Why Informal Science Educators need to grow a long tail (or: Joining the new media conversation)

Bill Hammack | University of Illinois, Urbana | hammack@netbox.com

In this white paper I argue that science and engineering communicators needs to develop content-rich social networking sites to effectively create informal learning experiences that increase interest, engage, and deepen understanding of science, technology, engineering, and mathematics (STEM). Such sites, labeled often with the nickname Web 2.0, move communicators from an "old media" model to a "new" one, and in the process engage a new generation. Sites focusing on user-generated content should supplement and possibly replace the current media formats that rely on polished, professional media. In this paper I spell out the philosophy and rationale underlying new media and its "long tail" in contrast to the principles of old media. The punchline: Simply using the web to deliver video instead of via, say, television doesn't make for new media. The latter requires three essential elements: a) an architecture of participation, namely the ability for the public to sort and rate it; b) the ability of a large group of people to create and upload content, and c) a "long tail" - essentially an infinite digital archive. I close the paper with two concrete examples of such Web 2.0 project appropriate to the National Science Foundation's Informal Science Education (ISE) program, using these examples to illustrate the ideas underlying new media.

Does "new" media really work?

Imagine for a moment that someone started a web site dedicated to mobile phones. Rather than being designed by a corporation, or people who were paid, its founder allowed *anyone* to discuss mobile phones. It seems pretty clear that this would become simply an uninteresting morass of useless opinions. In fact, this sounds like a recipe for a random free-for-all that will result in chaos. Yet, the reality turns out to be a web space that gets half a billion page views a year, and has incredibly rich and detailed information on cell phones: For exampe, it has details on how every mobile phone system in the world works. Mobile phone companies actually refer customers with complex problem to the site! *Howard Forums* shows the new media in action.[1] To understand why such a thing works requires an understanding of new media, and a complete re-orientation for anyone who has worked in old media. What follows forms a tutorial on the subject.

Howard Chui started a simple forum on mobile phones. In classic wiki fashion he allowed anyone to contribute and employed social filtering to be sure the site had high quality information. Now billions of page views later even phone companies send clients to the site.

1 www.howardforums.com. Here's how the site describes itself: **Who we are** HowardForums.com is the Internet's premiere mobile phone discussion board made up of a large and influential community. Specific forums include mobile phone related manufacturers, carriers (service providers), Smartphone/PDA (convergence), industry and technological advances. **Where we are** Operating out of Toronto, Canada with moderators and contributors from around the globe, our emphasis is on the North American (U.S. and Canadian) market. **What we believe** Mobile phones are the most popular consumer electronic devices and are the one device people won't forget at home! Here we strive to provide a forum that is comprehensive, constructive and conducive to discussing your opinions and experiences with mobile phones while appealing to as wide a range of cellphone users as possible. **Where we've been** Back in 2001, HowardForums.com was launched to address the lack of cellphone focused websites then. Since inception it has quickly and steadily grown to a member base of 200,000+ users. **Where we're going** Whether you are just contemplating your first cellphone purchase on a limited budget or are a die-hard cellphone user purchasing your third cellphone this year, we hope to continue providing a community that can benefit every kind of user for the future years to come.

New Media isn't just Old Media delivered in a different way

When I talk of "new media" or "Web 2.0" I don't mean simply delivering "old" media via the web. By old media I don't even mean a particular technology (movies, television, radio, newspapers, magazines, *etc.*) but instead a particular process. I've worked extensively in "old" media, so to illustrate that process let's look at the creation of one of my commentaries for public radio's popular *Marketplace*.

Web 2.0 refers to media that has significant social networking content; i.e., the ability for the public to rate, comment and produce media.

Typically I pitch a piece to a sub-editor; we'll discuss the piece thoroughly, look for any holes, logical leaps, discuss the news hook for it, and also search for a "snapper" for the ending. Together, then, we develop a script. That script goes to an editor or two above my sub-editor for approval. We then make changes, head to the studio and carefully lay down the audio tracks - taping again any parts that didn't sound just right. Usually we do the taping the day piece airs, so a few hours after my studio visit the commentary appears on *Marketplace* and is then heard by eight million people. Later, of course, it appears in a downloadable audio file. So it would seem this has a new media presence, yet it really doesn't.

What makes something "old" media is that process I described of polishing completely a piece, filtering it through many gatekeepers (editors, sub-editors and the like), editing carefully the final piece and *then* offering it to the public. The essential characteristic to old media lies in this model: Filter, then publish. The new media invert this completely: One publishes, and *then* filters. Wouldn't this, though, just be a

free for all -- a mishmash of video?

Isn't "publish, then filter" just a recipe for a useless free-for-all? (Or, the importance of folksonomy)

One key to a successful "publish, then filter" site lies in adding a social dimension. If you look carefully at a site like YouTube the public is able to rate and rank the videos. They do this astonishing well: Highly rated videos are indeed interesting and sometime informative. Or, consider a site like Flickr, designed to share photos.

Flickr features two billion photos! One of the earliest Web 2.0 applications, it, works as a photo repository fueled by social organization tools, which allow photos to be tagged and browsed by "folksonomic"[2] means or "social bookmarks."[3]

For example, sixteen users pooled together 1,712 images of Steuben County in Upstate NY, wineries and lakes, hunting and fishing, dining and shopping. No one organized such a thing, no media outlet would assign a team to it, yet it does have value. Other members of Flickr sort and rate these photos allowing a user to look only at the most interesting ones. On Flickr one can find thousands of these groups - the 219 members who took 2,271 photos of the latest Minnesota State Fair, or the 191 people who shared 5,719 images of the "Cans" Festival in London. So, while it seems that a Flickr, Wiki, or YouTube has *no* quality control, in another sense they are *completely* quality control - many videos, wiki entries, or Flickr photos are *never* viewed, they are deemed completely unworthy.

For example, someone started a Flickr group for the "British General Electric Company", which has only 2 members, one of whom contributed 21 of the 33 photos.[4] Even worse was the "LLI Liberty & Summit Conferences", which had 1 member who posted 15 photos.[5] No one participated in these groups and so they failed -- two of surely tens of thousands of such failures. So, failure in the "publish, then filter" world is high, but the cost of failure is low. What has changed in the last ten years - due to digital tools for video, sites for sharing with the world - is this dropping cost of failure.

Yet, even this doesn't explain fully the power of "publish, then filter." The description above implies that the procedure works only to find the "hits" that appeal to a mass audience, and while that works, it's only half the power of new media.

Beyond Mega-Hits: "Publish, then filter" makes use of the Long Tail

The web has blurred the borderline between a private communication and a public broadcast. In the past one would never listen in on a phone call, or open a letter, and similarly one knows that a commentary broadcast on public radio's *Marketplace* is designed for all; yet, the web is filled with things like this:

> *"A flower vendor was just packing up and he had a very nice, good sized rosemary plant. I was planning to cook a chicken tomorrow and missed the herb plants that I had at home, so I was glad to get a new one. On the way back to the tramstop, I stopped into Wilkinson's where at last I found a wastebasket." From a blog by* Felicita *written on September 27, 2008*

What is this? Surely something like this about a visit to the mall cannot replace the "old" media. Therein lies the key error in "old" media people not understanding new media: Simply, put: "They aren't talking to you!" -- plus, we aren't really talking about audiences.

Social networking sites like MySpace and Facebook have millions of accounts, yet the median number of friends in MySpace is two, the average is 55 - a skewed high at that. This means that social networking is largely done pairwise. A blogger like Felicita is one of millions of pairwise or a bit higher interactions. So, from an "old" mass media viewpoint this is a failure of sorts - an audience of tens or 100s - yet audience is the wrong word to use. What Felicita has is a *community*, a community which she, for whatever reason, resonates. Its a secret of Web 2.0 (social networking) sites that one doesn't need professional quality in video, or narrative technique, or performance to be successful. The success of a content-rich site is much like a dinner party: It isn't important what's on the plates, but instead what's on the seats. The social networking of Web 2.0 allows people to choose what appeals, rather than sit and receive coarse marketing message - with the cost of global communication so low the lowest common denominator in communication can be overcome. This means the tyranny of the most popular has been defeated by the long tail.

Even though social sites like Facebook or MySpace have millions of accounts, they are essentially a pairwise or slightly larger phenomenon. This reminds us to think in terms of *community* instead of *audience*.

In a popular 2006 book Chris Anderson outlined the essence of the long tail:

> *"The theory of the Long Tail is that our culture and economy is increasingly shifting away from a focus on a relatively small number of 'hits' (mainstream products and markets) at the head of the demand curve and toward a huge number of niches in the tail. As the costs of production and distribution fall, especially on-line, there is now less need to lump products and consumers into one-size-fits-all containers. In an era without the constraints of physical shelf space and other bottlenecks of distribution, narrowly*

2 What a wonderful word! Here, from Wikipedia, is its definition: "Folksonomy (also known as collaborative tagging, social classification, social indexing, and social tagging) is the practice and method of collaboratively creating and managing tags to annotate and categorize content. Folksonomy describes the bottom-up classification systems that emerge from social tagging. In contrast to traditional subject indexing, metadata is generated not only by experts but also by creators and consumers of the content. Usually, freely chosen keywords are used instead of a controlled vocabulary. Folksonomy (from folk + taxonomy) is a user generated taxonomy."

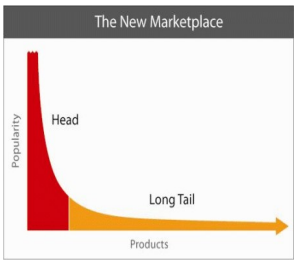
3 Social bookmarking is a method for Internet users to store, organize, search, and manage bookmarks of web pages on the Internet with the help of metadata. The essential component, though, is that these are shared with all users. Examples of these include del.icio.us - who pioneered tagging and coined the term social bookmarking - Digg, eddit, and Newvine.

4 For the curious: "This group is about the people, places and products associated with the GEC from its beginnings in 1886 until 1999 when it became Marconi plc."

5 Also for those with an inquiring mind: LLI is "a group of entrepreneurs and students of personal development who are changing the financial and personal courses of our lives. As part of that journey we attend conferences all over the world in places like Melbourne, Rome, the Atlantis Resort (Bahamas) and Hawaii."

targeted goods and services can be as economically attractive as mainstream fare."

The long tail means that we can now serve previously underserved audience: Prior to the Web it would have been extremely expensive to reach small audiences, but businesses like Amazon find that everything in their catalog is sampled once, perhaps not more than that, but at least once. The same applies to informal science education and its content.



The low cost of digital storage has created a "long tail" -- an essentially infinite bookshelf for Amazon.com, an infinite dial for radio, etc. In the past a retailer had to stock only the head of the tail because of the cost of shelf space. Now, able to keep everything, they see that every part of the tail is sampled.

Imagine an incredibly content-rich site that discussed, say, systems biology. One may well ask who would want to hear a nuanced technical discussion of the genome of a bacterium? Or, listen to the details of high-through put methods? Yet like Amazon.com and their infinite book shelf each of these subjects would likely get at least one pairwise interactions because the topic resonates with someone. And *that* is precisely what the a Web 2.0 long tail sit should do: To match up interests and entries. This moves the mass media component of informal science education from an emphasis on big media hits - a television show or a *New York Times* article - to a world where, instead, 1000 bloggers discuss in detail some aspect of science or engineering. What, then, are the details that make a social networking or wiki-style model work?

Wikis work!

Within academia the Wikipedia model gets little respect, yet for many subjects it works very well.[6] I use the site frequently and am often startled with the quality of information.[7] As of September 2007 Wikipedia has 2 million articles, and is the 11th most popular site on the web - the other top 10 are all commercial. So, Wikipedia's utility for millions of users has been settled, the interesting questions are why it works and how it can be used elsewhere. Four observations shed light on how the Wiki model works -- whether it be text-, still-photo-, audio- or video- based.

- **First**, the key idea to keep in mind is that something like Wikipedia is not a product, although the *-pedia* suffix makes one compare it to an encyclopedia, but a process - a process, not a product. A Wiki doesn't work by collectivism, but by continual and unending argumentation and emendation.

- **Second**, a good wiki usually focuses on a question of the form "How does this work" about an activity that its users want to engage in. For example, Flickr has a lively forum on HDR. Photographers make these High Dynamic Range images by combined three different exposures. This desire to do it oneself drives the forum.

- **Third,** unlike a corporation not all people who contribute to a project need to contribute equally. Some (many, in fact) do little, but a few do a lot. Why does this work here, but not in corporations and businesses? A car company, for example, must a) make cars and b) be a company. It takes a lot of work to be a company. Wikipedia, in contrast, doesn't need to be sure its employees show up. A company needs to ensure all workers are interchangeable and do same amount of work; Wikipedia contributors come and go. Return for a moment to the photos of Steuben country I mentioned earlier. Unlike a company not all workers need to contribute equality. Typical of a sharing site like Flickr or Wiki the effort is distributed in a skewed distribution: User *pawtrait04* - to use his or her screen name - contributed 1,547 photos, *kpmst7* 70, *danie.roman* 29, *Heron Hill Winery* 12, and *grockwell61* contributed 9 photos.

- **Fourth**, designating experts means no one writes an article. In a wiki more people are likely to start a bad article than polish a good one. One must truly trust the "publish, then filter" model and let the filtering remove the most atrocious ones. Still the writers need guidance. Jimmy Wales, one of Wikipedia's co-founders, notes:

"Any company that thinks it's going to build a site by outsourcing all the work to its users completely misunderstands what it should be doing. Your job is to provide a structure for your users to collaborate, and that takes a lot of work."

Not providing sufficient structure is the reason why an experiment *Wired* magazine carried out in "crowdsourced" journalism last year ended in failure.[8]

Applying Web 2.0 methods to Informal Science Education Projects

I want now to look at applying Web 2.0 tools to solve particular problems appropriate to the Informal Science Education section of NSF. The first focus on teaching teenagers about engineering, the second on reaching the broader public using "Citizen Science" methods. Where appropriate I contrast the old and new media approaches.

Communicating STEM to young audiences

Project Title: Because dreams need doing: Engaging 13 to 16 year olds in engineering projects.

Overview of project: A wiki-style web space that allows 13 to 16 years to learn about engineering projects that can build. A space to which they can contribute and edit project descriptions. The seed to generate a long tail comes from college-aged students at engineering open houses across the nation.

6 See The Chronicle of Higher Education's "live" discussion among academics about Wikipedia at http://chronicle.com/live/2006/10/halavais/

7 Errors, of course occur, but that isn't unique to Wikipedia and new media. Recently I was reading John Hales majestic *The Civilization of Europe in the Renaissance* - a 20th century masterpiece of history and a sterling example of "filter, filter more, then publish." On page 86 it announced that Francis I took over from his father Louis XII as King of France. Alas, Francis was a distant cousin. Unlike Wikipedia this error will last for years and years.

8 Assignment Zero. An experiment in "pro-am" (professional/amateur) journalism, in which journalism is run by the public rather than the media, Assignment Zero is an attempt at journalism without strings — one might call it an audience-run newsroom. In the Assignment Zero project, stories are thought up, chosen and researched by "citizen journalists", rather than designated by editors. The aim of this experiment was to promote social democracy — rather than the anarchy that one assumes would naturally result — and works to employ a crowd model that allowed several contributors to shape a story. It failed.

The problem: The U.S. faces a tremendous decrease in global competitiveness. As a measure consider that the U.S. is now a net importer of high technology products (plus $54 billion in 1990 to a negative $50 billion in 2001.) The seminal report *Rising Above the Gathering Storm* highlighted the main element in reversing this trend: Creating "a new generation of bright, well-trained scientists and engineers" who can "transform our future", noting that this must "begin in the 6th grade ...." The report mentions the need to "significantly enlarge the pipeline" of engineers, but as other have noted, this needs to be nuanced: It isn't the shear number of new engineers that solves the problem, but the type of engineer.[9]

The NAE's report *The Engineer of 2020* pinpointed the key issue: "Whatever other creative approaches are taken ....the essence of engineering - the iterative process of designing, building, and testing - should be taught from the earliest stages ...." This means that we need to develop a cohort of pre-engineering students who have actually done engineering. In a field like engineering, nothing can replace "doing" because therein lies engineering's essence.[10] Thus, a proper project for the Informal Education Section of NSF would be to reach thirteen to sixteen year olds who desire to create engineering projects in their time outside of class, but lack the information to make these projects successful - and lack, although, they don't know this, information on what really constitutes an engineering project.

Oddly, the communication problem doesn't lie in the students' lack of interest in engineering as might be supposed. Research reported in the excellent NAE Report *Changing the Conversation: Messages for improving public understanding of engineering* found that tweens and teens very much resonated with the goals of engineering -- of creating a better, healthy, greener world. Yet few could make the connection between this ideals and the work of an engineer. The report uncovered a critical step in engaging this age group was to involve them in actual engineering. To do this, though, they need a community, information, interactivity and role models that appeal to them.

Positioning Statement for Engineering

"No profession unleashes the spirit of innovation like engineering. From research to real-world applications, engineers constantly dis- cover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways. Few professions turn so many ideas into so many realities. Few have such a direct and positive effect on people's everyday lives. We are counting on engineers and their imaginations to help us meet the needs of the 21st century."

National Academy of Engineering
Changing the Conversation: Messages for improving public understanding of engineering

Contrasting old and new media approaches. The report *Changing the Conversation* bores in on creating a mass message. Using sophisticated polling methods they develop a positioning statement and several tags lines to test. Specifically, the created the positioning statement showing in the box. The question then becomes how to communicate this. The positioning statement, as noted in the report "is the conceptual foundation for a communications campaign, but it is not usually shared [directly] with the public."

Old media approach: The old media approach - which has its merits - involves filtering of possible taglines. The very capable marketing firm hired to do this work developed taglines and then tested (filtered) how well they played with specific demographics focusing on the teen audience with the hope of enticing them to become engineers. Not surprisingly no single message appealed to all groups, so they choose the "best" based on the teen sample and the marketeers' considerable intuition. They choose a tagline for marketing: "Engineering because dreams need doing." By *definition* the impact of this line is a compromise. The report goes on to suggest building a "public relations 'tool kit'" to be used in "advertising, press releases, [and] informational brochures." So, this typifies the old media approach. Could the same positioning statement be implemented with new media? Yes - and likely more effectively.

New media approach: Web 2.0 methods allow 13-16 year olds to create content meaningful to them, instead of having to use an "educated guess" at a message. The content created will reflect their interests and style. Also, having a long Web 2.0 tail means that in the right new media message vehicle we can reach all - perhaps a particular experiment will be popular with only a few, but the cheapness of digital storage allows a description of this project to be keep up forever. Recall the pairwise matching mentioned in the tutorial above.

Project specifics: To engage 13 to 16 year olds in actually doing engineering the *Dream's Project* will collaborate with Cybercamp Academy - a group that runs hundreds of after-school and summer campus for teenagers. They focus on computers and technology. The *Dreams needs doing project* will bring to them a rich repository (a "long tail" in new media language) of step-by-step engineering projects. As important the *Dreams* project will provide the proper web-based wiki tools and cyber space so that the camp's students can add to and extend the project -- that is, to participate and thus bring the full power of Web 2.0 to the *Dreams* wiki. This, of course, includes a careful design of the proper cognitive structures that underlie the wiki.

The FLIP camera fits in the palm of the hand, and downloads via USB thus making nearly instant video for posting. While its quality isn't professional, it is more than good enough for YouTube. In the new media world one shouldn't over emphasize video quality: Content , instead, is king!

To seed the "long tail" of user-generated content will be photos, videos, audio and text. Video will be generated by undergraduate students at the top ten engineering schools. Each of these schools has what's called an "Engineering Open House" in which - outside of class - the students build real, detailed engineering projects. The video blogging and wiki entries will document *how* their projects were done. Each can be rated and shared by the public.

The key to making a successful long tail lies in uploading a huge amount of content fitted with social bookmarks that allow users - like those at Cypbercamp - to rate, comment and forward video. A user of the site should be able to easily

9 See, for example, V. Wadha, et al. "Where the Engineers are" *Issues in Science and Technology*, Spring 2007.

10 For learning by doing, see Zhu, X., & Simon, H.A. (1987). Learning mathematics from examples and by doing. *Cognition and Instruction*, 4, 137-166.

search for content, browse by subject or department, sort by rating, length, and so on, and to rate and comment on videos. And the public should be able to upload their own howto videos. Additionally the videos should be easily downloadable to an iPod or other handheld device. The site should contain several RSS feeds:[11] One for all content, and feeds for specific subjects.

Why would such a site work and how does it move forward the mission of ISE?

- **Focuses on the "How do you do it?"** question so essential to making a successful wiki. In this case tweens and teens doing science projects can see the details and contribute their own videos, rather than saccharine videos *telling* how interesting engineering is.
- **Uses the medium of the next generation.** Marshall McLuhan said famously "The medium is the message." Never had this been more true today with the younger generation so important to the university's feature. Their expectation is getting information from content-rich social media. While someone of my age may look at a YouTube video as a novelty; to a younger person it is *the* way to communicate. New communication tools get socially interesting when they get technologically boring - for young people today the new social tools are passing normal and heading to ubiquitous with invisible coming soon. Informal Science Educators need to have a meaningful presence in Web 2.0 before invisibility fully arrives, otherwise our use of the medium will appear ham-handed and graceless.
- **Appeals to kids younger than the majority of participants** in the videos. In his insightful book *Convergence Culture,* Henry Jenkins notes that kids typically like to watch what people five to six years old than them are doing and model their behavior on that. This is part of the appeal of *American Idol*: Half of its audience is 13 year olds who want to see an 18 year old performing.
- **Involves the top ten schools** to create enough content to grow a long tail. In fact, because digital storage is so cheap this web space can grow forever.
- **Offers long term funding** *beyond* NSF support by ad revenues. In the "old" media ISE days the restriction on television and radio removed this opportunity. The audience of these videos is a prime demographic for advertisers.

11 "RSS is a family of Web feed formats used to publish frequently updated works - such as blog entries, news headlines, audio, and video - in a standardized format. An RSS document (which is called a 'feed', 'web feed', or 'channel') includes full or summarized text, plus metadata such as publishing dates and authorship. Web feeds benefit publishers by letting them syndicate content quickly and automatically. They benefit readers who want to subscribe to timely updates from favored websites or to aggregate feeds from many sites into one place. RSS feeds can be read using software called an "RSS reader", 'feed reader', or 'aggregator', which can be web-based or desktop-based." *Wikipedia.*

Citizen Engineering: Web 2.0 and the Masses

The development of social networking tools has given new impetus to Citizen Science, which Wikiepedia aptly defines as:

> "*.... a term used for projects or ongoing programs of scientific work in which individual volunteers or networks of volunteers, many of whom may have no specific scientific training, perform or manage research-related tasks such as observation, measurement or computation.*"

Citizen Science projects have engaged the public to classify over a million star clusters, to collect data on ecosystems, and to help researchers better understand birds and their habits.[12]

Web 2.0 social tools, then, offer the promise of vastly expanding citizen science projects, and of increasing their efficacy. Additionally, the goals of Citizen Science Projects square directly with the mission of NSF's Informal Science Education:

> "*The use of citizen-science networks often allows scientists to accomplish research objectives more feasibly than would otherwise be possible. In addition, these projects aim to promote public engagement with the research, as well as with science in general. Some programs provide materials specifically for use by primary or secondary school students. As such, citizen science is one approach to informal science education.*" *[*Wikipedia*]*

Bruce V. Lewenstein, Professor Science Communication at Cornell, notes two addition benefits to Citizen Science, which round out fulfilling ISE's mission: a) The engagement of non-scientists in true decision-making about policy issues that have technical or scientific components; and 2) the engagement of research scientists in the democratic and policy process[13]

I describe below a Citizen engineering project. In many ways engineering lends itself better to this approach than does science because it is a process-oriented activity with a teleological goal of producing something, rather than discovery about nature.

Project Title: Understanding Alternative Energy: What the public needs to know about the grid

Overview of Project: Citizen engineers use, in their homes, frequency meters to monitor the health of the grid and its changes in their community as alternative energy sources come in line. That data obtained by this citizen engineer is of vital importance to power engineers designing the next generation of grids. Using specially developed Web 2.0 tools the public can visualize the electric grid -- seeing it in their communities, but also the grid interdependence across large regions of the nation. The project participants will use power meters to find "energy vampires" - household appliances that draw energy covertly. The new internet-based tools provide a

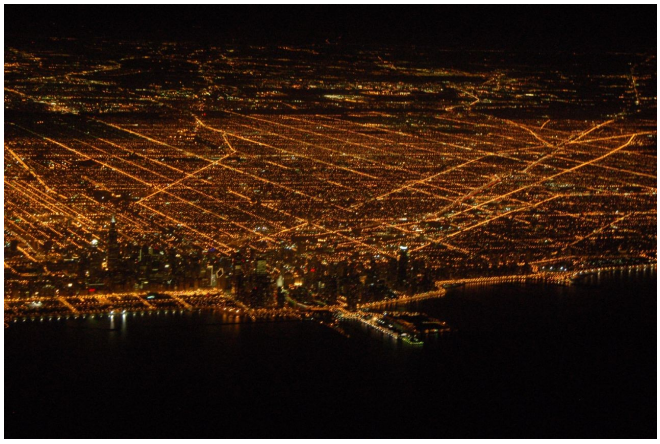
12 See www.galaxyzoo.com for details on stars, for ecosystems see C.B. Cooper, et al. "Citizen Science as a Tool for Conservation in Residential Ecosystem" Ecology and Society 12(2) issue 11; for studies with birds refer to the work of the Cornell Lab of Ornithology.

13 "What does citizen science accomplish?" Paper read at CNRS colloquium, 8 June 2004, in Paris, France.

forum for sharing information on how to use electricity more efficiently; e.g., strategies for detecting energy vampires and eliminating them.

The Problem: The public has great interest in solving the energy problems we face in the future, but little knowledge.[14] Currently 40% of our energy usage comes from electricity - power that is typically generated by coal, oil, and some nuclear. Clearly the United States will need to move toward alternative sources, and as that transformation occurs the public will be faced with difficult choices. While they remain fascinated about these sources, the public rarely appreciates that these new energy technologies have an Achilles' Heel: Transmission.

As a recent issue of the *Economist* pointed out "perhaps the greatest obstacle to the wider adoption of wind power is the need to overhaul the grid to accommodate it."[15] So, as the United States moves toward alternative energy sources, for its citizens to be effective -- as voters or in applying knowledge in their own communities -- they need to understand deeply the electrical grid. Many electrical and power engineers feel the public far underestimates the difficulty with which renewables can be added to the electric grid. In the grid's nuisances and peculiarities lies a major hurdle to using and incorporating non-fossil based alternatives into our nation's energy mix.



The Achilles' Heel for alternative energy sources is the electric grid. In its nuisances and peculiarities lies a major hurdle to using and incorporating non-fossil based alternatives into our nation's energy mix. To incorporate wind, solar, and other non-fossil fuels requires significant changes in electricity transmission. As one electrical engineer has said " the public far underestimates the difficulty with which renewables can be added to the electric grid." As the United States enters the 21st Century its citizen will be faced with difficult choices on what forms of alternative sources will be developed and used The "Citizen Engineering" project outlined in this white paper creates citizens with the knowledge to make informed decisions about the grid.

The public rarely thinks of the grid, yet it is the nervous system of our nation's energy infrastructure - we often concentrate on that system's "heart" (the generation of power by coal, oil, hydro or nuclear) but rarely think of its transmission. To facilitate that understand, and to create literate citizens, the project described below makes citizens an active part of monitoring and developing the new grid. The long-term goal is to develop smart meters for an intelligent grid - a grid designed to be more responsive to changes in load, and designed to get feedback to consumers.

As a report on the 2003 black out in the U.S. explains, the power grid requires the almost superhuman ability to predict the behavior of humans.[16] There is no way to store electricity cheaply in the vast quantities in which America uses it. Electricity flows at close to the speed of light, thus it must be produced at the instant it is used. And therein lies its Achilles' Heel in regards to alternative energy sources. Power plants distributed across the nation must feed the grid at just the right time. Picture the grid like a balanced tightrope walker: The air conditioners pull on one side attempting to tip it off balance, but the power plants push back to keep it in balance. But if something fails then the grid can became unstable. Just as a tightrope walker loses balance and sways back and forth in larger and larger arcs until he or she falls, the electrical power grid can become unstable.

Power Engineers need to know, to meet the U.S. energy needs of the 21st century, how new technologies affect the grid. They would like to know, for example, what happens to the grid if *everyone* installs compact fluorescent then how much would that effect the grid. Or, what if the sales of hybrid cars skyrocket -- cars that plug into the grid at night. In their studies of "load modeling" - a very important topic in the field now - they are concerned with "power electronics" in the home. A home solar system, for example, contains these power electronics. These devices can really mess with the grid.[17]

Project specifics. The electrical grid presents an ideal problem to tackle with Citizen Engineering methods. Typically such project make use of the thousands of eyes and brains of their participants to gather and, in some cases, to analyze data that stretches across a large distances; e.g., Cornell's Lab of Ornithology uses Citizen Scientists to track birds across the U.S. The grid is both highly local and interdependent -- The Blackout of August 2003, for example, occurred because a small northern Ohio failed to trim trim tree along a power line.

This project places a frequency meter, power meters and other devices in the home of every participant. This projects uses a new technology, called Frequency Monitoring Network (FNET), developed at Virginia Tech by YiLu Liu, a professor of electrical and computer engineering - and an expert on the electrical grid.[18] She and her team have developed a small

14 Rosayln Mckeown "Energy Myth Two - The public is well informed about energy" *Energy and American Society – Thirteen Myths* edited by Benjamin K. Sovacool and Marilyn A. Brown (Springer Netherlands 2007)

15 "Wind of Change", *The Economist Technology Quarterly* December 6, 2008 p. 22-25.

16 Final Report on the August 14, 2003 *Blackout in the United States and Canada: Causes and Recommendations*, U.S.-Canada Power System Outage Task Force, Washington, D.C. : U.S. Dept. of Energy, 2004 [Govt. Doc. Number E 1.2:2004017718]

17 Power electronics: A simple definition for power electronics would be "the control of `raw' input electrical power through electronic means to meet load requirements". Power electronics is interdisciplinary and is at the confluence of three fundamental technical areas - power, electronics and control.

18 S.-J. S. Tsai, J. Zuo, Y Zhang and Y. Lui "Frequency Visualization in Large Electric Power Systems" *Power Engineering Society General Meeting*, 2005 (IEEE) Issue 12-16 June 2005 p 1467-1473; L. Nystrom "Energy Grid" *Virginia Tech Research* Summer 2006, p. 1-5

box - called a Frequency Disturbance Recorder - to measure changes in frequency on the grid. The simplicity of the technology from a user's point of view is rather astounding. There are no installation costs; the user just plugs a unit into a standard electrical outlet. Of what value is knowing the frequency at many points on the grid?

The grid generates power at a specific frequency of 60 cycles-per-second. If any part of the grid deviates by as much as 1/20 cycle-per-second trouble develops; if it drops to 59 cycles per second then havoc, ala the Blackout of 2003, results. The frequency, then, is akin to a human pulse: Its measure and value tells us something about the health of the grid. With the fifty or so devices that Professor Liu has employed across the Eastern Interconnect - the grid that powers the mid-west, eastern seaboard and parts of Canada - and connect detect earlier than anyone else disturbances in the grid. The goal of this project will be to deploy thousands more of these devices and to get fine-scale information about the current health of the grid and about the grid's behavior as we add renewables and power electronics to the grid. Currently there are 50 or so meters out there, with 2000 plus researchers could truly understand the grid at a very local level, thus preventing disturbances nationwide, and providing the essential data for adding renewables.

Bill Hammack is the nation's premier communicator about engineering. He has created over 300 pieces for public radio, which have been broadcast on public radio's popular *Marketplace* show and internationally on Radio National Australia.

To incorporate these local frequency and power meters into a true citizen engineering project this project will develop the proper cognitive tools (e.g., a wiki) so each participant would be able to see share, discuss, and enhance their own observations. For example, they can monitor the behavior of their grid using revolutionary software developed by Professor Thomas Overbye of the University of Illinois.[19] Visualization software packs a large amount of information into a single-computer generated image - images that are useful, even indispensable to monitor the electrical grid. This allows a citizen to track flows of electric in their own community and to see how they are linked, and thus interdependent with much of the rest of the nation. In short, visualization allows a member of the public to comprehend the grid by lifting the truly significant events about the background noise. The power meters are used to locate "energy vampires"[20] in a home; the wiki will allow users to share thoughts and offer suggestions on how to improve energy efficiency in their houses.

About the author

Bill Hammack's work has been recognized by an extraordinarily broad range of scientific, engineering, and most importantly journalistic professional societies. From his engineering peers he's been recognized with the the ASME's *Church Medal*, IEEE's *Distinguished Literary Contributions Award*, ASEE's *President's Medal*, and the AIChE's *Service to Society Award*. From the journalists he has won the trifecta of the top science/engineering journalism awards: The National Association of Science Writer's coveted *Society in Society Award*; the American Chemical Society's *Grady-Stack Medal* - an award previously won by Isaac Asimov and Don Herbert (Mr. Science) - and the American Institute of Physics *Science Writing Award* -- all typically given to journalists. In addition he is a Fellow of the American Association for the Advancement of Science and of the American Physical Society.

Pioneering a new role for an engineering professor, he created a remarkable public radio series called "Engineering & Life", in which he shared with the public the wonder of engineering, while also emphasizing the responsibilities associated with technological change. His hundreds of radio pieces have been heard on public radio's premier business program *Marketplace*,which has an audience of 8 million, and around the globe on Radio National Australia's *Science Show*. In 2005-06 he broadened his "audience" to include senior government policy makers. He served a year as a Senior Science Adviser at the U.S. Department of State.

He served as an energy adviser for the Six-Party Talks to denuclearize the Korean Peninsula. He also work in State's Bureau of International Security and Nonproliferation, representing the U.S. in successful talks with Vietnam to remove highly enriched uranium, which can be used to make a small nuclear bomb. Through his pioneering work he is creating technologically literate citizens and government officials who will have a huge impact on the health of our democracy, our national economic productivity, and foreign policy.

Contact Info:

Professor William S. Hammack
Department of Chemical & Biomolecular Engineering
Box C-3, 600 South Mathews
University of Illinois
Urbana, IL 61801
217-24-4146
hammack@netbox.com
IM: ProfHammack (on nearly any system)

19 T.J. Overbye and J.D. Weber "Visualizing the Electric Grid" *IEEE Spectrum* February 2001

20 By this I mean "standby power", also called vampire power, phantom load, or leaking electricity. It refers to the electric power consumed by electronic appliances while they are switched off or in a standby mode. For example, a very common "electricity vampire" is a power adapter which has no power-off switch. Some such devices offer remote controls and digital clock features to the user, while other devices, such as power adapters for laptop computers and other electronic devices, consume power without offering any features. (See Wikipedia on Standby Power for more information.)