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How Citizens Learn and Use Scientific and Technical Information in Environmental Decision Making

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Abstract

There is concern that laypersons participating in environmental or natural resource decision making cannot or do not engage the scientific and technical information sufficiently to integrate that information into the decisions and reach a high-quality, science-based decision. This study examined how thirteen citizens participating in two Superfund clean-up decisions learned and used complex information. Citizens learned and engaged in discussion about scientific and technical issues, managed their learning and the use of information, and directed public decisions about risk and clean-up technology. Citizens needed access to multiple methods and techniques to learn, time and commitment to invest, and control over their learning. Multiple learning opportunities supplied a wide range of educational approaches conducive to the diverse learning styles and background knowledge of the citizens. Ramifications are discussed for public education and communication professionals, particularly the Technical Outreach Services for Communities (TOSC) and Technical Assistance to Brownfields Communities (TAB) programs.

Introduction

Environmental and natural resource decisions can be scientifically and technically complex. The sophistication of this information can be challenging to laypersons, such as citizens and other non–technically trained participants and stakeholder groups who engage in the public decision-making process. At the same time, the use of more participatory, multistakeholder processes in environmental and natural resource management has expanded dramatically over the past twenty-five years *(Bingham 1986; Crowfoot and Wondolleck 1990; Porter and Salvesen 1995; Wondolleck and Yaffee 2000)*. In 1999, the United States Environmental Protection Agency's (USEPA) Science Advisory Board raised concerns over the scientific and technical quality of decisions made collectively by multiple participants with backgrounds representing varying levels of scientific and technical knowledge, claiming that with:

> a greater focus on consultation and negotiation among directly involved stakeholders, there is a risk that the broad public interest in assuring that decisions are based on a full consideration of all available science may receive too little attention. *(USEPA Science Advisory Board 1999, 2)*

On one hand, the concern has merit—only 15 percent of adults in the United States currently say they are well informed about science and technology issues *(National Science Board 2002)*. A recent national study of U.S. ocean policy argued that a more scientifically and technically literate citizenry will be critical to ensuring ecological sustainability in the coastal and marine environment *(U.S. Commission on Ocean Policy 2004)*.

Nonetheless, in democratic societies, citizens have rights and expectations to fully participate in environmental and natural resource decisions no matter how scientifically or technically complicated they might be *(see Janoski 1998; Dahl 1998; Thomas 1995)*. How are these potentially competing societal objectives—public participation and scientifically based public decisions—reconciled? After months of public deliberations, the USEPA Science Advisory Board reached several conclusions in 2001, including:

> An adequate treatment of science is possible in stakeholder processes, but typically only if substantial financial resources, adequate time, and high-quality staff are available from the outset to all the necessary deliberation and provide the necessary support on an iterative basis through ongoing interaction with the stakeholders. Absent such resources, stakeholder decision processes . . . frequently do not do an adequate job of addressing and dealing with relevant science. *(USEPA Science Advisory Board 2001, 8; emphasis added)*

Further, the USEPA established outreach and technical assistance programs in the 1990s and 2000s to help build the scientific and technical capacity of citizens participating in environmental decision making. For example, the Technical Outreach Services for Communities (TOSC) and Technical Assistance to Brownfields Communities (TAB) programs are USEPA-funded, university-based programs that link community groups with educational and technical resources at no cost through a national network of Hazardous Substance Research Centers (HSRCs). They seek to "empower communities to participate substantively in the decision-making process regarding their hazardous substance problems" by helping them understand the underlying scientific and technical issues *(HSRC, "TOSC Welcome Page")*. TOSC and TAB enter formal partnerships with communities to foster two-way interactions, expecting the community to provide "knowledge, expertise and time" to facilitate the tailoring of services to the communities' needs *(HSRC, "TOSC Overview")*.

While TOSC was established in 1993 and TAB in 2001, neither program was involved in the research presented here which, in part, tests the USEPA Science Advisory Board's hypotheses regarding the integration of science and technology into public decision making. The data are analyzed from the perspective of learning styles theory, and the research examines how laypersons managed, communicated, and learned about the scientific and technical issues central to two cases of multistakeholder Superfund remediation and site redevelopment decisions. The TOSC and TAB programs are described in greater detail in the discussion section.

The research found that layperson participants learned complex scientific and technical information and used it to engage in public discussions with scientists and engineers. They took on increasingly responsible roles in shaping and managing how they learned and how information was used in the decision process. Citizens accessed and sought out multiple communication formats and educational techniques to obtain this sophisticated level of understanding. The concluding discussion raises several ramifications for the practice of public participation, outreach, and communication, particularly in programs like TOSC and TAB.

Learning Styles Theory

There are many theories on how people learn—constructivism, behaviorism, Piaget's development theory, neuroscience, brain-based learning, multiple intelligences, right brain/left brain thinking, communities of practice, control theory, observational learning, Vygotsky, and social cognition. A learning styles theory approach, for example, asserts that individuals perceive and process information in very different ways. Thus, how much people learn has more to do with whether the educational setting and activity is tailored to their particular style of learning than whether an educational activity is effectively implemented. Learning styles can be based on different cognitive preferences for processing information (e.g., *Kolb 1984; Riding and Rayner 1998*), personality (e.g., *Keirsey 1998*), or social interaction (e.g., *Grasha 1996*). Learning styles influence how people perceive, interact with, and respond to the educational setting and activities. Thus, learning styles theory suggests that citizens and other non-experts will need a wide array of educational settings and activities to learn unfamiliar and complex scientific and technical information.

In asking how nonexperts learn and use scientific and technical information in public environmental decision making, the USEPA Science Advisory Board hypothesizes that financial resources, available staff, and time are important factors. To this list, learning styles theory adds a variety of settings and activities.

Methods

The research findings presented here were elements of a larger study designed to determine the skills and abilities of participants in two long-term, participatory decision-making processes from 1993 to 1996: the New Bedford Harbor Forum in Massachusetts and the Pine Street Barge Canal Coordinating Council in Vermont *(Hartley 1998)*.

Pine Street and New Bedford were well-documented cases. Multiple data sources were collected and analyzed by the author: interviews of forty-nine participants, case documentation, meeting observations, and videotaped meetings. Structured and open-ended interview questions probed individuals' perceptions of their and other participants' skills and abilities that contributed to effectiveness in their and others' participation. Interviews lasted 60-120 minutes and were taped and transcribed. A variety of types of case documentation existed (e.g., meeting minutes, correspondence, technical reports, newspaper articles, legal memoranda, procedural protocols, draft and final agreements, fact sheets). The forum, the council, and their subcommittees met frequently over the three-year period of analysis, 1993–96. All forum meetings and two council meetings were videotaped and broadcast on local cable television, with over one hundred hours of footage that the researcher collected and assessed.

Cumulatively, these data sources made up the available documentation data that was analyzed with content analysis methods *(Lofland and Lofland 1995; Miles and Huberman 1994)*. In addition, the meeting observations and videotapes were assessed with an ethnographic technique designed to assess the images and scenes observed, dramaturgical analysis *(Feldman 1995; Goffman 1974)*. Dramaturgical analysis is a systematic technique of analyzing segments of group interactions for the roles individuals played, the actions they took to fulfill these roles, and the use of strategies to address issues or group challenges. The coding system identified behavioral patterns among the parties in the meeting. Codes were assessed by seeking patterns among the codes, as in content analysis.

Analysis of the data enabled identification of skills and abilities in fifty-eight participants in the two cases, thirty-three in New Bedford and twenty-five at Pine Street. This included all core participants in both cases, defined as those that attended more than 70 percent of meetings during the study period: September 1993-December 1996 for Pine Street and December 1993-December 1996 for New Bedford. Thirteen of the fifty-eight participants were citizens and community leaders with no technical or scientific training; forty-six participants had professional training and experience in a technical, scientific, or environmental management field. The thirteen laypersons included:

- Community group leader, adjacent town, housewife, early 40s
- Community group leader, environmental justice group, welder on a fishing dock, male, late 40s
- Community group leader, environmental justice group, former fishermen, mid-40s
- Community group member, environmental justice group, professional diver, late 50s
- Community group leader, local wetlands conservation organization, male, mid-50s
- Community group leader, downwind air quality, female, local artist, mid-60s
- Community group leader, downwind air quality, retired teacher, female, mid-60s
- Community group leader, downwind air quality, real estate agent, male, late 40s
- Local state senator, labor attorney, male, mid-40s
- Elected councilman, nonscience school teacher, male, late 50s
- Local businessman, graphic design, photography, early 40s
- Elected citizens neighborhood board official, male, early 40s
- Community leader, local environmental nongovernmental organization, female, mid-30s.

The findings reported here focus on these thirteen layperson participants and the learning and communicative skills, abilities, and strategies they employed to handle unfamiliar, complex scientific and technical information.

Cases of Public Environmental Decision Making

Pine Street Barge Canal, Burlington, Vermont: The Pine Street barge canal was built off Lake Champlain at the turn of the last century for barges full of timber and coal to supply saw mills and a coal gasification plant. As a result of these production activities, the barge canal, adjacent wetlands area, and groundwater under the site became contaminated with volatile organic compounds, polycyclic aromatic hydrocarbons, cyanide, and heavy metals. The eighty-acre site was placed on the original list of sites for clean-up by the Superfund law of 1980 (Comprehensive Environmental Response, Compensation, and Liability Act). In the 1980s, the lead agency responsible for conducting site and remediation assessments changed from the state to USEPA, and an immediate removal of contamination from a portion of the site was completed by USEPA. In 1987, USEPA initiated negotiation with the companies and landowners liable for clean-up costs to determine whether they would undertake the site assessments. However, "rancorous" negotiations, according to a USEPA official,[1] fell apart in 1988, and USEPA took the lead in conducting site studies. The final site assessments, which were completed by 1990 and supplemented in 1991 and 1992, concluded that the site posed no unacceptable human health risk, as long as the contaminated groundwater was not used for drinking. However, an ecological risk was present, and after further study of remediation options, USEPA proposed a remedy in November 1992.

> *"The Pine Street barge canal was built off Lake Champlain at the turn of the last century for barges full of timber and coal to supply saw mills and a coal gasification plant."*

The remedy called for dredging 175,000 cubic yards of contaminated canal sediment and surface soils. The dredged materials would be stored on-site in a confined disposal facility. A pumping system would prevent groundwater from flowing toward Lake Champlain, the drinking water source for the city of

Burlington and surrounding communities. The cost of the project would be $50 million.

Opposition was swift and harsh, and USEPA "was not prepared" for it, according to one USEPA official. Four days after USEPA released the proposed plan, the governor proclaimed it "bad environmentally" and vowed, "we will not sign off on their solution." Over a six-month public comment period, public opposition grew and USEPA was "badly mauled," according to one USEPA official, and "beat up," from the perspective of a state official. The proposed plan was criticized for the inadequacy of the scientific studies and the inappropriateness of the remedy. Political opposition grew, with local, state, and federal elected officials from Vermont challenging USEPA as an agency without "common sense." The local newspaper ran a five-day series on the decision, claiming USEPA "botched," "bungled," and "bumbled" studies, resulting in "flawed" risk assessments and "guesswork. " USEPA realized it needed a better dialogue with the community and in June 1993 withdrew its proposed plan *(Bazilchuk 1993)*.

> *"The Greater New Bedford area contained a thriving electronic capacitors manufacturing sector. . . . However, the industry practice . . . included discharging wastes directly into the river."*

New Bedford Harbor, Massachusetts: The Greater New Bedford area contained a thriving electronic capacitors manufacturing sector from the 1940s to the 1970s. However, the industry practice at the time included discharging wastes directly into the river. This resulted in extensive polychlorinated biphenyls and heavy metal contamination of the sediments in the Acushnet River, New Bedford Harbor, and Buzzard's Bay. The contamination closed fishing industries and prevented the navigational dredging of the harbor, since disposing of the contaminated sediments would be difficult, contributing further to the area's economic woes.

The Commonwealth of Massachusetts got the entire harbor, along with portions of the Acushnet River and Buzzard's Bay, placed on the Superfund list in 1982. In the same year, USEPA initiated litigation against the companies responsible for the contamination and settled for $110 million in 1992. USEPA conduced site assessment and remediation feasibility studies and issued draft findings in 1984. The study concluded that the site posed an unacceptable risk to human health and the environment and suggested three cleanup options for the most contaminated area: dredging the "hot spots" and incinerating the sediments, dredging and disposal in a confined disposal facility, or capping the site to contain and prevent further migration of PCBs and heavy metals.

Meanwhile, what the USEPA Region I administrator called a "long history of difficult working relationships" between USEPA and the city of New Bedford delayed a final remedy selection decision until 1990 *(Deland 1986, 1)*. After five years of discussions between USEPA and a community work group formed by the mayor of New Bedford, the work group voted 6-3 in support of the proposed incineration option. Nearly ten thousand cubic yards of sediment from five acres of hot spots would be dredged and stored in a confined disposal facility to dry. A temporary water treatment facility and incinerator would be built on-site to treat the water from the sediment and incinerate the dried sediment.

> *". . . USEPA realized it needed to improve the public dialogue with the community."*

By 1991 opposition to building an incinerator in downtown New Bedford had grown and three citizens' organizations were formed, reflecting health and safety concerns about incineration. The groups received information and advocacy assistance from national anti-incineration groups and made claims of environmental racism, since USEPA proposed placing an incinerator in a poor, minority area. They effectively mobilized opposition—rallies, letter-writing campaigns, support of local, state, and national elected officials—and forced USEPA and the Massachusetts Department of the Environment to halt implementation of the remedy.

The adversarial nature of the conflict further damaged the already frail USEPA-City relationship. USEPA filed a lawsuit against the city of Bedford to gain access to the site, after the city passed an ordinance prohibiting the transportation of incineration and wastewater treatment equipment on city streets without a city permit. Upon winning the case in federal district court, USEPA threatened the city with fines of $25,000 per day. The Massachusetts congressional delegation (Senators Edward M. Kennedy and John F. Kerry, and Congressman Barney Frank) lobbied USEPA and the White House. The community groups brought in "civil disobedience trainers" and prepared to halt construction of the incinerator.

Here too, USEPA realized it needed to improve the public dialogue with the community. While it did not withdraw its remedy decision immediately, it did seek a collaborative approach to solving the problem *(Hartley 1998)*.

Public decision-making process: By September 1993 the Pine Street Barge Canal Coordinating Council held its first meeting, followed by the New Bedford Harbor Forum in December 1993. They were structured in a similar manner. Both the council and the forum had professional facilitators and membership from a broad group of stakeholders: citizens, community-based organizations, local, state, and federal government (including senior USEPA managers on the forum), local and state elected officials on the forum, and private-sector responsible parties on the coordinating council. The community received technical assistance (e.g., private foundation and USEPA grant-funded experts, pro bono support). There was very little turnover in membership (less than 1 percent) during the three years studied in this research (fall 1993 to December 1996). Each group contained nearly twenty-five core participants, although many peripheral participants came and went. While the participants remained resilient and at the table, news media and general public attendance of the meetings dwindled quickly. The news media returned occasionally, but usually only when the groups were experiencing conflict.

"Open public meetings were held monthly on average in the local communities, and in New Bedford they were broadcast on local cable television."

Open public meetings were held monthly on average in the local communities, and in New Bedford they were broadcast on local cable television. Several subcommittees were established, increasing the overall meeting frequency to nearly biweekly. Both groups established formal operating protocols, including a call for consensus-based decisions. Furthermore, both groups also expanded the scope of the deliberations to consider broader local land use and economic revitalization issues—navigational dredging in New Bedford and business and community development in Burlington.

Several interim agreements were reached on new studies and specific remediation steps, resulting in a reduction in human health risk. Highly contaminated hot spots were dredged in New Bedford harbor and clean-up treatability studies conducted. Human health and ecological risk studies were conducted at the Pine Street barge canal, and access to the site was limited. The agreements also ratified an official role for the forum and coordinating council in future decisions at the site, possibly lasting over ten years.

"Community participants recounted an improved public dialogue, with genuine community involvement and better decisions that reduced risk."

All participants perceived the coordinating council and the forum as successful. State and federal government participants noted that the quality of the deliberations over a remedy improved dramatically. At the same time, the groups reached several interim agreements that reduced risk to human health and the environment. Community participants recounted an improved public dialogue, with genuine community involvement and better decisions that reduced risk *(Hartley 1998)*.

Research Findings

Citizens and other community members acknowledged that in the beginning of the decision-making process they knew very little about the scientific and technical issues they were about to engage with. A project facilitator commenting about one citizen noted, "One in particular, who considered herself the least sophisticated about the issues . . . has been involved in learning a lot of technical things." Another citizen and local businessman said,

> I [a citizen] knew nothing about any of this stuff . . . I had no idea that I was going to get into this in the intensity that it has and I've been extremely active . . . I'm really going in head first and I've learned the science, as much as I possibly could soak in.

A government official verified the citizen's perspective: "For having dumped someone who's business is not the environmental business, just dumped someone into this role [as a Council member], he's done very very well. He's a real quick study."

Increasing engagement in scientific and technical discussions: Over the three-year study period, citizens engaged in increasingly difficult technical and scientific tasks. In the early days of the forum, citizens' groups depended on self-funded technical advisors (December 1993-June 1994) and a USEPA Technical Assistance Grant (TAG) from June 1994 to December 1996. Forum members were given formal presentations on remedial technologies by private-sector vendors, and informational materials on many more. In total, the forum members heard from over a dozen technical vendors through the first twenty meetings (December 1993-May 1994).

As the community continued to expand their understanding of the technical issues, subcommittees were formed on dredging the harbor's hot spots (February 1994-September 1995), creating a scientific review panel called Sea Change (February 1994-February 1995), and drafting agreements among the parties (July-August 1994). Community members served central roles on the subcommittees, actively using their knowledge and directing the technical and scientific inquiry. A citizen cochaired the hot spots dredging subcommittee and was the primary spokesperson for that subcommittee, reporting technical and scientific information to the full forum. Citizens served central roles on the Treatability Studies Subcommittee (August 1996-December 1996).

Later in the second phase of the harbor clean-up, a local elected official on the forum chaired the Navigational Dredging Linkage Subcommittee (June 1995-December 1996), reporting to the full forum on technical and scientific issues addressed by the subcommittee. At the same time, the Sea Change organization sponsored a scientific panel on technical issues surrounding the use of confined disposal facilities to store sediment from the second phase of the harbor clean-up (November 1995). Citizens played a central role in developing technical and scientific questions for the panel to discuss. Community members were better versed in technical and scientific issues than in the days of TAGs and vendor presentations and evolved to a level that permitted them to direct the analysis.

In observations conducted during the thirty-third forum meeting, September 1996, and in the Treatability Subcommittee a few days earlier, citizens were dominating the questioning of contractors concerning the results of the first two treatability studies. Over 70 percent of all questions in the Treatability Subcommittee meeting came from citizens, and over 75 percent of all questions at the forum came from citizens and local elected officials. Citizens were asking fairly sophisticated questions without the assistance of outside technical support. For example, a senior USEPA technical official noted,

> they [citizens] were asking questions, "Oh, well if it works at 2,500ppm, how can you be sure it will work at 30,000ppm?" They were asking those questions. I'm saying, "Good questions." [They asked] "What do you [the contractor] mean you're not counting [that], you're throwing out this test? You are going to take the vendor's word they can stop those leaks around the thing?" Those are all questions we have to ask. It's good, now you're [citizens] asking them. You [the citizens] hear the answers.

Numerous other citizens showed a grasp of technical matters. After spotting discrepancies in contractor and USEPA split sample results, a citizen probed why the differences existed. Citizens recognized when air monitoring results showed that concentrations had reached potentially explosive levels and pushed contractors for information on their corrective actions. Citizens asked how many solvent extraction washes a batch sample had to go through before it was ready for dechlorination *(Hartley 1998)*.

How citizens and other laypersons learned complex information: Citizens and other laypersons invested considerable time and effort to learn, and they actively sought out information. For example, one citizen and local businessman estimated he invested over two thousand volunteer hours in three years. A project facilitator observed: "The citizens will work like dogs to acquire the information . . . it doesn't take long before the citizens pretty soon have . . . just outrun the local bureaucrats. . . . " A government official noted that "[Citizens] would attend more of the subcommittee meetings. . . . So, they became very well educated on the ins and outs of the project."

Citizens took many proactive steps, reaching out to find information. A citizen was singled out by other participants for her skills at networking to access informational resources. A government official noted that "[she's] done a great job in really bringing in some people who have great credentials and from a variety of standpoints, a good understanding of some of the issues." In the first year of the New Bedford Forum, the citizens took the lead to organize an independent, nonprofit organization, Sea Change. According to its mission statement, Sea Change's purpose included "communicating comprehensible information about environmental hazards to every layer of society . . . to endow communities by bringing them unbiased scientific information in ordinary language, so that they can make intelligent choices on environmental clean ups affecting their jobs, their health and issues of environmental justice" *(Sea Change 1994)*.

"[O]ne citizen and local businessman estimated he invested over two thousand volunteer hours in three years."

Using grant and foundation monies raised by the citizens, Sea Change convened interdisciplinary panels that reviewed questions and information which citizens had compiled and submitted. In a two-day public forum with day and evening meetings, the panel responded to questions and held open question-and-answer periods with the general public. Sea Change held two panels during the New Bedford Forum—Confined Disposal Facilities and Bioremediation—composed of what one government official described as "a panel of people from all over the country and some pretty high-level, high powered [scientists]." Furthermore, the laypersons actively managed the manner in which they interfaced with the complex scientific and technical information—they demanded experts speak to them in understandable language and sought multiple presentation formats. As one citizen commented, "One of our [Requests for Proposals] protocols with securing technical assistance was that we get people who were really good at presenting difficult kinds of concepts to a lay audience. . . . " On the forum and the council, citizens had the opportunity to absorb technical information in multiple formats, including vendor presentations, written materials, one-on-one consultation with technical assistance providers, panels of independent scientists with question-and-answer periods framed by citizens, regular communication with contractors on subcommittee meetings, and technology demonstrations.

Discussion

Learning styles theory suggests that there are multiple learning styles among the citizenry and that control over one's own learning is important to promoting learning. The USEPA Science Advisory Board hypothesized that financial resources, staff, and time were the critical factors for ensuring that scientific and technical information received adequate consideration in multistakeholder processes involving laypersons. While the sample size of this study is small and the findings should be interpreted cautiously, the results do support these assertions.

These findings are consistent with results from other examinations of public environmental decision-making processes in general (e.g., *Beierle 2002; Busenberg 2000; Daniels and Walker 2001; Hartley 2006; and Wondolleck and Yaffee 2000*). While citizens did not become technical experts or scientists, they did acquire sufficient technical and scientific sophistication to effectively engage in deliberation on the issues. The findings suggest that if laypersons have access to multiple methods and techniques to learn, time and commitment to invest, and control over their learning, they learn enough to effectively use complex information, direct technical and scientific inquiry, and arrive at scientifically sound and well-informed public decisions.

"While citizens did not become technical experts or scientists, they did acquire sufficient technical and scientific sophistication to effectively engage in deliberation on the issues."

Diverse background knowledge and learning styles need multiple approaches: Multiple approaches to presenting and sharing technical and scientific information were most conducive to learning, in part because individuals have different background knowledge and preferred learning styles *(Sandmire, Vroman, and Sanders 2000; Sternberg and Zhang 2001)*. Multiple approaches provided citizens the opportunity to acquire information in a manner most conducive to their own style and to shape and manage their learning. Some people may prefer the ambiguity and self-exploration of ideas available at a site visit with a technology demonstration, whereas others may favor a structured presentation by the vendor's engineer, and still others the opportunity to read and reread technical documents.

People are more effective learners if they can guide and influence the types of information to be learned. For example, people may be more motivated learners when they have a role in identifying the information and knowledge needed to make a decision *(Daniels and Walker 2001; Sullivan, Kuo, and Prabhu 1997)*. The forum and council participants had this active role in problem definition through directing the remedial investigations and search for remedy alternatives. In addition, citizens specifically looked for and created opportunities to manage the information they would learn. As their knowledge evolved, citizens and other laypersons could increasingly manage and shape the flow of scientific and technical information to maximize their learning.

Ramifications for public education and communication: TOSC and TAB: The findings have ramifications for managers of public education and communication programs, particularly those addressing complex scientific and technical information, such as the USEPA-funded, university-based TOSC (Technical Outreach Services for Communities) and TAB (Technical Assistance for Brownfields Communities) programs.

TOSC and the closely related TAB programs aim to provide alternative, independent, nonadversarial technical assistance that is flexible, tailored for community needs, and credible. They were created in the early 1990s in the USEPA with an emphasis on pollution prevention, stakeholder partnership and coordination, and environmental justice; thus, these programs concentrate their efforts on low-income communities at risk of toxic exposures in Superfund or brownfield sites *(Dearing et al. 1996; Harding 2001)*. There are five USEPA-funded TOSC and TAB programs nationwide, associated with the five university-based Hazardous Substance Research Centers (HSRC). All take similar overall approaches: forming interdisciplinary teams to provide services; conducting community needs assessment and dialogue to expand understanding of community; and entering with communities into written agreements detailing technical assistance services and expectations *(HSRC, "TOSC Welcome Page"; Oregon State University 2005; Colorado State University 2002)*. The interdisciplinary teams of faculty and students include expertise in public health, economic development, environmental regulations, public policy, communication, community relations, environmental engineering and remediation, and risk assessment *(Harding 2001)*.

TOSCs and TABs tailor their specific products and services to their regions *(Dearing et al. 1996)*. A wide range of services exist in the TOSC and TAB portfolio, including:

- Toll-free information lines for services
- Workshops, short courses, and other technical and educational programs
- Site assistance (e.g., review of technical documentation, assistance in preparation of written comments and participation for public hearings)
- General public education and print materials on hazardous substances and technologies
- Community capacity-building in site monitoring
- Face-to-face meetings and charrettes
- Web- and Internet-based instruction, electronic newsletters, Internet conferencing.

The Rocky Mountain Regional HSRC outreach Web site states, "Each of these methods will be used as appropriate to help communities better understand technical issues and support redevelopment of brownfields" *(Colorado State University 2002)*.

While neither TOSC nor TAB was involved with the New Bedford Harbor or Pine Street Barge Canal cases, the findings are directly relevant to TOSC and TAB services and educational activities. For example, investing in a variety of education and communication tools and mechanisms may be more effective than investing all financial resources in a few extremely expensive products. A wide array of tools (e.g., public meetings, print publications, workshops, one-on-one discussions, facility and technology demonstrations, Web sites) will promote learning among the public. While TOSC and TAB have a large portfolio of products and services, it may not be sufficient to use only a specific tool when that has been found appropriate; rather, a strategy of making all education and communication tools available is likely to reach the most people. The public will not likely learn from any one single public education activity, although if they invest time and other resources over an extended period of time, they may fully engage in public deliberations.

Funding is critical to the design, coordination, and implementation of a wide variety of educational opportunities, although TOSC and TAB provide no-cost options to lessen this burden. These cases relied on federal funding for citizens' organizations through technical assistance grants to citizens' groups.

There was direct federal and state support for on-site technology demonstrations, workshops or seminars, travel for experts from out of the region, or presentations by experts. Foundation and local fund-raising supported innovative educational activities. Tremendous in-kind local support (e.g., facilities for hosting meetings, transportation) helped implementation. Program managers need to both directly fund and facilitate access to a wide range of funding sources to pay for such a varied smorgasbord of educational activities to ensure public participation in decision making.

"[I]nvesting in a variety of education and communication tools and mechanisms may be more effective than investing all financial resources in a few extremely expensive products."

Time also proved an important factor for laypersons engaged in scientifically and technically complex decisions. Citizens learned quickly because they invested much of their own personal time, demonstrating tremendous commitment in these three-year-long cases. Program managers should consider acknowledging citizens' commitment and dedication, celebrate it, and give them encouragement throughout the process. Even though it is not easy, maintaining the motivation to learn and avoiding burnout among citizen participants in public environmental decision making is in the best interest of public managers.

Finally, the USEPA Science Advisory Board suggested that the availability of high-quality staff was important for layperson participation in high-quality science-based decision-making. TOSC and TAB seek to provide high-quality, multidisciplinary, university-based educational and technical staff assistance. These cases demonstrated that this hypothesis has some validity. Government staff attended all meetings, coordinated and oversaw much of the process, managed technical assistance grants, directly provided information and training, and engaged in all aspects of the scientific and technical deliberations. However, citizens themselves actively managed the information flow, sought out new information, demanded educational materials that conformed to their needs, and directed new scientific and technical inquiries. Thus the high-quality staff should facilitate citizens' taking an active role in managing their own learning and citizens' openness to learning new scientific and technical information themselves.

For TOSC and TAB this suggests that they can help provide citizens the tools to manage their own information and educational process, possibly even engaging with citizens in cooperative research ventures that have shown promise in other natural resource sectors in improving trust and advancing the perceived legitimacy of scientific information *(see National Research Council 2004; Hartley and Robertson 2006)*. Cooperative research partners laypersons and scientists throughout the entire research process, from hypothesis generation and research design to data gathering, analysis, and interpretation and dissemination of results.

Conclusion

This study contributes to understanding how citizens learn and use complex scientific and technical information, although as a small component of a larger study the findings should be interpreted as preliminary and exploratory. Nonetheless, the findings support and build upon past studies and assertions from learning styles theory and the USEPA Science Advisory Board. The citizens and other laypersons knew they needed to absorb very complicated scientific and technical information in order to effectively participate in the decision-making process. However, they invested time, money, and effort to learn. Citizens and nonexperts had multiple, diverse opportunities to learn, and maximized the opportunities to obtain information in a manner consistent with each individual's learning style. They increasingly managed the information flow and its application in the decision-making process. They sought to manage the manner in which they interfaced with information and had multiple opportunities to absorb technical information. They guided technical questions and inquiries critical for making a science-based decision. This indicates that public outreach and education professionals should consider providing a variety of learning forums and supply citizens with the tools they need to manage their own scientific and technical information gathering, use, and learning.

In closing, the research reported here explored how citizens learned technical and scientific information. A related topic worthy of attention is enabling government decision makers, technical experts, and scientists (particularly the nonlocal decision makers, experts, and scientists) to obtain unique "local knowledge" that citizens and other community leaders possess. Local knowledge can be equally complex, but not necessarily of a technical or scientific nature. However, based upon learning styles theory and these findings, it could be hypothesized that the same multiplicity of approaches, coupled with input of time and control over information provision by nonexperts, would be required before government decision makers, technical experts, and scientists could fully understand local knowledge. There is some indication that this is the case *(Adler and Birkhoff 2002)*.

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Note

1. Unless otherwise indicated, all quotations attributed to officials and citizens are from unpublished research in the author's files.

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