Information and Communication Technology Challenges to Scientific Professional Identity

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Abstract

Increasingly, information and communication technology (ICT) uses are transforming professional activities and interactions in ways that challenge traditional assumptions about professional identity. In this paper, we consider how ICT uses by research scientists in oceanography and marine biology shape professional identity. Empirical data are drawn from an ongoing study of ICT use in collaborative scientific research projects in these disciplines. We examine uses of basic communication technologies as well as scientific technologies with embedded ICT components. Our analysis suggests that development and use of ICT-enabled scientific technologies are identity enhancing for many scientists, facilitating their development of unique areas of scientific knowledge. ICT-related changes in data collection, collaborative coordination and scientific interaction also challenge traditional definitions of expertise and professional identity.

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1. Introduction

Increasingly, information and communication technology (ICT) uses are transforming professional activities and interactions in ways that challenge traditional assumptions about professional identity, and they may even call into question what it means to be a professional in a particular field (Walsham, 2002; Zuboff, 1988). Scientists frequently establish their research reputation and professional identity by developing a highly particular set of technologies that advance knowledge in their discipline (Latour, 1987; Knorr-Cetina, 1999). Over the past decade, many of these scientific technologies have incorporated ICT components that further enhance research knowledge, as well as the identities of the scientists who develop, use and refine them. IS researchers have noted some ways in which ICTs shape professional identities (c.f. Walsham, 2001), but very few studies have examined these co-construction processes.

Our own research into the roles of ICTs in collaboration among oceanographers and marine biologists in academia and industry has recently begun to illuminate this area. Preliminary findings from our ongoing empirical study suggest that development and use of ICT-enabled core scientific technologies are identity enhancing for many scientists, facilitating their development of unique areas of scientific knowledge. At the same time, ICT-related changes in data collection, collaborative coordination and scientific interaction challenge their perceived control over scientific expertise and professional identity. Interestingly, our data show that ICTs commonly used for self-presentation and identity management (like personal web pages) are less formative with respect to professional identity than core scientific technologies. While junior scientists regard "web presence" as a valuable addition to traditional methods of professional recognition (like research papers and presentations at conferences), senior scientists regard traditional channels of professional self-presentation as perfectly adequate. However, web presentations of scientific projects and the core technologies that establish project-based identities are highly valued by senior and junior scientists alike.

In this paper, we examine the co-construction of identity and technology among scientists, giving special attention to the incorporation of ICTs. Our analyses draw insights from our ongoing study to examine how three distinct classifications of ICT uses shape the multiple identities of oceanographers and marine biologists in academia and industry. In the next section, we review theoretical approaches to understanding professional identity and the roles of technologies in shaping identity. We then present data from our ongoing empirical research study of ICT uses in collaborative scientific research, which confirm and also challenge theoretical understandings. In our discussion, we analyze the co-creation of professional identity and ICTs by the research scientists of our study, particularly in project-focused environments. We conclude by considering the implications of a project-based conceptualization of scientific professional identity.

2. Theoretical perspectives on identity and technology

Identity concepts span many disciplines and sub-fields, including developmental psychology, social psychology, sociology, philosophy, post-modernism and post-structuralism. These concepts help us understand how people construct and present multiple identities throughout life, such as their professional identities. Sociologists like Whyte (1956) have described the ways in which people identify themselves with the kind of work they do and the organization where they work. His portrayal of the “organization man” showed that the workplace strongly influences our identities and self-presentations. Educational background and membership in professional associations also shape our sense of who we are, how we should conduct our professional activities, and how others should regard us. Although doctors, lawyers and scientists have held special titles and degrees for many centuries, the rise of professionalism in modern society has increased and standardized the ways in which people identify themselves and signal their occupational competencies (e.g. the MBA degree for managers, the CRS certification for realtors), and has also provided codes of conduct for interactions among these professionals and those they serve (Larson, 1977). New technologies have also presented professionals and scientists with interesting opportunities for coordination and interaction (Olson and Olson, in press; Finholt et al., 2002). Current understandings about these shifts in scientific and professional identity are informed by three main theoretical perspectives: interactionism, post-structuralism, and network theory.

2.1 Interactionists: Goffman, Giddens

For Goffman (1959), the self and presentation of the self can only be understood through a person's interaction with others. That interaction is defined as "the reciprocal influence of individuals upon one another's actions when in one another's immediate physical presence" [p. 15]. In other words, identity is co-constructed by interactors, and reciprocity is a fundamental component of identity. This shifts the conceptual focus from 'what is identity?' to 'how is identity enacted?' Goffman differentiates between types of identity as expressions of the self that are intentionally "given" and those that are unintentionally "given off". When we tell people something about ourselves, when we present ourselves in a particular way--that is our avowed identity. It may differ from the identity which others interpret from our self-presentation, and which they then ascribe to us.

Identity and self-presentation are influenced by a mode of interaction, which entails not only the format and forum of new ICTs, but also the scope and reach of the social relations which these technologies support. With worldwide computer and communications networks, for example, individuals are less bound by physical geography. They have the opportunity to witness events far away and to participate in them remotely. Giddens (1991) characterizes these shifts in time and place as key transformations of late modernity and globalization, in which distant happenings shape, and are shaped by, local circumstances. Building on Goffman's basic concepts, he describes how ICTs increase the flows of information available to the individual, and how the ongoing narrative of self-identity occurs in a global, rather than a local context, negotiated through self-exploration and interactions and relationships with others.

Relying on Gidden's theoretical work, Walsham and his colleagues have developed some helpful theoretical links between macro-level social transformations and the micro-level implications of ICTs for professional identity (Barrett, Sahay, and Walsham, 2001; Barrett and Walsham, 1999; Walsham, 2001; Walsham, 1998). They conclude that workplace introductions of new ICTs and their associated work practices play important roles in structuring systems of professional expertise, creating concerns about deskilling among professionals. As traditional roles and skills are challenged by increased reliance and trust in these systems, professionals experience anxiety about their identity.

Although opportunities for re-skilling and empowerment also arise as new technologies, techniques and practices evolve, Walsham and his colleagues are primarily concerned about the negative implications for professional identity. They acknowledge that empowerment is possible, however, ICT interventions tend to reshape professional roles and redistribute organizational power in predictable ways, influencing how professionals see themselves and how they are viewed by others. Zuboff (1988) identified a similar dichotomy of automate (deskill)/informate (empower) outcomes, as ICTs are used in professional work. She suggests that both potentials exist, but finds that those in authority have favored automation over empowerment (Zuboff and Maxmin, 2003).

2.2 Post-structuralists: Derrida, Foucault, Deleuze

For Goffman, identity co-construction was a face-to-face affair between people. IS researchers have extended his concepts to examine self-presentation within environments mediated by interactive technologies, like the telephone and email. In a postmodern sense, these technologies have become essential extensions of ourselves, without which it is difficult to interact effectively. Fischer (1992) reminds us that ICTs have been resources for identity construction and self-presentation since the early diffusion of telephone technology. Thus, technological possessions and competencies are very much a part of modern identity (Belk, 1988).

Derrida (1978), however, moves beyond modernist concepts of ICT-enhanced interaction. He transitions identity through the "text" that is exchanged by interaction. That text itself is so malleable that it allows others to deconstruct and reconstruct it in multiple ways that are beyond any individual's ability to control. For Derrida, these multiple potential selves that others construct are just as "real" as any that we consciously avow. With this conceptualization, he transforms modern reality into postmodern textuality, where new digital ICTs offer unprecedented abilities to manipulate the text of personal and professional interactions, whether as words, images, sounds or as a recombinant mélange of forms.

Foucault (1977) and Deleuze (1992) have also observed that identity-defining "texts" can easily be manipulated – especially by those who control the ICTs and have the ability to exercise social and political power. Poignant presentations of the downside of public information, market demographics (Rule, 1974) and criminal profiling (Laudon, 1986) have documented the 'Panopticon-like' surveillance and control capabilities of new ICTs. But, as Poster and his colleagues have noted (Poster, 1990; Lamb and Poster, 2003), new ICTs, like online databases and the Web, allow for both greater control and greater freedom of expression; and it is the latter potential which fascinates technology enthusiasts.

Drawing on Derrida's concepts, Stone (1996) and Turkle (1995) heralded the Web as a watershed event in the coming of post-modern society. In their scenarios, identity is freed from the constraints of the physical being sitting at the computer interface, to represent whatever and whomever that person wants to be in the virtual world of cyberspace. Their analyses assume not only the possibility of sustaining multiple identities in the disembodying context of cyberspace, but also the desirability of doing so. Turkle (1995) writes: "... we shall see fundamental shifts in the way we create and experience human identity ... in the real-time communities of cyberspace, we are dwellers on the threshold between the real and the virtual, unsure of our footing, inventing ourselves as we go along" (p. 10).

Clearly, the desirability of multiple identities depends on where one thinks the control of these constructions resides, and on what their social consequences might be. ICT researchers have tried to reconcile post-modernist projections with observable changes in ICT-intermediated identities. Wynn and Katz (1997) contrast the individualistic, psychological view of "self" that underlies post-modern analyses with interactionists' understanding of self in relation to others. Although an individual may present different facets of self to different audiences, either through exaggeration or deception,[1] Wynn and Katz argue that people are more likely to attempt to maintain a common thread to their identity. Furthermore, clues to identity are "given off" tacitly, even in text-only media, making it difficult to sustain multiple, or deceptive, identities within a community for any length of time (Whitley 1997). Because virtual and face-to-face interactions often overlap, ICT manipulations of the "text" are more likely to be used for an instrumental purpose in a context that draws social conventions about appropriate behavior from the non-virtual world (Miller and Arnold 2001; Wynn and Katz 1997).

Nonetheless, ICTs do open up new forums for self-presentation and interaction, and personal web pages have garnered a fair degree of research attention. In an essay in *Communications of the ACM*, Erickson (1996) suggested that these presentations would enable new types of social knowledge networking, because web pages could be used to construct identity in a way that freed “interactors” from obligations of reciprocity. In other words, the right mix of personal and professional presentation within web pages would enable asynchronous interactions that intimate closeness, but maintain more social distance than other communication technologies, like the telephone or even email.

[1] See Goffman (1959) for a thorough description of the ways in which people present themselves fictitiously.

Early projections such as Erickson's were speculative, but preliminary studies such as Bly et. al. (1998), Walker (2000), and Miller and Arnold (2001) provide data about the effectiveness of intermingling the personal and the professional on home pages. Their discussions focus primarily on the professional person, her extended self within an organizational context, and the degree of personal identity tolerated in corporately or institutionally maintained pages. As Wynn and Katz (1997) also noted, they find that the personal home page does allow for new ways to express identity, by adding context to the presentation of self through links to pages and sites that others have developed for different presentation purposes. "This *is* postmodern in the sense that the browser has access to a much broader text and thus is in a position to construct an independent interpretation of the page creator" (Wynn and Katz, 1997, p. 322). The person viewing such a web page, in which links are meant to characterize the larger social context of the page creator, engages in identity construction by following links and making perquisite associations. However, such actions would not involve reciprocity or co-construction of identity through the kinds of social interaction that Goffman (1959) described; unless these actions result in some kind of feedback to the page creator delivered through underlying social or professional networks.

2.3 Network theorists: Latour, Castells

According to Taylor (1989), what we say about ourselves reflects our basic moral sense about what is "good" or what is "good to be." For example, "I am a good scientist" might be demonstrated by meticulous application of the scientific method in collecting data samples. These avowals, audience reactions to them, and our reactions to those reactions help shape our identities. As Taylor has observed, "a self exists only within what I call 'webs of interlocution'" [p. 36]. These webs of interlocution – or networks of social and professional interaction – are fundamental to identity construction, as Latour (1987) has shown. His studies have examined in detail how scientific facts are constructed through networks of axiomatic knowledge, that link texts to one another in support of scientific statements. The texts, the facts, the laboratories, the reputations, the instruments and methodologies all build on one another in a complex entanglement of references within and among networks to create a discipline. Latour's network-centric explanations situate "identities" as scientific knowledge, self-knowledge and knowledge about others within a complex, dynamic framework of alliances and exchanges.

Knorr-Cetina's studies (1999) of physicists and molecular biologists demonstrate the ways in which science, technologies and scientific identity are co-constructed through such networks. She describes the 'construction of the machineries of knowledge construction,' and explains how the identities of people and objects take shape in the process. Within the physics community, for example, instruments like particle detectors take on a life of their own. They "see" things that humans cannot, and "speak" by producing particular kinds of texts. These technologies act as mediating devices within the physics community, and they are "loved" by the scientists who work closely with them (see also Latour, 1996). Those scientists identify and become identified with their technology (Traweek, 1988).

Such outcomes contrast sharply with the depersonalization of patients and research subjects in micro-biology, where science focuses on turning living beings into molecular production sites and distilling their essence into genetic information – the AGCT text. In the process, people are stripped of their identities – even the laboratory scientists themselves, who may come to be regarded simply as information processing tools (Knorr-Cetina, 1999.) This objectification can be understood as a step in the process of creating disembodied knowledge (Foucault, 1970); but Knorr-Cetina's analyses show that the processes of identity construction (in physics) and deconstruction (in micro-biology) operate within very similar logics and networks.

Latour and Knorr-Cetina describe how core scientific technologies are enlisted in identity construction and deconstruction processes. As we will argue, their logic can be extended to ICTs, as well, because ICTs are increasingly embedded within scientific devices. However, Castells (1997) concept of project identity provides another theoretical link between ICTs, networks and identities that deserves further investigation.

Castells stresses that globalization is a key phenomenon shaping what he calls "the network society," and that ICTs are key components and enablers of globalizing practices among organizations and across markets, facilitating the flows of capital and knowledge-based resources through electronic interactions. ICTs create the basis of the network enterprise – a new distributed, project-oriented, economically lean, easily reconfigurable organizational form, but networks also allow for the rapid reconfiguration of other collective identities. Castells identifies three types of *collective* identities taking shape within the network society:

- legitimizing identity, "introduced by the dominant institutions of society to extend and rationalize their domination over social actors";
- resistance identity, "produced by those actors who are in a position/condition of being excluded by the logic of domination"; and

- project identity, “proactive movements that aim at transforming society as a whole” (Stalder, 1998.)

This concept of *project identity* resonates strongly with the findings from our study, but Castells' “projects” differ from the scientific projects that we will describe here, and the organizational projects that we have discussed elsewhere (Lamb, 2003). In Castells' analyses, the projects that shape people’s identities are grand-scale social projects and movements, such as women’s rights, environmentalism, and religious fundamentalism. In our own studies, we see that people find much of their identity in smaller, more modest “projects.”

In the balance of this paper, we present findings from our study that illustrate the co-construction of identity and technology among scientists. Our data shows that ICTs do shape scientists' identities, but they do so most often indirectly – by providing a venue for the presentation of project identities, and by sustaining and creating networking opportunities.

3. Research design and methods

Our analysis of professional identity and ICT use is based on empirical data drawn from an ongoing socio-technical study of research collaborations in academia and industry (Davidson and Lamb, 2000). To date, we have interviewed over sixty research scientists in oceanography and marine biology[2]. (See Table 1.) The study uses qualitative methodologies to examine multiple aspects of research scientists' collaborative associations and organizational environments, and pays particular attention to their socio-technical networks and uses of ICTs. It is being carried out as a multi-year research project in four steps of data collection and analysis:

[2] Future interviews will include research scientists in astronomy.

Step 1: Characterize the social networks, ICT uses, and technical, institutional and informational environments of academic researchers. In this step, we conduct semi-structured interviews with academic research scientists from the University of Hawaii in each discipline, to collect data on their collaborations and the array of ICTs they use in these research endeavors. We then identify an academic research group for in-depth study and analysis.

Step 2: Characterize the networks and environments of industry researchers. In this step, we develop a sample of industrial firms operating in the scientific area and conduct a telephone survey to determine which firms engage in collaborative scientific research activities. From this screening, we select firms for site visits and identify a case study for in-depth analysis.

Step 3: In-depth case study of ICT use in scientific collaboration. We plan to conduct 6-8 in-depth case studies from the three disciplines of scientific collaborations that extend from academia to industry or from industry to academia.

Step 4: Network traversal study of ICT use in scientific collaboration: Using a methodology for tracing influential associations from the focal actor through the network, we will conduct follow-up interviews with individuals and organizations identified in the case studies as key collaborators, to examine how these collaborative influences may shape or be shaped by ICT uses.

We began our study with scientists who have organizational links to academic departments and research laboratories at University of Hawaii, because it is a leading research institution in oceanography and marine biology with a wide range of projects and technologies under study. Both fields draw researchers from around the world, and from a wide spectrum of scientific disciplines, such as physics, geology, engineering, chemistry, biology and zoology, as well as from oceanography and marine biology. In interviews lasting approximately one hour, we ask these scientists to review their background, to describe in depth one or more collaborative research projects, and to discuss their uses of ICTs in these projects. Our early decision to use a very broad definition of ICTs has improved our basis for analysis by helping us consider a wide array of configurations, ranging from communication technologies such as e-mail and the Internet to ICTs embedded in scientific technologies such as sonar interpretation software. During each interview, which is later recorded and transcribed for analysis, we visit the laboratories and view the technologies used by the researchers. Prior to the interviews, we examine the researchers' homepages and any web sites that describe their research programs, so that we can ask them to talk about these self-presentation forums.

To date, we have completed Steps 1 and 2 for both disciplines. We have conducted two case studies of academic research groups (one in each field), which have included interviews with graduate students and technical staff members, and one industry case study with managers and researchers at an oceanographic firm. As part of Step 4, we have also begun to interview scientists at academic institutions and other research organizations, who collaborate with our study participants. Table 1 details the types and numbers of interviews conducted.

Table 1: Interviews Conducted

Discipline	Research scientists	Research associates	Students working with faculty	Non-UH academic researchers	Managers and administrators	Totals
Marine Biology	19	2	8	0	2	**31**
Oceanography	21	6	1	5	0	**33**
Industry	7	2	0	0	8	**17**
Total	**47**	**10**	**9**	**5**	**10**	**81**

Our data collection and analysis are guided by a social actor model, developed through prior research (Lamb and Kling, 2003), which uses institutional theory to characterize *people and their ICTs* along four dimensions: affiliations, environments, interactions, and identity. We are using this model to construct our interview instruments, and to guide further theoretical sampling. We examine interview data using qualitative data analysis techniques (Miles and Huberman, 1994) and qualitative analysis software (NVivo), and we refine themes that emerge from the study data through iterative rounds of data collection and analysis. This theoretical sampling approach (Strauss and Corbin, 1987) allows us to pursue interesting themes that arise in early interviews by refocusing subsequent data collection. It is not intended to provide a statistical representation of the study population (i.e. scientists), nor to support quantitative analysis of our data. Rather, we use it to develop theoretical concepts and to explore their interrelationships within the context of our study.

One theme that emerged from our early analysis is the relationship between professional identity and ICT use (Lamb and Davidson, 2002). We have pursued this theme in our iterative analyses, guided by the social actor model and supplemented by the theoretical concepts discussed in Section 2.

In the next section, we present our findings from this analysis of professional identity and ICT use in collaborative scientific research among oceanographers and marine biologists. We first discuss the types of ICT use we observed; we next identify those aspects of professional identity related to ICT use, and then we examine how ICTs and professional identity are co-constructed through the conduct of research.

4.0 ICTs and professional identity: findings and analysis

Our data suggest that three distinct classifications of ICT use shape the multiple identities of oceanographers and marine biologists in academia and industry. (See Table 2.) However, the relative importance of each ICT use type in constructing and enacting scientists' professional identity is highly dependent on the functional aspects and interaction contexts of their research. To illustrate this point, we will describe the three types of ICT use we observed, and then furnish examples of those uses in context.

4.1 ICT use categories

Embedded ICTs. Over the last few decades, scientific technologies have increasingly relied on digital and computational components that make it possible for researchers to collect new kinds of data or to analyze data in new ways. As the components have become smaller and cheaper, these ICTs have moved out of the computer rooms and processing labs, and into the devices that scientists deploy 'in the wild.' We call these devices *core scientific technologies*, and we describe the information and communication component technologies inside or connected to the devices, that directly relate to scientific data acquisition and analysis, as *embedded ICTs.* (See Appendix A for an illustration of an oceanographic application of embedded ICT use.) ICTs become embedded as core scientific technologies are developed or applied by researchers, usually working in project teams. (See Table 2 for a list of the embedded ICTs that we have observed in our study.) Building and using these often fragile core technology assemblies, and getting all the components to work as desired, entails close collaboration. As Latour, Knorr-Cetina and Traweek have described, and as our data confirms, these highly interactive core-technology-building projects are primary sites of identity construction.

Table 2: Categories of ICT use in scientific research

Embedded ICTs
Technologies for scientific data collection and/or manipulation embedded within or connected to core scientific technologies, e.g., • Towed arrays of sonar devices with signal interpretation and mapping software (See Appendix A) • Buoys with data collection and digital storage, satellite transmission capabilities • Animal tracking tags with digital storage or satellite transmission capabilities • Laser microscopes with software for 3-dimensional digital imaging *Technologies for data/system modeling and analysis of digital or analog data collected with core scientific technologies,* e.g., • Supercomputers with modeling software for climate analysis • Special-purpose analytic and visualization software • Gene sequencing software and databases • Geographic information systems (GIS) software (e.g. Arcview) • Off-the-shelf visualization technologies (e.g. Matlab)
Coordination ICTs
Technologies used to work and coordinate analysis with scientific collaborators, e.g., • E-mail with attachments • FTP sites for data exchange • Private project web sites (See Appendix B) • Teleconferencing, videoconferencing • Collaboratories (specialist collections of coordination, observation and analysis technologies)
Dissemination ICTs
Technologies for communication of findings with scientific community, e.g., • Visualizations and data collections • Multimedia presentation tools • Personal web pages • Protected project web sites • E-journals • Electronic indices and print-journal archives *Technologies for dissemination of scientific knowledge to non-scientific communities (outreach),* e.g., • Multimedia presentations • Personal web pages (See Appendix C) • Public project web sites • Television and popular publications (e.g. Discovery Channel and National Geographic)

Coordination ICTs. Tight collaboration is not always necessary in scientific work. Often, researchers can work at a distance and share the results of their work, or coordinate local interactions by using some widely available and well-understood ICTs. When email, the telephone, or internet technologies are used to coordinate the work of researchers who are separated in time or space, we call them *coordination ICTs.* Scientists are not typically constructing the ICT in-use, as with embedded ICTs. (However, project website construction presents an interesting counterpoint to this general observation, which we will discuss in some detail in subsequent sections and in Appendix B.) Therefore, the identity shaping processes associated with coordination ICTs are different. Many oceanographers and marine biologists routinely work with research colleagues in other institutions around the world, and they use coordination ICTs like the Internet, e-mail, and other communication technologies to exchange data, plan meetings and research trips, write papers, and so on. As interactionists have described, these ICT uses provide new ways to avow identities, but they can also become part of the identity shaping process to the extent that they sustain and create networking opportunities, and establish modes of reciprocal interaction.

Dissemination ICTs. Although in some cases the technologies themselves are nearly identical, we distinguish between coordination ICTs and *dissemination ICTs* based on the interaction contexts in which scientists commonly use them. (See Table 2 for a list of the dissemination ICTs that we have observed in our study.) Researchers use dissemination ICTs to share scientific findings within their discipline and with the broader scientific community, and also to make scientific knowledge more accessible to other social groups (including K-12 educators and students). Information formats and content vary widely within this category, but the identity shaping influences are similar, as we will discuss. These disseminations are often the resources for identity construction, deconstruction and reconstruction that capture the attention of postmodern analysts.

4.2 Disciplinary anchors for scientific identity

Scientists, like other professionals, identify themselves in terms of their area of expertise and the kind of that work they perform. Researchers in our study differentiate themselves, sometimes with noticeable difficulty, using three main identifying criteria: their domain of expertise, their primary method of research, and the type of phenomena that is their focus of study.

From their self-descriptions, we can see that scientists' identity is rooted in the academic disciplines in which they are trained, although many have crossed "fields" to practice their research. For marine biologists and oceanographers, identity is also closely tied to research interests in ocean and marine phenomena. These phenomena are inherently multidisciplinary, drawing together scientists from different domains, for whom shared interests may outweigh disciplinary background as a source of professional identity. This oceanographer, trained in physical chemistry, highlighted these issues as he explained what he thought might appear as a disciplinary anomaly:

> "It turns out that oceanography, as a relatively new discipline is somewhat more open to be [an] interdisciplinary or multidisciplinary character of the subject than many of the traditional scientific disciplines are. One might think someone with my background would be more comfortable in a chemistry department, but traditional chemistry departments are extremely snooty about what is chemistry, and virtually all of the atmosphere chemists that I know are in engineering schools now, national labs, oceanography departments, things like that, but rarely ever in a chemistry department. So partly it's appropriate for me to be in oceanography because I study air-sea exchange, among other things. I'm very interested in marine atmosphere."

Such distinctions influence the social milieu in which identity is enacted and the audience to which the professional self is presented. Interdisciplinary scientists publish in journals, attend conferences, and form collaborative associations focused around marine studies.

Another salient aspect of scientific identity is the distinction between field researchers and modelers. For field oceanographers, going on cruises for data collection is fundamental to what it means to be a researcher. Research projects, tasks, funding requests, and collaborations are closely tied to the act of going to sea. This scientist emphasized not only the important role that field trips play in his research, but also his dedication to these experiences:

> “I am a field oceanographer, so I do a lot of my work in the field much like a geologist would be in the field … we stay out in the sea for periods of up to two months at a time. So I think recently I did a calculation that I have been at sea for three years since I have been a graduate student, you know if you add up all the days.”

The research methods and technologies that field oceanographers use -- scientific research vessels, sea-deployed instruments -- are well-fitted to the marine environment; and, increasingly, their technologies include ICTs to advance detection, monitoring, communication and analysis capabilities. As further examples will show, utilizing new and innovative research technologies that capitalize on ICT advances to investigate the oceans and marine life is an important source of professional identity.

In contrast, modelers usually conduct their work in an office or lab, and they rely primarily on computation and visualization technologies to simulate theoretical principles. Oceanographic field research and modeling efforts do overlap: modelers often use empirical data collected by field researchers for model verification. In fact, funding agencies, such as National Science Foundation (NSF), encourage the integration of empirical findings through modeling, particularly in relation to climate research. Modeling can be done with little interaction or collaboration between modelers and field researchers, particularly if empirical field data are made available through online archives or on request via e-mail attachment or CD. Nevertheless, the act of sharing data can have a profound effect on scientific identity, as we will show.

An analogous distinction among marine biologists is made between those who study organisms and those who use marine organisms to study fundamental biological processes. Some marine biologists study whole organisms or systems within organisms and their behaviors in their natural environment, in a marine laboratory, or both. These scientists typically go into the field for data collection, sample collection or observation. For them, scuba diving to observe marine life, maintaining and maneuvering boats to observe and collect data, are adjunct research skills. In contrast, researchers who study marine organisms primarily at a cellular or molecular level typically operate within a laboratory. Access to organisms in their native environment may be useful to these scientists, but it is usually not essential for their work. Advances in microbiology technologies, such as gene sequencing and laser microscopy, have increased the focus on and funding for this type of marine research, seemingly at the expense of field research. According to some of those we interviewed, this shift in resources draws more graduate students toward laboratory research, and may inadvertently decrease the prestige in being a marine science field researcher.

4.3 Linking identity to core scientific technologies with embedded ICTs

The “who I am” of professional identity is interwoven with “what I do,” and what scientists do is increasingly influenced by ICT developments. For all research scientists, making a unique contribution to scientific knowledge is a highly valued aspect of professional identity. A number of researchers stressed the unique aspects of their work, in statements like these:

> "To be honest, I'm probably the only person in the world who does it right now. That's my claim to fame."

> "What I've done is a lot of technique development and making measurements that no one has made before."

Making unique contributions results in recognition among peers, in institutional rewards such as tenure, and in grant funding. ICTs are becoming critical components in many core technologies of scientific research, thus influencing scientists' ability to make unique contributions. They can influence what research questions are asked, by whom, and how the research work is carried out. The core technologies that ICTs are part of can do even more to shape identity; they can serve as a reference to (i.e. "stand in for", in Latour's theory) a researcher or an entire research team.

One research group in our study has become known internationally for their core technology, and the scientific identities of the group's lead researchers are closely associated with it. They design and build towed arrays of sonar devices and sonar interpretation software to produce bathymetry maps of the ocean floor. (See Appendix A for an example of this kind of core technology with embedded ICTs.) This instrumentation generates new opportunities for research, as well as revenues from services. The quality and detail of the resulting maps are unique among groups doing ocean floor mapping. Therefore, commercial firms and other researchers contract with the group to provide highly precise sea floor mapping services, based on referral and their technology-based reputation. Group members' attention is constantly focused on improving the capabilities of their core technology configurations – which often means adding or upgrading ICTs. The senior scientist, describing the work of her group's chief engineer, explained:

> "He’s constantly pushing us in directions of developing new tools that will help any of our clients get better maps of the sea floor. We're doing everything from changing the frequency so you can see different kinds of features, to trying to penetrate into the bottoms instead of mapping the top -- all sort of tools that we’re developing here."

Without its core technologies, the group itself would not exist. In fact, several years ago, their only operational towfish (a housing containing the core technology configuration) was lost at sea during a voyage. The group nearly disbanded, for lack of revenues and the ability to conduct their ongoing research, during the time it took to outfit a new and improved towfish.

As ICTs have advanced, many researchers have found a way to make their unique scientific contribution by integrating embedded ICTs into existing research programs in ways that open up entirely new research opportunities. This marine biologist’s explanation illustrates how advances in digital storage and communication technologies helped create a new scientific identity for him:

> "I changed from sensory zoology, into what has been my bread and butter for the last 20 years or more. And that’s the use of electronic tags, which we put on the tuna, and then follow them around, to see where they go, and when they go, trying to decide what it is about these certain [places] which are important to their behavior. And at that time, it was a field that was just getting going, because of the miniaturization of the components, which made the tags of a reasonable size that you could [attach the] tag on the outside of the fish, or cut an incision and put it inside of the fish. And so I turned then into an open ocean tracker, basically."

Tagging and tracking technologies continue to evolve as devices with satellite communication and underwater sensing capabilities improve. New devices provide opportunities for this scientist and his students to explore scientific questions about marine animal behaviors in new ways, but they often require special modifications first. For example, radio waves do not propagate well through salt water, so tags used for land animals, or even marine mammals, cannot be directly applied to the study of fish. Marine biologists who apply tag technologies must adapt them to the marine environment and to the physiology and behaviors of the organisms of interest, often by collaborating closely with tag manufacturers and encouraging them to enhance their devices in particular ways. Through collaboration, these researchers are co-constructing the technology and their scientific identity just as effectively as the researchers who build their own core technologies with embedded ICTs.

Even when scientists do not develop new embedded ICTs, ICT use may still be integral to their professional identity, particularly when off-the-shelf technologies are used to collect unique and scientifically interesting data. Being cutting edge in terms of the *types* of data collected is a highly valued scientific contribution for oceanographers and marine biologists, alike. Field researchers look for opportunities to collect data never before collected or never collected from a particular ocean region, or to gather and consolidate region-wide or global data sources. For example, one scientist in our study has assembled a data collecting device from standard technologies to examine chemical interactions in seawater that have not been previously understood. Another has deployed "standard" ICT-enabled sensors in remote areas of the Southern Pacific, where few empirical data have been collected.

A few scientists emphasized that embedded ICTs, however enabling, are nonetheless secondary to the scientific questions of interest. This marine biologist's comment highlights his conception of ICTs as the means, not the ends, for research:

> "I've incorporated these things [new technologies] when they became useful to me…I'm not going to go out and buy a supercomputer because somebody else is doing it. But when it's useful to me, my god, I'm going to get in there and I'm going to take advantage of that."

Another researcher displayed a more disparaging attitude towards those who become focused on technology, rather than the scientific questions about marine phenomena:

> "When a new technology comes in, you have the tech head who kind of perfected telemetry or uplinks with satellites and things like that, but they don't understand the reason that they were doing these experiments in the first place … There are always people that would rather do uplink satellite code than walk around on a boat."

This field researchers' comment hints that scientists are aware of the identity tensions (e.g. between "tech heads" and "boat people") that emerge as embedded ICTs become more important in marine research fields.

4.4 Embedded ICT challenges to professional identity

Advances in embedded ICTs not only enhance, but also seriously *challenge* professional identity by making some areas of scientific expertise obsolete. This is readily apparent among field oceanographers. Although there continue to be cases in which cruises are necessary, data are increasingly available from remote sensing stations on the sea floor, in floating buoys with satellite uplink capabilities, and from satellite imagery. These sources of oceanographic data offer advantages over traditional methods of collecting data via periodic cruises. Several oceanographers commented that in the future, they would have less reason and opportunity to go to sea – yet going to sea has traditionally been one of the earmarks (and often one of the great pleasures) of the field oceanographer.

This double-sided relationship that scientists have with embedded ICTs is evident within a group of researchers who maintain an ocean monitoring buoy. This group collects and maintains ocean readings that were once unique and are now invaluable, particularly since the group has accumulated a longitudinal dataset for over ten years that can be extremely useful for modeling climatic change. For the research project leaders, this data collection program has led to world-wide recognition and collaborative opportunities to help develop similar stations elsewhere. However, the buoy and its associated databases, once perceived as cutting edge science, are now threatened by technological obsolescence. Satellite systems are increasingly used for similar types of data readings and for real-time data transmissions – reducing the need for time-consuming and expensive cruises out to the buoy to gather data. Some scientists in this group believe that funding agencies are less interested in supporting the project – even though the longitudinal archive is an important resource to the wider scientific community – because it is 'old technology'. In response to the diminishing value of their ICT-embedded core technology among fellow researchers and funding agencies, these researchers are moving on to projects that are more technologically cutting-edge, such as the development of seafloor monitoring systems.

In marine biology, research approaches are shifting from traditional observational studies of organisms towards cellular and molecular investigations, as ICT-related advances in core scientific technologies expand the types and pace of research that can be done. One scientist explained how technologies such as gene sequencing and laser microscopy have influenced biological sciences:

> 'The nice thing now [is that], because molecular biology is getting easier and easier, you can ask the same kind of question to many different kinds of animals, and then try to find the kind of information that we've been looking for, for centuries. Same questions, but the technologies have changed."

Another noted how certain ICT capabilities and skills are becoming increasingly vital, and that individual scientists must update their skills to keep current with developments and to maintain their professional identity:

> "I'm a cellular developmental biologist. I am on the cusp of the molecular age … In terms of information technology and things like that, it is quite clear in my field that learning how to deal with massive datasets is the wave of the future, and if you don't fasten your seatbelts and get ready for that, you're going to be left behind."

The potential for embedded ICTs to facilitate new and unique scientific contributions attracts funding and resources, sometimes at the expense of traditional areas of marine biology research. This shift challenges not only the professional identity of older, established scientists, but perhaps more critically, junior scientists, like marine biology field researchers, whose research interests are focused on environmental and behavioral questions. This young scientist lamented the increased emphasis and status of molecular studies over his own type of research (field studies of marine animals):

> "Many, many [marine biology] labs are moving towards molecular biology, and molecular biology is great. It's a tool, but that's all it is. It's a tool, and it's getting to the point now where you have so many molecular biologists, and you don't have any organismal biologists anymore. And no one's trying to hire [in] organismal biology."

For scientists who are well established in their careers or nearing retirement, shifting priorities may be less problematic for professional identity. But young scientists, such as this one, are likely to find less support, in terms of funding and career opportunities, than marine researchers utilizing molecular techniques -- *unless* they can find ways to leverage ICT-enabled technologies in their field research. One approach would be to follow the example of marine biologists, noted earlier, who collaborate with technology manufacturers to develop new core technologies for field research. Alternatively, new researchers can incorporate a multi-disciplinary range of research approaches into their program, building their professional identity across a broader base of technologies and scientific fields. We have noted this trend among marine biology graduate students, who are integrating traditional behavioral, habitat and ecological research methods with molecular DNA-analysis techniques.

4.5 Coordination ICTs and remote collaboration

When email, the telephone, or internet technologies are used to coordinate the work of researchers who are separated in time or space, we call them *coordination ICTs.* The research scientists in our study routinely use coordination ICTs, including teleconferencing and less commonly videoconferencing, to share data and analyses, to plan meetings and excursions, and to exchange proposals and manuscripts. These ICTs are widely available and do not confer special status or identity enhancing distinction to scientists who use them (although they may have done so in earlier years). E-mail, in particular, is regarded as essential to collaborative scientific research efforts, but its use is commonplace.

Although they have little direct influence on identity, coordination ICTs sustain the networks that connect scientists and provide feedback about their work. Some configurations, like collaboratories or FTP-enabled project websites, can even create new networking opportunities for scientists who share their data and technologies with others. The efficiency with which findings can be shared within a community enhances the collaboration process itself, as this senior oceanographer noted:

> "It's created a whole new way of thinking about how we go about doing our science. It used to be the oceanographers went out and did their own thing and reported out at scientific meetings after they had all their work done and their papers written and whatever … but now people are truly collaborative."

Being "a good collaborator" can augment an individual scientists' reputation and can facilitate and encourage future collaborations. ICTs that help researchers collaborate better, can thereby indirectly shape their scientific identity.

Many of the researchers we interviewed are associated with collaborative research projects or groups. These groups frequently set up project web sites to provide details about their scientific efforts, and to keep everyone posted about ongoing or upcoming events. Some project web sites are maintained on the same web servers as a scientists' personal web pages, but they contain information about the research lab and its equipment, about the members of the research team, and about the project or series of projects. Other sites have similar content, but are maintained on servers at one of the collaborating institutions, or on study-funded web sites. Although project websites may be deployed as public sites without password protection or security measures, their intended audience is the group of collaborating scientists, not the broad scientific community nor the public. (See Appendix B for an example of this kind of project website.)

Project sites often include individual or group photos, photos and diagrams of scientific technologies like towed arrays or buoys, links to online FTP sites with scientific data, graphic representations of data analysis, video clips of animals (for marine biologists) or scientists at work on cruises (for field oceanographers), and hyperlinks to funding or coordinating programs (and sometimes to/from the scientists home pages). Thus, project websites situate the identity of individual researchers within the context of the research they contribute to, the core technologies that they build and deploy, the organizational and institutional affiliations that sponsor their research, and the other people who collaborate on the project. Compared to their personal web pages, these web sites are more detailed, up-to-date, and personalized, indicating that researchers find them to be a more important forum of interaction.

4.6 Dissemination to the scientific community

Dissemination of scientific findings to the broader scientific community occurs primarily through traditional channels, such as peer-reviewed academic journals and academic conference presentations. Publication is an essential element of scientific identity (as the lengthy listings included on every academic's CV illustrate). Researchers become known within their field or sub-field by their journal publications, research conference participation, and through their social network of mentors, collaborators, and former students. For senior scientists, like this one, traditional channels may be sufficient for identity enactment and self-presentation:

> "I guess I'm at a state in my career where I can say: 'Check out my publications, if you want to know what I'm doing.' "

ICTs improve the access and visibility of publications in traditional channels, for example, though electronic indexing and online versions of journals; but it is the publication in the journal or conference that establishes professional identity, not the distribution technology (electronic or paper).

However, both oceanographers and marine biologists are finding that ICTs which enhance the visualization of complex phenomena are particularly useful for knowledge presentation, as well as knowledge discovery. This oceanographer explained how visualization software enhances communication of the meaning and interpretation of seafloor sonar scanning data:

> "We've also been working to use stuff like illustrators to create three-dimensional perspectives …This is how you would see it [the phenomenon] on a flat map projection. And when we turn it into a three-dimensional rendering, we can actually see the lava flowing down the sides of the [underwater] volcano… And so we spend a lot of time talking to people and trying to develop ways of take advantage of Quicktime, you know, that will show them what we're trying to argue scientifically."

Digital photography and laser microscopy also make it possible for marine biologists to collect and process data much more efficiently and rapidly, reducing time-consuming bench work by days while producing more effective three-dimensional images. These images can powerfully represent scientific phenomena, in ways that communicate the uniqueness and value of the scientists' work, and thus her professional identity. However, print journals (including their online versions) limit the degree to which ICTs can be exploited for visualizing or otherwise explicating data and findings. This marine biologist expressed his frustrations about the limitations of traditional print media:

> "I'm sort of a history of science fan, and when you go back to journals in the 19th century, the papers are about 150 pages long … Now, you collect all this data, and you have to digest it down into the simplest story that fits into six pages … It's frustrating, especially if you do this hard work, [and] it boils down to figure 1 … If I can do a true-focus rotation image of my organism, it's never going to go on a page of a journal."

Scientists could utilize other ICTs, such as web sites, to present more detailed data or include animated visualizations. However, the researchers we interviewed were reluctant to use the Internet to self-publish data, because journal publications confer legitimacy and recognition, and web publication could preclude the possibility of subsequent journal publication. Several scientists mentioned the alternative approach of e-journals or companion websites for paper-based journals, which could take advantage of ICT-enhanced data presentations and visualizations, but such forums are not yet common, nor highly regarded, in their fields.

Compared to standard journals, conferences offer researchers many more opportunities to use multimedia in presenting scientific findings, but not everyone takes advantage this situation. One marine biologist described a conference he had recently attended, noting that the most impressive uses of presentation ICTs were by graduate students:

> "So there we were, two days of paper. And the flashiest, everything with PowerPoint, of course, were the grad students, and then it got worse. There were some of my colleagues, a little older than me, but still middle aged, very active, who were still using their [35mm] slides. And then the Associate Director of the University of [X], with his damn overheads, having to pull this thing out, and writing stuff in bad penmanship! It was age-related, yes it really was."

Not all senior scientists are ICT-averse. One described his use of Powerpoint presentations with embedded videos in his talks:

> "And now I embed these little video clips in the Powerpoint slides, and it looks really nice … It's never been more fun, really, than now to give a talk."

Despite the fun associated with more sophisticated presentations, he voiced skepticism about the kind of value these ICTs might add:

> "I sometimes wonder if it's just flashier presentation. 'Cause I could have done the same thing with ten slides, right? … I sometimes ask myself whether flashier tells more or not."

Other senior researchers we talked to seemed comfortable with their limited skills; largely because they can rely on the superior ICT-related knowledge of their graduate students to develop impressive presentations and visualizations when needed. Although scientists may disavow the importance of big flashy presentations, they clearly hold some value for them – the walls of their corridors are lined with huge multi-color visualizations of their data; and a few of our interviews with them included guided tours of this "artwork."

4.7 Dissemination ICTs and identity management challenges

Once researchers have published their findings in journals, it is expected in some scientific communities, and sometimes required by funding organizations such as National Science Foundation (NSF), that they will share their data with other scientists. We found this to be the case among oceanographers, but less so with marine biologists, whose raw, empirical data may be less useful beyond the local research context. ICTs that play an important role in the distribution of research data and related information include: FTP sites that make data files available to other researchers, e-mail for distributing data files to requesters, and CD-ROM technology for recording large datasets and for sharing data with colleagues who do not have good Internet access.

Scientists can increase their professional recognition by sharing their data. However, using ICTs to share data with researchers at a distance can introduce identity management problems for scientists whose reputation and identity is intertwined with their data. Oceanographers become very familiar with the data they collect. Through their expertise in creating and deploying core technologies with embedded ICTs to manage data processing, they come to understand the contextual nuances of the data collected. An oceanographer commented:

> "I've been doing this for so long… after a while I can take a spectrum and tell you whether this is realistic or not, whether something is wrong, whether something is a little bit funny with it."

He can differentiate between technology glitches and real data, but he knows that others cannot. When he posts his raw data on an Internet FTP site, it may be used in ways that are beyond his control. Its incorrect use or interpretation could negatively impact his professional reputation. He worries, as this researcher does, that other scientists, who lack contextual understanding, will make erroneous interpretations if they download the data without talking to him about it:

> "I have no problem giving the data to anyone who wants it. But I do have a problem in letting anyone just grab it. Because part of this investigation is about using unusual technology to study the ocean. And if you don't know what you've got, you don't know how to interpret the raw data and what it means, you can make a mess of it."

“Making a mess of it” would reflect poorly not only on the researcher who downloads the data and publishes articles using it, but also on the data creators.

This identity management problem can be mitigated in two ways: by cleansing the data of segments that could be misinterpreted before it is posted to the FTP site, and by encouraging site users to interact with project researchers while making their analyses. To do this, data site sponsors must know who is downloading from the site, and they may add access controls, like an ID/password filter, for this purpose. Some do not post their data to an FTP site at all. Instead, they force the requester to send an e-mail asking for the files, thus ensuring that the data creators know who the data users are, and can discuss any data peculiarities with them.

Another identity management issue can arise if a researcher uses downloaded empirical data, but does not attribute the data to the scientists who invested their time and resources in its collection and archiving. Several oceanographers commented that a good scientist should at least acknowledge the data source in publications, and possibly offer co-authorship to the data set creators. However, when ICTs facilitate anonymous downloading of data, this is less likely to happen. A researcher explained the identity dilemma that ICTs pose:

> "On the one hand you want to put all the data you have out there on the web, so that everyone can use it, and that it could be exciting and you can collaborate and go forth. But on the other hand, again, you want to get credit for kind of having that data. There’s something about the web and email where people just… it’s a lot easier to not think about where you got your information. It's on the web--it’s kind of like this amorphous thing, as if someone didn’t do a lot of work to put it out there."

Access controls help researchers counter the adverse effects of anonymous downloading. One oceanographer explained why he took this approach:

> " I set up the registration screen to try and remind my colleagues that there is an obligation and ethical issues concerned with using data ... I've been extremely disappointed in this kind of idea that unless you are one of the people that originated an idea for a paper then you shouldn't be co-authored."

An FTP site password system allows him to track users, and to possibly contact people who download data, or simply to monitor who is using the site. The FTP site activity log also helps him document the site's claims of importance when he is writing proposals for project continuance to research funding agencies.

4.8 Dissemination to the non-scientific community

Because basic scientific research in the US is publicly funded, agencies like NSF encourage, and more often require, funded scientists to make outreach efforts to inform the general public about how science is advancing thanks to its support; and to provide resources for public educators of K-12 students. Although the researchers we interviewed rely primarily on traditional channels (journals, conferences) for scientific dissemination of knowledge about their research activities, they increasingly regard the Internet, and the World Wide Web in particular, as important forums for public presentation of their projects.

Many research teams have constructed more "polished" versions of their project web sites to communicate key findings to the broader scientific community or the general public. These public project web sites, intended for outreach, typically contain research project plans and core technology diagrams, underwater video clips, photos of scientists at work, scientific explanations (with artistically rendered graphics and animation) aimed at nonscientists, and so on. They have a more refined appearance and user-friendly interface than the private project web sites that scientists construct to collaborate with one another. Each collaborating scientist is well-represented within this project context; but there may also be a link to her home page, or additional contact information below a group picture. Some sites encourage students to contact the scientists directly; or invite them to watch the scientists work through a webcam connection. The importance of outreach project sites is evident in the commitment of research funds for their development and maintenance. Some sites are maintained by the researcher's staff, while others are outsourced to government support services associated with the research funding agency.

An oceanographer, who was working in a global climate research project, described how its private project site grew and developed into a more polished public project site:

> “It began as a very informal thing, but was directed totally at those who were getting the experiment organized. And so it was not pretty to look at. It didn’t include a lot of web background information, but you could go there and find a list of participants and could find a list of what things were going to be measured on the ship, what things were going to be measured on the airplane …drafts of science plan, and that sort of thing. However, as it got closer and closer to the time of the experiment, we began to realize, partly as the result of prompting from our program managers, the importance of outreach in making the results of the experiment available to more than just the scientific community, to help in educating kids and making them excited about this kind of enterprise. And so this [project] website was cleaned up a little bit to give a little bit more background, to direct people to the prospectus."

This explanation highlights how interactions with program managers from funding agencies can shape professional presentations to non-scientific audiences. It also highlights the difference between “cleaned up” project web sites that direct an image toward the public, and “not pretty to look at” project web sites that are intended for use within a close-knit group of research collaborators.

Although senior researchers think the Web is important for project presentations, they do not place a high value on personal web pages as venues for self-presentation. Most do have a personal web page on a University server, usually in a standardized format, with routine information about research interests, courses taught (if any), educational background, lists of publications, and perhaps a photo. When linked to online bibliographic indexes, home pages that list publications can provide easy access to a researcher's work for other scientists, funders, and students. Web pages can also be used for more expansive self-presentation, when they include personal information, and when they include links to affiliated academic institutions, research projects, or graduate students. But few scientists in our study have taken advantage of these opportunities. In fact, most do not take much interest in their personal web pages, and many pages had not been updated for several years. When asked about their personal web pages, these responses were typical:

> “I’ve been really slow in getting my web pages up to date. Some people are a lot more into self-promotion that I am.”

> “I think it’s fine if you have the time to do that kind of stuff…it can be very informative. I guess I’m a little bit old fashioned. I don’t think it’s necessary.”

> “I haven’t looked at my website in years. I don’t know what’s in there, really.”

> “No, I keep saying I’m going to do it, I just don’t have time to do it…I’ve been saying for five years now, I’m going to do it.”

Even those who professed that web pages were important actually spent little or no time maintaining their home page, sometimes citing lack of skills or lack of staff as the reason. But the cost of hiring a student to maintain a page is fairly small, so the perceived benefits of an updated website must be even smaller. This marine biologist’s comments hint at another explanation:

> "I want to have a website, don’t get me wrong, and I would like to have nicer pictures of the animals I work on … I think in some ways I worry a lot about the web because there’s a lot

> of really bad information, there's no quality control, and then there's a lot of issues. So I prefer not to use it…"

He does not see how to differentiate his pages from hundreds of other "junk" pages on the Web. Web pages don't convey the legitimacy of established forums for self presentation, they don't help this researcher maintain his scientific professional identity. Established researchers emphasized that they are known to colleagues through their appearances in conferences, their journal publications, and their social network of past and present collaborators. To this valued peer community, self-presentation through a personal web page apparently offers little incremental value. Researchers typically said web pages were useful for attracting potential graduate students, but had little importance for self-presentation to peers. Some researchers did not even value using the Web to attract graduate students, because they received sufficient contacts through established channels or were not interested in taking on new students.

Most of the researchers we talked to were well established in their careers.[3] The junior faculty members we interviewed, however, did have web pages that were more personalized, detailed, and up-to-date. When we asked them about the importance of their personal web pages, they said that they thought personal pages provided opportunities to present themselves and their work as scientists; and they expected that other scientists would use their pages to make evaluations about their work. One junior oceanographer described her motivation to keep her site current:

> "I want to show who I am and where I'm at. This is what I'm doing, and isn't that interesting. If you've got something that's very similar or you want to do something that's very similar, email me."

Unlike senior researchers whose scientific reputations are established, junior researchers have not had time yet to build their professional identity through established channels such as journal

[3] Our selection of interviewees reflects the high proportion of senior faculty at the University of Hawaii.

publications. This junior researcher finds her personal website particularly helpful for attracting potential graduate students (as did some more senior researchers), but she also perceives it as helpful for making herself known in the research community (which senior researchers did not). We noted similar attitudes among several of the graduate students interviewed, who were anxious to publicize their research projects and had not yet built their publication history. One recent graduate, who now works in a teaching university, devotes considerable attention to his web sites for an additional reason. Because his institution does not carry a research classification, it does not normally obtain funding from public agencies. He views his web site as a way to present himself as an active researcher and to attract attention and funding to his research efforts.

In addition to creating more personal web page information, junior researchers were also more likely to use Internet information, particularly home pages, to learn about colleagues. This researcher explained that she uses home pages to learn about colleagues she has not met, and she keeps her own pages up-to-date, believing that others may try to learn about her in the same way:

> "It really is helpful for me to look at a web page for what is their latest project, what are some interesting papers, what are some interesting things that they've done. So I try to update my website every year. I go in every year, and I just spend a day, and I do it. For me, I get a lot more student contacts, because they look at my website, and they can understand what I'm doing. I try and make an effort so that it's understandable."

In contrast, few senior researchers reported using others' personal web pages to profile potential collaborators, because they are familiar with others in their field though conferences or previous collaborations. Even among junior researchers who do occasionally examine others' web pages, it is the scientific value of the information they find there, more than the manner of presentation, which they report contributes to perceptions of professional identity.

5.0 Discussion

By segmenting our findings into three broad categories of ICT use (i.e. embedded, coordination and dissemination), we have provided a basis for examining the different roles that ICTs play in shaping identity, and for explaining how each of the theoretical perspectives that focus on identity formation (i.e. network theory, interactionism and post-structuralism) may inform one aspect of use better than the others. In this section, we will review the main insights from each category of our findings (see Table 3 for a summary), examining them in the light of current theorizing about scientific and professional identity. We will then move the discussion toward a conceptualization of project-based identity.

Table 3: Summary of key themes and discussion points

Co-construction of professional identity and core technologies with embedded ICTs
• ***Changing conceptions of scientific research***: Core scientific technologies with embedded ICTs influence basic tasks that define scientific research in a given field. [See 4.3] • ***Enhancing scientific identity***: Development and use of embedded ICTs create new areas of specialization and expertise, allowing scientists to make unique contributions. [See 4.3] • ***Challenging scientific identity***: Embedded ICTs may supersede existing technologies and related expertise, obsolescing previous styles of research. [See 4.4]
Collaboration and coordination through ICTs
• ***Making distant collaborations efficient***: ICT uses make distance collaboration more viable and provide new forums for identity enactment. [See 4.5] • ***Developing project identity***: ICT uses link collaborating individual researchers to their core technologies and create new sites for collective identity. [See 4.6]
Scientific presentation and knowledge dissemination through ICTs
• ***Visualizing scientific discoveries***: ICTs enable new ways to represent scientific concepts that make findings accessible to diverse audiences, enhancing self presentation. [See 4.8] • ***Creating identity management issues***: ICT dissemination of scientific data challenges scientists' ability to manage professional identity. [See 4.7] • ***Augmenting traditional dissemination channels***: ICTs are valued for public dissemination of knowledge about projects, but not as alternatives to traditional channels for dissemination within the scientific community. [See 4.8]

5.1 Co-constructing the scientist and the technology

Much of the data that we have presented in this paper confirms the importance of core technologies in shaping scientific identity. Our research links ICTs into this co-construction process when they become part of core technology configurations that scientists build, refine and use. In important ways, this finding is no different from what others have observed about scientists and their technologies (e.g. particle detectors, Traweek, 1988), or high-tech workers and their ICTs (e.g. software applications, English-Lueck and Savari, 2000). All of these streams of research support the network theorist concept that technology is one of the primary foundations on which professional identity is created, maintained and promoted.

Through our own data analysis, we can see how this process unfolds in the context of scientific research, and the roles that ICTs play. Unlike many professional groups, in which the design of new technologies and their application in practice are separate activities over which the professional may have limited control or influence, scientists play an active role in shaping or selecting new technologies for their research. They embed ICTs within core technologies to facilitate new types of research that will address their interests and enhance their expertise. In this use, ICTs tend to be *identity enhancing*, because they enable researchers to make unique scientific discoveries. As a bonus, if an ICT-enabled device configuration is uniquely valuable scientifically, the scientists who create it will become closely identified with it, or "known for it".

Embedded ICTs that are identity enhancing in some ways, may also be identity challenging in others. By embedding new ICTs into core scientific technologies, field oceanographers are redefining how their research can be done, and thus what it means to be a field researcher. Professional identity adjustments are thus made in response to new embedded ICTs. Also, as one area of scientific enterprise derives greater institutional rewards from its ICT uses, it may inadvertently diminish the status, legitimacy and funding of other streams of research. This shift in resources can make it more difficult for some scientists to pursue their chosen research objectives.

Embedded ICT use can also challenge traditional scientific identity by infusing a new domain of expertise into the research context. The technical knowledge needed to develop or utilize core scientific technologies with embedded ICTs is usually quite distinct from the knowledge and understanding of the scientific phenomena under study. The oceanographers and marine biologists we interviewed think of themselves as scientists, not technicians, yet the technical knowledge needed to conduct their science is increasing. Collaborations commonly bridge the gap between these knowledge domains. However, young researchers, whose professional identity is developing, find it prudent to become proficient with a broader range of ICT-enabled research approaches and knowledge domains than was necessary in the past.

5.2 Coordinating collaboration

Multidisciplinary collaborations are one way in which requisite expertise can be pooled to construct core scientific technologies with embedded ICTs. As these projects become a focus for collaborative interaction, they also help to define the research group or community of practice in which individual scientists enact their identity. Networking and communication technologies like email, teleconferencing, FTP downloads, and so on, play a routine but vital role in the day-to-day activities of enactment and self-presentation that interactionists have described so well. Among scientists, these coordination ICT uses make distance collaboration more viable by providing new forums for identity enactment, like collaboratories and project websites.

Interactionists have explained how identity and self-presentation are influenced by a mode of interaction, which entails not only the format and forum of new ICTs, but also the scope and reach of the social relations which these technologies support. Within project websites, ICT uses link collaborating individual researchers to their core technologies and create a new forum for collective identity enactment. Researchers create project web sites to coordinate with close collaborators during grant preparation, to post and present data used in decision-making during distributed experiments, to collect and preserve metadata about conditions under which the data collection took place, and to share raw data results among collaborators. Researchers enact their professional identity among distant collaborators and colleagues as they work with the available ICTs to accomplish their part of the scientific work and make it accessible to others on the project team. Collaborators are not judged by the flashiness of their data presentation, but by the ease with which others on the team can use that data to accomplish their own tasks and on the analytical insights that each scientist brings to the ongoing collaboration.

Interestingly, as more and more ICTs are embedded into core scientific technologies, the possibilities for coordination ICT use increases. Many of the ICTs that scientists use routinely to coordinate their work are virtually the same as the technologies they embed in their core scientific technologies. Seamless integration of these ICTs at the technical level creates a pervasive communication and an interaction capability that can facilitate collaboration between and among people and their core devices.

This kind of ICT-enabled interaction capability is what collaboratory promoters have hoped would spark scientific collaboration. However, in our own study we see that this works the other way around: the collaborative context sparks the construction of the project website. This twist of causal logic could suggest an alternate starting point for collaboratory designers, who have tried to apply what they know about coordination ICT uses to construct virtual laboratories where scientists like physicists and astronomers can share data and sophisticated technologies, find common areas of interest, and eventually collaborate. Studies of their collaboratories (Finholt, 2002; Olson and Olson, 2001; Finholt et al., 2002) have shown that they are not well-used by the intended audience of scientists. Analysts suggest that although some technical difficulties persist, it is the social issues, like communication policies, disciplinary practices and cultural differences, that present the biggest roadblocks to collaboratory use. These findings are relevant to our study, because the "home-grown" project websites that we have observed are not so different from collaboratories, except that their technologies are often much less sophisticated, and they are very well-used. Through our own limited comparative analysis, we would speculate that collaboratories may never be well-used, unless they become sites for scientific identity construction.

5.3 Presenting and disseminating scientific knowledge

ICTs provide new ways for scientists to visualize their discoveries, making new concepts more readily apparent to their peers, and also more accessible and interesting to non-scientific audiences. These presentations benefit the scientists who create them in two ways: 1) the sophisticated display gives the public some confidence that the researcher has a high level of technology acumen, and 2) they help the academic community attribute status to the researcher. Although several scientists in our study doubted that flashier presentations could make better science, in other studies we have found that people often use "technology-savvy" as a proxy for professional competence, especially when they do not have any other basis on which to make an adequate judgment (Lamb and Kling, 2003.)

Presentation ICTs can help the academic community attribute researcher status, even though ICTs used for elaboration, presentation and dissemination of scientific knowledge have a much less formative role than the ICT-enabled scientific technologies that are central to professional identity. Scientists enact their identity primarily within networks of peers, even when using a public forum like the Web (Agre, 1995.) Communications within these institutional circuits support the invisible colleges that Crane (1972) and others have described. It is within these communities of practice that professional identity is enacted and presented. Many of the researchers we interviewed are middle-aged males with senior positions in their specialty areas, and their professional identities are well developed among colleagues and collaborators. Public self-presentation forums such as personal web pages are not highly valued by senior scientists, but junior researchers do find them useful. Hesse et. al (1993) found that oceanographic researchers who are peripheral to the field due to ethnicity, age, gender, or years of experience use ICTs differently from their more established colleagues. We do not know if those scientists valuations of ICTs have changed over the intervening ten years, as they have become more senior or more central in their fields. In 2003, however, our data show a very similar finding, albeit with a somewhat different array of ICTs. Most senior scientists are satisfied with existing channels for professional self-presentation (e.g., academic journals, conferences), although many would like to see them enhanced through selective ICT inclusion (e.g., e-journals or companion web sites for print journals.) They seem to be aware that web postings can be deconstructed in ways that are beyond their control, and are not anxious to add their “text” into this postmodern mix.

As post-structuralists have observed, using ICTs to disseminate data disengages the scientist-creator from the data interpretation process (Poster, 1990). Among scientific professionals, this disengagement can give rise to the lack of social obligation and reciprocity that Erickson (1996) speculated about, and contributes to the identity management issues that occur when flawed interpretations by others are attributed to the original research team, or when the team is not given credit for their work by others who use their data.

The sites scientists construct for public outreach are more focused on projects than individual scientists (e.g. http://www.divediscover.whoi.edu/; http://saga.pmel.noaa.gov/aceasia/.) Our data does not indicate to what degree these sites allow for the kind of identity interplay that post-structuralists like Derrida have theorized about, although we can see clear opportunities for such constructions, deconstructions and reconstructions when scientists link their homepages (even belatedly) to their project pages, and these are later "cleaned up" for public consumption. The kind of ICT-related identity construction showcased in our findings is more interactive than the opportunities for "intertextuality" between authors and readers discussed by Wynn and Katz (1997.) Therefore, we would speculate that the scientists in our study would not give much attention to these public interpretations, unless they are used as evaluation criteria by others within the scientists' communities of practice, such as NASA or NSF program managers.

5.4 Understanding projects and project identity

The research project is a pervasive organizing construct in scientific research, and project-based identity is an equally pervasive theme in our analysis. One of the first things we observed in our study was the difficulty that scientists had in *placing* themselves within the standard disciplinary classifications of scientific inquiry. Some explained that they were educated in one discipline (e.g. geology), but now conducted their geological research under the auspices of another discipline (e.g. oceanography). They often went on to say that they are not the only "changling" in their department, which is populated with scientists from several different backgrounds. Others drew distinctions between themselves as, say, marine biologists, and other marine biologists who use entirely different methods and technologies to conduct their research (e.g. molecular marine biologists and field marine biologists.) Some had a descriptive label that succinctly expressed their scientific identity (e.g. "I'm a cellular developmental biologist"), but most of the researchers we interviewed suffered through several minutes of explanation when asked to identify themselves as scientists. They only seemed to feel comfortable that they had given us an adequate explanation once they had reached the point of describing themselves in terms of their most important research projects.

For these scientists, the project has been emergent as a site of identity largely by default -- it is currently the best-fitting container that they have for professional identity. They use the project as an anchoring context, particularly when other identity “containers” (i.e. individual, field, discipline, department, University) don’t adequately aggregate the most important aspects of scientific professional identity. Project groups tend to span various specialties within the field or to be multidisciplinary, and they increasingly involve scientists at institutions around the globe. Collaborators share project-centered aspects of their scientific identity as identity-shaping interactions occur throughout the project. When exchanges are made via ICTs, like project web sites, a project identity is presented to the participants and others who use the site. Project websites provide a public space in which individual identities are aggregated and a group identity can be constructed, maintained and presented to colleagues, to the scientific community, and to the public. These sites combine the coordination and knowledge dissemination uses of ICTs, and typically showcase core technologies with embedded ICTs, pulling together the professional identities of collaborating scientists in a way that transcends traditional identity boundaries. As multidisciplinary, interdisciplinary and cross-disciplinary collaborative research becomes more prevalent, the capacity of traditional disciplinary categorizations, like field or sub-field, to contain and define scientific identity may deteriorate further. This may lead to the predominance of the project as a site for identity construction.

Network theorists have emphasized the *project* as a focal point for collective identity construction and presentation. According to Castells (1997), project identities are inducing new forms of social change. They are part of a shift in terms of focus (from individual identity to more collective forms of identity), as well as in the way people handle the presentation of their multiple selves (from integration to fragmentation.) in modern society.[4] Other information society researchers, like Florida (2002), echo Castells' observations: “Where people once found themselves bound together by social institutions and formed their identities in groups, a fundamental characteristic of life today is that we strive to create our own identities... along the varied dimensions of our creativity.” [p.7] Florida links this kind of identity construction, not to the general public, but specifically to a “class” of creative professionals that includes scientists, and he suggests that these people are the primary source of regional and global economic viability.

[4] See Castells (1997: 6-12) “The Construction of Identity” for a quick synopsis of this viewpoint.

Project identity and creative identity may be synonymous. For the scientists in our study, we see that creativity unfolds more and more frequently in project-focused collaborations. Once constructed, however, it does not seem to be so easy to separate out any "part" that can be attributed to an individual collaborator. (Analogously, once a core technology is constructed, it can't usually be disassembled and distributed, and still remain operational.[5]) Therefore, the project may be the smallest unit of identity that can be useful in a study of creativity. If creativity is becoming ever more vital to a class of people; and if their creativity is enacted around core technology construction in collaboration with others; and if those projects are the smallest logical unit of identity that can encompass the technology, the collaborators and the creativity, then project-based identity may become increasingly important to a wide variety of researchers, managers and policy-makers – even in contexts of high individualist rewards.

6. Conclusions: Future Directions for Research

In this paper, we have shown how three distinct uses of ICTs are shaping the identities of scientists in oceanography and marine biology. Notably, the technologies that are developed and used in close collaboration with others in pursuit of scientific knowledge are most influential in shaping professional identity. These findings are remarkably consistent across both disciplines. However, we expect that some differences among scientific fields may become evident through further interviews with industry scientists and with the astronomers that will participate in our ongoing study. Other studies by academic researchers have noted that the technical tasks and norms of a discipline strongly influence how its members use ICTs (Kling and McKim, 1999; Walsh, 1998).

[5] One of the project groups in our study was contractually forced to disassemble the core technology they had worked to create at the end of the project. Their "piece" now sits gathering dust in a storage shed. The rest of the device was divided among two other collaborators, and is presumably in a similarly non-functional state.

Although the professional identities of oceanographers and marine biologists center around core scientific technologies and the potential to make unique contributions to scientific knowledge through these ICT-enhanced technologies, for researchers in other disciplines, particularly in the social sciences and humanities, “core technologies” (in the strict sense of technology) may not exist to serve as a focal point. How does professional identity develop among scientists in such fields? Do coordination and dissemination ICTs take on a heightened role in professional identity? Or, is research in such fields migrating towards methodologies in which ICTs can constitute a core technology (e.g. education technology vs. education)?

These questions could motivate some interesting extensions to our current research, particularly if they are related to some of the more troubling questions that our analyses have raised. Several marine biologists suggested that a transformation from observational field work to laboratory methods based on gene sequencing technologies was radically reshaping marine science. Does this mean that some important kinds of research will no longer be done? Are similar transformations, instigated by increasingly pervasive ICT use, occurring in other fields as well? In light of such potential shifts, is the appreciation of ICT-enabled professional presentations by junior researchers ascendant within the larger community, or will it give way to a more “traditional” evaluation of established dissemination channels? (That is, will senior scientists *ever* have up-to-date web pages?)

Further research will clearly be needed to understand how scientists’ professional identities change over time, and to examine the dynamics of ICT uses in other disciplines. Such study will require different methodologies from our current research (e.g. longitudinal study, content analysis, and ethnographic analysis of rich data sources). We also believe that insightful research along these lines will be based on a different unit of analysis – the project. A project-based conceptualization of scientific professional identity would mean that we would need to consider *people and their ICTs* as our unit of analysis in order to study creativity, collaboration, and related ICT use, development and adoption. We would need to abandon conceptualizations of people as ICT "users" and ICT technologies as "servers". We would, instead, need to approach our study using the project identities that social actors have constructed for themselves, and find most comfortable for self-presentation.

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Appendix A: Embedded ICT Use

Figure A1: MR1 Towfish Launch

Figure A1 shows a sonar towfish being launched from a vessel at sea. The technology inside the towfish (the subsurface electronics) will be used to map the ocean floor of the region by recording the behavior of sonar wave emissions.

The subsurface electronics digitize the sonar detection, and communicate that data stream through the towfish cable to a configuration of surface electronics onboard the launch vessel. (See Figure A2 – right side.)

The surface electronics, many components of which are identical to those used in information systems typically found in many businesses or home offices, are used to interpret and display near real-time images of the ocean floor for further scientific analysis. (See Figure A2 – left side.)

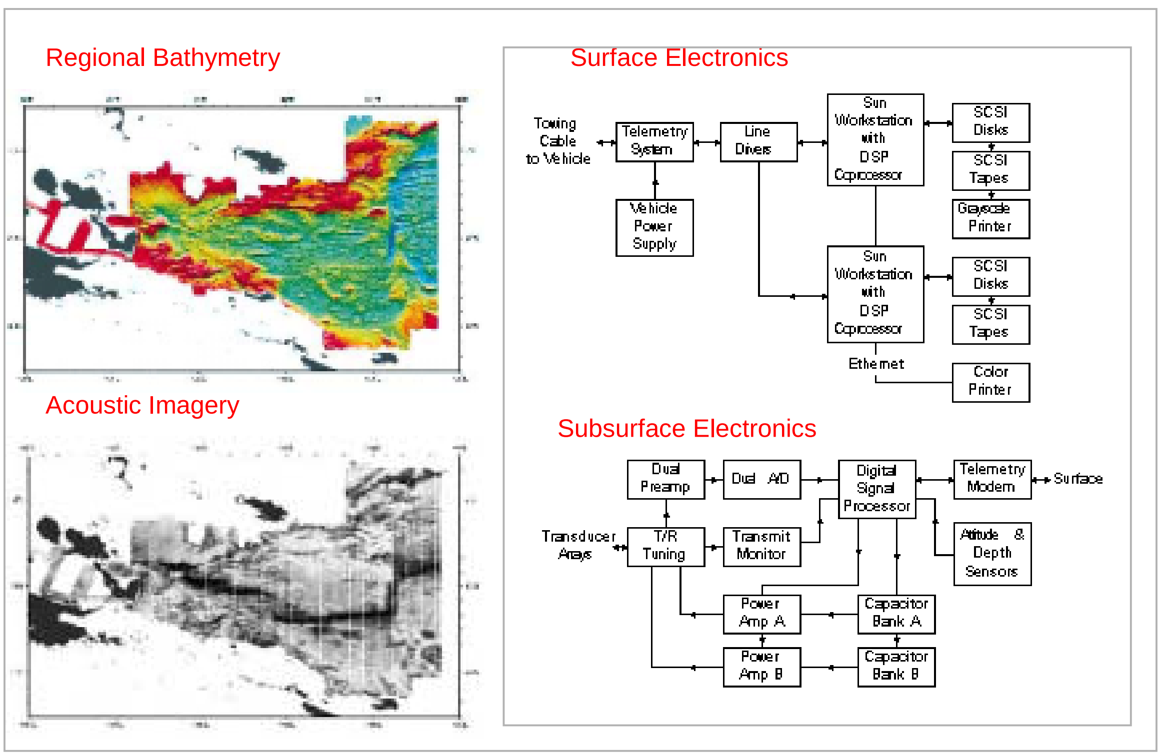

Figure A2: MR1 Electronics and Image Display

For a more detailed discussion of this technology, see: Mark Rognstad, "HAWAII MR1: A New Underwater Mapping Tool", technical paper available at: http://www.soest.hawaii.edu/HMRG/MR1/index.html

Appendix B: Coordination ICT Use

The following websites have been used to coordinate research activities on a series of related projects.

The first site represents what we have described as a "private project website."
See: http://hahana.soest.hawaii.edu/hot/hot_jgofs.html .
Much of the site is publicly accessible, but it is primarily used 'privately' by a small group of collaborating researchers to coordinate their data collection activities. It is locally maintained and actively used.

This group also participates in a much larger atmospheric study that uses what we have described as a "protected project website" to coordinate "in season" field project activities.
See: http://www.joss.ucar.edu/ace-asia/catalog/ .
This site is accessible to the public and maintained by the study funding agency. It is only actively updated, however, when research is underway. At the time of this writing, it is in "post field season" mode.

For ongoing interaction with the wider scientific and non-scientific communities, the agency has developed what we have described as a "public dissemination website."
See: http://saga.pmel.noaa.gov/aceasia/ .
This site is very similar to the "public project website," except that it has been "cleaned up a bit" to provide a more understandable presentation of the study objectives and findings for a wider audience.

Appendix C: Dissemination ICT Use

The following websites are representative of the contrasts we found between senior and junior faculty members.

The first site belongs to a senior faculty member and contains a "thin" profile of his research activities. See: http://www.soest.hawaii.edu/~markm

The second site belongs to a newly graduated Ph.D. student and contains a "rich" description of his research projects. See: http://www2.hawaii.edu/~carlm

Note that both scientists' personal web pages contain little or no personal information.