Sociological Perspectives on Energy Efficiency Program Efforts to Promote the Adoption of High Technology Diagnostics by HVAC Technicians

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ABSTRACT

This paper explores how theories and findings from the sociology of work may inform our understanding of the promotion and integration of high-technology diagnostic tools in the work practices of in-field technicians. An increasing number of energy efficiency programs promote improved heating, ventilation and air-conditioning installation practices through the use of high-technology diagnostic tools. The authors shift focus away from the economic barriers of technology adoption and highlight the changes in everyday work life that new diagnostic tools entail. From this understanding, the authors identify two additional barriers that may be important in technician decisions to adopt new technologies: 1) the need for technicians to make real and experience the new technology before adopting and 2) the increased dependence on social networks that stems from the need for help and information with increasing use of new technologies. To explore the first barrier, the authors draw upon research on other workers who work with machines in the field to conceptualize how use of diagnostic tools might impact HVAC technician work. To investigate the second barrier, the authors explore the application of the sociological concepts of *communities of practice, social capital* and *social networks*. The authors use this literature to develop a protocol for in-field observation and interviews of HVAC technicians, which can be used to help inform local program design. The authors pilot this methodology in the field with one HVAC technician and briefly report results. In conclusion, the potential implications for programs are highlighted and future research needs are discussed.

Introduction

In addition to reducing energy use, many energy saving programs have developed strategies to reduce peak demand. In most parts of the country, peak demand occurs on the hottest or coldest days of the year when people use their air-conditioners or heating the most. Therefore, demand side management (DSM) program administrators often work to improve the energy efficiency of heating, ventilation, and air-conditioning (HVAC) systems in residential and commercial buildings. Because commercial customers are more likely to pay a demand charge or face a "time of use" rate that increases during peak periods, an incentive to acquire efficient HVAC systems already exists for the building owner. However, because residential customers pay an average rate they lack the incentive to reduce peak demand[1]. Promoting high-efficiency HVAC equipment with good performance at high ambient temperatures has been a common strategy for voluntary DSM programs to reduce their peak load. In addition to promoting equipment that achieves high energy-efficiency performance, such as Energy Star-labeled equipment, program administrators increasingly target equipment installation and maintenance practices. Improving the installation and maintenance of residential HVAC systems has been estimated to yield up to 35% energy savings over baseline (Neme et al., 1999).

[1] Exceptions exist. Many utilities allow residential customers to voluntarily adopt a time of use rate.

Residential HVAC Programs Promoting High-Tech Diagnostic Tools

HVAC contracting businesses and the technicians they employ have been identified as an important ally for improving the in-field performance of residential HVAC systems. A number of recent DSM programs have promoted high technology diagnostic tools to the HVAC industry (See Table 1 for a few examples). These portable tools have been designed to be carried with the technician and used on installations and service calls. They are meant to automate and increase the capability of traditional technician hand tools such as manifold gauges and thermometers. The tools are designed to automate data acquisition, calculate system performance indicators like superheat and sub-cooling, provide front-line decision support using diagnostics, and help document performance improvements (Rossi, 1999). Many companies market these tools including, but not limited to, Honeywell™, Field Diagnostics™, Mowris and Associates™, Enalysys™, and Testo.™. CheckME™ offers a similar service that allows technicians to convey system performance data by telephone to a call center where operators use diagnostic software to verify performance. Programs have promoted these tools with the goals of enabling a technician to: 1) perform tune-ups, 2) identify when a quality installation is achieved, 2) provide a quality installation faster, and 3) provide independent verification to the customer and the utility/program administrator that the system is operating efficiently. In addition to the immediate energy savings and peak demand reductions that result from the completion of each quality installation, there is often the secondary goal of building an infrastructure of capable technicians that will continue to achieve quality installations without financial incentive.

Programs promoting such tools and associated practices have utilized a range of program approaches including:

- Linking the use of tools to the provision of HVAC equipment rebates
- Providing free initial training and/or reimbursing additional hands-on training
- Providing an incentive payment for each job completed with a tool
- Partially or wholly reimbursing the cost of purchasing of tools.

These programs are sometimes designed to overcome the cost of acquiring tools and uncertainty about the financial benefits (economic factors), which are often considered the key barriers to the HVAC industry's adoption of these technologies. Programs have also offered information and training sessions in order to overcome other potential barriers, such as lack of awareness of the tools and their potential benefits, and lack of knowledge on how to use these tools.

Past research on a variety of high-technology diagnostics has noted that the existence of advanced technologies does not automatically advance the goals of efficiency, but rather that the integration of the technologies with human systems will provide advances in efficiency (Buckley and Proctor, 2002; Rohracher, 2002). The potential "lies not in the technology, but rather in the socio-technical network and negotiation of the social context" (Rohracher, 2002, p. 251). This paper seeks to draw from the sociology of work[2] literature to provide insights on this negotiation. Sociology of work is also known as industrial sociology or sociology of industrial relations, and

[2] Because we are seeking to explore the connections between the empirical and theoretical developments in the sociology of work to the practical example of efficiency programs promoting advanced diagnostics to HVAC technicians, we often use sociological terms unique to the discipline that may be unfamiliar to those outside the field. We alert the reader to the use of these technical terms with italics.

is the study of the interaction of people within industry and the workplace. It includes the study of boss-subordinate, management/trade-union, and worker/technology relations, along with the macrosociological study of the impact of industrialization on whole societies. In this paper, we use sociology of work to provide additional insights on the social context of the workplace and the barriers to technicians integrating new technologies into their work processes.

Table 1. Examples of 2005 Residential Program Promoting HVAC Diagnostic Tools

RESIDENTIAL PROGRAM	PROGRAM DETAILS
Connecticut Light & Power and United Illuminating Company **Residential Heating and Cooling Program**	On new installations and retrofit installations, if the installing contractor commissions the new equipment with the Honeywell Digital Assistant or similar pre-approved tool, there will be an additional $50 incentive to the contractor upon successful download of the data from the Honeywell tool. This additional $50 incentive to the contractor will encourage those who already own the tool to use it correctly and those who do not have the tool to purchase one and get trained to use it. Program encourages contractors to pursue enhanced training offered through their companies alone or in conjunction with the Connecticut Heating and Cooling Contractors (CHCC) and NATE.
Cape Light Compact, National Grid, Northeast Utilities, NSTAR Electric, and Unitil **Massachusetts Cool Smart with Energy Star**	In 2005, the program initiated Quality Installation Verification (QIV) services, with expert classroom and hands-on field training. Technicians learn to use leading edge diagnostic tools (Honeywell Service Assistant and the CheckMe! phone-in service in addition to other tools approved by the program) to check and document proper refrigerant charge and system airflow for qualifying equipment. The program accomplishes this through: A QIV incentive of $150 for each rebated system which passes charge and airflow tests and is properly reported to COOL SMART • Free classroom training on QIV testing and procedures • Reimbursement for hands-on QIV field training of up to $125 after three QIV "passes" by technician • Reimbursement of up to $150 for purchase of a digital thermometer (flow grid) or hot wire anemometer which meets the program specifications after three QIV "passes" by technicians
California Public Utilities Commission Third-Party Statewide Program (Mowris and Associates) **RCA Verification Program for New Air Conditioners**	The RCA verification program provides several cost-effective methods to verify proper refrigerant charge and airflow. These include: 1) Personal Digital Assistant (PDA); 2) cell-phone telephony; 3) web-enabled PDA; or 4) web-enabled PDA cell phones. Verification information is collected and archived in a database where it is checked for accuracy and can be viewed over the internet by consumers, inspectors, dealers, and program managers. Verified jobs are randomly selected for inspections to ensure high quality results.

Excerpted from CEE Residential HVAC Program Summary 2005 and Mowris, 2004.

Our focus on the past sociology of work literature suggests that two additional factors influence decisions to adopt these technologies: 1) HVAC technicians have highly experiential *ways of knowing* based in the bodily senses and 2) additional knowledge about their work is often learned through talking with others about their experiences. Focusing on these human dimensions of HVAC technician work, we discuss two additional barriers to technology adoption in addition to the commonly recognized economic realities: purchase barriers and market operations barriers (AEC, 2005). Purchase barriers are factors that interfere with decisions to buy and adopt. Because of how technicians understand their daily work, technicians need to "see it and make it real" and "have experience with it" before they can make a decision to invest or utilize (AEC, 2005, p. 8). This means that before purchasing a new tool, technicians may require an opportunity to physically try it out and the field so they may experiment using it. We argue that because the nature of HVAC technician work is highly experiential and based in the senses, these purchase barriers are particularly relevant.

The second barrier is a market operations barrier. Because we theorize that high-technology tools, particularly those with automation, entail different *ways of knowing* and understanding a technician's work, being able to access help and additional information in this process becomes highly significant. The lack of professional expertise or "lack of resources in the market that customers (in this case, a technician using a new tool) can go to for help or information" can be an important barrier (AEC, 2005, p.8). In studies of other service technician industries (such as photocopier technicians), it has been found that help is often provided by communities of practice, the formal and informal networks of other technicians that have encountered problems before and are called upon to help problem solve (Orr, 1996, 1998; Bobrow et al., 2003). These communities of other technicians, in addition to formal documents produced by management or manufacturers of equipment, are key sources of help and information that enable the successful use of new tools.

In this paper, we first review the relevant sociology literature on the nature of field technician work and changing technologies as it relates to our hypothesis of the importance of purchasing and market operations barriers. From this literature survey of other studies and theorizations of the workplace and technological change (there is little written specifically on HVAC technicians), we develop guidance for observation and interview of HVAC technicians. We present results from the observation and interview of a residential HVAC technician which was used to develop this guidance. Acknowledging the inability to make any conclusions from the study of a single observation and interview, the authors suggest avenues for future research and discuss potential implications for programs promoting diagnostics.

HVAC Technicians and their Work: The Bureaucratic Understanding

According to the Bureau of Labor Statistics (BLS, 2004), there were approximately 250,000 heating, ventilation, air-conditioning, and refrigeration technicians in the U.S. in 2002. About half of these worked for heating and cooling contractors. Fifteen percent were self-employed as mechanics or installers. The rest worked for various businesses like fuel oil dealers, refrigeration and air-condition service and repair shops, schools, and stores that sold heating and air-conditioning equipment. The median hourly earnings of heating, air-conditioning, and refrigeration mechanics and installers were $16.78 in 2002. The middle 50 percent earned between $12.95 and $21.37 an hour. The training and educational backgrounds were varied, with some learning on the job only through apprenticeships and others having two to four years of schooling in technical trades. BLS describes the job of technicians as installing, maintaining, diagnosing, and correcting problems throughout the entire system by adjusting system controls to recommended settings and testing the performance of the entire system using special tools and test equipment. BLS writes "Heating, air-conditioning, and refrigeration mechanics and installers are adept at using a variety of tools, including hammers, wrenches, metal snips, electric drills, pipe cutters and benders, measurement gauges, and acetylene torches, to work with refrigerant lines and air ducts. They use voltmeters, thermometers, pressure gauges, manometers, and other testing devices to check airflow, refrigerant pressure, electrical circuits, burners, and other components."

HVAC Technicians and their Work: Alternative Understandings

Though broader theories of sociology have informed our understanding of energy use (i.e. Humphrey, Lewis, and Buttel. 2002), there has been little application of theories of sociology of work and technology change to understanding the market transformation of industries, or specifically in this case, HVAC technician practices. We suggest that these more theoretical conceptualizations provide a broader frame for understanding technical work practices that may provide insights in a number of different settings. To begin this process, we draw on a number of studies that have focused on workers that fix and operate machines analogous to HVAC equipment in a variety of environments.

Orr (1998) advocates for understanding the actual work process that is undertaken by technicians in the field rather than depending on managerial discourses like the one by BLS on HVAC work. A number of studies done on photocopier service technicians provide insight into how they work to diagnose a problem and the resources they draw on. Orr (1996, pp. 1-2) describes the work of field service:

> "The practice of experienced technicians maintaining photocopiers is a continuous highly skilled improvisation within a triangular relationship of technician, customer, and machine. Technical service work is commonly conceived to be the fixing by rote procedure of uniform machines, and routine repair is indeed common. However individual machines are quite idiosyncratic, new failure modes appear continuously, and rote procedure cannot address unknown problems. Technicians' practice is therefore a response to the fragility of available understandings of the problematic situations of service and to the fragility of control over their definition and resolution."

In addressing non-routine problems in the field, Yamauchi et al (2003) found that service photocopier technicians engage in two ways of diagnosing and solving the problem. The first way is through *instruction following* where technicians follow company or manufacturer produced repair analysis procedures. The second way the authors call *gleaning*. *Gleaning* is the practice of collecting information from many sources, but mostly depending on other technicians and informal *tips*, which are documents written by technicians describing their invented solutions to hard service problems. Orr (1996) in his ethnographic studies of technicians found that informal everyday conversations and telling of stories by photocopier service technicians were crucial for knowledge sharing.

This understanding of how field technicians solve problems indicates that the *community of practice* may be an important part of a HVAC technician's everyday work understanding. A community of practice is defined as a collection of individuals who are bound by sets of relationships, formal and informal, who share common practices (Wenger, 1998; Lave & Wenger, 1991). Communities of practice have a shared way of thinking about their abilities individually and collectively and a shared understanding of how to talk about the world in which they work (practice). We can think about professional associations as a formalized community of practice though they are often informal. Professional associations often formally undertake efforts to promote the diffusion of knowledge through conferences, trainings, and publications. Professional associations also often aim to provide opportunities for informal exchanges of everyday conversations and story telling that share knowledge about practicing as a HVAC technician. There are multiple professional associations established for HVAC professionals, the largest of which are the Air-Conditioner Contractors of America (ACCA). SMACNA, PHCC, Service Roundtable, Refrigeration Service Engineers Service (RSES) are other examples.

The importance of communities of practice in field technician work, the role of which we will investigate more fully for HVAC technicians, connects to the broader literature on social dimensions of technology diffusion and adoption: *social capital*. *Social capital* can be considered the access individuals have to resources through their social connections or ties (Bourdieu, 1986; Coleman; 1988). The popular understanding of social capital is the oft-recited phrase "it's all in who you know." The people you know determine your access to resources and these resources can include money, tools, and information.

In this paper, we hypothesize that the level of access to observation, information or help in utilizing new technologies and practices may reduce the purchasing and market barriers to adopting a diagnostic technology. Providers of these social capital resources may be utility programs, diagnostic tool manufacturers, technician management companies, and the formal and informal networks of a technician's *community of practice*. Utilizing this lens, technology diffusion can be seen as a social process of formal and informal information exchange among members of a social system (Rogers, 1983). Drawing on the work of others who have applied the ideas of social capital to technology diffusion (i.e. Frank *et. al*, 2004), we emphasize the importance of interpersonal networks in the diffusion process. The choice to adopt a technology or not is understood as socially segmented, constrained, and influenced by social networks. Holding constant the availability of resources from those outside their informal communities of practice (i.e. utilities, manufacturers), we hypothesize that a technician with more links to other technicians has more potential resources at his or her disposal and is more likely to adopt a new technology.

Another potentially important set of insights into the nature of HVAC contractor work is provided by Zuboff's classic book on technological change, *In the Age of the Smart Machine*. Zuboff studies the impact of the transition of a mechanized workplace to an automated workplace and its impacts on the worker. For example, in her study of a pulp and paper mill, she found workers that had worked with machines all their lives had a difficult time adjusting to the automatation of the factory they worked in. She found that these changes in technology, though seemingly on the same continuum, resulted in a shift in *how the workers know their work*. Her study builds on the idea that there are different *ways of knowing* things. Workers can acquire knowledge about and understand a given phenomenon (i.e. their job, a problem with a machine) through different processes. Examples of ways of knowing include scientific, experiential and intuitive. She discusses these different ways of knowing by looking at the different skills workers use when acquiring knowledge about their jobs. In a mechanized pulp and paper mill, she finds the workers skills are *action centered*. An action centered skill means that it is a skill based on deriving information about a problem through physical cues and senses (touch, sound, smell, etc). When nuanced and detailed information is known in this way it is difficult to tell another person exactly how it should feel or smell – the other person will have a much better knowledge of it if they feel and smell it for themselves. The information, because it is known through being present and embodied, is not easily communicated, highly personalized, and only has meaning in the context in which it is perceived. The pulp and paper mill workers knew "the condition of paper coming off a dry roller by the sensitivity of his hair to electricity in the atmosphere around the machine" or "the moisture content of a roll of pulp by a quick slap of his hand" (Zuboff, 1984, p. 58). Upon the introduction of computer-based technologies that monitored the plant's activities, workers felt confused, removed, and unhappy. Workers described an inability to understand, "to see what was going on" or to utilize their former experiential and bodily knowledge. Zuboff described this as a shift in the ways that workers knew things and that with automation workers utilized more *intellective skills* than *action centered* skills. Intellective skills are those based in understanding and trusting in abstract symbols (computer read-outs) and inferential understanding (interpreting those abstract symbols). Though both *action centered* and *intellective skills* use both mind and body, and there is never a pure use of only one, the shift of emphasis to *intellective skills* with automation increases the emphasis on the mind and decreases the emphasis on experiential sensing through the body.

Informing Programs: Developing a Framework for Learning from Technicians

Drawing on these studies and theorizations of workers and machines, we propose that two streams of investigation should be undertaken: 1) observation of the activities of HVAC technicians on the job and 2) interviews of HVAC technicians. To help inform future field studies on this topic, the authors conducted one interview of a HVAC technician on the job. The technician we observed was male and 28 years old. He had been working as a HVAC technician since high school (10 years), where he had attended a four year technical school. He worked for a small company of 6 employees that advertised as being "family owned" and provided service for residential and commercial heating and cooling. He had worked for this particular firm for 4 years. Conducting one technician interview may help inform future studies, but isn't intended to be representative. We view this research as providing initial insight into whether HVAC technician work is similar to other research on field technician work and technology diffusion. This pilot observation is also used to inform refinement of future research in the area. Future studies should observe and interview a statistically-valid sample of HVAC technicians with a variety of characteristics including differences in company size, size and type of buildings they service, years of experience, training, gender, association status (member, non-member) and use of technology.

For observation of a technician, we contacted a contractor from the area of Southeast Michigan and requested the opportunity to observe the technician on the job. As observers, we noted how the technician worked to diagnose and the fix the problem, paying special attention to how the contractor attained information about the problem. After observing the technician on the job for a day, we interviewed him, collecting basic socio-demographic information and questions about automated technologies and the contractor's social networks. Appendix 1 provides the observational guide and set of questions asked.

Ways of Understanding and Knowing Problems

Our observational results provided some support for the hypothesis that HVAC technicians gather information and learn in similar ways to photocopy repairmen and others who have been studied and work with machinery. One of the authors accompanied the technician on a job call for a broken furnace at a residence, as he was informed by the office manager. Upon arriving at the household, the technician first talked to the homeowner and asked her when it had broken and if it had been consistently broken or cycling off and on. She answered it was running, but consistently shut off before reaching the temperature on the thermostat, so she was always cold. She then took him down to the basement and showed him the furnace. The homeowner gave the owner's manual to him and he asked the homeowner to adjust the thermostat to a number of different settings and watched and listened to the furnace and the result. He consulted the owner's manual. Due to previous problems with this particular model, the technician assessed that the flame rectification system may be faulty. This observation lent support to our hypothesis that HVAC technicians may conduct and understand their work like other workers in the literature. Our observation found that 1) the customer served as an important source of information and part of the interaction that takes place between the HVAC technician and the machine (furnace), 2) he utilized his physical presence and observational senses to help diagnose the problem, and 3) in addition to consulting formal documents, he utilized experiential knowledge unlikely to be found in a formalized document. This observation supports our theoretical understandings of the multiple ways in which technicians know the machine they are fixing, and suggests that there is merit in thinking about how new technologies on the job may alter or interfere with this process of understanding the air-conditioner or furnace they are servicing.

Social Networks and High-Technology Diagnostics

In the subsequent interview, the technician reported that he talks most often to his fellow technicians about his work, and occasionally his boss too. He believed that his boss had the most formal training and knowledge, but was less willing to ask him for advice since he was often busy. He reported that he did not talk very often to technicians outside his current company, but that he was still socially friendly with a few from his previous firm and that they did discuss various work issues in social settings. He was not a part of any trade organization and stated that he worked enough during the day and wished to do other things with his time off. His company was not associated with ACCA or any other contracting business association. He had attended a training to refresh basic skills when he started with his new firm, but could not remember who sponsored the training. None of his peers used high-technology diagnostic tools that he knew of. He was slightly familiar with the high-technology diagnostic tools, having heard of them, but thought they were probably unnecessary to do his job.

This technician provides us one look at what HVAC technician's social network may look like without membership in a professional association. It is a limited network with a small number of people he depends on for advice and help, being limited to the two firms he has worked for. Since neither one has purchased diagnostic tools, he has had little opportunity for exposure to these tools.

Recommendations for Energy Efficiency Programs

There is little available evaluation data on the promotion of diagnostics in programs to date. In a comparison of two programs (NYSERDA's commercial HVAC maintenance program and the Connecticut Light and Power Program described in Table 1), multiple lessons learned about the implementation of HVAC diagnostic programs are presented (Taylor, 2004). Among them, it's reported that technicians respond much better to field-based training than classroom and that they benefit greatly from feedback early and often. Additionally, it's reported that technical support is essential to helping technicians understand how the diagnostic tool works and how a fault in the system is identified. Other lessons learned include that the technician's understanding of the refrigeration system is a major barrier to successful use of the tool and that firms which outfit and train higher percentages of technicians outperform less equipped firms by a large margin. These findings are consistent with our inferences drawn from the sociology literature. In this section, we discuss some of the potential implications of these broader theorizations and understandings of HVAC technician work for programs and offer some recommendations. To provide guidance to program managers in focusing on human dimensions of new technology use, we identify two sets of questions that program managers should consider when designing a program promoting high-tech diagnostic tools. We then subsequently offer three specific recommendations for HVAC technician training around the adoption advanced technologies.

1. What ways of knowing and skills does the tool we are thinking of promoting require? Are these skills different than the ones already possessed by those who are intended to use the tools?

   The possibility that the use of high-technology diagnostic tools may shift how a technician understands and knows his job from experiential knowledge (*action centered skills*) to more abstract thinking (*intellective skills*) is important for understanding the integration of a tool into everyday work practices. This provides insight into the observation that training is not just about learning how to use a new tool. It should not be assumed that technicians have the skills needed to interpret and understand the implication of the results of advanced diagnostics. Teaching which buttons to push may not be enough to accomplish the goals of maximizing system efficiencies and creating lasting market change. Instead, a program promoting high-technology diagnostic tools may need to focus on empowering technicians through a new set of skills that enable the interpretation and understanding of the results provided by the tools. To accomplish this, training that enables more abstract thinking skills, such as the fundamentals of systems and thermodynamics, should be emphasized. It is only with these skills and subsequent empowerment that technicians are likely to perceive tools as useful and embrace them fully.
2. If high-tech diagnostic tools require new skills and knowledge, where will those using the tools receive help from outside of the program? How can these other resources be leveraged?

   With the recognition that the integration of new tools into the work practices may require new skills and result in new challenges, our review highlights the importance of thinking of how technicians deal with new problems and get help in their fieldwork. Technicians in the field may have unique social networks that are different than the owner of the contracting business or the purchasers of the diagnostics. These social networks may be capitalized upon as important ways to support the successful use of the tools. Exploring the structure of the technician's networks, where they will go to for help, and the business model of the companies they are working for, may inform program design. Providing inexpensive opportunities for technicians to join existing networks and enable a community of practice to develop may be an important way to help diffuse knowledge. One interesting development to note is the existence of a virtual community of practice. The website http://hvac-talk.com/vbb/ has over 150,000 posts under its residential and commercial HVAC sites (though some of these are customers, there is an effort to keep it an accessible industry website and not a site for "do-it-yourselfers" to get free professional information). Many of the postings are reports from the field and problems that are recently encountered and particularly troublesome. The Service Roundtable™ (www.serviceroundtable.com) is another example of an on-line network for technicians and business owners to share experiences and improve their capabilities.

In exploring these questions in the context of promoting high-technology diagnostics to HVAC technicians, perhaps the most program relevant conclusion to emerge is that training is a necessary (though not sufficient) condition for the successful use of new technologies in the workplace and that a sociology of work perspective provides some guidance on how that training may be structured to overcome the barriers we've identified. Based on the assumption that our theoretical conceptualization of HVAC technician fieldwork proves accurate, we suggest that there are three keys to optimally designing HVAC training to enable successful technician adoption and mastery of tools and the resulting persistence of savings programs are seeking.

1. Provide hands-on-training, which builds on a technician's experiential *ways of knowing.*
2. Provide training in the basic principles of HVAC systems and opportunities to practice applying more abstract knowledge
3. Leverage *social networks* and *communities of practice*: Offer training through established social networks such as trade associations where technicians are likely to be able to access those they are trained with in the future for help

Implications for Future Research

The findings of this research do not suggest dramatic change by program administrators is necessary, as they often already include significant training. We would in part attribute this to the fact that recently developed programs have often involve HVAC industry representatives that understand how technicians work from experience - though they may not place this knowledge in the more abstract terms like *ways of knowing* and *communities of practice*. We hope that this paper highlights the importance of accounting for the human dimensions of work processes in the promotion and implementation of new technologies. We particularly wish to advocate for a dual focus on both the purchasers (contractors) of the technology and the users (technicians) who must integrate these tools into their daily work lives. We would suggest that the protocol developed Appendix 1 or one like it could be used to explore the application of these concepts in more diverse situations providing further depth and support to these understandings. Observing and interviewing technicians that have adopted technologies would be foremost to improving our knowledge in this area. In addition, the sample of technicians researched should have a broad range of experience, training, and professional networks to shed light on how these factors influence the successful use of high-technology diagnostics. The advancement of our understanding of the integration of technologies into human work processes can contribute to the true market transformation of the HVAC industry and the persistent energy savings utilities and customers are seeking.

Appendix: Observations Made and Questions Asked of HVAC Technician

HVAC Technician Demographics

1. M or F
2. Age
3. Years of Practice
4. Years of education
5. Current Work Title and Company
6. Membership in professional associations

HVAC Technician Ways of Knowing (Questions guiding observation of the contractor)

1. What type of information was the contractor provided before arriving at the job?
2. When arriving at the job, what was the first thing the contractor did?
3. How did the contractor go about diagnosing the problem?
4. How did the contractor know that he had fixed the problem?

HVAC Technician Ways of Knowing (Questions asked of the contractor)

1. How did you know what the problem was?
2. What are the most common problems you find?
   a. How do you know when it is one of these problems?
   b. What tools do you typically use for these problems?
3. What was the most difficult problem you had to fix?
   a. What made it a difficult problem?
   b. How did you diagnose it?
   c. How did you fix it?

Social Capital and HVAC Networks

1. Who do you talk to about the technical aspects of your work?
2. When and how often do these talks usually take place?
3. Are you a member of a trade association (ACC, SMACNA, Service Roundtable, and PHCC)?
4. Do you pursue training? How often? From whom? What kind? Why?
5. If you seek help to solve a difficult problem on the job, who do you ask?
6. Have you used a high-technology diagnostic – defined as a “tool that automates data acquisition, calculates system performance indicators like superheat and sub-cooling, provide front line decision support using diagnostics, and documents performance improvements”?
7. If you have not used them, have you heard of any of them? (Aeroseal, Service Assistant, RCA Verification, Enalysys, and Testo)
8. Do you talk to anyone who uses a high-technology diagnostic?
9. What do you think of them? (perceived benefits, disadvantages)
10. Why do you think that?

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