



Intervention to Improve Purchasing Decision-Maker Perceptions of Ventilated Tools

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Abstract: A theory-based intervention strategy to improve purchasing decision-maker perceptions of ventilated tools was developed, implemented, and tested. The intervention was designed to target key constructs of the prevention through design adoption readiness model (PtD ARM), a previously published conceptual model. A Web-based intervention was developed that included information about the health effects of construction dust, a testimonial by a firm owner, and a video demonstrating side-by-side use of both ventilated and nonventilated tools, which provided visual evidence of dust generation and productivity performance. In a pretest/posttest with a control group and an experimental design, purchasing decision makers ($n = 49$) were contacted by telephone. A validated survey instrument was used to collect perception data and open-ended responses regarding barrier information. Gain score t-test analysis found significant improvements in perceived ease of use, health knowledge, and perceived risk in the intervention group. Open-ended results identified barriers to the use of ventilated tools. The intervention methods presented in this paper can be used by future researchers and occupational safety and health practitioners to improve the use of safety innovations. DOI: 10.1061/(ASCE)CO.1943-7862.0000961. © 2015 American Society of Civil Engineers.

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Introduction

Overview

Drywall finishing operations are associated with worker overexposure to mineral dusts that have negative impacts on health. Ventilated tools have been found to reduce worker dust exposure; however, adoption of these tools in the industry is not widespread. Therefore, this paper describes a theory-based intervention strategy to improve drywall finishing firm adoption of ventilated drywall sanding tools. Respiratory disease among construction workers in general and plasterers and wall finishers in particular is a major public health concern. Workers in these trades suffer from disproportionately high rates of respiratory disease and disability. Drywall finishing operations have been associated with worker overexposure to dust containing known particulate respiratory health hazards such as silica, talc, mica, and calcite. Despite the existence of effective engineering controls, such as ventilated sanders and low-dust drywall compound, worker exposure persists. Previous work by the authors identified key barriers to the adoption of dust control technology and diffusion of innovation in the construction industry. In previous studies by Young-Corbett and Nussbaum (2009b), ventilated drywall sanding tools were found

to be highly effective in reducing dust; however, a survey study revealed industry-wide usage to be very low. Through interviews of firm owners and workers and through a laboratory-based comparison of the usability of several tools, Young-Corbett and Nussbaum (2009b) identified barriers to technology adoption related to productivity, work quality, and perceptions of benefits and risks. Previous work by Koebel (2008) examined construction industry characteristics that influence adoption of new technologies and identified strategies for enhanced innovation diffusion. This paper describes work that translated these previous findings into an intervention strategy to improve dust control adoption by firms. Diffusion strategies are required to promote the successful dissemination and adoption of innovations. While there has been considerable attention given to the diffusion process and variables influencing adoption, these data come solely from retrospective studies; there is no evidence regarding prospective strategies to promote diffusion of safety and health innovations in the construction industry. The development and evaluation of a diffusion intervention strategy presents a significant opportunity to recommend a diffusion strategy for other safety innovations in the construction industry.

Health Hazards of Drywall Dust

Workers in the wall finishing trades suffer from disproportionately high rates of respiratory disease and disability. Epidemiologic studies have found associations between drywall finishing work and the morbidity and mortality of respiratory disease. In a study of proportionate mortality patterns for male construction workers in North Carolina, Wang et al. (1999) found a significant cancer risk for drywall workers. This group had significantly elevated proportionate mortality ratios (PMRs) for malignant neoplasm of the pharynx (PMR = 178), trachea, and bronchus (PMR = 118) and of pneumoconiosis/other respiratory disease (PMR = 152). Specifically, drywall finishers and laborers were found to have a statistically elevated risk of death from cancer of the pharynx (PMR = 133) and lung (PMR = 110) and respiratory tuberculosis (PMR = 675).

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Drywall finishing operations have been associated with worker overexposure to dust that contains known particulate respiratory health hazards. The National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of worker exposure to drywall dust and potential health effects associated with drywall finishing work during renovation activities (Miller et al. 1997). This study of workers performing drywall sanding tasks evaluated the main constituents of the drywall-joint compound, worker respiratory symptoms, and dust exposure levels. Drywall finishers were exposed to as much as 10 times the permissible exposure limit (PEL) of 15 mg/m³ for total dust. The PEL for respirable dust (5 mg/m³) was also exceeded. Respiratory symptoms were found to be common among drywall finishers and tended to improve when workers were away from the workplace. Joint compound constituents were identified as calcite, quartz (silica), talc, mica, gypsum, clays (aattulgite and kaolinite), and perlite, with the two most prevalent constituents being calcite and mica. The term *mica* refers to a family of minerals of similar chemical composition and physical properties. They are potassium aluminum silicates with variable amounts of iron and magnesium. Mica has been associated with pneumoconiosis (Verma et al. 2003). Calcite, a form of calcium carbonate (CaCO₃) found in limestone, chalk, and marble, has been implicated in airway obstruction (Bohadana et al. 1996). Bohadana et al. (1996) found a significant across-shift decline in all parameters associated with airway obstruction in chalk-powder (calcite) manufacturing workers. Calcite exposure levels correlated with a decrease in airway function. Quartz (crystalline silica) has well-documented effects on the human respiratory system and has been associated with silicosis, a fibrotic disease of the lung, and malignant neoplasm of the lung (Mead et al. 2000). The International Agency for Research on Cancer (IARC) has classified quartz as a *Group 1 human carcinogen*, a classification indicating that sufficient evidence of causality exists in the scientific literature (IARC 1985).

Ventilated Construction Tools

A NIOSH hazard control study found that ventilated sanding systems reduce drywall dust levels by 80 to 97% (Mead et al. 2000). This evaluation of five commercially available ventilated drywall sanding systems found that four of the five systems reduced dust concentrations by more than 90%. A study of the relative dust control effectiveness of drywall sanding technologies found that ventilated sanders produced significantly less dust of both respirable and thoracic size classes than did a conventional block sander (Young-Corbett and Nussbaum 2009a). The ventilated tool reduced respirable concentrations by 88% and thoracic concentrations by 85%. Despite the existence of dust control technologies for the mitigation of this hazard, worker exposure to dust persists in the drywall finishing industry (NIOSH 2000). A survey of owners of drywall finishing contracting firms revealed that ventilated sanders, low dust-joint compound, and wet methods are not employed by most workers (Young-Corbett and Nussbaum 2009b).

Barriers to Adoption

Much of the research on innovation in the construction industry has focused on the barriers to adoption (Slaughter 1998). Adoption of innovations in construction has been defined as a firm's use of a technological innovation in at least 25% of the cases in which it has an opportunity to use the innovation. Industry barriers to adoption include market changes, negative perceptions of innovation, and inflexible performance standards. Frequent downturns in the construction market may deter firms from adopting innovations (Blackley and Shepard 1996). Regulatory bodies in construction can also have an impact on the success of innovations. The development of new products or processes in construction is not always

welcomed by all parties (Oster 1977). Building codes and construction regulations often serve as constraints or drivers of innovations (Manseau and Shields 2005). Stringent standards for product performance, safety, and environmental impacts can create pressure for firms to innovate, improve quality, and upgrade technologies (Gann et al. 1998). Unions may resist innovations that are viewed as labor-saving or labor-eliminating products or processes (Blackley and Shepard 1996).

Cost, risks, uncertainty, and limited control over the way construction work is performed and the products that are chosen make diffusion of innovation in the construction industry difficult (Blackley and Shepard 1996). Barriers that affect the implementation of innovations also include contract issues, the cost of research, lack of information about available innovation, and lack of awareness of the potential cost savings of adoption (Ling 2003). Evidence that products and processes will provide an advantage over existing methods and products can serve as a driver for adoption. A study by Toole (1998) found that builders become more likely to adopt a product if they have witnessed that product in successful use elsewhere. Builders are frequently unwilling to adopt innovations because of concern about risk and lack of awareness of benefits (Manseau and Shields 2005).

One significant barrier to adoption for safety and health innovation in the construction industry is a lack of knowledge of health risks (Kramer et al. 2009). The lack of understanding that hazards exist or that controls are available can influence the decision to adopt. Managers tend to devote more attention to items that are failing than to those that are meeting their targets (Mitropoulos and Tatum 1999). In a study of owner perspectives on dust control, a telephone survey was conducted to identify barriers to technology adoption and explore firm owner perception of risk (Young-Corbett and Nussbaum 2009b). Barriers associated with technology usability, productivity, and costs were identified. Additionally, a misperception of the risk to worker health was interfering with motivation to adopt the prevention through design (PtD) innovations.

Research by Koebel (2008) has documented the complexity of innovation diffusion in the construction industry. Several industry characteristics are considered impediments to innovation, particularly site variability, the *one-off* project character of most building construction jobs, the regulatory climate, industry fragmentation and decentralization, a low level of research and development (R&D) investment, boom-bust business cycles, and the position of construction companies in the supply chain (Koebel 1999, 2008). Key factors influencing diffusion can vary across firm size, including the role of champions and the information channels influencing diffusion.

Although prescriptive building codes are often perceived as impediments to innovation in construction, governmental regulations can be very instrumental in influencing innovation adoption and diffusion, but the impacts are complicated and sometimes have opposing effects (Baldwin and Cave 1999). The traditional model of regulation frequently mandates adoption of specific health and safety practices or adherence to standards of performance. The long history of automotive safety innovations points to the coevolution of regulatory mandates and safety innovation diffusion (Leonardi 2010). Jensen et al. (2011) found that effective federal energy policies include both incentives and impediments for the adoption of lignocellulosic ethanol as a low-carbon fuel source. In the macroeconomic literature on induced innovation, regulations impacting factor prices are expected to induce innovations in response to prices. Jaffe and Palmer (1997) found that regulatory compliance costs had the expected positive effect on the patenting of environmental technologies by industry. Taylor et al. (2005) also found that regulatory stringency induced innovation and diffusion of sulfur dioxide control technologies; Kammerer (2009) reported similar results for

environmental product innovation among appliance manufacturers in Germany. Bossink (2004) found that government regulations and incentives were drivers of innovation in construction networks in the Netherlands, whereas *market pull* from the building owner did not induce construction innovations. The timing, character, and composition of regulations, including the mix of mandates and incentives, are likely to be important in the diffusion trajectory of PtD health and safety innovations in the construction industry.

In a study of two national surveys of innovation adoption in the residential construction sector, factors affecting technology adoption by small and large firms were identified. Small builders were found to be more receptive to innovation and the influence of key “technology champions” (Koebel 2008; Baldwin and Cave 1999). Demonstration projects that introduce new technology to owners of small firms were found to convert these builders into champions of the innovations. In large-scale production residential building firms, it was found that technology adoption decisions were more likely to be made by purchasing units of the organization. Therefore, the technology champion model had less impact in this sector. The study suggested that these larger firms should be targeted with information about affordability, efficiency, and productivity of innovations to increase adoption and diffusion within the large-scale residential construction sector. Therefore, the present study selected a Web-based information dissemination approach for the intervention targeted at large-firm purchasing decision makers.

Theory-Based Intervention Strategy

Because the adoption of ventilated sanding tools involves adoption of an innovative *technology* for the purpose of preventing a *health* outcome, a conceptual model that weaves together constructs pertinent to technology adoption and health behavior change was employed as the theoretical framework for the intervention strategy described in this paper. The PtD adoption readiness conceptual model describes the parameters and causal relationships that influence and predict construction stakeholder *adoption readiness* for PtD technology innovation (Weidman et al. 2014a). The conceptual framework for the prevention through design adoption readiness model (PtD ARM) (Weidman et al. 2014a) integrates elements of three previously validated frameworks: the technology acceptance model (TAM) (Davis 1989), the health belief model (HBM) (Rosenstock 1960), and the diffusion of innovation model (DOI) (Rogers 2004). Well-established theoretical frameworks were chosen from the fields of health promotion, technology adoption, and innovation diffusion. These theoretical frameworks are highly interrelated and address from their own perspectives very similar outcomes: the decision to use new practices or products. A framework integrating these theoretical models was needed to describe constructs that are pertinent to decision making that is related to both health behavior and technology adoption.

In the PtD ARM, *actual usage* is predicted by the construct adoption readiness, the model’s endogenous variable. Adoption readiness has several modifying antecedents: *self-efficacy*, *perceived ease of use*, *perceived usefulness*, *trust in organization*, and *social system influences*. These constructs were extracted from the three foundational theoretical frameworks. All of these constructs are thought to positively correlate with the endogenous variable, with the exception of social system influences, which could correlate positively or negatively, depending on the influence under consideration. In the model, perceived usefulness is thought to be modified by *trust in technology*, *relative advantage*, *reliability*, and *compatibility*. Perceived ease of use is thought to be modified by the *complexity* of the technology and whether the stakeholders have the chance to become familiar with the technology (*trialability* and *observability*).

Self-efficacy is thought to have modifying effects on perceived ease of use as well. The HBM constructs of *perceived risk* and *perceived benefits* are thought to influence stakeholder trust in the PtD technology. Perceptions of the severity of health outcomes and individual susceptibility to health outcomes will impact perceived risks.

Health Belief Model

The HBM was developed in an effort to predict health-related attitudes and behaviors and has been applied to study all types of health behavior. The HBM has been used to explain both adoption (compliance) and maintenance (adherence) of behavior change. It has been employed in various configurations of the original model developed by social psychologists in the U.S. Public Health Service in the 1950s. (Hochbaum 1958; Rosenstock 1966, p. 331). The original HBM contained the following four key constructs:

1. Perceived susceptibility: An individual’s assessment of his or her risk of getting the condition;
2. Perceived severity: An individual’s assessment of the seriousness of the condition and its potential consequences;
3. Perceived barriers: An individual’s assessment of the influences that interfere with or discourage adoption of the promoted behavior; and
4. Perceived benefits: An individual’s assessment of the positive consequences of adopting the behavior.

Subsequent to the Rosenstock (1966) version of the HBM, other authors added modifying factor constructs that have been found to influence the aforementioned perceptions. These are demographic variables, sociopsychological variables, perceived self-efficacy, cues to action, health motivation, and perceived control.

Technology Acceptance Model

The TAM was developed by Davis (1989) to explain the factors that influence the decisions to accept or use new technology (Venkatesh 2000a). The TAM was originally designed to understand and predict user intentions to accept new computer technologies but has been used to understand technology acceptance in various fields of study, including medical technology, communication systems, and information technology (Hu 1999; Chau 1996; Venkatesh 2000b; Brown 2002; Yi et al. 2006). Holden and Karsh (2010) discuss the utility of this model in health-related context and review the extant literature pertaining to TAM applications to healthcare information technology. The TAM has been used to show that prospective adopters’ behavioral intentions to use a technology correlate to the actual usage of the technology (Chau 1996). If potential users do not fully accept the new technology, they can obstruct the new system and cause it to be underutilized (Brown 2002). The TAM comprises two main constructs: perceived usefulness (PU) and perceived ease of use (PEOU) (Davis 1989).

DOI Model

Rogers’ (2004) DOI model is a model that describes diffusion as “the process by which an innovation is communicated through certain channels, over time, among the members of a social system” (Brown 2002). Rogers (2004) theorized that innovations would spread through society in a pattern that is normally distributed and that market saturation would be described by a logistic function. Innovators select the technology first, followed by *early adopters*, and then the majority, until the technology or innovation is commonly used. The Rogers (2004) model is essentially a process of incremental learning and transfer of knowledge from the initial set of users to potential users. Innovation is defined as a significant improvement in a product, process, or system that is

new to those who will be developing or using it (Manseau and Shields 2005). One of the necessary components of an innovation is the ability of the innovation to improve some aspect of the adopter's performance of a work task (relative advantage) (Toole 1998). Much diffusion research has focused on the conditions that increase or decrease the likelihood that a new idea, product, or practice will be adopted by members of a given culture. The mechanism of diffusion is described as a five-step learning process: knowledge, persuasion, decision, implementation, and confirmation. The earlier stages of diffusion—launch and early adoption—are more critical in establishing the overall trajectory of the diffusion curve.

Methods

Intervention Design

The intervention for the large-firm decision makers was designed to target improvements in the following constructs, as they were identified in the authors' previous work as barriers that interfere with firm adoption of dust control technologies: perception of risk to worker health associated with drywall dust and perceived negative impacts to work productivity and quality. The design of the intervention included the PtD ARM constructs of relevance to large-firm purchasing decision makers: perceived risk to health, health knowledge, PU, PEOU, and trust in technology. The intervention aimed at improving these constructs within the purchasing decision-maker population, as these constructs were identified as barriers to adoption of dust control tools and methods in previous studies (Young-Corbett and Nussbaum 2009b). Purchasing decision makers play a sizeable role in the adoption of new products and methods in large companies and are responsible for the decisions made and innovative risks taken (Koebel 2008). Previous studies indicated that major barriers to adoption were concerns about productivity and construction quality, as well as a lack of knowledge of health risks to workers (Young-Corbett and Nussbaum 2009b). Therefore, this intervention contained elements to address the three topics of productivity, quality, and health.

Productivity Study

To develop information about quality and productivity for inclusion in the intervention, a time study was conducted of drywall finishing with ventilated and conventional sanding tools. Work measurement is a discipline within the field of industrial engineering in which work operations are categorized into discrete tasks and the cycle time and worker motions required to fulfill the tasks are quantified. The cycle time is the time it takes for an average trained worker to carry out a specified task, from start to finish, at a defined level of performance. In a time study, several time metrics are assessed: task cycle time, normal time, allowance factor, and standard time. Each work operation is broken into discrete tasks, and the start-to-finish cycle time for each is measured. In the drywall sanding operation, there were two clear tasks: sander preparation and sanding. Cycle times for each were measured in this time study. Normal time is the sum of all task cycle times involved in a single operation. Allowance factors are adjustments made to the normal time to obtain the standard time to account for lost time due to personal needs, fatigue, and unavoidable delays. This quantification of the standard time of tasks is useful in the improvement of operation productivity and also in making direct comparisons between task methods to determine their relative productivity. Identical sanding tasks were performed using two different tools: a pole hand sander and a ventilated sander. Power analysis [Eq. (1)] determined that a minimum sample of 19 task cycles should be measured with each method.

$$n = \frac{z^2 p(1-p)}{h^2} \quad (1)$$

where n = required sampling size; z = 1.65 for a 90% confidence level; p = estimate of idle proportion = 6% = 0.06; and h = acceptable error of 9% = 0.09.

$$n = \frac{(1.65^2)(0.06)(1-0.06)}{0.09^2} = 18.96 \approx 19$$

The sanding sessions were video recorded, and analysis was performed to obtain data about the task cycle times. The sanding area square footage completed in a given amount of time was measured to determine the productivity of the workers. Table 1 provides the results of the time study. The quality of the finished surface was evaluated by a professional drywall finisher with more than 10 years of experience. The rater assigned a quality score on a scale of 1 = poor to 10 = excellent. The tasks performed with the ventilated sander scored significantly higher in both the cycle time and quality metrics. The average quality score for the hand-sanding method was 7.5 and for the ventilated sander was 8.2. The standard time metric for the ventilated sanding method was 72.5% of that with the pole sander. The quality and productivity results of this time-motion study were included in the Web-based intervention. Also, a side-by-side video clip (Fig. 1) of the task being performed with each tool provided participants with visual evidence of both the difference in dust generation and the difference in task cycle time for the two sanding methods.

Firm Owner Interview Video

Because previous work has identified that construction decision makers are more likely to adopt an innovation when they see that their peers are doing so, a video clip testimonial was used in the Web-based intervention. In this clip, the firm owner is seen holding the tool and enthusiastically endorsing its use in drywall finishing operations. He describes the benefits to productivity and the reduction in dust.

Health Risk Knowledge

Aimed at improving purchasing decision-maker knowledge of the health risks associated with drywall finishing dust, content was created regarding health impacts. This content covered the health effects, such as irritation, asthma, chronic respiratory disease, and lung cancer. Also covered was the evidence that drywall finishers are overexposed to silica and other mineral dusts.

Web-Based Intervention Structure

A website was developed that would contain the intervention materials and also provide a portal through which the participants would complete the survey instrument and receive their gift certificate compensation. There were 10 pages in the website, including an

Table 1. Mean Time in Minutes by Sanding Method

Time metric	Sanding method	
	Hand	Vacuum
Sanding time	21.53	16.37
Preparation time	0.11	1.89
Total normal time	23.79	17.45
Allowance factor (%)	9	8
Standard time	26.14	18.97

Benefits of Vacuum Sanders - Productivity

Vacuum sanders save your company time. A group of student researchers at Virginia Tech University conducted a time-motion study analysis comparing vacuum sanding and pole sanding and found that along with significant reductions in dust exposure, the powered vacuum sander increased productivity by 27%. The physical effort required by workers was reduced when measuring fatigue factors and finish quality was comparable to hand or pole sanding when reviewed by an experienced drywall finisher.

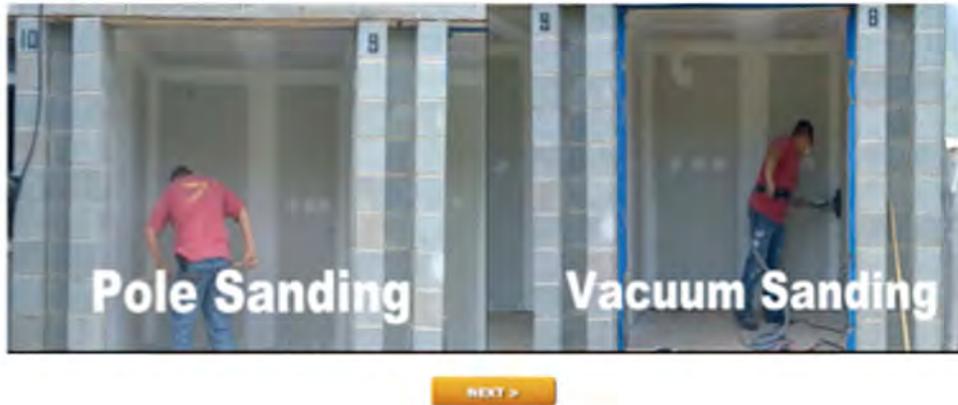


Fig. 1. Screenshot of side-by-side video showing both tools (images by Justin Weidman)

overview of the study, informed consent, health risk information, ventilated tool information, the firm owner interview video, and the time-motion study video and information.

Data Collection

Data for the study were collected utilizing a previously validated survey instrument (Weidman et al. 2014b). The instrument contained scaled items pertaining to PtD ARM model constructs and open-ended questions pertaining to barriers to adoption. Model construct questions addressed health knowledge, perceived risk, PU, trust in technology, PEOU, and adoption readiness. Health knowledge items targeted participant knowledge of the mechanisms by which drywall dust impacts worker respiratory health. Perceived risk items aimed at assessing participant knowledge of the prevalence of respiratory disease and the likelihood of acquiring illness from exposure to drywall dust. PU items assessed participant perception of how the powered sanding tool would benefit work production. Trust in technology items were written to measure participant perception of how well and reliably the powered sander would perform. Ease of use survey questions measured how easy the participants believed that it would be to operate the equipment. Adoption readiness items measured the participants' willingness to purchase and implement the powered sanding tools in company work operations. The survey instrument was developed through a rigorous protocol involving construct operationalization; cognitive methods; and testing for unidimensionality, reliability, and validity. Model constructs were operationalized through a multistep process involving review of the literature for existing scales, selection of previously validated items, adaptation of those items, and card-sorting protocols for verifying construct item correspondence. An initial item pool was subjected to cognitive interviewing techniques using a focus group of subject matter experts (SMEs) to check for item understandability, clarity, and meaningfulness. A revised item pool was then administered to a group of participants

($n = 100$) at the national Association of Wall and Ceiling Industry annual conference, and these data were employed in statistical analysis to determine reliability and validity through confirmatory factor analysis, Chronbach's reliability coefficient, and Bentler-Bonnett's coefficient. Through an iterative revision process, which ensured sufficient reliability and validity, final instrument scales were established for evaluating the adoption readiness for workers and employers in the drywall finishing trade (Weidman et al. 2014b).

Each scaled item was scored on a 7-point Likert scale with the following: 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neither disagree nor agree, 5 = somewhat agree, 6 = agree, and 7 = strongly agree. For the intervention group ($n = 25$), data were collected at the initial time of contact (pretest), immediately following the intervention (Posttest 1), and 3 months following the intervention (Posttest 2). For the control group ($n = 25$), data were collected at the initial time of contact (pretest), 1 day following initial contact (Posttest 1), and 3 months following initial contact (Posttest 2). The statistic of interest was the *gain score*, which is defined as $\text{gain score} = (\text{posttest score}) - (\text{pretest score})$. Firms were recruited from the national trade organizations for drywall finishing: the Finishing Contractors Association and the Association of Wall and Ceiling Industries. Because large firms were the target population for this study, firms with a minimum of 100 employees on the payroll were included in the sample population ($n = 857$). Firms were randomly assigned to treatment and control groups.

The Virginia Tech Center for Survey Research phone bank service made telephone contact with key purchasing decision makers at large companies. In the initial telephone contact, consent to participate was obtained. Pretest survey data were collected at this point for control group participants by directing them to the online survey instrument. For intervention group participants, a follow-up e-mail was sent to the purchasing decision maker that contained a link to the intervention website. Participants were asked to log in, take the pretest, participate in the intervention, and then take a

posttest. Three months following the submission of the initial posttest, reminder calls were made to control group participants, and e-mails were sent to intervention group participants with a link to a second posttest. The second posttest was designed to measure the impact of the intervention on perceptions over time. Participants were compensated with a gift card to a national home supply retail store.

Data Analysis

Scaled survey items were analyzed using the independent t-test of the gain scores to test for differences in the control and intervention groups. All statistical analyses were performed using *JMP 9.0.0*. Content analysis procedures were used to analyze the open-ended survey response items included on the survey instrument. The research team developed codes that were both exhaustive and mutually exclusive for each set of questions. These codes were then assigned to each unit of response by independent coders who had been trained on the category code definitions and coding process. Interrater reliability was calculated for each set of codes using Krippendorff's alpha, with significance set at $\alpha = 0.80$ (Krippendorff 2004). Items that did not have adequate rater agreement were not included in the frequency counts.

Results

Scaled Survey Items

As summarized in Table 2, significant differences in gain scores between the intervention and control groups were seen for the following constructs: health knowledge, perceived risk, PU, and PEOU. Of those, intervention group improvement in health knowledge and PU was only evident in the second posttest and not the first. There were no significant improvements in the intervention group scores on the trust in technology construct or the adoption readiness construct when compared to those of the control group. There were no significant differences between the pretest scores of the treatment and control groups ($p = 0.29$).

Open-Ended Survey Items

Interrater reliability was within acceptable limits for the content analysis methodology for the open-ended survey items (Table 3). Krippendorff's alpha exceeded the established level of 0.80; therefore, agreement between the evaluators was deemed acceptable. Fig. 2 shows the codes and response frequencies. Of the 184 units of response to the survey item on barriers, 69 concerned the effectiveness of dust control of the tool, 45 pertained to specific

Table 2. Technology Perceptions: Control and Intervention Groups (t-Tests of Gain Scores)

Construct	Degree of freedom	Mean	Standard error	p-value	Significance
Health knowledge Posttest 1					
Control	23	-0.13	0.38	0.29	—
Intervention	24	0.17	0.37	—	—
Health knowledge Posttest 2					
Control	23	-0.13	0.48	0.08	a
Intervention	18	0.89	0.54	—	—
Perceived risk to health Posttest 1					
Control	23	-0.60	0.54	0.05	b
Intervention	24	0.63	0.53	—	—
Perceived risk to health Posttest 2					
Control	23	-0.60	0.63	0.03	b
Intervention	18	1.22	0.70	—	—
Trust in technology Posttest 1					
Control	23	0.04	0.41	0.28	—
Intervention	24	0.37	0.40	—	—
Trust in technology Posttest 2					
Control	23	0.04	0.52	0.11	—
Intervention	18	1.05	0.59	—	—
Perceived usefulness Posttest 1					
Control	23	2.22	1.28	0.23	—
Intervention	24	3.54	1.25	—	—
Perceived usefulness Posttest 2					
Control	23	2.21	1.66	0.20	—
Intervention	18	2.17	1.88	—	—
Perceived ease of use Posttest 1					
Control	23	-0.04	1.01	0.01	c
Intervention	24	3.13	0.99	—	—
Perceived ease of use Posttest 2					
Control	23	-0.04	1.45	0.02	b
Intervention	18	4.22	1.64	—	—
Adoption readiness Posttest 1					
Control	23	0.39	0.41	0.56	—
Intervention	24	0.29	0.40	—	—
Adoption readiness Posttest 2					
Control	23	0.39	0.70	0.71	—
Intervention	18	0.22	0.79	—	—

^aSignificant at 0.10.

^bSignificant at 0.05.

^cSignificant at 0.01.

Table 3. Interrater Reliability for Content Analysis

Reliability parameter	Result
Percent agreement	94%
Scott's pi	0.922
Cohen's kappa	0.922
Krippendorff's alpha (nominal)	0.922
<i>N</i> agreements	173
<i>N</i> disagreements	11
<i>N</i> cases	184
<i>N</i> decisions	368

limitations of the tool, 23 were concerns about diminished productivity, 10 related to a lack of experience with the tool, 9 were concerns about reduced finish quality, 9 identified cost barriers, 9 identified specific conditions of use that would render the tool useless, 8 claimed that the tools were too new to the market, and 2 responses stated that other finishing methods were superior.

Discussion

This study demonstrates that theory-based intervention strategies can have a positive impact on perceptions associated with the adoption of new innovations. Specifically, decision-maker knowledge of the risks to worker health and PU and usability of the ventilated sanding tool were positively impacted by the Web-based intervention strategy. However, not all targeted constructs were influenced by the intervention. Perhaps most importantly, the readiness to adopt the innovation was unaffected by the intervention. Thus, further work is needed to more fully address the barriers to safety and health innovation and widespread diffusion within the construction industry. Responses to the open-ended questions of the survey instrument provide some insights into the persistent resistance to adoption of this tool. Respondents primarily identified factors associated with the perceived dust control effectiveness of the tool and limitations associated with the job site and logistics. The intervention approach included a video demonstrating the dust control effectiveness of the tool. On one side of the video, the sanding tool was operated without ventilation, and the worker was barely

visible in the resultant cloud of dust. On the contrasting side of the video, the ventilation system was in use, and there was no visible dust present. However, this evidence must not have been sufficient to influence purchasing decision-maker perceptions of the effectiveness of this tool.

The intervention strategy did not specifically address site and logistics barriers. Further work is needed to elucidate these barriers and develop solutions to overcome them. Research by Koebel (2008) has documented the complexity of innovation diffusion in the construction industry. Several industry characteristics are considered impediments to innovation, particularly site variability, the one-off project character of most building construction jobs, the regulatory climate, industry fragmentation and decentralization, a low level of R&D investment, boom-bust business cycles, and the position of construction companies in the supply chain (Koebel 1999, 2008). These themes were reflected in the findings from the open-ended questions of the survey. Most notably, site variability and decentralization were themes identified in the *limitations* category of the content analysis of the responses. Therefore, the need for ventilated construction tools that can adapt for use in various sites and settings is a suggestion for future research and exploration.

A paradoxical finding of this study was evident in the health knowledge and PU constructs; there were significant differences in the Posttest 2 scores but not in the Posttest 1 scores. This result is unexplained by the data of the current study; however, the authors speculate that a possible explanation could involve additional mental processing time for the intervention materials. In the months following the intervention, perhaps participants reflected upon the materials while observing the work of their firms. This finding could be further explored in future intervention studies of this nature.

Conclusion

This paper presents a successful intervention strategy to improve purchasing decision-maker perceptions of the risk to worker health of drywall dust and the usefulness and usability of ventilated sanding tools. The intervention strategy aimed to address barriers to adoption of dust control technology found in previous studies

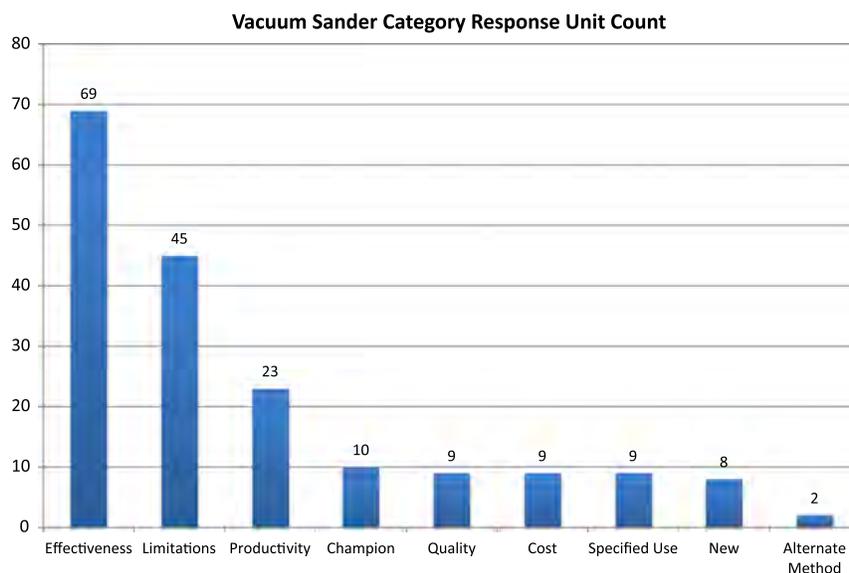


Fig. 2. Categories and frequencies of responses to the question: “Why doesn’t your firm use ventilated sanders?”

(Young-Corbett et al. 2010). Constructs specifically targeted by the intervention were perceived risk to health, PEOU, PU, and trust in technology. These constructs are all expected to ultimately impact the model's endogenous construct: readiness to adopt. While the Web-based intervention strategy did positively impact participants' perceptions of the risk of drywall dust, the usefulness of the ventilated sander, and the ease with which the tool can be used, there was ultimately no significant impact on decision makers' readiness to adopt the tools within their firm operations. Analysis of an open-ended question soliciting information about barriers to the widespread adoption of the ventilated sanders identified that concerns about tool effectiveness, function, and worker productivity were most common. Less prevalent were concerns about drywall finish quality, cost, and availability.

Practical Applications

It is recommended that the construction industry continue to develop effective intervention strategies using the methods used in this research and continue to develop theory-based methods to improve the safety and health of those in the industry. The success of interventions relies heavily on the relative advantage that the innovation provides to the users. Successful interventions to increase innovation usage require that rewards be shared between the players involved in the construction process, including clients (Manseau and Shields 2005). The PtD adoption readiness model integrating the HBM, the TAM, and the DOI model has produced some significant results for increasing the intent to use control methods and should continue to be used and refined to design, implement, and evaluate future safety and health interventions.

Contribution to Body of Knowledge

The findings of this work can be directly applied to improve construction safety and health. To improve contractor willingness to use safety equipment, training interventions can be developed based on the findings of these studies in the following ways. Training should emphasize the health risks associated with the work, the effectiveness of the technology, and the impacts of the technology on productivity and quality. The findings of this work can also inform future research investigations in several ways. The prevention through design adoption readiness model (PtDARM) can be used in future studies of intervention design, innovation diffusion, and health and safety behavior change. In addition, the intervention strategies found to be effective in the current work can be applied to other PtD innovations, other construction trade sectors, and other occupational health and safety hazards.

Limitations

This research only addresses drywall dust control and not other types of occupational dust control. As with most survey research, the data collected were self-reported. This research was conducted in the United States during an economic downturn for the construction industry. Interventions might be less effective when an industry is faced with a declining market because support for occupational health and safety activities decreases (Goldenhar 2001). Not all of the PtD adoption readiness model constructs were impacted by the intervention strategy described in this paper. Future research is needed to explore intervention methods that would positively impact those model constructs not impacted by the current study and also to explore differences in responses between first and second posttest scores.

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