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# Problematizing the Experts: The One-Dimensional Engineering Understanding of the Users and its Contextual Frameworks

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**Abstract** What is engineers' conception of their users and the public? And what makes it so difficult to be changed? Studies in public understanding and participation of science and technology have depicted the pre-commitment of criticism against the deficit model in scientists' conception of the public and enriched our understanding of the public's knowledgeability of science and technology. Literature of technoscientific practices also explores the framing of users in technoscientific practices. Following the insights and adopting the concept of framing, this paper examines engineering researchers' knowledgeability by illustrating their understanding of the users when they are developing new devices and by showing the contextual practices that frames their vision. This paper tackles the issue by examining the fieldwork in an university engineering research team in Taiwan. It is argued that engineering researchers have their own sociology concerned with the technical aspect of their users and society. This paper proposes an analytical framework; the engineering vision and agenda emerges and being practiced in the conjuncture of frames of publication-oriented regulation, delivery-assured practical work, and diversity reduction team networking to situate the engineering vision. The notion of frame also highlights the dynamic, relational, and conjunctive constitution of the experts' knowledgeability. It is suggested that with more understanding of the interlocking mechanism of these frames, then we can alleviate the one-dimensional engineering vision and only then is the ambition of interdisciplinary collaboration possible in Taiwan.

**Keywords** Science communication · Laboratory practice · Framing · Engineering research · User

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## 1 Introduction

Literature of science, technology, and society studies has enriched our understanding of the nature of the public's knowledgeability of science and technology and of the reason why it fails to be realized in developing better, or maybe more appropriate, science and engineering (Wynne et al. 1990; Irwin and Wynne 1996a, b; Friedman et al. 1999). Wynne's (1995) classification of the major approaches in public understanding of science and technology, survey researches, cognitive psychology, and constructivist anthropological and social research, clarifies the dialogue within the field and provides insights into their respective presumptions about the public's knowledgeability. Deficit model is identified in the enlightenment problematic regarding to scientific literacy of survey researches and in those contextless constructions of lay mental models of cognitive psychology (Layton et al. 1986; Wynne 1991a, b; Wynne 1995). For example, in survey studies, it is assumed that the public should have correct understanding and use of technical knowledge, and the public's knowledgeability is reduced to contextless scientific literacy and attitudes toward science.

In contrast to that, interpretative and critical anthropological and social researches adopt a "relational construction" model which uses qualitative methods to examine those "not accessible to large-scale survey methods, which cannot avoid imposing exogenous, standardized, and determinate definitions of the critical terms on the social actors from whom they extract responses" (Wynne 1995: 282–3). In these studies, the public's knowledgeability is located in its social context rather than the expert's agenda. For example, they study public understanding of science and technology usually in their experiences of actual events and of practical using of technology in daily life rather than in the form of abstract knowledge (Segall and Roberts 1980; Martin 1989; Wynne 1991a, b, 1992, 1995; Michael 1992; Jasanoff 1993; Irwin and Wynne 1996a, b; Irwin 2006). It is evident that these in-depth studies highlight the practical concerns such as trust, dependency, practical ignorance, and reflexivity that frame the public's knowledgeability. In contrast to the deficit model framed by the expert's interest of scientific literacy, when being framed in the daily concerns, lay knowledgeability shows its multiple practical implications and alleviate the normative assumption of the deficit model.

Conceptualizing the situation in terms of the frames of reference, or more exactly framings given their dynamic nature, is to emphasize the Goffmanian idea of frame analysis for understanding the multiple frameworks available constituting different situation, event, or field for the actors to make sense of their situation (Goffman 1986). In STS, similar versions of frame analysis is implicitly employed in the controversy studies that examine the different cognitive, social, and political frames of references in constructing knowledge (MacKenzie 1981; Shapin and Scaffer 1985), and the term frame is adopted more explicitly in the analysis of "technological frame" proposed by Bijker and Pinch who highlight the framing practices in the contested trajectory of making an artifact (Bijker 1987, 1995; Pinch and Bijker 1987). Apart from the material dimension, among the similar concepts, Bijker's usage of framing embodies the aim of Goffmanian analysis, specifying the situational frameworks for the individuals to make sense of what is going on and what to do in a particular event, in technological developments (Goffman 1961: 8–11). Bijker emphasizes that firstly, a frame is a dynamical constitution; it is neither an individual's characteristic nor a characteristic of a systems or institutions. Secondly, a frame exists in the relational interactions and it is "located between actors, not in or above actors." Finally, the multiple frames interfere each other and the consequent unfolding of practices is contingent on the contextual contest; as Bijker points out, "existing practices does guide future practices, though without logical determination" (Bijker 1995: 123). Following Bijker's insight, in this paper, the concept is mobilized to highlight the contextual frames of practice that highlight the dynamic, relational, and conjunctive making of the experts' knowledgeability: the specific way of doing and understanding of a technology as well as its users.

In either cases of deficit or relational construction, both the public and the expert are problematized. As science communication and public participation of science are always about the issue of interaction between the experts and non-experts, explicating the user/public end highlights the critical merit of the literature. As the criticisms against deficit model indicates, part of their pre-commitment, if not most, lie in the way the public is understood and framed by the practitioners via the making of science and technology, that is, the realization of technoscientific practitioners' knowledgeability of the public (Prewitt 1982; Wynne et al. 1990; Irwin and Wynne 1996a, b). Furthermore, as will be discussed below, our knowledge of the practitioners' knowledgeability and its realization are advanced in the study of technoscientific practices, and this paper is following this approach to examine the experts' practices.

## 2 Problematizing/Understanding the Expert

The following reasons specify the current enquiry. One the one hand, exploring the practitioners' contextual knowledgeability of the public is part of the efforts to make appropriate science and technology in general. To achieve this, it would be vital to figure out how the public/user is conceptualized in the making of science and technology. Apart from Wynne's comment on deficit model, existing literature has studied practitioners' knowledgeability in terms of how scientists and engineers are framed by the other actors and framing the public into their enterprise at the same time, for example, with their own academic career in mind, the marine scientists persuade the fisher stop fishing scallops during re-incubation (Callon 1986a, b; Latour 1988); in terms of how the artifact that materializes mission-oriented engineers' understanding of users and manipulate this understanding via disciplinary material configuration and standardization, for example the road bump that might damage one's car can slow down the driver (Leigh-Star 1991; Latour 1992; Moser and Law 2002); and in terms of the various ways how engineers, scientists, policy makers, and users who have different interests contesting over the technological frames of an artifact, for example the design of a bicycle should become safer or more sporty (Pinch and Bijker 1984; Akrich 1997; Oudshoorn and Pinch 2003; Oudshoorn et al. 2004). In the case of electrical vehicle, Callon (1986a, b) even suggests that engineers in companies with competing technologies have different visions, and in order to realize their enterprise, the engineers are doing both the technical works to solve the battery problem and the sociological work that portray the society where the novel vehicle is going to work in order to interest the other actors, such as environmentalists and the government. Following these insights, this study first examines what is and what frames engineering researchers' understanding of the user, public, and the social situation when they are thinking about realizing their technology.

On the other hand, this investigation wishes to contribute to understanding the difficulty of redirecting the engineering research practice in Taiwan in specific by addressing the local context. Along with the emerging repertoires of science café, consensus conference, and risk assessment initiated to transform the interaction between technoscience and public by non-government organizations, government, and scholars, there is also a new initiative for improving the interaction from the technoscientific end in Taiwan. The initiative has been proposed in the last three *National Science and Technology Development Plan* for a decade. Its general principle is to redirect the development of science and technology from research-oriented to user/industry-oriented approach. In order to achieve this, interdisciplinary collaboration with other non-technoscientific teams to figure out the social impact of their technology and the user's actual need are highlighted. For example, studies of ethic, legal, and social issue of genome and bioengineering has been one of the key entries proposed and sponsored in the last two plans (National Science Council 2005, 2007). The Department of Engineering and Applied Science in National Science Council (NSC), one of the major execution agencies of the plans for engineering research and development and also the major sponsor of academic engineering research, has followed the key measure of "promoting the mutual development of technoscience and a human society" by initiating special calls for extensive interdisciplinary projects aiming at drawing the engineering researchers' attention to the social needs and to work with researchers in humanity and social sciences ever since 2001 (National Science Council 2001, 2005, 2007).

In these projects, the public and the user are in the focus. The aim of interdisciplinary research is to bring the engineering teams closer to their users, which means the researchers have to understand what and how the users think and want. All of the interdisciplinary research projects have similar demands. For example, in one of the calls for proposal of such projects, it is stated that "human-based" and vision-oriented technological development has been the principle of industrial development in advanced countries, and this is also the guideline for the industry of science and technology of the next generation in our country. The Executive Yuan has indicated in the National Science and Technology Plan in 2005 that in the next wave of industrial competition of the twenty-first century, our country should make good use of our advantages on informatics and electronic engineering and manufacture technology of civil industry to combine with the creativity of humanity so as to create the industrial infrastructure of the new century….*The plan concludes explicitly that our country should actively propose the fundamental "human-based" (以人為本) concept to integrate healthy/comfort/safety issues and try to apply engineering to support quality living and efficient working….*

…*Our country is lack of vision-oriented interdisciplinary manpower and research experience, it is necessary to reinforce the training of interdisciplinary talents and the execution of vision-based projects*. This year is planned to facilitate the collaboration between civil engineering, architecture, mechanics, electronic engineering, informatics, material, chemical engineering, medical engineering, medicine, planning and design, energy, environment, and humanity to train up interdisciplinary talents….*The two substantial objects are: the collaboration of humanity and technoscience….and the execution of vision-based research projects* (Department of Engineering and Applied Science 2007, my translation and emphasis).

I have been invited to participate in some of the interdisciplinary teams for these projects. In my experiences when writing the proposal bidding for such projects, the most frequently used terms among the engineering team members in our meeting are "user-oriented/-centered" (使用者導向/中心), "the communication between humanity and technoscience" (人文與科技溝通), and "interdisciplinary interactions" (跨領域互動), and the team usually designs very complicated illustration to indicate the interdisciplinary teamwork, especially how users can be taken care of in the whole process.

Despite the initiative and the demand of the sponsoring policy, however, as the following case will show, in the development of such user-oriented technology, the engineering teams have a very particular and persistent technical thinking about the users and the public, which is immune to the alternative influence from the interdisciplinary collaboration. By examining the context of the practice of one of such project, this paper wants to explore how and why the practitioners' understanding of the public are framed and it is resistant to the alternatives. By doing so, this paper hopes to indicate some alternative strategy in improving the practitioners' knowledgeability of the public and, hence, improving the interaction between technoscience and the public in Taiwan.

## 3 Study Case and Data Collection

The materials discussed in this paper are collected mainly from my fieldwork of participation in these interdisciplinary projects; especially from an E-housing project I have worked for in the last one and a half years. The team is made of six subgroups: two non-engineering, one team of privacy law research and the sociology team I am in charge of, and four engineering laboratories, bio-electronic engineering, wireless communication, chemical engineering, and bioinformatics. Apart from my team, the other five teams are based in one of the top national universities. In addition to the interviews and fieldwork in this project, I also use some materials collected from the interviews with some engineering professors in the fieldwork of other similar projects.

Apart from on-site ethnography and semi-structured interviews, my team photographs and films the interactions and practices of laboratory members in meetings, training, doing experiments, and other occasions. We also collect research notebooks, sketches, presentation files, theses when students have finished their degree, and other documents and files available. Most of the materials and interviews are originally in Chinese, and the excerpts used in this paper are translated by the author. In order to protect the interviewees and their technology, most of the following description of people, technology, and location are modified or using assumed names.

I am not claiming that the case is a typical representation of all of the laboratories in Taiwan because the team is in one of the top universities in Taiwan. The background information might be useful for locating the team. Firstly, in terms of the leaders' qualification, the team I studied is in one of the few prestigious universities and two of the leaders are the representatives of the successful career of an engineering researcher; they are leaders of the latest national projects, winner of research awards, fellow of professional societies, owners of patterns, and one of them is the deputy director of the university's office of research and development. Secondly, in terms of the laboratories' makeup and performance, they are all middle-sized; each host around 15 postgraduates. There are two established laboratories and two starting-ups; the established laboratories host more PhD students and have post-doctorial researchers, and one of the established laboratories has a joint laboratory lead by a project professor invited from another country in another project. The publication in the last 2 years is more than five papers in science citation index journals (SCI) per year in average and the best impact factor (IF) is 4.169 in the established laboratories and less than one SCI paper and the best IF is 4.180 in the starting-ups. On average, the team's performance is equal to the average of the faculty of the university's engineering department (3.23 SCI in 2007 statistics), and the university's SCI publication is ranked as number sixth among the universities in Taiwan. Finally, in terms of the team's representative, the case I present in this paper is very similar to the other two interdisciplinary projects I participate in another "research university;" in these collaborations, I have visited four laboratories in one project and taken part in the presentation of 35 laboratory's technology in another big project; the way they present the technology and their users are quite similar to this case. Namely, the case I present here may not be typical in Taiwan, but is not atypical among the prestigious universities where most of the interdisciplinary research granted is invested.

## 4 The Technoscientific Understanding of the User/Public

Let us briefly introduce the research project. The basic idea of the E-housing project is about enhancing living quality and safety by implanting high-tech devices into the housing environment. For example, in this e-bathroom team, a biosensor that can detect protein and sugar in the urine will be developed and installed in a toilet, and the data collected by the sensor will be transmitted through the wireless sensor network to a database and can be read on a monitor in the bathroom by the user or in the hospital by a medical personal. In order to do this, the bio-electronic engineering team in subproject 1 have to build the biochip that is sensitive to the trace of protein, and the chemical engineering team in subproject 2 has to modify the surface of the biochip for binding the glucose molecule in order to detect sugar in the urine, and the wireless communication team in subproject 3 is making the wireless networking device, and subproject 4, the bioinformatics team, will construct the user interface and the database.

Apart from these engineering teams, the law research team provides survey of international and Taiwanese law and regulations related to the individual privacy of E-bath, especially about the collection, transmission, storage, and usage of such personal health information. Our sociology team is invited to study the trial users' response to the device when its prototype is accomplished. Before then, we are studying the working of the laboratories.

Despite the device being still under construction and not a real user has been involved, in the fieldwork, we still found out that user/public do exist in various situations. Apart from the discussion of privacy issues in which the user, their family, and the public are of course in the focus, the absent users frequently present in technical discussions of "application scenario" and the design of interface. Different from the technical discussion when the user/public is straightforwardly reduced to their functional existence, for example in a fingerprint identification the system might be easier to use than a pin number system for the children and the elders, the application scenario discussions are much more sophisticated and will be used here to examine the researchers' understanding of the user/public.

In the meeting for proposal writing, most of the time is devoted to the discussion of application scenario. According to the engineering professors I interviewed, developing "application scenario" is a new requirement for these new interdisciplinary projects and most researchers are still learning how to do it. Despite that picturing the scenario is not the engineering people's major strength, they did manage to pull bits of information together into the proposal. In the E-housing project, we had regular meetings and the laboratory leaders and students brainstorming for the scenario. Just like the professors in their lab meetings always push their students to think about how to relate their work to the audience in presentation, along with the descriptions of technologies and technical information, my engineering colleagues present their idea of the users and the society for their technology in the application scenario in the proposal.

These efforts are what Callon (1986a, b) calls the sociology done together with the technical works when engineers are developing a device in order to interest other actors, in this case the NSC. There are four major threads of my engineering colleagues' sociology. The basic thread is the user's rush daily routine. In the proposal, one of the potential users are those living rush working life and another are those who are unable to care for themselves and even vulnerable to the accidents in home environment, such as elderly people. For example, subproject 1 starts with an office worker who finds out the abnormal indexes for his/her (the gender of the user is not identified throughout the proposal) urine protein and sugar and goes to the hospital for an examination. (HYM 2006, because of the promise of anonymity the actual reference is not disclosed). Two of the four major strengths subproject 3 identifies itself are: firstly, efficiency, that such an e-bath is efficient for those too busy to care for themselves as well as for those elders whose family are too busy to care for them and, secondly, safety, that the proximity sensors deployed on the floor on the bathroom will alarm through wireless network for help when an elder falls down on the floor and cannot get up (HYM 2006: 75).

In the second thread, it is proposed that those users live in an aging and high-tech society. The social situation is described in a mixture of evolutionary and revolutionary tones that after the electrification, home appliance and living environment are increasingly connected to the internet (E化, cyberalization[1]) and

[1] The term E化 originally means transform something into a digital format, such as create a word file of a document, but it is also used to refer to the connection to the internet, such a creating a homepage. This term is enormously popular in Taiwan but there is no corresponding term in English, so here, the term "cyberalization" is created to fit the Taiwanese context.

embedded with artificial intelligence (智慧化). The proposal writes, "the electrification of bathroom environment is an ongoing process….Just like the fast booming of the research for electrification of vehicles, in the future the electrification of bathroom will surely be the noticed" (HYM 2006: 75). Moreover, "with the prevalence of optical fiber networks, technoscientific building and digital housing will become one of the basic requirements….Therefore, intelligent home appliance is substituting for the traditional appliance…through network connection, intelligent appliance are equipping with 'humanized' features" (HYM 2006: 56, 64). What accompany this evolving high-tech society are a decreasing birth rate and an ever aging population. It is identified that despite the current aging index in Taiwan (52.0%) being lower than those in the Euro-American countries, it is still higher than the average among Asian countries. More powerful technology, older population, and less manpower, the combination of these trends brings about the third thread: the preventive telemedicine.

It is indicated that such high-tech infrastructure will literally realize the practice of preventive medicine. Based on a toilet system already developed and commercialized which will be constructed, the engineers are thinking about the active intervention of medicine to fight against disease even before the users are aware of the symptom. "Cyberalized homecare function will be one of the most important function of high-tech housing…it can transfer health record to the family doctor or community healthcare centers in advance and the user can be completely aware of one's health condition, and thus achieve the idea of prevention is more important than treatment" (HYM 2006: 56). In this homecare system, "the user only have to sit on the toilet, the computer will show the analysis of one's body, and can also transfer the health record to the family doctor for arranging examinations such as cholesterol. Network is everywhere and the toilet is no exception; this is the trend of future cyberalized, intelligent home appliance….In other words, our daily life, working and entertainment will be completely connected to the Internet…and none of them can escape from the cyberalized home appliance" (HYM 2006: 64).

Finally, following the direction of searching for the basis of knowledge economy for the next generation in National Science and Technology Development Plan (National Science Council 2001, 2005, 2007), proposing for the possibility of creating a high-tech healthcare industry is one of the major foci in these interdisciplinary NSC projects, and the e-bathroom project is no exception. With regard to this, the proposals not only identify the major international companies, such as Cisco, Panasonic, Philips, Whirlpool, and their state of the art housing healthcare products, but also specify the potential industrial value of such technology. According to the statistics from In-Stat/MDR, "it is estimated that the scale of global Internet related family appliance will reach 102.6 billion dollars, in which intelligent appliance is 81.3 billion dollars that makes up the major share" (HYM 2006: 64).

## 5 The One-Dimensional Engineering Understanding and its Social Context

So we have a set of scenarios: the users living a busy lifestyle in an ever aging society where people are too busy to care for themselves and the others, and the revolutionary high-tech housing environment that turns out to be the active guardian or our health and the future of our economy. These scenarios portray a much more vivid picture of the researchers' understanding of users, public, and society than any other observations we made in the fieldwork. This version of sociology is like a default setting in my engineering colleagues' mind. Despite that I am supposed to do the sociology work in this project, this version of engineering sociology consistently reappears in similar formulation in various occasions as the project goes on. My sociology ideas sometimes raise their interests, and the postgraduates are more interested in our ideas than the laboratory leaders. For example, I present the result of our survey of people to the team such as that most people are concerned about how technology can help improve the cleanness and comfort of their toilet rather than monitor their health, and the team leaders are interested and say that they will think about it in the future. Although I am not sure how much impact we can make, I am sure that we are unable to change the engineering sociology easily. I also hear similar experiences among STS and sociology people who work with engineering and medical people in such interdisciplinary projects.

This engineering sociology is one-dimensional; the user is reduced to one's technical being, which is to be alleviated by the new technology and the technology will therefore reorganize social institutions and become the basis of a new economy. Although it is a project for developing the advanced user-oriented technology for the future, according to the scenarios, it is more likely that the user is devised for the technology. According to my observation in other cases, this is quite common in those interdisciplinary projects.

In Latourian term, the engineering sociology of the lifestyle, social trends, and economy potentials are part of the effort to translate other actors' interest to the team's technology. Therefore, it is focused on the partial future, usually those considered to be able to deliver and interested to the sponsors, not those the users are interested but may not be the strength of the laboratory. However, this does not explain why when the sponsor is pouring resource to pursue user-oriented and interdisciplinary vision, those researchers fail to response accordingly and such a one-dimensional sociology is still prevalent among the sponsored project. This is an important question not only because it concerns the engineering researchers' knowledgeability of the user but also because it is the key to understand the difficulty of promoting interdisciplinary research policy and developing better technology in Taiwan.

Despite that this understanding can be explained from a cultural perspective, whether it is a Habermisian (1971) specification of positivist interest of manipulative knowledge or from a popular understanding of technoscientific people's mind set in Taiwan, called technoscientific thinking (理工思維), or from a individualistic perspective, whether it is a utilitarian one that thinks the engineering sociology is merely a propaganda to please the sponsor for the budget or a personality one that assumes engineering researchers are assertive, these accounts not only contradict other observations in the fieldwork but also cannot offer a practical strategy to change the situation. Although engineering people are less good at exploring and expressing the multitude of human existence other than the technical aspect, they are completely technical all the time. For example, it is commonly observed that when a senior student teaches the juniors new techniques, they are also aware of and making use of the social and emotive situation of their communication, especially when it involves females. Apart from that, attributing the causes to the vague culture, mind-set, or human nature is almost like saying that the situation is unchangeable.

Following the insights into public understanding and technoscientific practices reviewed above, this engineering understanding should be explained in its context. In the debates over the public understanding of technoscience, the relational construction model leads us away from the problematic deficit model, judging the laypeople with the standard of the expert's technoscientific knowledgeability, and teaches us to look into the lay knowledgeability in social contexts. Furthermore, following the insights in exploring technoscientific practices that problematize the expert, the following discussion wants to situate the persistence of my colleagues' engineering sociology into its social context and show that such an explanation is eligible for a practical solution.

## 6 Framing Engineering Sociology

Based on my fieldwork observation, the persistence and prevalence of this version of engineering sociology is closely related to researchers' response to the field of engineering research. Using the idea of framing to analyze the context of engineering research, there are three levels of frame: regulation, team networking, and practical work. While it is observed that these three frames entangled in research practices, an analytical framework is used here to specify each of them; these frames can be regarded as corresponding to the development of a researcher's career, laboratory, and technology. A researcher's name is like an abbreviation of the dynamical development of the trinity of 'career–laboratory–technology.' As will be discussed below, the frame at each level has a specific focus/effect; the regulations confine the researchers' career to the accumulation of publication, the networking reduce laboratories' diversity, and the practitioners are mainly concerned with assured delivery in the practical work of making technologies. Among the conjuncture of these frames of practices emerges the one-dimensional engineering sociology.

## 7 Regulation

By regulation I mean not only the requirements itself but also its effects on the actors. In the following, I will focus on two major issues in the regulation frame: the first one is about the content, what the regulation aims for, and the second is its form, how the regulation exercises and affects the regulated researchers. I will start from the former. In the recent years, the academic regulation system is undergoing micro and macro changes. At the micro level, it is the regulation applied to the researchers; at the macro level, it is applied to the universities. The Minister of Education and NSC try to rationalize the reward system in the academic field and the quantity of publications is one of the major bases for performance evaluation. According to Prof. Lin (we work together in another project) who started his career in the early 1990s, the trend starts around the late 1990s. Before then, academic researchers do not have to worry about their performance and productivity; the NSC even offered extra grant and prize for those who did publish their research projects. However, nowadays, things are different, and publication, more specifically SCI and SSCI papers, determines the researchers' career, the credits for grant competition, and even the ranking of the universities. Despite that there are criticisms against the tendency; the publication-based evaluation system is linked to the review for tenure track and monetary rewards. Furthermore, the total publication performance of a university accounts for one of the major indexes for deciding the distribution of extra research grant, such as the Five-Five Project (50 billions NT dollars/1.1 billion EUR in 5 years, 五年五百億計畫) for booting up the top universities into the world's top hundred best. Namely, publication performance links and unifies the micro and macro reward systems at the same time.

As an engineering research need monetary resources to support the people and the experiment expenditure, the publication-based reward system is translated into a "project in and paper out" system to organize the working and organization in a laboratory and among researchers. This system obviously contradicts those user/ application-oriented interdisciplinary projects aiming at facilitating creativity and bringing the users into the laboratory development of technologies. Given the contradiction, research teams still apply for those user-oriented projects for those grant can directly strengthen their resource and thus indirectly increase the publication. As for the user-oriented requirement, most of the teams only try to meet the basic requirement, such as highlighting the users in their proposal and presentation just as the e-bathroom team has done, rather than implant such a rational into their training and daily works.

Apart from that, the system is not only encouraging the researchers to produce more paper but also discouraging them from producing good papers. A junior researcher Hsu comments on this: "now they are even using a credit system for counting the credit of each paper. It takes a good team many years to produce a good paper. But don't forget, it has to be divided by the number of participants and the time span…. Relatively speaking, whatever in terms of credits or paper counts, (in the case of a good paper) the C/P ratio is always low…(the team mentioned before) they did six thousand experiments and published a paper on Nature. Sure, Nature is marvelous! But the team is based on the collaboration of four or five laboratories and took them a long time….Given the fact that the credit for Nature is 20… and they produced the classical 'must cite' illustration, but being divided by five laboratories and takes the time span and manpower into account…forget it! I don't even think about doing that. First of all, the NSC won't support me, second, it is too risky and if nothing comes out I guess I am finished…". One interesting thing which happened in this interview quite vividly echoes Hsu's words. This interview was interrupted once by the secretary of Hsu's department. She gave Hsu a sheet of paper and asked him to fill in by the end of the week; after she left, Hsu showed me the paper. It is a balance sheet of Hsu's performance in this semester with a list of the credits for different levels of publication. He said "three papers and the total credits are around ten. You see what I mean."

Apart from the papers NSC wants, the other government departments also support engineering research and they want something different; for example, the Ministry of Economy encourages the transfer of technology from universities to the industry by supporting the project for Industry and Academic Collaboration (IAC, 產學合作) in order to enhance the development of high-tech economy. I will use this case to illustrate the effect of the form of the regulation framing. Of course there are also regulations on this. Since the paper-based regulation system strongly pushes the researcher to focus on publishing in order to benefit both the individuals' career and the institutions' development, such an industry-oriented initiative, which is akin to the user-oriented one, has its disadvantage. Apart from that, such an initiate has its own deficit in the way it works, which cannot realize its potential for enhancing user-oriented engineering.

Mentioning the review system for grant application will be enough for illustrating the point and it can be exemplified in Prof. Hsu's words in a group interview; he says, "In fact I hope to work for the industry, because the industry in Taiwan does not have much R&D…the development…has a big lag with the academic research, so, I really wish to do something for them. But every time when it comes to writing for support, even a small one, there are so many limitations. Then in a big IAC, you have to even go through the NSC's approval, such and such, etc. These are discouraging, first, they are troublesome, and then, you have to document the ideas in the proposal and have it reviewed. For the company, they do not want it… How can I give the information of my latest product out to the something called NSC and then being reviewed by someone we do not even know….For those companies, these (ideas) are the source of their profit. This turns out to be a vicious circle. They refuse IAC but they do not have enough R&D, in the end, most of them can only follow what others have been doing. Then, the collaboration between us (researchers) and them (companies) sometimes becomes under table. The system is not flexible enough to allow for a good IAC environment."

In an interview with Prof. Lee who leads the law team, he related this to the rationale behind the regulation. He says that "most of our regulations are designed to prevent from fraud. It has a deeper root in the mentality of preventing the 'bribing culture' (紅包文化). In order to prevent from fraud, so the regulation is usually designed in a negative thinking, you should not do this or that or you should do this or that for review, not a positive thinking. It seems that if we encourage something then a hole will be created in the system for private interests. Many of the regulations on research are based on the same rationale." Thus, in the conjuncture between the strong paper-driven reward system and weak user-oriented one, the interest of the researchers are relatively clearly defined at the institutional level.

## 8 Practical Work

Against such a background, we have a picture of the primary concern of the researchers and their perspective on their researches. Here, we turn to the frame of practical work. PhD students, who are mandated to managing the laboratories, including proposing for new researches, are maybe those most concerned with the practicality. In engineering, it takes the support of a specific technology/technique to do researches and publish. While a specific technology/technique takes long-term efforts to develop, the efforts do not guarantee the realization of a technology. Thus, engineering researchers are usually quite conservative in setting up the goal. The conservative attitude is observed at three different levels. At the first level, it is about the practical requirements. A PhD student, Jane, says that they always have to take the laboratory's current capacity into consideration. Because of the requirement of publication, they are usually more conservative about their proposal and they rarely think about different possibilities; all they think about is assured delivery. Moreover, in order to be more efficient in publishing the research, the organization of the division of labor in most of the laboratories develops into a hierarchical pyramid shape: the master students are the majority who do the experiments for their theses, which is usually part of a project, to produce the raw data, the PhD students are in the middle and they supervise the master students' progress, analyze and interpret the raw data, and draft a paper, and the leader on the top, sometimes the post-doctoral researchers in some mega-laboratory, gives direction and finalizes a paper. In this organization, the assured delivery attitude is also a common response among the postgraduate students who cares only about their own thesis project and the problems at hand.

At the second level, it is about the strategy of career planning. For example, Prof. Lai says, "A good research idea does not come out automatically, we have to repeat existing research by using our own methods and see if anything comes out….Being a junior, you have to worry about budget, peoplepower, equipments, etc., and you have to make sure that you can deliver….So, we always try the safest idea, not those innovative but risky ones….It is very difficult for junior researcher or small laboratories to propose a new area or new idea (in the context of interview, he means not only technical but also the proposed future application)."

At the third level, it is about the development of expertise and tracing the moves of the industry. Prof. Sam echoes this in a different sense when commenting on the changes of his main line of research, from wireless device to solar energy; corresponding to this, he says, '"when I was junior, the industry of high frequency communication is hot and it was my background training, so I did what I did best and established my lab steadily…now I am not so pressed by the reviews and tenure these things, and solar energy is hot now. These are basically following the same manufacture procedure on similar materials, silicon or the third and fifth group of elements on the period table, so my lab is starting to go into this field."

As is indicated in these accounts of practical requirement, career planning, and expertise development, together with the other regulations, such as those on tenure review and project application, the frame of practical work is structured by various interlocking arrangements regulating these researchers' daily life. The professors care about the immediate industrial application, grant support, and the network with other teams, the PhD students worry about the publications and the projects' progress, as well as the master students' performance and the building up of the laboratory's techniques, and the postgraduates worry that their systems will not work and that their scheduled graduation date will be delayed. The students and leaders have witnessed, lived through, and expected such a way of arranging the practicalities in their laboratories and careers. The conservative attitude practiced in practical frame directly obstructs the possibility of taking the alternative vision of the relation between the development of a technology and its user into account in laboratory practices.

## 9 Team Networking

Furthermore, the practical dimension perpetuates beyond the working of a laboratory, and this has to do with the frame of team networking in which the daily practical work of a laboratory is situated. As studies of technoscientific practices have pointed out, a laboratory has to link itself to or organize its own scientific or technological network in order to secure its technoscientific fact or artifact (Collins 1982a, b; Shapin and Scaffer 1985; Callon et al. 1986; Latour and Woolgar 1986). In a similar way, each engineering laboratory is situated in some relatively stable collaborative networks, only that they are more concerned with applying and doing projects. Such a team network relationship is not only exercised in a project collaboration but also in their students' examination committee and other occasions. As a laboratory is built on a steady progress, a team has its own specific research strength based on those of joint laboratories and a team grows when a new member joins in. This is an ironical growth. On the one hand, the growth comes from the recruitment of a new member, usually a junior one. When a junior researcher starts the career, his/her laboratory lacks necessary equipment and resources and the only way to start one's research is to join the established teams for the necessary help. For those existing team members, the most important differences between a starting-up and an established lab is that while the former is relatively flexible and usually follows the team's direction, the latter already has its own direction that might interfere with the team's unspoken consensus.

Given the requirement of equipment and resources for engineering research, team networking is acknowledged to be necessary among most of the junior researchers I talked to since it is the only way to start one's own career in the era of big science and engineering, but its implicit adverse effect on the diversity of research is less mentioned. In this sense, on the other hand, this sure is the growth of the strength of the team, but not necessarily of the junior researcher, since he or she usually starts from doing the "services" the team requires rather than what they want to do. It thus reduces the impact the new member makes on the stability of the team.

Apart from the effect resulted from the dynamics between team formation and a researcher's career, the diversity is reduced in the interaction in the team networking, such as the process of applying for a project. As Prof. Hsu says, "as you mentioned that engineering researches and even their imagination of the users are all quite similar…in fact, one of the major reason is that the NSC only open for proposal in some frames.…We engineering people are goal oriented…for example, in an interdisciplinary project we will see what are the objectives, and we are guided by the objectives and we will think about what else we need in order to get the money.…For example, this project is called advanced quality living, and we will see what technology we (the team) have, then bring in the others…so when the big frame (from NSC) comes out, we bring in what we have into the frame and bring out a theme.…So, you won't expect much difference…". This comment exemplifies the situation of the law and sociology teams in the project. Such a call for interdisciplinary collaboration between engineering and humanity is completely foreign to the engineering team. While the non-engineering groups are invited into the collaboration, the diverse perspectives can only make slow progress, if not no progress at all, as the old team itself is still occupied with the theme of what they do best, in other words what they can deliver. Here, we can see how the interaction between the practical, team networking, and regulation frames reduce the diversity of the researches and their attempts.

## 10 Conclusion

Following the way of situating the lay understanding of science and technology into its practical context, this paper locates the one-dimensional engineering understanding of the users into their contextual practices in terms of the frames of regulations, practical work, and team networking. Here, I would like to point out some further issues. It is worth mentioning that while the practitioners situated in these frames might frame the users with the understanding in the construction and promotion of their technology, the users, as is indicated above, are situated in different frames of practices in their everyday encounter with a technology (Pinch and Bijker 1984; Akrich 1997; Oudshoorn and Pinch 2003; Oudshoorn et al. 2004). Apart from the "laboratory life" presented here, it would be important to follow the different framing practices, such as those of the users, that shape the trajectory of a technology in its "social life" and study how the practitioners make sense of the differences (Whyte et al. 2002). Moreover, this analysis is based on the fieldwork of laboratory practices, and it is worth mentioning that many other social and industrial issues might also contribute to the framing of engineering sociology. For example, our interviews also indicate that the conjured economy-first idea and the success of the semi-conductor and computer-related industry in Taiwan does also play a role, however indirectly, in framing this technology-first vision. Finally, the analysis here is more of a Weberian ideal type construction, and empirically, there are actors of different ambition challenging the one-dimensional vision. For example, some engineering professors are also aware of the all too focused training of their students and try to bring in some philosophical and social thinking into their teaching and laboratory training, though they are minority in current academic engineering field.

The aim of this paper was at depicting the major forces that frame the situation of the engineering researchers and their implication to their visions. Using the idea of framing is trying to highlight the multiple frames of reference for the actors to make sense of their situation and the consequent embodiment of the frames in their routine practices. The vision of engineering research in Taiwan is explored here; the one-dimensional vision confined to the technical being of the users and society emerges and being practiced/sustained in the conjuncture of frames of publication-oriented regulation, delivery-assured practical work, and diversity-reduction team networking. It is only in this entanglement between the objectified practical routine and the subjective understanding of and adaptation to the situation that the engineering understanding is so difficult to be changed; for us outsiders, this engineering sociology is about the visionary, not the technical, aspect of research and might thus has more degree of freedom, but on the contrary, it is exactly because these non-technical aspects are not part of engineering technical routines and cannot find a place in the organization of the frames of practices; thus, none of the resource and thought will be allocated to them. Given this situation, the aim of this paper was threefold.

First of all, in the general context of the studies of science, technology, and society, it joins the criticisms that aim at facilitating science communication from the other end. This paper tries to point out that as we have already had more and more literature on lay understanding of science and technology and institutional design to facilitate public participation of science and technology, it might be also useful to explicate the ways practitioners of science and engineering understand their users and the public and what contributes to the obduracy of such a specific way of understanding. The notion of frame mobilized here is best for explicating the dynamical, relational, and conjunctive making of the knowledgeability of the experts. The point is that the researchers neither have a technoscientific mind-set or culture by nature nor merely do they follow institutional regulations and constrains; they are situated and they participate in the framing practices in order to create their strength in enhancing the credit of their careers, the development of their laboratories, and the stability of their team networks.

Secondly, more specifically in the Taiwanese context, it aims at pointing to the difficulty of promoting the development of interdisciplinary and user-oriented researches. It is argued that the new rationale and initiatives are difficult to change the researchers and their teams who are shaped by the publication-oriented regulation, delivery-assured practical work, and diversity-reduction team networking frames. This is not claiming that these frames will prevent the researchers from making any differences, but the evidences do show that they have adverse effects on reducing the diversity of researches, diminishing innovative ideas, and discouraging user-oriented attempts in the doing and organizing of laboratory practices and the practitioner's understanding and strategy of doing engineering. Most of the presentation of users in current discussion focuses on the proposal writing meeting and the proposal. That is because it is very unfortunate that for the moment, as the power of NSC's initiative for facilitating interdisciplinary collaboration exercised via reviewing proposal and determining the distribution of the grant, the engineering teams, not only the one presented here, usually only talk about and think about the user in the proposal writing stage accordingly. I believe that the situation will improve slowly in the future depending on the changes of the frames and the intervention of different practices.

As for this, what this paper tries to do is developing a framework to think about the forces that work on the engineering researchers and portraying the specific constitution of the forces in the current Taiwanese situation. The framework developed here can be further examined in the future by doing comparative study, such as Japanese are famous for developing human-centered technologies, and specifying the various styles of doing engineering and understanding users in different contexts, such as those in Taiwan and Japan, and their effects. It is hoped that this study and its potential comparative implications can provide ideas about, apart from initiating interdisciplinary projects, what else can be done to these frames in order to facilitate the realization of these user-oriented development of appropriate science and technology research in Taiwan.

Finally, it is about what can be done. Although STS works are not expected to change the way engineering researchers do and think immediately, it does not mean that they will not make a difference. As I have described above, team networking is one of the major frames and the participation of a new member will bring in new ideas and technology into the team in the long term; the new member has to fit in the team's already stabilized working style and path of development first, but the new inputs they bring in will slowly blend in and shift the style and path gradually. This not only exemplifies the strength of using the multiple framing processes to think about the multiple influences on the development of a technology but also can be used to think about the possibility of making differences to the situation. This is about the potential benefit of interdisciplinary collaboration between STS and engineering. Such collaboration is still new to both camps in Taiwan, and I have experienced and heard many unsuccessful cases when people from these two cultures work together in teaching and doing researches. Attributing the problem to differences in cultures, mind-sets, or even personality offers no practical solution; following the argument presented here, it seems that part of the problem comes from the two camps being shaped in different frameworks and have different vision and agenda of the collaboration. It is hoped that the analytical framework and depiction of the way our engineering colleagues think and do things and the particular frameworks that make them so might facilitate further mutual understanding and collaboration.

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