Emerging Technologies: Public Health Educators' Knowledge and Attitudes Towards Global Sensor Networks

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Abstract

The planet-wide networking of sensing devices planned by some computer corporations will have major implications for socio-political systems including national security, public health, and environmental monitoring. The early acceptance or failure of these deployments will depend on first users' knowledge and attitudes about it. This correlation study used two adapted instruments, one on knowledge of technology and one on attitudes, and captured demographic information on 155 Public Health educators as well. It found that Public Health university educators were not very knowledgeable about sensor systems and had moderately positive attitudes about the idea of global sensor deployment. A slight positive correlation between knowledge and attitudes on global sensor networks was found. Public Health educators are on the forefront of environmental and global health research and policy and as such their involvement in development and implementation are critical to the public's acceptance of this technology.

Keywords: Global sensor networks, public health, technology acceptance, knowledge and attitudes

1. INTRODUCTION

Technology enhances human capacity to understand and dominate the environment. Integrated principles borrowed from diverse fields are yielding new and unprecedented gains that are making this possible, thereby improving prospects for securing lives, properties, the environment, and health. Recent terrorist attacks and man-made and natural disasters in several corners of the globe underscore a need for early threat detection technologies. These can assist decision makers in honing in on the most probable causes or sources and facilitate response measures. Emerging technologies such as sensing devices for planet-wide networking have promise for early detection of a diversity of threats, however real capabilities are undeliverable unless the innovation is understood and valued. The threat of rejection of innovations can be mitigated if the attitudes of potential users and decision-makers are known. Attitudes are important in predicting the reaction of people to new ideas and things (Fishbein, 1975). Once known, perceptions can be influenced with exposure to and information about the products and their uses.

The planned implementation of global sensor networks that are under development at some companies, Hewlett Packard, for instance, and their intended and potential uses make this study an important one for practitioners in both the field of information systems and in public health because of their dependence on reliable data for decision making during emergency situations.

2. EMERGING TECHNOLOGIES

For technology like the sensor network system, that are finding diverse utilization due to emerging threats of public health dimensions, users' pre-implementation knowledge and their perceptions about it are critical. Although sensing or sensor devices have been in existence for decades, contemporary utilization as planet-wide network systems is novel making them emerging innovations about which possibility, value, and consequences are still a mystery.

The process of information technology acceptance often commences before individuals have interacted with the technology. The success or failure of a new technology depends on users' acceptance which depends on the preconceived knowledge, perceived usefulness and the users' behavioral intention toward it (Davis, Bagozzi, & Warshaw, 1989; Davis & Venkatesh, 2004; Jain, 2006). One significant component of technology diffusion is the knowledge about the availability of a new technology and its potential (Rogers, 1995). Rogers observed that people's perception of new innovations are often not based on scientific assessments, but rather subjective evaluations of what is learnt through social channels or what is perceived as advantageous to the user. By implication, awareness becomes a significant component of knowledge about an innovation.

Knowledge is the first stage of the innovation-decision period for potential users or adopters; prospective users must first learn about the innovation, and then must be persuaded about the value of it. A theoretical framework developed by Attewell (1992) to study the diffusion of complex technologies in organizations revealed that knowledge, including technical skills was an important barrier to diffusion. He found that organizations tend to delay the adoption of complex technologies until employees acquire sufficient technical know-how to implement and operate new innovations successfully. Technology acceptance models have been tested on post-prototype technology (Davis & Venkatesh, 2004). One reason for the development of a myriad of models is the importance of technology to development. According to Jain (2006), research findings are relevant when developing costly or risky technologies, because an early estimation of technology acceptance can be made before too many limited resources are expended allowing for modification of the technology before implementation. For an emerging innovation like the sensor network system, awareness of potential users' pre-implementation knowledge and attitudes is important because of potential ramifications that may not yet be obvious to developers.

3. SENSORS AND SENSOR NETWORKS

Advances in micro-electro-mechanical systems (MEMS) technology coupled with wireless communications and digital electronics have enabled the development of low-power, low cost sensor nodes that are not only portable in size but multifunctional and have capabilities to communicate, untethered, over short distances (Akyildiz, Sankarasubramaniam, & Cayirci, 2002). Sensor networks represent a huge improvement over traditional sensors. A sensor network is composed of a large number of sensor nodes, which can be densely deployed in remote regions, inaccessible terrains, and disaster zones (Akyildiz et al., 2002). Their protocols and algorithms are designed to have self-organizing capabilities. Akyildiz and his team pointed out that the unique feature of sensor networks is the cooperative nature of sensor nodes: "sensor nodes are fitted with an on-board processor…instead of sending the raw data to the nodes responsible for the fusion, sensor nodes use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data" (p. 394) which enable them to be used in a diverse range of applications.

Technology companies have conceived of a wide range of practical applications for sensor networks, using them for warning, early detection, and prevention in engineering, wildlife settings, "smart" buildings, and disaster response systems (Liaskovitis, 2009). Kornguth (2005) suggested the use of advanced sensor systems as integral components of bio-detection technologies designed for warning, detection and surveillance of bio-terror and agents of biological warfare. To be fully prepared for biological threat prevention and management, Kornguth (2005) suggested multiplexed, multi-array sensor systems should be a component of a network for rapid detection and identification. This sensor system ideally would be capable of recognizing all bacterial or viral genomic materials that determine bio-agents' virulent natures, pathogenicities and antigenic characteristics.

Until now, one of the most difficult aspects of creating a detection system was the development of multiplexed sensors capable of detecting several toxic agents. This is no longer the case. As a result of recent advances in science and engineering, the once science-fiction idea of a globally deployed wireless network of sensors, or sensors as components of larger systems, is under development for national security. An example is the Hewlett Packard Central Nervous System for the Earth (CeNSE) which is comprised of sensors able to be deployed on a global scale for on-site monitoring of physical locations. This has involved the development of nanotechnology-based sensing devices, embedded in everyday electronics, and capable of detecting structural and environmental threats. Hartwell, senior researcher and project team leader of the Hewlett Packard Central Earth Nervous System program, envisions sensing nodes about the size of a pushpin affixed to standing structures such as bridges and buildings to warn of structural pressures; they might also be embedded along public roadsides to monitor traffic patterns, road conditions and weather changes (Wylie, 2009). These networks of sensors will have the capability for recognizing patterns that enable quick identification of aberrant situations. Some systems will contain analytical components that will accelerate investigations by health responders (Berndt, Fisher, Craighead, Hevner, Luther, & Studnicki, 2007). These can be coupled seamlessly with an integrated communication capability able to convert large scale data into immediately useable information (Kornguth, 2005) for such things as biological agent detection for use by responders in the field (Stark, 2007).

4. ROLE OF PUBLIC HEALTH

The field or sector that requires all of these functionalities in one or more of such systems is Public Health. Public Health is interested in human health as it is influenced by- and as it influences- the environments in which humans reside. Any perturbation or changes to the environment either by natural or artificial infusion of a chemical, a technology or other entity becomes a concern for the public health field. Although the benefits of sensing devices are marketed by corporations, hence the promotion of the data these sensors can deliver, the risks are yet to be determined. Public Health professionals' perceptions of risks and benefits are factors that are critical for the acceptance of a widespread use of sensing devices.

It is not known what Public Health professionals know about sensor networks or what their perceptions and attitudes are about them. The main purpose of this study was to learn about the relationship between Public Health professors' knowledge about sensors and attitudes toward planet-wide sensor systems deployment. Public Health was chosen because it has significant responsibility for educating those who might be tasked as first responders, participating and advising research teams, policy makers and national agencies, across the United States. A second purpose of the study was to create a model to predict attitudes about the deployment of sensor systems based on knowledge and demographic factors of Public Health university faculty and researchers. An understanding of Public Health professionals' knowledge about this emerging technology, and their attitudes about it, will enable system designers to predict behavioral patterns towards use of this technology which can lead to effective implementation and integration strategies.

5. METHODS

The aim of this study was to determine whether knowledge of Public Health professionals about world-wide sensor systems would correlate with attitudes, and whether any relationship between the two variables could enable the creation of a predictive model for those seeking to construct and deploy a network that these professionals would value and use.

Participants were drawn from the Association of Schools of Public Health in the U.S. A simple random sampling technique, a blind drawing of ten school names from all 48 school names, was used to select the sample of schools. The sampling frame consisted of faculty whose contact information was found on the ten university websites. A request to complete the web-based survey along with a description of the study was emailed to 1553 Public Health faculty university email addresses in December, 2010. The number of potential participants who actually received the request and survey could not be determined, but of the 205 returned, 155 were complete.

The study participants were 55% male, 45% female. Their ages ranged the full spectrum of decade intervals on the survey, under 40 (17%) to over 70 (5%), most (78%) of ages from 40 through 69 [40-49 (23%), 50-59 (29%), 60-69 (26%)]. Education levels, as expected, were high, 75% with doctorate degrees, 19% with MD degrees. Socio-politically, the majority were liberal (73%), 17% were centrist, and 10% were conservative.

More than 40% of the respondents had been working in Public Health education and research for more than 25 years; about 10% have spent less than 5 years, 15% have been in the field 6-10 years, and 13% 11-15 years, and 10% 16-20 years. Core areas of fields of interest were widely distributed with Epidemiology the most represented (23%). Health Policy Management (14%), Biostatistics (13%), Social and Behavioral Sciences (10%), and Environmental Health Sciences (10%), and Global Health & Nutrition and Maternal & Child Health were each represented by 5.5% of the respondents. The remaining 14% did not specify or selected "Other."

The survey employed two instruments including a Knowledge scale that was adapted and expanded for this study from Imran (2009), and the Semantics Differential Scale (SDS) (Christensen & Knezek, 1998; Osgood, Suci & Tannenbaum, 1957). Both scales were combined, with demographic questions, to form one 22-item questionnaire that took about 10 minutes to complete. The first section included demographic questions asking gender, age, education, sub-specialty, work experience, use of primary and secondary data in research, and socio-political leaning. The second section asked seven questions about knowledge constructs about sensors/biosensors: *use of senor/biosensors, capability of sensor/biosensor systems, impact of senor/biosensor systems, cost of deploying, benefits of deploying, type of business or organizational activities in which sensors/biosensors can be deployed, and any plans to deploy a worldwide sensor network systems*. Response categories ranged from 1 to 5, 1 = none and 5 = expert knowledge. Reliability was measured using Cronbach's alpha and was found to be 0.911.

The Semantics Differential Scale (SDS) (Christensen & Knezek, 1998; Osgood, Suci & Tannenbaum, 1957) used to measure the attitudes of the participants to the global deployment of sensor systems followed. The SDS is a seven-point bipolar rating scale, with seven rating points to choose from, that uses adjective pairs to rate attitudes on ten items: *Unsafe (1)….Safe (7), Meaningless…Meaningful; Uninspiring…Motivating; Tedious…Interesting; Outdated…Innovative; Bad…Good; Complicated…Simple; Useless…Useful; Unreliable…Reliable; Time consuming…Time saving.* A high rating of 7 is equal to a very positive attitude where a low rating of 1 is equal to a very negative attitude. A factor analysis was performed to test this adapted scale; *Complicated…Simple* loaded by itself as a second component. Without that pair of adjectives, the Cronbach alpha was 8.69. The Cronbach alpha for all items was a respectable 0.83, therefore the item was kept in the scale.

Of the 205 surveys returned, 155 were fully completed. Scores for each of the items on the Attitude scale (SDS) and the Knowledge scale were summed and a mean score on each for every participant as well as a total score for each demographic category was calculated. Items and total scores on the Knowledge scale were correlated with items and total scores on Attitudes using a two-tailed test. Multiple regression analysis was performed to test the predictive ability of Knowledge on Attitudes.

6. RESULTS

Public Health educators (N=155) in this study had very little knowledge about sensors. Forty percent had no knowledge and another 36% said they had little knowledge. Only 8% claimed a lot or expert knowledge.

Seventy-eight percent of respondents had "none" to "little knowledge" about the use (M=1.79) of sensor systems or their benefits (M=1.73). More than 81% of respondents had "none" to "little knowledge" about capability (M=1.69) or impact (M=1.67) of them. Some Public Health educators had knowledge about the types of organizations (M=1.67) in which sensors could be deployed (83%), but most (94%) had "none" to "little knowledge" about any plans (M=1.35) for deploying such systems. And only 10% had some knowledge about the costs (M=1.48) of deploying them.

In order of mean scores on a scale of 1 (no knowledge) to 5 (expert knowledge), the least amount of knowledge was on plans to deploy a global sensor network. Their highest level of knowledge was about benefits and uses of global sensor networks. The range of scores was 1.0 to 5. (Table 1)

Table1
Participants' Mean Knowledge Scores, scale 1-5

Knowledge	**% No-little**	**Mean**
Total Knowledge	76	1.63
Use of sensors/biosensors	78	1.79
Capability of sensor/biosensor systems	82	1.69
Impact of sensor/biosensor systems	80	1.67
Cost of deploying sensor/biosensor systems	90	1.48
Benefits of deploying sensor/biosensor systems	78	1.73
Type of business or organizational activities in which sensors/biosensors can be deployed	83	1.67
Any plans to deploy a worldwide sensor network systems	94	1.35

Attitudes toward sensor deployment were moderately favorable (M=4.57, N=155). The range was 1.9 to 6.5. Mean scores on individual items were above the median of 3.5, indicating favorable attitudes. Simplicity, arguably a favorable attitude, had the lowest mean (M=2.48). Public Health educators consider the technology complicated. They also judged reliability only slightly higher than neutral (M=3.97). As a time saving device, they scored higher than seeing them as time consuming devices (M=4.35). Motivating outscored uninspiring (M=4.55), safe outscored unsafe (M=4.76), and good outweighed bad (M=4.97). Attitude scores were highest on useful (M=5.12), interesting compared with tedious (M=5.34), and the highest on innovative (M=5.38) versus outdated. (Table 2).

Demographic variations on knowledge and attitudes

Oldest Public Health educators (70+) had the highest levels of knowledge about sensors (M=1.98) and the most favorable attitudes (M=4.87). Those under 50 had a mean knowledge score of 1.26 and attitude scores of 4.31. These differences by age were not statistically significant.

Table 2
Participants' Mean Attitudes Scores, scale 1-7

Attitudes	**% at least moderately Favor-able**	**Mean**
Unsafe…Safe	52	4.76
Meaningless…Meaningful	63	4.83
Uninspiring…Motivating	48	4.55
Tedious…Interesting	69	5.34
Outdated…Innovative	75	5.38
Bad…Good	55	4.97
Useless…Useful	63	5.12
Unreliable…Reliable	24	3.97
Time consuming…Time saving	38	4.35
Complicated…Simple	2	2.48

Level of education differences also were not statistically significant although means were highest on knowledge for medical doctors (M=1.72). Very few master's and bachelor's level respondents rendered those comparisons irrelevant. Attitudes did not differ by education level (range M=4.40-4.58).

Number of years working experience did not have significance on levels of knowledge or on attitudes. Means were different across all categories only by .21 on knowledge and .46 on attitudes.

Socio-political perspective did not influence knowledge or attitudes significantly; means varied only by .29 on knowledge and .48 on attitudes; however mean scores were higher for those who identified as 1 (M=4.9) and 2 (M=4.8) on a 7 point scale of very conservative (1) to very liberal (7) (M=4.48).

Differences in knowledge by gender were found to be statistically significant [F(1,155)=13.49, p=0.00] but not in attitudes. By Public Health discipline, differences in knowledge were also significant [F(8,155)=3.281, p=0.002].

As would be expected, those in Environmental Health Sciences were most knowledgeable (M=2.31). They also, by mean, had the most favorable attitudes. However attitude differences between disciplines were not found to be significant.

Correlation between Knowledge and Attitudes

Total Knowledge mean score correlated slightly positively with total Attitude mean score (r=0.286, N=155, p=.000). The linear regression unstandardized coefficient was .302; for an increase of one point on the attitude scale, knowledge scores must increase 3 points. (Table 3).

Table 3

Model		Attitudes B	Std. Error	Beta	t	Sig.
1	(Constant)	4.068	.153		26.67	.000
	Knowledge Score	.302	.082	.286	3.68	.000

Individual Knowledge items correlated even more slightly positively with the total Attitude mean score about global sensor networks with the exception of plans to deploy a worldwide sensor system (r=0.13, N=155, p=0.09). Knowledge about this item was very low. (Table 4).

7. DISCUSSION

Public Health educators are from diverse discipline areas that cut across a wide swath of human needs and services including environmental health, biostatistics, epidemiology, nutrition, health policy, and global health. Despite their low level of knowledge about world-wide sensor systems and networks, it is remarkable that respondents were generally favorable about them. *Meaningful, innovative, interesting* and *useful* were adjectives agreed to by more than 60% of the respondents, and *safe* and *good* by more than half. However, almost three quarters of respondents thought global sensor systems were complicated things. Also, most indicated they were skeptical about their reliability or time-saving attributes. Being male and being a practitioner of Environmental Health were factors slightly more likely to influence more knowledge about sensor systems. None of the variables examined were found to play a role in attitudes. No demographic factors had significant relationships between knowledge and attitudes about these systems.

Table 4
Knowledge Items correlations with Total Attitude

Knowledge	Pearson corr	Sig.(2 tailed)
Use of sensor/biosensor	0.248	0.002
Capability of sensor/biosensor systems	0.269	0.001
Impact of sensor/biosensor systems	0.262	0.001
Cost of deploying sensor/biosensor network systems	0.256	0.001
Benefits of deploying sensor/biosensor network systems	0.319	0.000
Type of business or organizational activities in which sensors/biosensors can be deployed	0.287	0.000
Any plans to deploy a worldwide sensor network system	0.133	0.098

The findings of this research suggest that attitudes toward a global deployment of sensor systems and network are somewhat dependent on individuals' knowledge about them. *Benefits of sensor systems,* a component of the knowledge scale was observed to have the strongest correlation with attitudes, which suggests that this component could be a strong driver that could be employed to influence more positive attitudes toward global sensor network deployment. According to Rogers (1995), a major and significant component of the Innovation Diffusion Theory is knowledge about the availability and potentials of a new technology. He observed that people's perceptions about new innovations are not often based on scientific assessments, but rather on a subjective evaluation of what is learnt through social channels or what is perceived as advantageous. It is not known how much of the knowledge they (PH respondents) do have was learnt through social channels or professional ones. Considering the low level of knowledge about sensors and plans for a worldwide sensor network deployment, the respondents' attitudes about this technology may stem from what they perceive as advantages from a public health standpoint (*useful, good, time-saving, reliable, safe*) or from an academic standpoint (*innovative, meaningful, interesting, motivating, complicated*). These may, at this time, given the dearth of knowledge, be preconceptions about global sensor systems and networks.

Knowledge, attitudes and behavioral intentions of potential users have an impact on the ultimate acceptance or failure of emerging technologies, the costs of which are often enormous. To avoid failure, minimize complications, and improve the prospect of acceptance of promising innovations, knowledge and attitudes that may impact their acceptance and usage should be investigated during the various stages of prototype development. There are always concerns about the failure of technologies due to user's preconceptions (Davis & Venkatesh, 2004; Jain, 2006). Predictive and stable measures of perceived usefulness can be captured from users who have received information about the functionality of a system even if they have not had direct hands-on experience with it. Through the mock-up description of the concept of global sensor deployment that was provided for this study--an approach also used by Davis and Venkatesh (2004) -- respondents generally showed that they perceived the technology as useful. Perceived usefulness is a determinant of behavioral intention toward a technology.

Rogers (2005) stated that prospective users must first learn about an innovation and this is subsequently followed by persuasion about the values of such innovation. The finding of moderately favorable attitudes of this small sample of Public Health educators, even without them having specific knowledge, is encouraging for the proponents of a global sensor network. Whether Public Health professionals become users or not, they will have instrumental roles to play in research and testing, education, policy recommendations, and usage. They should be involved or informed about development and plans by inventors and companies' intent on implementing them, and with increased levels of knowledge and involvement, they have a more than reasonable chance of becoming persuaded about the value of global sensor network systems.

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