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Educating citizen scientists in a convergent culture

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Abstract

This paper provides an exemplar of citizen scientist methodology in the undergraduate classroom. It suggests that Kolb's experiential learning cycle be expanded to include the concepts of participatory culture and generative knowledge.

The Western world has many reasons to be grateful for technological advances it enjoys each day due to the efforts of citizen scientists—men and women who, despite limited training, profoundly advanced scientific discovery. Citizen scientists invented wireless radio, television, Apple computers, and thousands of other helpful devices. Scientists with much greater theoretic, academic, and practical skills improved these devices; yet citizen scientists, equipped with only basic scientific skills, generated initial ideas and prototypes. In the newly emergent convergent culture, this trend holds even greater possibilities and challenges. It is crucial that the role of science pedagogy in such a culture accounts for increased citizen participation by leveraging its benefits and minimizing deficits for the advancement of science. Using a science education case study, this paper will explore the relationship between citizen scientists and the newly emergent convergent culture. It introduces a pedagogical model that melds Kolb's (1984) experiential learning cycle with the integrative knowledge process proposed by Peet et al. (2010).

Convergence culture

Convergence culture (Jenkins, 2006), or participatory culture, refers to the vast societal movement underway that is uniting all forms of media and information into a participatory and collective intelligence. Jenkins describes convergence culture as the place "where old and new media collide, where grassroots and corporate media intersect, where the power of the media producer and the power of the consumer interact in unpredictable ways" (p. 259-60). What we see today is no accident; it is the result of major shifts towards convergence that unite global corporations, media communication, and scientific research.

Convergence in corporate America often involves the merging of human, financial, marketing, and production resources. For example, car manufacturers produce competing brands of cars at the same facility under the same corporate and manufacturing structure. In media, the concept of convergence was formerly described as trans-media, a series of cross-promotional consumer strategies (Hay & Couldry, 2011). For instance, a popular book might be heavily promoted and rewritten as a movie, adapted as a video game, and finally repackaged as a set of action figures. Today, however, convergence in media describes the reality in which books,

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radio, television, film, music, and the Internet have merged into a singular, convenient source—smartphones, tablets, and laptop computers (Thornton & Keith, 2009).

In a convergence culture, access to news, advertising, information, education, and entertainment converges in a singular device as well. These devices also empower individuals to participate in convergence culture by creating, uploading, and sharing information. One outcome of convergence culture is the ability of ordinary people to participate in social justice efforts. The Rodney King video shot by a local citizen (George Holliday) from his balcony is an early example of this phenomenon. The video, which documents police misconduct, was seen around the world and had a profound impact on society. Today there are many such videos; in fact, it has almost become commonplace for citizen videos to "go viral" before public officials have any idea about problems or events that are unfolding. Any citizen with a smartphone has the ability to document and post events as they unfold on national media sites.

The implications of this shift on education in general and science education in particular are profound. As Jenkins (2004) describes,

> Imagine a world where there are two kinds of media power: one comes through media concentration, where any message gains authority simply by being broadcast on network television; the other comes through collective intelligence, where a message gains visibility only if it is deemed relevant to a loose network of divergent publics. Broadcasting will place issues on the national agenda and define core values. Grassroots media will reframe those issues for different publics and ensure that everyone has a chance to be heard (p. 35).

The implications of Jenkins' description are not limited to media. If his predictions come true, education will be reshaped as well. Previously, education considered valid by both institutions of learning and society at large was obtained by expert knowledge. In convergence culture, higher education will continue to shape knowledge, yet citizen scientists will reframe issues and reshape information for differing publics. In today's environment, citizen scientists will contribute alongside the experts and may well become just as recognized, if not more so, than the experts.

Given these changes, it becomes even more important for science educators to create interactive and participatory experiences that shape the scientific mind and take advantage of new possibilities for science education in a convergence culture. Cooper (2012) admonishes science educators that "education efforts should seize the opportunity to emphasize the key and distinct roles students can play" in the production of scientific knowledge (p. 1); but as Lynda Jenkins (2011) notes, a context and strategy for making science relevant to students' lives must first be established. Citizen science is a feature of today's participatory culture by which educators can empower students with experiences that make science more personally relevant and benefit communities beyond the walls of the classroom.

Citizen scientists

In the convergence culture, traditional sources of scholarly information are losing their authority as unique gatekeepers of scientific information. New challenges face the academy to ensure the participatory culture of academic and citizen scholars will generate true scientific advancement. Citizen science offers a powerful response to new challenges. Mueller, Tippins, and Bryan (2012) depict citizen science as “a community-centered science, community science, participatory community-action research, street science, traditional ecological knowledge, social justice, scientific literacy, and humanistic science education” (p. 12). Embedded in these various descriptions is the reality that the generation of scientific knowledge is no longer the academy’s exclusive purview.

Traditional scientists have strong research skills and specific training in the observation of specialized subject areas. They generate, consolidate, and share information within a narrow community of scholar experts. Citizen scientists, on the other hand, may or may not receive broad training in science. Yet as Cooper et al. (2009) note, many scientific efforts, such as the studying of large-scale patterns in nature, require a vast amount of data to be collected over a span of years. In such cases, traditional scientists are able to partner with citizen scientists to accomplish far beyond what the academic community alone might achieve. The catastrophic breakdown of the nuclear reactor in Fukushima, Japan, illustrates the point.

After the 2011 Fukushima catastrophe in Japan, concerned citizens from all over the nation began collecting and posting data about radiation levels in public sources (Lundahl, 2013). Using simple Geiger counters, citizens collected over 14,000,000 data points, a feat impossible for a single researcher. In rather short order, a participatory culture emerged to monitor and self-report radiation data instead of depending upon governmental pronouncements or scientific studies. Other examples include the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS), by which over 20,000 people in the United States and Canada record and report local rainfall data; the SETI@home program that employs 1.5 million personal computers to search radio signals for signs of extraterrestrial life; and the “great shoe spill” of 1990 that enabled scientists to track ocean currents by employing beachcombers worldwide to report landfall of the 60,000 Nike shoes that had been washed off a carrier during a storm.

These examples illustrate how citizen science benefits the academy in terms of data collection; but the role of the citizen scientist is not limited to reporting data. Citizen scientists operate within a convergent, participatory culture. The size and scope of today’s social networks potentially means that citizens can reach larger mass audiences with information than traditional scholars who have smaller and more narrowly defined audiences. Additionally, citizens are using information gained from public and social sources to challenge the findings and legitimacy of authorities in more and more areas. In other words, convergence culture is responsible for a not-so-subtle shift in the way that science is both practiced and perceived. For science education, the new landscape requires a revised pedagogy. Instructors empower students to become effective citizen scientists by equipping them with both scientific knowledge and with skills for understanding, navigating, and contributing within a convergent and participatory culture.

Science pedagogy for convergence culture

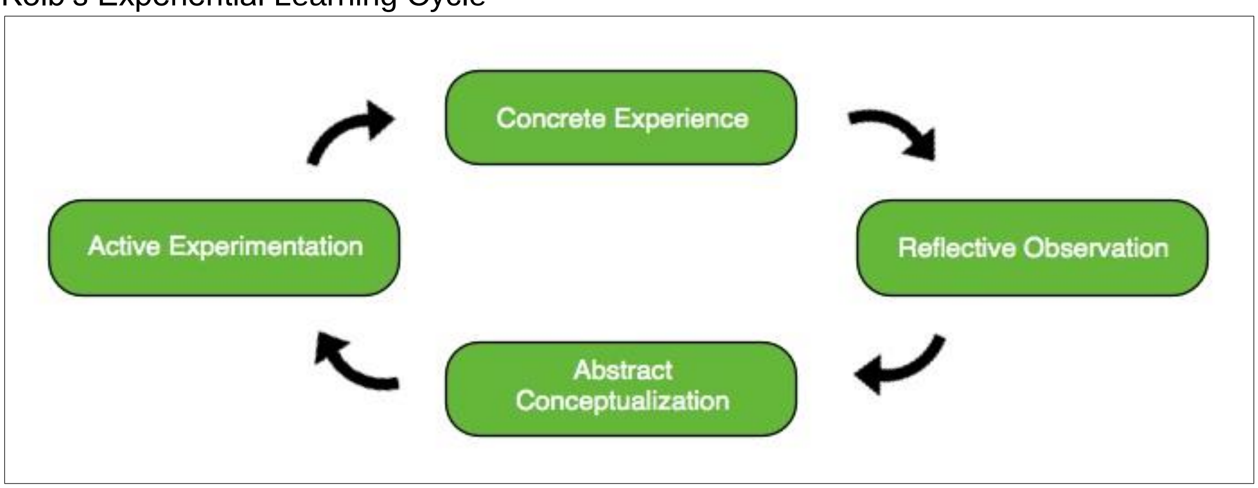
The pedagogies of traditional science are as old as the dialectical methods of Socrates (470-399 BCE), Aristotle's treatise on *Animals* and *Meteorology* (382-324 BCE), and Pliny the Elder's *Natural Science* (AD 77-79). The learning theories employed today were strongly influenced by philosophers such as John Dewey (1938), who asks,

> What is the definition of Inquiry? That is, what is the most highly generalized conception of inquiry which can be justifiably formulated? . . . Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole (p. 104).

Dewey's discussion of inquiry is bedrock for the study of science; these concepts are expressed pragmatically through a set of procedures that are often called the scientific method. While there are many approaches to the study of scientific method, it is typically divided into the following steps: (1) identify and define the problem; (2) determine a hypothesis or reason why the problem exists; (3) collect and analyze data; (4) formulate conclusions; (5) use the conclusion to reformulate the original hypothesis. Regardless of the approach, it can certainly be argued that each step of the scientific method is grounded in ordered, experiential learning. Kolb (1984) captures this point in his helpful model of the experiential learning cycle.

Kolb's four-part cycle is a convenient model for science education; it is based upon a process of empirical observation, data collection, and theory building. First, learners participate in a concrete experience (some form of exploration), followed by a period of recorded observations and reflections. From this, students develop more abstract concepts that might enable the transferability of the single experience to numerous other life situations. Finally, students test their understanding in a variety of life situations to see if their abstract concepts function in the real world. Kolb believes the process to be a *recurring cycle*, as indicated by the model below.

Figure 1.
Kolb's Experiential Learning Cycle



Kolb's model of the experiential learning cycle is tremendously useful for teaching science in traditional ways (i.e., in a closed, classroom environment in which learning happens within and among students but is rarely "pushed-out" to the external environment). In a convergence culture, students and instructors have opportunity to engage the external context beyond the walls of the classroom, and not merely as those who gather and use information but as producers and contributors of new knowledge and insight. The closed nature of Kolb's model works well for experiential learning within a closed classroom environment; however, Kolb's model is limited for empowering citizen scientists to make meaningful contributions in a participatory culture.

As early as 1934, the preeminent science philosopher Karl Popper voiced a similar criticism regarding the closed nature of a scientific community. Popper (1959) claims that,

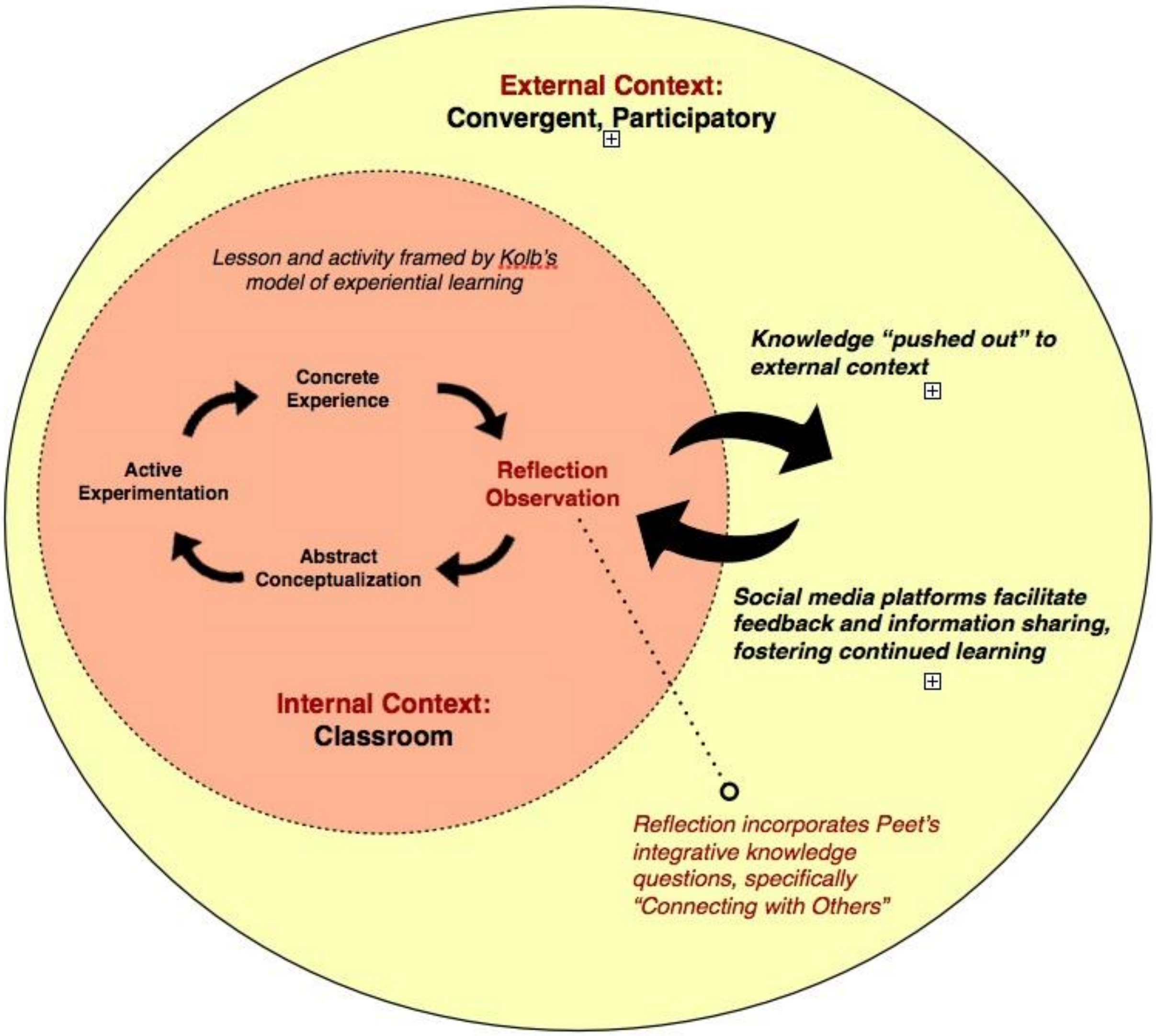
> The task of formulating an acceptable definition of the idea of an 'empirical science' is not without its difficulties. Some of these arise from the fact that there must be many theoretical systems with a logical structure very similar to the one which at any particular time is the accepted system of empirical science. This situation is sometimes described by saying that there is a great number—presumably an infinite number—of 'logically possible worlds.' Yet the system called 'empirical science' is intended to represent only one world: the 'real world' or the 'world of our experience' (p. 39).

Convergence culture enlarges 'the world of our experience' and opens new spaces for exploration in science education.

Experiential models such as Kolb's often focus on the development of students into scientists through the cultivation of expert knowledge. Kolb's model describes the learning that takes place in a somewhat closed environment where scientists teach prospective scientists (i.e., students) who in turn create knowledge that is shared primarily among a scientific community, thus perpetuating prevailing views to the potential exclusion of other worthy ideas. Missing from his model are the additional components necessary for success in a participatory culture—sharing and communicating with the world outside of science and the academy. An additional concern is that Kolb's reflection stage might not adequately describe the deeper learning process occurring within students as they participate both with science and among the larger culture.

Pedagogy for a convergent, participatory culture requires that teachers "think outside the box." In the expanded model proposed below, Kolb's experiential learning cycle is expanded to include the reality of participatory culture and notions of embodied, integrative, and generative knowledge (Peet et al., 2011). In this model, students are encouraged to briefly exit the Kolb cycle at the point where they reflect upon their experiences so that they might share their findings with a broader community through a variety of electronic media (e.g., blogs, wikis, videos, podcasts, etc.). Knowledge is pushed out from the science classroom context to a larger external environment of divergent social media platforms consisting of numerous tangential constituent groups, some which have had little formal science training. For instance, reporting on discoveries made in the science classroom might be specially tailored for specific communities related to law, justice, technology, philosophy, and humanities, to name but a few. Information is pushed out and shared via social media platforms that target and are designed to be found by diverse publics. As ideas are shared more broadly through social media, new ideas are generated and fed back into the internal science community (i.e., the science classroom) for consideration. It is precisely this kind of diversity that is needed to more adequately challenge prevailing scientific thinking and attitudes.

Figure 2.
Citizen Science model that incorporates experiential learning, convergence culture, and integrative knowledge.



Peet et al. (2011) describe a set of pedagogical practices that produce both integrative knowledge and generative learning. The term integrative knowledge reflects a multidimensional construct that includes becoming an intentional and reflective thinker, a process orientation towards knowledge, and the ability to work with others to address social problems. Process orientation involves learning to apply academic skills and thinking to life challenges, a dimension not always included in science pedagogy but necessary for participatory culture. When these dimensions are added to the Kolb model, its focus broadens. The revised model shapes citizen scientists in a convergence culture; it seeks to empower intentional and reflective learners who take personal responsibility for growth, for lifelong learning, and for contributing knowledge beyond the classroom walls.

As instructors lead students through Kolb's stages of experiential learning, the reflection stage can be augmented with strategies proposed by Peet et al. (2011), providing students a better space for critical reflection and an opportunity to consider the broader implications of learning. To facilitate reflection, instructors lead students through "a process of storytelling, listening, dialogue, and documentation that helps students identify and document the tacit knowledge embedded within their key learning experiences" (p. 16). Reflection is a classroom rather than individual exercise:

> By having students generatively listen to one another, they learn how to surface, identify, and document their own and each others' tacit capacities, strengths, and skills (i.e., the specific types of adaptive behaviors needed to interact with people from backgrounds different from their own). (Peet et al., 2011, p. 16).

Reflection as a learning community reveals tacit insights that might otherwise have remained unvoiced; likewise, reflection encourages students to recognize that new knowledge can have different levels of significance and hold deeper implications for different people and groups.

The reflective process helps emerging citizen scientists to notice connections between disparate facts, concepts, and theories. Moreover, the process encourages students to identify how new knowledge can be broadly applied across many areas of study and interest. Through reflection, students may ask, "For whom does this knowledge hold special implication?" In this way, reflection shifts the focus from the internal classroom context and brings the larger, external context into view. Students begin considering how they might package and communicate new knowledge for a broader public.

Empowering knowledge creation in a convergence culture

Within a participatory culture, the nature of knowledge creation and sharing is altered. Wikipedia offers an example of how today's information society has changed the way human knowledge is generated and communicated (Bayliss, 2013; Maehre, 2009). Wikipedia is a feature of the information society that harnesses the potential of knowledge sharing and global collaboration. Previously, the traditional encyclopedia organized and preserved knowledge; under the former paradigm, an individual or small pool of experts was chosen to provide content for select topics, "trickling down" expert knowledge to inform society. However, in the emerging paradigm the expert's voice becomes increasingly difficult to identify as knowledge is collaboratively produced through crowdsourcing, as is the case with Wikipedia.

As citizen scientists, students become creators and sharers of knowledge, tasks that require skills for critical thinking and information literacy. Today's culture is saturated by information; critical thinking and information literacy help students navigate an ocean of images, text, video, and sound to evaluate information for its authority and currency. At the same time, students with information literacy skills learn to effectively synthesize and communicate discoveries (cf. Information literacy competency standards, 2000). In a participatory culture, students need skills for finding and evaluating information; they also need to be taught how to produce reliable and credible documents that inform the culture of their citizen science experiences in a variety of differing formats, including the social media.

Science teachers have the opportunity to transform students into citizen scientists who collaborate with others in an information society to contribute their own voices, experiences, and ideas. This is exactly the way knowledge is created in a participatory culture—not only by experts but by a larger community of intellects as well. Through collaboration with librarians, science instructors can develop strategies for empowering students with information competency (cf. Pritchard, 2010). For citizen science, information competency includes teaching students how to make the information they produce more *findable* (e.g., through tagging and indexing). In this way, students will not only find and use reliable information, they will be empowered to contribute their own voices, creating and clarifying new knowledge for a broad public.

Citizen scientist exemplar lesson

The following case study provides an illustration of how concepts, theories, and models discussed in this paper were applied in an actual classroom. The project was conducted in the laboratory setting of an Introduction to Forensics class. The lesson was an exploration of the prevalence of cocaine contamination on American currency, where it is estimated that over 80% of currency in circulation has detectable amounts of the illicit substance (Jourdan, Veitenheimer, Murray, & Wagner, 2013). Students were introduced to a specific incident where police had confiscated money from a legitimate businessperson on the basis that it had detectable amounts of cocaine. With the possibility of larger social implications made evident, students tested bills for traces of cocaine; they then became the teachers as guests were invited to class to discover the prevalence of contamination on their own bills as well.

Methodology. The exercise is rather straightforward. Students either supply or are given dollar bills and a chemical solution for washing them. The wash is analyzed and the results are recorded and submitted for grading. Students learn how to maintain a chain of custody of "evidence," how to process evidence to collect the sample, and how to determine the amount of drugs in the sample. In past exercises, after students were taught forensic procedure, they reported findings in a traditional, written format; however, to convert this experiment into a citizen science exercise, three new pedagogical dimensions were added. First, guests from across campus were invited to the laboratory to participate in the analysis. The guests included the university President, the Vice President of Academic Affairs, the Dean of Students, the campus Chief of Police, and several of the students' favorite professors. Secondly, instead of a traditional written report, results were reported via social media and on a specially created wiki website.

Finally, to allow for a more comprehensive and collaborative project, students were assigned to work in groups. Groups were encouraged to interact and help explain or clarify new concepts for each other.

As mentioned above, an exciting event was planned for campus notables to attend. Guests provided their own dollar bills for analysis. As a fun aside, guests were told that the campus Chief of Police was there to arrest those with contaminated money. The students, who had been trained in the procedure, taught the guests how to conduct the forensic exercise.

A rubric was developed, specific enough to ensure students understood assignment requirements yet general enough to allow creativity. The example report included an introduction, procedure, result, and conclusion, with few specific instructions given for each section. Students were told to report their findings on a specially created wiki using the language of an average citizen with little or no background in science. They were encouraged to make the report interesting while not forgetting the fundamental information a reader would need to understand the project. The look and feel of the website was a significant percentage of the lab assignment grade. Students were introduced to a librarian and encouraged to seek help for finding resources to augment their reports.

Results. Feedback from the students was positive. Many students claimed they knew that cocaine trafficking was a problem, but they had no idea of how closely it affected them. Showing that 97% of the dollar bills in their wallets were contaminated with cocaine residue demonstrated personal relevance. Another positive outcome involved student ownership of learning. After learning how to perform the analysis, they were required to teach it. This impacted the students' learning of the topic at a deeper level. An added advantage was that student interaction with important campus administrators lent a degree of gravity to the exercise, as well as providing a "cool" factor for the students.

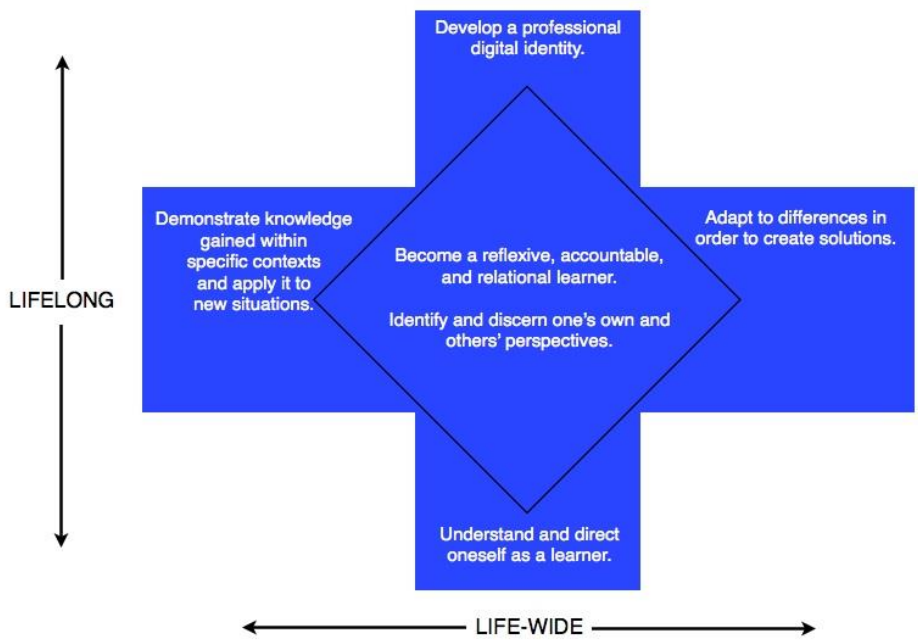
Concerning their reports, students remarked that they enjoyed presenting information on a webpage rather than in a standard research paper. The research was equivalent to a traditional project, but they found the reporting format more interesting. Since the webpages were public, students could observe the other groups' analyses as well as invite friends and loved ones to view their results. This type of public reporting encouraged the students to analyze what other groups were doing in relation to their own analysis. Finally, the students enjoyed seeing their data added to the data pool in real time. They saw collective results update as new data was added.

Exemplar and models

Pedagogical strategies for the citizen science exemplar developed out of consideration of Kolb's model for experiential learning, recognition of today's convergence culture, and a desire for developing deeper integrative knowledge in students. As described, Kolb's model posits four stages in the experiential learning cycle: abstract conceptualization, active experimentation, concrete experience, and reflective observation. These stages provided structure for the exemplar lesson. Initially, students had limited awareness of the pervasiveness of cocaine contamination on currency. The issue remained outside their sphere of concern until the classroom exercise brought it into focus, making it relevant to their lives. Increasing student awareness of the issue marked the abstract conceptualization stage of Kolb's cycle. Active experimentation involved students learning to test bills and report their initial findings. Then, students taught the process to others, providing a concrete experience that confirmed their learning. The experience became more personally relevant as students realized the incriminating test results of their tainted money. Questions regarding broader societal implications of their findings began to arise.

At this point—the reflective observation stage of Kolb's cycle—six dimensions of integrative knowledge described by Peet et al. (2011) help to make sense of classroom observations in a broader, cultural context. Their model (below) describes "capacities that foster critically reflective lifelong and life-wide learning" (p. 16). Students are led through a series of core activities that draw out implications of learning both for self and others, how new knowledge is adapted and applied in different contexts, and how learning is captured and presented in a digital context. For empowering citizen science, our model diverges from theirs at the point of digital presentation: they describe a digital portfolio whose viewing audience is limited (primarily to the university setting); we envision scientific knowledge gained in the classroom presented to diverse publics through social media and other online platforms.

Figure 3.
Peet et al. (2011) conception of the dimensions of integrative learning.



As they are guided through reflection, students ask questions of broad significance, such as, "For whom does this knowledge matter and why?" In the exemplar, students learned about search and seizure laws and heard stories about travelers whose money was confiscated because it was tainted with cocaine. The experiment clearly demonstrated to students that any person might be falsely accused of drug use as a result of contaminated currency. Students began to recognize the broader social implications of their learning for justice, commerce, legislation, etc.

Then, when students endeavored to teach the experiment to others, they passed on more than the technical aspects of the exercise; empowered through reflection, students were able to offer "So what?" answers regarding the activity's relevance both to individuals and to society.

As part of the reflective process, students devised strategies for pushing new knowledge out to the external context through a Web-based wiki created for the project. Students researched the issue, locating and evaluating information to help frame and support their reports. Their own collected data could be compared with the findings of others. The wiki provided an opportunity for students to inform and engage audiences outside the classroom context.

In a convergence and participatory culture, it is quite possible for students to contact and collaborate with others outside the classroom, like the scientists and researchers whose names they encounter in their research, bringing new knowledge and insights back into the classroom. Students can choose to tailor their reports for specific publics, such as travelers or tourists who may prefer to avoid carrying cash; or, they may choose to address social-justice concerns by generating more public awareness of currency contamination. Beyond the wiki, students can create public service announcement videos, develop blogs, or post findings on Facebook, depending on the audience(s) they intend to inform. The interactive and collaborative potential of today's participatory culture provides students with learning possibilities that far extend the walls of the classroom.

In summary, the exemplar lesson incorporates experiential learning, convergence culture, and integrative knowledge in a citizen science exercise. Students may perceive society's drug problem as remote and disconnected from their personal lives; however new knowledge about the prevalence of cocaine contamination generates purpose and passion for the laboratory experience, especially when students test bills from their own pockets. The laboratory setting provides opportunity to develop new knowledge and skills. After students have performed the exercise themselves, students experience a role reversal: it is now their responsibility to teach, requiring that they understand and communicate skills and concepts. Through reflection, students come away from the experience with new ways of imagining the future; they have learned that the drug problem is not just "out there." Ideas for addressing the problem surface; students determine how best to present and push information out to the external context. Interaction among students and with the external context leads to new insights for addressing the issue. Proposals then become new abstract conceptualizations, from which Kolb's cycle of experiential learning begins anew.

Conclusion: Citizen science and citizen scholars

Though the exemplar project was designed for developing citizen scientists, the concept can be adapted for all disciplines. The process of designing a citizen scholar project is relatively straightforward; as a starting point, all that is needed is an interesting project. The cocaine analysis described above has been repeatedly taught using more traditional methods and required minor adjustments to adapt it as a citizen science project. At its core, citizen scholar projects take advantage of convergence and participatory culture by including a public reporting component. This reporting component transforms a traditional assignment by extending its impact beyond the classroom walls. Knowledge is generated and presented to the public, informing or perhaps inspiring others in new directions.

Citizen scholar projects can be fruitfully incorporated in all disciplines, including communications, philosophy, theology, psychology, business, art, music, and information studies. Or, in general education courses, instructors can take advantage of the diversity of student interests by encouraging creativity in reporting. For example, consider the citizen science exemplar described above. If offered in a general science course, science majors might elect to report results in a more traditional manner; communication majors might create a public service announcement or news report about their findings; political science majors might produce a blog about social injustices that result from people being falsely accused of cocaine trafficking; business majors might focus on economic implications of the study; and math majors might use statistical arguments to discuss the validity of collected data. Creative reporting strategies make citizen scholar projects more relevant and memorable for a diverse population of students.

Finally, citizen scholar projects not only empower students for knowledge sharing, they are also enjoyable both to facilitate and to experience. L. Dee Fink (2003) stresses the importance of creating significant learning opportunities for students. Fink says significant learning experiences are created when students are engaged at a high energy level; the impact of these experiences results in significant and long-lasting change. The goal of citizen scholar projects is to better empower students for lifelong and life-wide learning in a convergence and participatory culture. Convergence culture views students as potential contributors of knowledge; citizen science and citizen scholar projects empower them with skills to better understand, engage, and contribute in today's participatory environment.

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