student Calleja-López documents yet another variation of this type of learning. In this case, "politics" replaces "decisions." After being told by a laboratory practitioner that there are no politics in the laboratory, Calleja-López asked a question about a technical diagram that the practitioner had drawn to illustrate the project he was working on. The practitioner demurred, and then pointed to his own diagram. "Actually," the practitioner said, "there are politics here." He paused and then pointed to another place on the diagram and stated, "and here." In a moment of surprise as he stared at his diagram, the practitioner then exclaimed, "politics is everywhere!"

The acknowledgement that there are social and ethical processes and dimensions in the laboratory in which scientific and engineering researchers participate, especially when this was earlier denied, either tacitly or explicitly, is suggestive of different forms of thinking than are typically encountered by investigators in laboratory research settings. Laboratory practitioners themselves have endorsed the collaborative interactions that lead to such discursive shifts as desirable forms of learning. For instance, one practitioner suggested to Schuurbiers that STIR type interactions could be integrated "in each and every Ph.D. project." In another case, management doctoral student Paul Ellwood discovered in his U.K. study that a flip chart he had previously made to explain to his lab mates the differences between positivism and constructivism had been pasted on a laboratory wall. When he inquired into the reason for its display, he was told, in effect, "we thought it would remind us that there are different ways of thinking." Similarly, at the conclusion of a public talk by political science masters student Miorin on his U.S. study, one of the audience members attending the talk identified himself as a participant in the study and stated emphatically that the interactive experience had been "a real educational experience."

Other types of practitioner learning have been found to take place during the studies. For instance, investigators often encounter among their soon-to-be collaborators an initial reluctance to engage, at times coupled with skepticism of methods and motives, after they have been invited into the lab. As one research participant stated, this can be due to fears that investigators are there to enforce what they deem as unhelpful notions of "ethics." In this light, anthropology doctoral student Stavrianakis, who conducted studies in U.S. and in Swiss synthetic biology labs, reports a transformation in how one of his research participants thought about ethics in relation to science. The participant was initially wary of the potential threat that talk of "ethics" held for her research practices; later, however, she stated that she had come to consider that it was possible to envision situations in which both ethics and natural science "work well together." The process of "opening up" laboratory discourses to wider social and ethical aspects has been documented by a number of investigators, but it can nevertheless be a very daunting proposition. As philosophy doctoral student Lucivero, who conducted studies in the Netherlands and the U.S., was semi-playfully told by her second laboratory director, "you make us think about things we are not supposed to think about."

These accounts suggest that what may count as common knowledge among STS practitioners can be more ambiguous—in some cases perhaps even off limits, even taboo—among material practitioners, who often tend only over the course of several weeks of observation and engagement to acknowledge their own agency and participation in decision and other social processes. Consequently, participating in and facilitating reflexive learning in real time and *in situ* can take significant effort and requires the research traits of both patience and persistent. In other words, "integration work" can be rewarding—both in itself and because of its material outcomes (see below)—but it can also be stressful.

It is important to note that integration work can have mutual effects and thus typically supports learning on the part of the investigator as well. For instance, STS doctoral student Luk, who completed studies in physics laboratories in the U.S and in China, took a graduate level physics course and met weekly with the instructor—the laboratory director of her U.S. site—in order to aid her comprehension of the scientific material and her interactions with the lab researchers during her first STIR study. In another case, political science doctoral candidate Conley, who conducted studies in genetics laboratories Canada and in the U.K., was able to acquire not only interactional expertise but also contributory expertise, despite being initially completely unfamiliar with much of the scientific theory and material practices of genetics research. Conley's consistent use of the STIR protocol enabled her to "cross over" and become adept at laboratory experiments in polymerase chain reaction (PCR). This modest acquisition of what were seen by her genetics research collaborators as exemplary technical skills in a short period of time allowed Conley to achieve recognition, build trust and social capital, and probe deeper and more effectively into broader societal dimensions and practices relevant "inside" the laboratory during her first study. Moreover, it allowed her to better understand and communicate broader social, ethical and policy implications involving the type of research the laboratory conducts with actors "outside" of the laboratory—including clinical experts, policy practitioners, patients, activists and plaintiffs in legal proceedings related to advancements in genetic science.



STIR investigators are thus encouraged to neither represent or to think of themselves as being socially or ethically enlightened. Rather, the STIR program is meant to help investigators aim for a collaborative discovery and description of social and ethical dimensions that were likely not previously perceived or inquired into in the specialized setting of the laboratory. The resulting learning and shifts in reflexive awareness are posited to be preconditions for more concrete changes in scientific research and laboratory practices that accord with responsible innovation and that will be discussed in the next section.

Changes in practice

The midstream modulation framework posits reflexivity and learning as enablers of more effective *deliberate* (i.e., goal-directed) or *deliberative* (i.e., critically enhanced) decision processes. While regularly using the STIR protocol in close proximity to research decision-making and feeding observations and findings back into the research context, investigators have found that laboratory decision-making can itself undergo both subtle and dramatic alterations. That is, reflexive learning, in

which practitioners acknowledge their own roles within broader social processes, may be related to observed shifts in material and other aspects of laboratory practices. This suggests that enhancing reflexive, responsive and other decision capacities of laboratory researchers (for instance, through *in situ* interdisciplinary dialogue and collaboration) can itself serve as an integral and productive aspect of the laboratory research process itself.

With its focus on generic decision components that can be mapped onto just about any laboratory activity, the STIR protocol is designed to clarify and enhance both *deliberate* and *deliberative* forms of midstream modulation. In the language of the protocol, the "considerations" (values, goals, concerns and other decision criteria) that practitioners articulate while describing their everyday research decisions tend to increase in number and broaden in quality as a result of the routine collaborative exercises. Values mentioned can expand to include ethical, environmental, public and other societal dimensions of the research in question. Simultaneously to this, another alteration in laboratory decision processes can be noted: decision "alternatives" can expand to include options that were not previously identified or perceived as viable. Occasionally, these two forms of decision process expansion can interact, resulting the modulation of research decisions themselves. These modulated decisions can result in concrete changes in material and other laboratory practices, including its behavior as an institution.

For instance, Schuurbiers' critical questions about ethical and safety practices during a laboratory presentation sparked a hefty debate in the laboratory group with the result that several people in the lab started wearing lab coats again. As one researcher stated, "I was thinking that one day I should take the decision to wear [my lab coat], even though I'll raise some eyebrows… Then came your presentation…and I remembered how I used to take care of my safety and my clothes." In another case, Ellwood reports a deliberate modulation of the research direction undertaken by practitioner who was studying the propensity of nanoparticles in dishwasher detergent to adhere to plates after washing. The researcher had shifted his focus from "wet" cycle studies—which had yielded no such adherence—to "dry" cycle studies—which were on the other hand quite revealing. Ellwood notes that the change from "wet" to "dry" came up during an earlier use of the protocol. He concludes that the use of the protocol "provided a hitherto unavailable practice" that enabled a lab practitioner "to work through a wider range of innovation issues than those that were emanating from his innovation partners" (Ellwood and Panzda 2011).

Conley's learning and hands-on experience in her first lab engagement study (described above) provided her with a firm basis for commencing her second study, both in terms of her ability to dialogue with laboratory researchers and, in some cases, to share with them techniques that would help at least one lab scientist conduct more successful experimental results. Additionally, she reports a change in laboratory policy—the initiation of a patient newsletter as a form of public outreach—that occurred during her first study in relation to her use of the protocol

with one research and her facilitation of a dialogue on responsible innovation with the laboratory group as a whole. Lucivero, in her U.S. study, observed that the vision underlying the laboratory's long-term research agenda had changed over time, to the point that there were now two, contradictory visions being used to justify if not guide the research. When she fed this analysis back to the research group as a whole, the lab director acknowledged that a tension in the research vision might exist, noted the beneficial contributions of the embedded philosopher, and he suggested that it might be approaching the time for the research group as a whole to reconsider the research agenda.

Laboratory practitioners generally see these changes in material and other forms of laboratory practices, when they do occur, as productive. This can be seen in Ellwood's, Conley's and Lucivero's cases, and in other cases not reported here (including the studies by Calleja-López, Kim, Schuurbiers and Zhu—as well as PI Fisher's own STIR studies). Changes in practice, however, can also be disruptive of established norms, assumptions and routines.

For example, in Miorin's case, as a result of a dialogue about an environmental engineer lab's nanomaterial disposal practices, one researcher initially rejected the utility of such a dialogue as "a waste of time" since it appeared to slow down his research without producing a clear beneficial outcome. Moreover, the researcher dismissed potential public concerns about such disposal practices. However, soon afterwards, the researcher ceased throwing nanomaterials in the municipal waste and called a lab meeting to determine whether they should be disposed of as hazardous waste. Both the researcher and the group as a whole could not conclusively resolve the situation. This lead the researcher to formulate an argument with Miorin that such dialogues and discussions, even when they do not immediately lead to changes in practice, can nevertheless be valuable because they can reveal "upstream" policy issues that might otherwise not come to light without knowledge of and experience at the micro-level context of research practices. Laboratory engagement typically involves mutual learning, and thus Miorin was in the process himself forced to rethink his understanding of the precautionary principle as a result of this and subsequent interactions with the lab.

Such changes in material and other laboratory practices are proofs of concept for the more general possibility and utility of approaches like that of the STIR program in structuring interactions among various research and innovation actors and activities. Furthermore, changes in practice suggest that there may be longer term

and more far reaching outcomes, namely in the form of responsible innovation capacity building—both among natural scientists and social scientists. For, in order to support new and crucial forms of capacity building, individuals will likely need to be able to directly experience how material practices can change for the better as a result of more systematically and reflectively attending to their societal dimensions.[1] The same can be said for the learning and reflexive modulations that have been documented by the STIR project. In other words, the documented outcomes of learning, changes in discourse, and changes in practice are potential pedagogical mechanisms for increasing the socially responsive capacity of scientists, engineers and social scientists to deliberate—to take broader dimensions of their work into account and to more reflexively and effectively participate as future experts in the governance of science and innovation processes. The STIR-induced productive disruption of established routines can, it is suggested here, build deliberative and socially responsive capacities of both lab participants and project investigators.

Residual effects

In a number of the studies, research participants have commented on the utility of discussing their research decisions over time with STIR investigators. Typically, this generates an expectation of regular encounters, to the point where it is somewhat disruptive for the investigator to exit the lab. For instance, after Schuurbiers' U.S. study, three of four participants returned to contact him several times with further observations and with requests regarding the broader aspects of their laboratory research. Reflecting on the STIR study he hosted in his laboratory a year and a half after it had been completed, Schuurbier's second laboratory director observed that some changes in practice had "stuck," although others had not. (The director suggested that the changes were lasting only if they were related to the given graduate student's research motivations.)

Signs of enduring interdisciplinary relationships and increased social capital include coauthored pieces. For instance, both Conley and Phelps have been invited to coauthor pieces with their laboratory hosts; Miorin and Stavrianakis have reported plans to coauthor pieces with participants; and PI Fisher published a correspondence in *Nature* with three of the STIR laboratory directors. Moreover, nine collaborating laboratory practitioners—including five

[1] Consider the saying (attributed to Confucius) that appears in the University of Colorado at Boulder's engineering Teaching and Learning Laboratory: "I hear and I forget. I see and I remember. I do and I understand."

distinguished scientists and engineers who direct laboratories and research institutes, two laboratory Ph.D. students, and two recently graduated laboratory Ph.D. students now working as professional scientists and engineers—agreed to travel in most cases thousands of miles in order to co-present with the "embedded" social scientists with whom they interacted at the 4th project workshop in Washington, D.C., which was webcast and which will soon be archived for on-demand viewing.

Finally, several project investigators have continued to carry their integration skills forward in new professional contexts. In her role as community director at an ASU student development complex, Conley has introduced the STIR protocol into training sessions for residential assistants (RAs). She reports that the RAs were better able to clarify the goals and rationales of their daily practices as state employees as a result of using the protocol. Meanwhile, Schuurbiers is currently working full time as an officer at the Dutch Center for Genomics and Society with the task of exploring the demand side among private laboratories and R&D centers for socio-technical integration.

Responsible Innovation

The findings of the STIR project are potentially relevant for policy aspirations pertaining to "responsible development" and "responsible innovation." Accordingly, STIR findings and project participants have been circulating in a number of professional research and science policy contexts. For instance, project participants organized (Phelps) and presented in (Horst, Thoreau) a panel for the 2011 annual meeting of the *Society for the Study of Nanoscience and Emerging Technologies* entitled "Mapping Responsible Innovation in Public and Private Sectors." And in summer 2011, PI Fisher was the sole American to attend workshops on "responsible innovation" organized by the European Commission in Brussels and by the French and British governments in London.

Responsibility in the case of laboratory research can be a difficult and even counter-productive concept given that, in research and innovation systems, the locus of responsibility is diffuse. Therefore it is not surprising that one of Stavrianakis' respondents explicitly linked her initial reluctance to engage with him to her assumption that by "ethics" he had meant something intrusive, misguided and ultimately unproductive. STIRers have suggested that the term "response-ability" and "responsive capacity" may be preferable terms.

Project investigators are asked to study the research and innovation policies that relate to their laboratory sites and that call for some form of responsible innovation. Phelps, Ellwood and van Oudheusden in particular have concluded that regional and national science policies that explicitly or implicitly call for socio-technical integration and other forms of responsible innovation are characterized by essential tensions that underlie these policies. For instance, discourses around the "responsible innovation" of emerging science and technology (such as nanotechnology) in the U.S., the U.K., Belgium and the European Union reveal

notable divergences between the notions of "responsible" and of "innovation." While these and other tensions are often reproduced at the micro-level of socio-technical discussions in the laboratory, investigators find that the nature of these discussions can change over time and can begin to take more factors into account, often in more reflexive ways. Thus, tensions and dilemmas that show up at the macro-level of public policy can be productively acknowledged, engaged and worked through with the help of integration activities at the micro-level.

According to the midstream modulation framework, more reflexive modes of thought and of discourse are posited as prerequisites for more socially robust forms of material and other science and engineering practices. Initial results from the STIR project reported here appear to provide some measure of empirical validity to this theoretical position. In particular, the enhanced learning and changes in practice documented above can be seen as building capacities to *innovate responsibly*. That is, conceptual capacities are developed for understanding what responsibility might mean in the societal contexts of laboratory research; meanwhile, responsive capacities are developed for finding creative and innovative ways to societal concerns, challenges and other broader dimensions of research.

Project findings suggest that STIR concepts, tools and techniques may prove valuable assets in the toolbox of interdisciplinary methods aimed at responsible innovation, as defined by various national and regional science policy bodies. With this in mind, we foresee the following likely outcomes from integration research activities: improved methods for conducting laboratory engagement studies; a more robust theoretical basis for midstream modulation of technological trajectories; a more informed general rationale for conducting laboratory-based participant-observation as a form of expert practitioner engagement; increased capacities to participate in responsible innovation and the anticipatory and reflexive governance of science and innovation processes; a lasting and growing network of social scientists, laboratories and policy makers interested in sustaining socio-technical collaborations.

It is important to note the specific rationales and any subsequent policy recommendations for socio-technical integration are likely to differ from one another depending on the local, regional or national policy motivations, political contexts, and epistemic cultures encountered in each of the twenty laboratories that make up the international set of research sites located in ten countries on three continents.

Project results indicate that laboratory engagement

studies that employ the STIR protocol and follow the framework of midstream modulation have demonstrated to junior—and in some cases senior laboratory researchers (e.g., the cases of Hansen, Kim, Lucivero and Luk)—in a real-time, hands-on manner, and in a variety of contexts, the pervasiveness of social, ethical, and political dimensions within their work, which were previously undetected or unattended to. As stated, what may count as common knowledge among STS practitioners can in fact be much more ambiguous—if not taboo—among material practitioners, who often tend only over the course of several weeks of observation and engagement to acknowledge their own agency and participation in decision and other social processes. Occasionally, such acknowledgement occurs in tandem with shifts in material or other laboratory practices. These developments are often unexpected and creative responses to problems that were either not previously recognized by laboratory practitioners or that were not taken up as problems to be addressed from within the scope and purview of laboratory research. Such experiences are understood to build reflexive, deliberative and responsive capacities. *STIR investigators are helping to pioneer new forms of collaborative engagement and expertise.*

Midstream modulation proposes that the acknowledgement of previously unattended to social and ethical dimensions of their work by science and technology practitioners constitutes a prerequisite for an increased capacity on the part of these practitioners to effectively take such broader dimensions of their work into account, and for their more reflexive participation in the governance of science and innovation processes. *The STIR project continues to provide evidence supporting these intuitions.*

Training

Graduate student investigators have been trained in conducting laboratory engagement studies and in analyzing and communicating the outcomes. Laboratory engagement studies consist of integrative fieldwork that supplements more traditional laboratory-based participant-observation, primarily by feeding back descriptions and findings into the research environment being studied, but also through other collaborative practices, both material and discursive. Training has taken place through workshops organized by the PI in the U.S., Norway and Japan, through regular project meetings run by the PI, through individual meetings and sessions with the PI, and through research site visits by the PI. As a testament to the competence and dedication of the project investigators, all core investigators have either completed or are presently completing both of their two paired engagement studies. The final of the original planned 20 studies commenced in December 2011

in Dalian, China. Meanwhile, students participating in the project have been actively publishing and presenting. Each of the 10 core paired lab engagement studies (with one exception) span two different nations or national regions, providing a globally engaged context for the student investigators that is enhanced by the international makeup of the team and the fact that workshops have been help on three different continents. Doctoral students have made presentations to the project team during the first three workshops and during the project meetings, to the laboratory research groups with whom they collaborate, and to various professional and policy audiences at academic conferences and the 4th project workshop. All of the core students and several of the associated students have committed to submitting comparative, narrative accounts of their lab engagements for a planned volume on STIR project findings. Most of these papers have been under development or revision since the 3rd project workshop in summer 2010, when students received extensive feedback on their drafts, from PI Fisher, co-PI Guston and from other senior collaborators who were recruited for this purpose by the PI. In several cases, these drafts were submitted to journals for publication and students have written new papers for the volume.

Outreach

STIR project public and academic outreach activities take the form of a project website, publications and presentations meant for more general audiences, a short promotional video, plans to develop a full length documentary film, and plans to develop a sustainable international network that can continue socio-technical integration efforts beyond the current funding cycle.

Fisher is co-PI on a separate NSF supplemental grant, through the Science of Science and Innovation Policy (SciSIP) program, that funded the production of several short videos for policy practitioners and science policy researchers. In 2011, thanks to

this grant, Fisher and CSPO co-director Sarewitz (PI on the SciSIP grant) collaborated on the production of three short, humorous and informational videos meant to inform science policy analysts and program directors of "new tools for science policy." One of the three videos is devoted to the STIR project, and it has been positively reviewed and circulated in their agencies by program officers at the NSF, Genome Canada, the Research Council of Norway (RCN) and the European Commission. Program officers at the RCN are planning to disseminate the video to laboratory scientists in an effort to inform them about and interest them in socio-technical collaborations.

The STIR project website contains basic information about the project, its personnel, its activities, and its publications. The URL is http://cns.asu.edu/stir/. General information about the project and its societal relevance have taken the form of news and travel stories, correspondence in *Nature*, and various public and policy talks. For instance, a general audience story reports on the initial project award (Arnold 2009), a second general audience story (in Dutch) details the personal experiences of one of the doctoral student investigators (de Gruyter 2009), short pieces in *Nature* (Fisher et al. 2010) and *EMBO Reports* (Schuurbers and Fisher 2009) are meant to introduce the project widely to audiences of academic natural scientists and engineers (Fisher et al. 2010).

Fisher has had extensive conversations and interactions with Theys, a Belgian Ph.D. student and established documentary filmmaker, about filming project activities for a planned documentary on modern laboratory life. Due to the quick start and rapid completion of most of the STIR project studies, which were completed well ahead of schedule, this may require requiting additional investigators and participating laboratories. As co-promoter of Theys' doctoral thesis, Fisher intends to continue to support and contribute to the final product. *Lab-Life* is a documentary directed by Frank Theys and produced by Savage Films (Belgium) and Cobos Films (The

Netherlands) in a coproduction with the public broadcaster ZDF/ARTE (Germany/France), supported by the Flemish and the Dutch Film Funds, the European MEDIA program and the CERA Art Foundation. The film will have a cinema release (90 min.) and a 60 min. or series version for television and will be distributed by Autlook Films (Austria).

Project Publications (31)

Journal Publications (10)

1. Antonio Calleja-López. December, 2009. "Ciencia e integración: el proyecto STIR (Socio-Technical Integration Research)." *Argumentos de Razón Técnica: Revista española de ciencia, tecnología y sociedad, y filosofía de la tecnología*, v. 12: 157-165.

2. Shannon N. Conley. 2011. "Engagement Agents in the Making: On the Front Lines of Socio-Technical Integration." *Science and Engineering Ethics* 17(4): 715-721.

3. Erik Fisher. 2011. "Public Science and Technology Scholars: Engaging Whom?" *Science and Engineering Ethics* 17(4): 607-620.

4. Erik Fisher. Under review. "Inquiry as Intervention: Undoing Boundary Work in Laboratory Engagements." Submitted to Daniel Barben, guest editor for a special issue of *Social Studies of Science.*

5. Erik Fisher, Cathy Slade, Derrick Anderson and Barry Bozeman. 2010. "The Public Value of Nanotechnology?" *Scientometrics* 85(1): 29-39.

6. Hannot Rodríguez, Erik Fisher and Daan Schuurbiers. Under review. "Integrating Science and Society in European Framework Programmes: Trends in Project-Level Solicitations." Submitted to *Research Policy*.

7. Daan Schuurbiers. 2011. "What Happens in the Lab Does not Stay in the Lab: Applying Midstream Modulation to Enhance Critical Reflection in the Laboratory." *Science and Engineering Ethics* 17(4): 769-788.

8. Daan Schuurbiers and Erik Fisher. 2009. "Lab-scale Intervention." *European Molecular Biology Organization (EMBO) Reports* 10(5): 424-427.

9. Daan Schuurbiers, Susanne Sleenhoff, Johannes F. Jacobs & Patricia Osseweijer. 2009. "Multidisciplinary engagement with nanoethics through education - the Nanobio-RAISE Advanced Courses as a case study and model." *Nanoethics* 3(3): 197-211.

10. WANG Qian, ZHU Qin & LI YiYun. 2010. "Philosophical Reflections on the Management of Nanotechnological Risks." *Chinese Science Bulletin* 55(00): 0-8.

Book Chapters / Other Separate Publications (7)

11. Antonio Calleja-López. 2010. "Reflexive Modulation." Encyclopedia of Nanoscience and Society. David Guston (Ed.). SAGE Reference.

12. Paul Ellwood, Erik Fisher and Krsto Panzda (forthcoming). "Organizational Capability Life Cycles for Responsible Innovation." In Gorman, M.E, Savage, N. and Street, A. (Eds.), *Emerging Technologies: Socio-Behavioral Life Cycle Approaches.* Singapore: Pan Stanford.

13. Erik Fisher. 2010. "Integration." Encyclopedia of Nanoscience and Society. David Guston (Ed.). SAGE Reference.

14. Erik Fisher and Roop L. Mahajan. 2010. "Embedding the Humanities in Engineering: Art, Dialogue, and a Laboratory." In Gorman, M.E. (Ed.), *Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration.* Cambridge, MA and London, England: MIT Press.

15. Robin Phelps and Erik Fisher. 2011. "Legislating the Laboratory? Promotion and Precaution in a Nanomaterials Company." Sarah Hurst (Ed.) *Biomedical Nanotechnology, Methods in Molecular Biology Series*. Humana Press, USA. 339-358.

16. Hannot Rodríguez, Mingyan Hu and Erik Fisher. Forthcoming. "Socio-Technical Integration in Research Policy: The Situation in the United States, the European Union and China." In S. H. Christensen, C. Mitcham, B. Li and Y. An (Eds.), *Engineering, Development and Philosophy: Encounters among Chinese, European, and American Perspectives*. New York: Springer.

17. Daan Schuurbiers. 2010. "Midstream Modulation." Encyclopedia of Nanoscience and Society. David Guston (Ed.). SAGE Reference.

Conference Proceedings / Other One-Time Publications (7)

18. Antonio Calleja-López and Erik Fisher. 2009. "Dialogues from the Lab: Contemporary Maieutics for Socio-Technical Inquiry." *Converging Technologies, Changing Societies. Proceedings of Society for Philosophy and Technology*. University of Twente, The Netherlands. July 7-10.

19. Erik Fisher, Simon Biggs, Stuart Lindsay and Jie Zhao. 2010. "Research thrives on integration of natural and social sciences." Correspondence. *Nature* Vol 463. 25 February.

20. Farzad Mahootian. 2011. “A Systems Approach to Self-Reflexive Science: Preliminary Findings from Laboratory Engagement Studies.” Society for the Philosophy of Science in Practice. University if Exeter, U.K. June 22-24.

21. François Thoreau. Submitted. “On Reflections and Reflexivity: Unpacking Research Dispositifs.” *Annual Meeting of the Society for the Study of Nanoscience and Emerging Technologies 2010 Proceedings*.

22. Ramón Queraltó. 2009. "El impacto ético de las actividades científico-tecnológicas. El caso de la Nanotecnología¨y el proyecto STIR." *Asociación para el Diálogo*. Sevilla, Spain.

23. Ramón Queraltó. 2009. *Boletín Interno de Noticias de la Universidad de Sevilla*. March 11.

24. Qin Zhu, Yang Yu and Erik Fisher. 2010. “Toward and Empirical Ethics in Technology: Embedded Ethicist as a Case.” *Applied Ethics and Applied Philosophy in East Asia Proceedings of 1st International Conference in Kobe*. Kobe University, Japan. July 26-27.

Dissertations (2)

25. Daan Schuurbiers. 2010. *Social Responsibility in Research Practice - Engaging applied scientists with the socio-ethical context of their work*. Simon Stevin Series in Ethics of Technology, vol. 6. Technical University of Delft.

26. Qin Zhu. 2011. Dalian University of Technology.

Other Publications (5)

27. Cathy Arnold. 2009. “$500,000 NSF Grant Boosts Center for Nanotechnology in Society.” *ASU Insight*. 29(32): 2. April 10.

28. Erik Fisher and Daniel Sarewitz (Producers). 2011. “STIR (Socio-Technical Integration Research).” Short Film. Consortium for Science, Policy and Outcomes.

29. Byoungyoon Kim. 2009. "Socio-Technical Integration Research." *NanoWeekly* 313: 10-11 (in Korean).

30. Daan Schuurbiers. 2010. “Maatschappelijke verantwoordelijkheid.” *TU Delta* 42(31). 3 November.

31. Maartje de Gruyter. 2009. "Ethiek op de werkvloer: Bewustwording is het toverwoord." *CSG-magazine LEV*. Vol 2. 18-22 November.

Professional Presentations and Conference Papers (60). Not included are approximately fifty presentations and poster presentations made during STIR project workshops, CNS-ASU annual meetings and NSF site visits to the CNS-ASU.

1. Troy Benn. 2010. "The Environmental Implications of Consumer Nanotechnologies." American Industrial Hygiene Conference and Expo. Denver, CO. May 27.

2. Antonio Calleja-López. 2011. *Annual Meeting of the Society for Philosophy and Technology.* University of North Texas. May 26-29.

3. Antonio Calleja-López. 2010. "Laboratory Experiments and Co-Laboratory Performances." Annual meeting of the Society for the Social Studies of Science, University of Tokyo, Tokyo, Japan. August 25-28.

4. Shannon Conley. 2010. "Integration in Context: Vancouver, British Columbia Site." Annual meeting of the Society for the Social Studies of Science, University of Tokyo, Tokyo, Japan. August 25-28.

5. Shannon Conley. 2010. "Examining Capacities for Integration in Canadian and UK Genetics Laboratories." Poster presentation. Enhancing Communication in Cross Disciplinary Research conference, Coeur d'Alene, Idaho. September 30 – October 2.

6. Shannon Conley and Erik Fisher. 2011. "Socio-Technical Integration: Collaborating with Geneticists in Patient Engagement." *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

7. Paul Ellwood. 2010. "Responsible Innovation as an Organisational Capability: The Contribution to STIR from a Management Scholar." Annual meeting of the Society for the Social Studies of Science, University of Tokyo, Tokyo, Japan. August 25-28.

8. Erik Fisher. 2011. "Lost in the NanoWorld: 10 years of Emergence." *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

9. Erik Fisher. 2011. "'Stirring' the Governance Capacities of Experts-in-the-Making." *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

10. Erik Fisher. 2011. "Future Regimes of Science, Politics and Convergence Work." *The Future of Science and Society: A Symposium in Honor of Arie Rip.* University of Twente. June 17.

11. Erik Fisher. 2011. "Responsible Innovation R&D: the US Experience." Franco-British Workshop on Responsible Innovation: From Concepts to Practice. Residence of the French Ambassador, London. May 23-24.

12. Erik Fisher. 2011. "STIR Spin-offs: Beyond the Laboratory Engagement Study." Institute for Innovation and Governance Studies. University of Twente. May 11.

13. Erik Fisher. 2010. "Public Value Integration in Science Policy." Science of Science Policy Measurement Workshop. Office of Science and Technology Policy. National Press Club, Washington D.C. December 2-3.

14. Erik Fisher. 2010. "Science, Democracy and the Reinvention of the Liberal Arts." Lowdenslager Annual Lecture. Western State College. Gunnison, CO. 28 October.

15. Erik Fisher. 2010. "Midstream Modulation and Socio-Technical Integration Research." Ethics in the laboratory - Encouraging reflection through interdisciplinary collaboration. Technical University of Delft. Delft, The Netherlands. October 22-23.

16. Erik Fisher. 2010. "Socio-Technical Integration Research." NSF Science of Science and Innovation Policy Workshop: Building a Community of Practice II. American Association for the Advancement of Science. Washington, D.C. October 19.

17. Erik Fisher. 2010. "What is Midstream Modulation?" Reflexive Systems Biology Kick-Off Meeting University of Bergen. Bergen, Norway. February 27.

18. Erik Fisher. 2010. "TA-Trends in the USA." Keynote lecture. Instituut Samenleving & Technologie. Flemish Parliament. Brussels, Belgium. February 26.

19. Erik Fisher. 2010. "The Political Ethnography of Lab-Level Bureaucrats: Probing the Capacity of Research Decisions." Midwest Political Science Association 68th Annual National Conference, Chicago, Il, April 22-25.

20. Erik Fisher. 2010. "Lab-level Socio-technical Integration." Genome British Columbia, GSEAC Retreat. Vancouver, British Columbia, Canada. June 9.

21. Erik Fisher. 2010. “Midstream Modulation of Emerging Technology: Probing the Capacity of Research Decisions.” Research Council of Norway. Oslo, Norway. June 2.

22. Erik Fisher. 2009. “Integration and Reflexivity: Integrating Social Science and Humanistic Work with Laboratory Research in Emerging Science and Technology.” S.NET Pre-Conference Workshop: Real-time Technology Assessment and Anticipatory Governance, University of Washington, September 8.

23. Erik Fisher. 2009. “Laboratory Engagement. STIR: Initial Project Results.” TA NanoNed Annual Meeting. Utrecht, The Netherlands. June 30.

24. Erik Fisher. 2009. “The 'Two Cultures' in Science Policy.” Center for Science and Technology Policy Research. University of Colorado. Boulder, Colorado. June 25.

25. Erik Fisher. 2009. “Integrating Science and Society in Nanotechnology Laboratories.” The Nano Renewable Energy Summit. Denver, Colorado. June 22-23.

26. Erik Fisher. 2009. “Integrating Ethics and Engineering in the Laboratory: Reflections of an Embedded Humanist.” GILEE Workshop on Integrating Ethics and Societal Issues into a Graduate Curriculum. Virginia Tech. Blacksburg, Virginia. June 8-9.

27. Erik Fisher. 2009. “The 'Two Cultures' in Science Policy Today.” University of Colorado-Denver, School of Public Affairs. Denver, Colorado. May 7.

28. Erik Fisher. 2009. “Socio-Technical Integration Research.” Workshop on Research Funding and the Good Life. University of Twente. Twente, The Netherlands. March 18.

29. Erik Fisher and Derrick Anderson. 2009. “From Lab to Legislature: Public Value Mapping of Nanotechnology Science and Innovation Policy Making.” The Dupont Summit on Science and Technology Policy, Carnegie Institution for Science, Washington DC, December 4.

30. Erik Fisher and Antonio Calleja-López. 2009. Reflexive modulation of laboratory practices for the governance of science and technology. Society for the Social Studies of Science, Annual Meeting. Washington DC, October 28-31.

31. Erik Fisher and David H. Guston. 2010. “Integration of Social Science and Humanities Scholars with Natural Scientists.” Anticipatory Governance of Emerging Technologies: Foresight, Engagement and Integration. Euroscience Open Forum. Turino, Italy. July 2-7.

32. Erik Fisher and David H. Guston. 2010. "Changing Practices: An Engagement of Expert Epistemologies in the Making." Ninth Annual Meeting of the Science and Democracy Network. Kavli Royal Society International Centre, Chicheley Hall, UK. June 28-30.

33. Erik Fisher and Topi Heikkerö. 2011. "Public Deliberation in the Education of Science: Contemporary Practices and Classical Ideals." *Annual Meeting of the Society for Philosophy and Technology.* University of North Texas. May 26-29.

34. Michael E. Gorman and Shannon Conley. 2010. "Ethicists as Part of Interdisciplinary Collaborations in Nano and Emerging Technologies." Ethics in the laboratory - Encouraging reflection through interdisciplinary collaboration. Technical University of Delft. Delft, Netherlands. October 22-23.

35. Federica Lucivero. 2011. "Plausible Expectations and Desirable Futures: Reflections on a Lab Engagement Study on Medical Diagnostics." CNS-ASU Occasional Speaker series. Arizona State University. January 28.

36. Christine Luk. 2010. "Reflexive Modulation and Reactionary Resistance @ the Single Molecule Biophysics Laboratory." Annual meeting of the Society for the Social Studies of Science, University of Tokyo, Tokyo, Japan. August 25-28.

37. Farzad Mahootian. 2011. "Metaphoric Redescriptions of Laboratory Engagement." *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

38. Krsto Pandza, Paul Ellwood and Erik Fisher. 2009. "From Social Aspirations to Organizational Capability: Identifying Micro-Foundations and the Role of Strategizing." Interactive Strategy Process Work-in-Progress Workshop/ SMS Pre-Conference: Advancing Strategy Process Research. Washington D.C. October 11.

39. Robin Phelps. 2011. "The Institutional Context for Responsible Innovation in the Public and Private Sectors: Intentional Tensions?" *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

40. Robin Phelps. 2010. "Responsible Innovation: Institutions Shaping the Conduct and Trajectory of University Research." Poster presentation. Gordon Research Conference on Science and Technology Policy. Waterville Valley, NH. August 8-13.

41. Hannot Rodríguez & Erik Fisher. 2010. “Socio-technical integration in European Framework Programmes.” Poster presentation. Gordon Research Conference on Science and Technology Policy. Waterville Valley, NH. August 8-13.

42. Hannot Rodríguez & Erik Fisher. 2010. “Tracking the Pervasiveness of Socio-Technical Integration in the European Research and Development Framework Programmes.” Workshop on Science and Governance: Global and Comparative Perspectives. Arizona State University, Tempe, AZ. April 25-26.

43. Daan Schuurbiers. 2011. “The Pilot Plant: Scaling up Bright Ideas from Social Research.” Life Sciences Momentum. November 22.

44. Daan Schuurbiers. 2011. “Communication, trust and responsiveness.” Free University. Amsterdam, The Netherlands. January 18.

45. Daan Schuurbiers. 2010. “Managing ‘nano’.” Emergent Technology Dynamics. Utrecht University, Utrecht, The Netherlands. November 24.

46. Daan Schuurbiers. 2010. “Ethics on the work floor.” Ethics in the laboratory - Encouraging reflection through interdisciplinary collaboration. Technical University of Delft. Delft, The Netherlands. October 22-23.

47. Daan Schuurbiers. 2010. “In and beyond the lab - Interdisciplinary interactions in a molecular biology laboratory.” Annual meeting of the Society for the Social Studies of Science, University of Tokyo, Tokyo, Japan. August 25-28.

48. Daan Schuurbiers. 2010. “Responsible Innovation.” Centre for Society and Genomics Advisory Board Meeting. Utrecht, The Netherlands. February 12.

49. Daan Schuurbiers. 2009. "Leuk idee, maar wat hebben we eraan?" Centre for Society and Genomics Research Days, Berg en Dal, The Netherlands. October 1.

50. Daan Schuurbiers. 2009. “In and out of the lab - Midstream modulation in molecular biology.” Kluyver Centre Programme Day. Wageningen, The Netherlands. September 24.

51. Daan Schuurbiers. 2009. “Responding to social concerns in the laboratory.” CSPO Work in Progress Meeting. Tempe, Arizona. April 29.

52. Daan Schuurbiers, Erik Fisher and Harro van Lente. 2010. “A whole new set of lab responsibilities? ‘Responsible innovation’ and its consequences for research practices.” Risky Entanglements? Contemporary Research Cultures Imagined and Practiced. Vienna, Austria. June 9-11.

53. Anthony Stavrianakis. 2010. "Modalities of Fieldwork in Synthetic Biology." SynBERC Retreat. JBEI Emeryville. February 28.

54. François Thoreau. 2011. "Responsible Innovation: A Comparative Analysis of Nanotechnologies in Flanders and Wallonia, Belgium." *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

55. François Thoreau. 2010. "Modulations of the laboratory: articulations between individual and institutional dynamics in a Flemish R&D center, Belgium." Annual meeting of the Society for the Social Studies of Science, University of Tokyo, Tokyo, Japan. August 25-28.

56. François Thoreau. 2009. Integrated Research and Protected Spaces: A New Role for STS? Society for the Study of Nanoscience and Emerging Technologies Inaugural Conference, University of Washington, Seattle. September 8.

57. François Thoreau and Erik Fisher. 2010. "On Reflection and Reflexiveness: Positioning the Self, Enframing the Other." Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies. Darmstadt, Germany. 9 September - 2 October.

58. Brenda Trinidad. 2011. "The Responsibility of Being Responsible: Narratives of Innovation and Leadership from Integrated Laboratories." *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

59. Michiel van Oudheusden. 2010. "Developing notions of responsible innovation in Flanders, Belgium: The case of nanotechnologies," Paper and presentation for the Annual meeting of the Society for the Social Studies of Science, University of Tokyo, Tokyo, Japan, August 25-28.

60. Arnim Wiek. 2011. "STIR and the City: Integration Research and Sustainability Science." *Third Annual Conference of the Society for the Study of Nanoscience and Emerging Technologies*. 7-10 November.

Project Activities

Laboratory engagement studies (23). These studies include 19 of the original planned 20 studies, plus 4 additional STIR studies. Fieldwork has been completed at the following sites:

1. Broomfield, Colorado

2. Arizona State University (6)
3. Seoul National University, South Korea
4. Colorado School of Mines
5. University of British Columbia, Canada
6. Swiss Federal Institute of Technology, Switzerland
7. Leeds University, United Kingdom
8. Delft Technical University, The Netherlands
9. Lawrence Berkeley National Laboratory
10. University of Copenhagen, Denmark
11. University of Oxford, United Kingdom
12. Queens University, Belfast, Northern Ireland
13. Leuven, Flanders, Belgium
14. Chinese Academy of Sciences, Beijing, China
15. York, United Kingdom
16. University of Twente, The Netherlands
17. Ministerio de Ciencia e Innovacion, Madrid, Spain
18. Liege, Wallonia, Belgium

Workshops (4) for graduate student investigators, project collaborators, natural science and engineering reseach participants, and policy practitioners:

1. STIR Workshop 1: Constructing Foundations. Arizona State University. 17-19 January 2009.
2. STIR Workshop 2: Inquiry as Intervention. Vatnahalsen Hoyfjellshotell, Norway. 4-7 July 2009.
3. STIR Workshop 3: Comparisons, Hongo Campus. University of Tokyo. 24-25 August 2010

4. STIR Workshop 4: International Network for Responsible Innovation. Woodrow Wilson International Center for Scholars, Washington, D.C. 16-17 February 2011.