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### Recommended Citation

Prins, Esther and Frey, Shannon (2016). "Community Science Education: Critical Science Literacy and Community Engagement Related to Shale Gas Development," *Adult Education Research Conference*. <https://newprairiepress.org/aerc/2016/papers/32>

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## **Community Science Education: Critical Science Literacy and Community Engagement Related to Shale Gas Development**

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**Abstract:** This paper examines how adults in a non-formal education class on shale gas development in two rural counties expanded their scientific knowledge, developed critical science literacy, and applied what they learned in the course.

**Keywords:** adult education, informal science learning, critical science literacy, environmental science education, natural gas development

### **Introduction**

Shale gas development has proliferated in the USA, raising concerns about its risks and benefits (Alter et al., 2010; Schafft, Borlu, & Glenna, 2013). This paper presents findings from a research project with community members in two rural Pennsylvania counties affected by gas drilling or pipelines; they attended a non-formal education course on the physical and social science of shale gas development (SGD). This paper examines how participants understand science, develop and apply critical science literacy, and engage in their communities with increased scientific understanding. We argue that the opportunity to expand scientific knowledge shifted how adults learned about and shared information, their relationship with science, and their perceptions of themselves as scientifically knowledgeable citizens.

### **Theoretical Framework**

The course objectives and study findings are situated in literature on informal science education (Borun et al., 1996; Dierking et al., 2003), environmental adult education (Haugen, 2009; Jansen, 1995; Roy, 2000), and critical science literacy (Barton & Tan, 2010; Priest, 2013). Informal science education emphasizes the value of science learning within and beyond the classroom, and considers scientific knowledge to be constructed through personal experience and meaning making (Dierking et al., 2003). One field that has applied tenets of informal learning is environmental adult education. Following this literature, we view learners as active participants and emphasize the dissemination of information across diverse groups and throughout communities, and the importance of participants' knowledge building (Haugen, 2010; Jansen, 1995; Roy, 2000). Furthermore, environmental adult education emphasizes the relationship between socio-political matters, science, and the environment demonstrated in this study.

Critical science literacy informed the design of the course and our research questions. Critical science literacy views science as a social practice (Priest, 2013); as such, it integrates functional and technical-scientific literacy with "critical engagement with text, ideas, and ways of knowing and being that frame the discourse and practice of science" (Barton & Tan, 2010, p. 4). In examining how scientific information is applied and used to effect change, critical science literacy scholarship acknowledges scientific knowledge as situated in specific socio-historical contexts (Weinstein, 2008). Given the controversial, expedited nature of SGD and Pennsylvania's history of economic growth based on resource extraction (e.g., timber, oil, coal), we must understand the historic, cultural, and social contexts within which participants received and interpreted scientific information through the class, the media, and other sources.

### Context and Research Methods

In response to Pennsylvanians' limited knowledge of drilling procedures, water, and other SGD topics (Alter et al., 2010), this National Science Foundation project (Marcellus Matters: Engaging Adults in Science and Energy) included four components: the Marcellus Community Science Volunteer Program (MCSVP, the focus of this paper), an online network for participants, community-based theater, and environmental planning workshops. The project focused on rural counties with SGD activity and aimed to increase adults' ability to evaluate claims about shale exploration and to develop an educational model that can others can adapt.

The MCSVP course sought to enhance rural adults' knowledge of engineering and science regarding energy consumption, production, and policy, thus enabling them to share their knowledge and foster deliberation in their community about this complex, divisive issue. Along with Penn State colleagues, we were involved in designing the 8-week course (later lengthened to 10 weeks). The 2.5 hour sessions (taught by PSU faculty or Extension staff) covered energy choices, the scientific inquiry process, geology and seismic testing, engineering, water, land-use planning, socio-economic impacts, gas pipeline regulations, and strategies for fostering dialogue about contentious topics. Two themes cut across the classes: understanding how science is done and critical science literacy (evaluating the accuracy and trustworthiness of SGD information). The course included presentation, discussion, interactive activities, and field trips.

This paper addresses two questions: (1) How do participants apply what they learned in the program? (2) How do participants understand science, and themselves as scientifically knowledgeable individuals? We collected data from two of the seven MCSVP courses: a fall 2012 course in Clearfield County and a spring 2015 course in Lancaster County. The latter had no SGD activity, but a controversial gas pipeline was being planned. Of the 22 Clearfield students, 13 (5 women, 8 men) agreed to participate in the study. Of these, 9 wanted to be interviewed *and* complete activity logs (see below); the other 4 only completed the logs. Out of 42 Lancaster learners, 36 agreed to participate in the study. Due to time constraints we interviewed 20 people selected to achieve equal gender representation (10 men, 10 women) and maximum variation by education, profession, county, and employment. Another 15 people did only activity logs. Learners had varied current and past professions (e.g., education, business, engineering, science, factory work, farming, college students, retirees) and were in their 20s to 70s. Most were over 50. They had differing views on SGD (many felt conflicted) and took the course to gain knowledge and/or to form an opinion based on scientific facts, not "emotion."

Triangulating data sources enhanced data quality (Mathison, 1988). We *observed* 6 out of 8 Clearfield classes and all 10 Lancaster classes. *Telephone interviews* (n=64) were conducted at the beginning and end of the class and 6 months later. These focused on learners' views on SGD, ways of gathering and assessing SGD information, application of information learned, and self-perception as knowledgeable about science and SGD, among other topics. Participants used researcher-created *activity logs* (bi-weekly during the class and monthly for the 6 months afterwards; n=289) to indicate (1) how they applied what they learned (open-ended responses for 3 categories: personal, interpersonal, community/public) and (2) how often they did so (3-point Likert scale). Participants received gift cards for their involvement in the study.

Guided by the research questions and content analysis (Braun & Clarke, 2006; Patton, 1990), we identified a coding scheme, themes, and subthemes, and then compared our analysis for analytical triangulation. The quantitative activity log data were analyzed to determine the average frequency of applying knowledge in personal, interpersonal, and public domains, and open-ended responses were analyzed to ascertain the most common types of activities.

## Findings

As participants gained information during and after the class, most felt more confident sharing their knowledge, believed that others perceived them as more knowledgeable, became more critical consumers of SGD information, and (to varying degrees) became more involved with community events. Since the media are citizens' main information source on SGD (Alter et al., 2010) and journalists' presentation of scientific information shapes public perception (Kohl et al., 2015), a key objective of the class was to provide strategies for understanding, questioning, and assessing science information sources (e.g., newspaper articles, websites). Participants overwhelmingly applied these strategies to SGD information they encountered, as shown by the following comments: "I read it [media sources] with more of the mind;" "I've used it to do some more critical reading of the media articles that are coming out;" and "I don't just take one source. You have to take a number of different sources." Participants also applied these critical analytical skills to topics other than SGD. A participant wrote in the activity log, "My newspaper reading has been more critical on any topic." Likewise, Phil commented on his newfound "ability to examine information and...make judgments as to accuracy...how much faith you can put in it. I mean...that's something I can apply to things outside of [shale gas] information. I can look at any contentious issue...but now...it's something I think about a little more."

Participants developed a more skeptical attitude not only toward SGD information in the media, but also toward scientific inquiry and scientists. With some exceptions, participants shifted from an unquestioning view of science as "cold, hard facts" to a more nuanced understanding of science as constructed. This shift echoes the course's emphasis on learning how science is done. This pattern was less noticeable in Lancaster, where many participants had educational or professional backgrounds in science and thus had some analytical tools to distinguish more versus less credible scientific studies (e.g., peer review, sample size, replicability). However, even some of these participants saw science in a new light. For instance, a senior chemistry major remarked, "Before the class I thought it [university research] was more straightforward. Then when they [presenters] went over it, I saw kind of how much more complicated it is and how much your findings can vary." She linked this insight to a presenter who showed how three studies on the same topic each used different models and drew distinct conclusions. Not all participants developed a more complex view of science. For instance, in all three interviews a high school-educated woman viewed science as consisting of cut and dried facts. This view contrasts with another participant who argued that what we currently consider to be fact changes as new scientific knowledge emerges.

In a few cases demystifying scientific inquiry had an unintended effect: abandoning trust in science as a source of information and turning toward individual, personal experience as more credible. Several participants applied the information from the class sessions to question material presented, expressing that some of "the information in the class was somewhat more pro-development than some of the information that I'm seeing in the periodicals." Other participants expressed some disappointment upon learning that science does not always provide definitive answers or that scientists begin with assumptions—or what one participant called "pulling numbers out of your doofy." Overall, though, participants concluded it was still worth trusting and investing in scientific inquiry and knowledge—especially compared to other sources.

Participants also communicated that although they wanted to base their opinions on facts rather than emotions, the actions of SGD companies could change their views. Even if a process was scientifically sound, a company's negative actions could affect the community and influence views as much as applying scientific information. As Lillian acknowledged, for people to

support SGD, “the science needs to be tempered with humanity.” This view was more prevalent in the county where more participants had encountered SGD company representatives.

A commonly expressed view was that more scientific information about SGD can help communities make better-informed decisions. For instance, Jerry stated, “But the more we know about it—when I say we, I mean the citizens of Pennsylvania or the US of A, or citizens of the earth—how to like the more knowledge you acquire, the better we will all be, unless some nefarious Doctor No type uses it to enslave the masses, or whatever it is they do.” However, participants emphasized that scientists need to make research available and communicate more clearly with the public, and some expressed doubt that scientific data would sway people who had made up their minds.

The activity logs and interviews show the myriad ways that participants applied what they learned to their lives outside of class, both during the course and for the next 6 months. Not surprisingly, the average number and frequency of activities decreased after the course ended. Lancaster participants reported fewer activities and lower frequency during and after the class, perhaps because there was no drilling in the county and discussion about the pipeline had waned.

	<i>Instances of applying learning (average # per activity log)</i>		<i>% of all reported activities that occurred...</i>					
			1-2 times		3-4 times		5 or more times	
	During course (bi-weekly)	After course (monthly)	During course	After course	During course	After course	During course	After course
Clearfield	5.3	4.4	52%	45%	33%	27%	15%	29%
Lancaster	3.8	2.3	60%	53%	25%	28%	14%	19%

Participants applied learning from the class in their *personal* life by reading, researching, and assessing SGD information in newspapers, Internet, movies and videos, Facebook, and other sources. In Clearfield this category accounted for 36% of all activities during the course and 34% afterwards, compared to 38% during and 45% afterwards in Lancaster. Learners sought information on topics such as SGD permitting and violations, gas pipeline safety and regulation, inspection reports, and many others. They also practiced critical science and media literacy: “I was able to identify falsehood and bias in ‘letters to the editor’ in the Lancaster paper.”

Examples of *interpersonal* activities included communicating with family, friends, neighbors, and work colleagues about SGD-related topics such as abandoned wells, water contamination, or energy costs. Illustrative activities included talking “to friends with different views on water contamination,” “with my wife about permitting,” with “family about leasing” or “economic impacts [of SGD] on our community;” having “many conversations regarding PA budget and the severance tax proposal;” and writing and responding to Facebook posts. One person posted on Facebook a class chart on US energy sources and uses “to see how many responses it would generate.” Beth emailed a summary of what she learned from class to neighbors in another county where she and her husband own property (leasing is a contentious issue in the association). In Clearfield, interpersonal activities comprised 44% of all reported activities during the course and 26%, compared to 44% and 48%, respectively, in Lancaster.

Examples of *community/public* activities included attending community meetings on SGD, volunteering to test water, attending SGD-related rallies, communicating with state legislators, and writing letters to the editor, among others. For instance, a teacher said, “I’ve talked about it in my classroom. And basically use it in examples of things that are going on now and things that are going on around us. My kids in my environmental science class do [a regular assignment on] current events.” Another participant wrote monthly letters to his state senator and representative to express his views on SGD and share information he had learned with them.

After the course, Don started a monthly SGD discussion group with class members and a few other Lancaster residents at a local bar; they were still meeting 6 months after the class ended.

In Clearfield, public activities comprised 18% of all reported activities during the course and 39% afterwards, compared to 12% and 10%, respectively, in Lancaster. We attribute this to the lack of drilling and declining public discussion about the Lancaster pipeline. After the course, Clearfield participants increasingly applied their knowledge in more public ways, which may stem from their increased confidence, passion, or involvement with SGD issues. For example, Abby was previously concerned about the environment, but the class “started the whole ball rolling,” compelling her to become more involved and to follow SGD issues “for the rest of [her] life.” Similarly, reflecting on her deep concerns about climate change, Anita remarked, “Sometimes it’s just too much to bear.” These comments highlight the emotional dimensions of learning about and becoming more publicly involved in environmental and energy issues—a hidden aspect of developing critical science literacy.

With some exceptions, participants reported increased confidence and concern, passion, or involvement with SGD issues, regardless of their stance on the topic. When asked if she felt more confident sharing her SGD knowledge six months after the course, Abby replied, “Oh, my gosh, yes!” and added, “You know, I’m certainly not an expert by any means, but I know that just among family and friends, and in the community *now*, I suppose they would perceive [me as knowledgeable].” Earl linked his confidence with his refined position on SGD: “I become more confident or...you know, in my knowledge of it, so I could actually move my opinion of it.” Although Don had a science background, he felt more confident in having reliable sources because “in knowing [good sources] and using the proper information, yeah, you feel more confident.” Similarly, Beth described increased confidence in having reliable information from class to share with others. The class binder containing handouts, PowerPoint slides, and supplementary materials—or what Beth called a “whole big binder of facts”—was often cited as a confidence booster because participants could review information and share it with others.

### Conclusion

The study helps elucidate science learning among adults in the nation’s first non-formal, university-sponsored course on shale gas development. The course enhanced participants’ scientific confidence, involvement in accessing information about SGD and gas pipelines and speaking with others about these topics, and for some, their involvement in SGD-related public activities. Since participants had varying views on SGD, their involvement also took different forms. The course’s emphasis on critical science literacy and understanding scientific inquiry encouraged skepticism toward scientific information in the media and a more complex understanding of science. This helped to demystify the scientific process and gave participants “more tools in [their] critical thinking tool belt,” such as strategies for evaluating research studies and media reports on SGD, including funding sources, institutional affiliation, peer review, incorrect use of correlational data, and the like. The course, and our findings, emphasize the role of researchers in helping the public understand “how science works” (Priest, 2013), and can inform efforts to involve citizens in analyzing complex, contentious social-scientific issues.

In future analyses we hope to elaborate on how participants could simultaneously develop more trust in university research *and* a more skeptical, critical attitude social-scientific studies and media reports. Another topic for future inquiry is how participants juxtaposed emotions and facts, characterized emotion as an undesirable component of scientific knowledge production and decision making, and attributed emotion mainly to people who oppose SGD and gas pipelines.

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