Formative assessment for STEM learning ecosystems: Biographical approaches as a resource for research and practice

Brigid Barron
Graduate School of Education, Stanford University

Overview

Educational assessment systems are frequently challenged by divergent stakeholder needs. A major insight from experts who work on school assessment systems is the need to clearly articulate and evaluate assessment choices in relation to these distinct goals (Gorin & Mislevy, 2013). The out-of-school STEM ecosystem faces similar challenges. This background paper presents ideas for new assessment methodologies that include biographical and narrative approaches, measures of sustained learning, and social network representations to complement more traditional approaches that capture average effects of a particular program. It also considers how these forms of documentation might be useful as a tool for the formative assessment of nascent interests in order to help educators and parents broker and guide next steps for learners within and across systems to support interest, identity development, and learning.

> *I sincerely believe that for the child, and for the parent seeking to guide him, it is not half so important to know as to feel. If facts are the seeds that later produce knowledge and wisdom, then the emotions and the impressions of the senses are the fertile soil in which the seeds must grow. …Once the emotions have been aroused – a sense of the beautiful, the excitement of the new and the unknown, a feeling of sympathy, pity, admiration, or love—then we wish for knowledge about the object of our emotional response. Once found, it has lasting meaning. It is more important to pave the way for the child to want to know than to put him on a diet of facts that he is not ready to assimilate.*
>
> *—Rachel Carson, 1956*

In the summer of 1956 an article entitled "*Help Your Child to Wonder*" appeared in the monthly magazine, *A Women's Home Companion,* written by the scientist and environmental activist Rachel Carson. Carson's pedagogical advice to parents called for a focus on affective and aesthetic experience rather than facts, to nurture the desire to learn about the natural world. She went on in her article to speak to the importance of paving the way to genuine interest over time and through a variety of activities that help a child notice details, generate questions, and

experience beauty. She stressed the importance of guides who can share in the experience of joyful discovery and delight, deemphasizing the need for adults to have extensive knowledge in order to serve as effective learning partners. She recommended walks during the day and the night, rain or shine, and if possible investment in a simple magnifying glass to bring a new world into view by revealing the mysteries of taken for granted sights.

Learning as distributed across time and settings

We will return to Rachel Carson's own learning story shortly. For now, it is of note that her perspective is consistent with recent theorizing about how people learn. Consequential learning is increasingly recognized as interest-driven, extended over time, and distributed across the settings of home, school, and community, including online virtual spaces. Studies that chart the evolution of interests prospectively or retrospectively point to the important roles of early experiences, family-supported hobbies, as well as schools in sustaining engagement in STEM (e.g., Tai, Lui, Maltese, & Fan 2006; Crowley, Barron, Knudson, & Martin, in press). The incorporation of *identity* has been increasingly important for conceptualizing these cross-setting learning dynamics as it helps make visible relationships between persons, domains, and pursuits over time (Calabrese-Barton, Kang, Tan, O'Neill, Bautista-Guerra, & Brecklin; 2013; Lave & Wenger, 1991; Holland & Leander, 2004; Hull & Greeno, 2006). For example, Nasir & Hand (2008) develop the idea of practice-linked identities. This construct expands notions of identity development from more individually-focused, psychological perspectives, to a more social and situated view that considers how people form understandings of themselves through deepening engagement in culturally and historically situated and socially enacted practices, as well as how interactions with peers and adults can shift individual perspectives.

Recent policy-oriented documents reflect this broader view of learning including NRC reports on science (Bell, Lewenstein, Shouse, & Feder, 2009), syntheses of empirical work across disciplinary domains (Barron & Bell, forthcoming), as well as foundation-funded reports on interest-driven learning in the arts (Peppler, 2013), and on the role of digital technologies in connecting learning opportunities across settings (Ito, et al., 2013). These conceptualizations build on earlier work focused on the role of community based organized activity settings for youth (Eccles & Gootman, 2002; Heath & McLaughlin, 1993; McLaughlin, Irby, & Langman, 1994) but more explicitly focus on understanding synergistic connections between community and school settings. This view of learning is motivating a generation of new efforts to design opportunities that can help catalyze cross-setting connections to create more intentional and equitable pathways for expertise development. These experiments in turn will generate the need for empirical approaches that allow for units of analysis that go beyond individuals to include a broad range of learning partners including mentors, teachers, and collaborators (Barron & Bell, forthcoming).

The need to broaden our repertories of assessment tools and practices

What does this socially-grounded and distributed view of learning mean for how we assess the effectiveness out-of-school learning opportunities? The field of informal science education has been paying a great deal of attention to assessment and it is the focus of one of the chapters in the Bell et al. (2009) NRC report. A recent set of BOSE papers (Allen & Bonney, 2012; Ellenbogen & Nelson, 2012; Feder & Weiman, 2012; Friedman, 2012; Gitomer, 2012; Karjick, 2012; Renninger, 2012; Suter, 2012), (retrieved from http://sites.nationalacademies.org), provide an excellent overview of the growth in assessment capacity as well as the challenges confronting the field. The desire for standardized measures, the pushback from professionals who feel that

creativity is squelched when such measures are imposed, and the increasing pressure from funders to document efficacy are some of the challenges associated with generating a comprehensive and shared approach (Ellenbogen & Nelson, 2012; Renninger, 2012). It is clear that given the heterogeneity of informal learning experiences with respect to time, intensity, and goals no single approach will be sufficient (Gitomer, 2012; Krajick, 2012). Instead a diversity of approaches are needed that can be tailored for particular purposes.

The need of the field as a whole to generate a robust set of findings that can help justify innovation and scale adds urgency to the goal of expanding our repertoires of assessment practices. Findings that can inspire imaginative designs are also needed. This is particularly important for the newer learning goals related to interest and identity (Allen & Bonney, 2012; Suter, 2012; Feder & Weiman, 2012). The most common approaches to assessment and evaluation typically focus on near-term measures that are easy to administer and score. Well-designed tools of this kind are an important component of an assessment toolkit and there are several ambitious initiatives under way to develop common survey instruments that can be shared across projects (e.g., the Activation Lab from Pittsburg, the Devise project from Cornell) with associated meetings to compare efforts (Shields, 2014). However, to support STEM learning ecosystems designed to connect informal learning opportunities and school-based experiences across time we will need additional approaches that can represent interest and identity phenomena as they emerge over varying timescales.

Complementary approaches to assessment that could be useful for multiple stakeholders include: 1) biographical data and narrative representations; 2) scales and indices that target sustaining learning choices; and 3) maps of learning partnerships within networks. This background paper explores the question of how these types of assessment might complement

more traditional approaches that capture near term changes in interest or knowledge for both summative and formative purposes. It also considers how these forms of assessment might help adults guide next steps for learners within and across systems to support interest, identity development, and learning.

The danger of relying solely on near term assessment

One thing that biographical studies of learning make clear is that it is typically not one experience that leads to a sustained interest but a confluence of opportunities and supports that facilitate connections to a domain (Bloom & Sosniak, 1985; Sosniak, 1990). In most cases, a wide array of activities, people, programs, material resources, and teachers sustain engagement and it is the accumulation of diverse sets of variably engaging experiences over time that account for expertise development, though occasionally one powerful experience is transformative (see Mezirow, 2000). An important implication of the distributed nature of learning is that a single experience may not have an immediately recognizable or detectable effect on knowledge or interest, despite the fact that it may contribute importantly to outcomes that show up later.

There is a real danger that if our assessment toolkit only includes near term measures, we will be at risk of losing the opportunity to build a robust STEM ecosystem because we won't be able to communicate its real value. We need to develop and define a broad range of approaches that can capture the complexity of learning across time and setting. We know from retrospective studies of scientists, science teachers, and science-interested citizens that there are multiple pathways to enduring interests.

Consider the career pathway of Rachel Carson who, while famous for launching the environmental movement with her book *Silent Spring* (1962), was a latecomer to science. In fact, her passion for science did not emerge until she was a junior in college, and was a result of a

biology class she took to fulfill a science requirement. Despite protests from her parents and professors, she switched her major from English to Biology, graduating from Pennsylvania College for Women in 1929, soon after earning a degree in Zoology from John Hopkins in 1932 (Lear, 1997). Carson had long planned to be a writer. At age 11, she published her first story in the children's literary magazine *St. Nicholas* (1918). In addition to being immersed in literature Rachel grew up with plenty of experience out in nature. Her mother engaged her in daily nature walks, drawing on ideas from Anna Botsford Comstock's 1911 *Handbook of Nature Study: For Teachers and Parents.* The 800 plus page handbook was linked to a broader movement led by progressive educators and scientists and it included hundreds of experiential activities organized around specific plants, animals, minerals, and constellations. It was also illustrated by Comstock, who was not only a self-trained award-winning artist, an author, but a teacher-educator, the first female professor at Cornell, and a founding member of the Nature Study movement. There was a congruent focus in the children's magazine *St. Nicholas*, and they published numerous articles on nature as well as fiction.

The influence of these guided nature walks and the associated Nature Study philosophy comes across strongly in Carson's own pedagogical perspectives communicated in the 1956 magazine article directed to parents. We can also speculate that her early experience observing the natural world, accompanied by her mother and enriched by the curriculum embodied in the *Handbook of Nature Study* laid the foundation for her transformative experience in a college biology class. And it is safe to say that both that experience and her immersion in reading and writing literature were influential in her later career pathway and eventual groundbreaking contribution to environmental science which took the form of beautifully written non-fiction works on the role of pesticides in damaging human and eco-system health. However, had she

been asked early on about her interest in a career in science, she probably would have said no, despite the enduring influence of her connection to her local ecology and informal inquiry experiences. One of her lessons for us is that we want to avoid relying solely on near term assessments. We need approaches that can capture continuities and discontinuities, in relation to all kinds of learning opportunities and that are formative in nature, to guide next steps for learners within and across systems. A second lesson is that we might be wise to not only focus narrowly on STEM knowledge but rather work to understand and nurture cross-disciplinary interests that connect science and other areas such as writing, art, history, and music. This cross-disciplinary focus is in line with recent arguments by Danielle Allen, who makes the case that the humanities are particularly generative for political and social agency (Allen, 2014).

Stakeholder needs for assessment, including informal educators, parents, and learners

In a background paper invited by the Gordon Commission, Bob Mislevy (2012) makes the point that one assessment system cannot meet all the diverse purposes that stakeholders have. He offered four metaphors of assessment. One of these, the *feedback metaphor*, foregrounds the importance of thinking about the perspectives and needs of different people, including the learners, noting that the value of assessment data varies depending on who is using it and for what purpose. Given that we are in the early phases of envisioning STEM learning ecosystems, it makes sense to build on this metaphor and begin to imagine what needs different stakeholders might have (also see Gorin & Mislevy, 2013 for an excellent discussion of assessment design for the formal educational system with respect to the *Next Generation Science Standards*). Proving that an informal science experience is of high quality and contributes to learning is of course an important goal. However, we might also ask that our assessments be designed with additional requirements in mind from the perspectives of different stakeholders (also see Friedman, 2012).

In particular, there is a need for tools that are designed to provide formative assessment data not only for learning (e.g., Black & Wiliam, 1998) but I would argue for interest development, personal learning ecologies, and program design. For example, our data collection and representational tools should provide information that *inspires innovative designs and engages in the continual improvement of opportunities*. We should also ask that our *tools support parents, educators, and learners themselves* by helping them reflect on how to broker or assemble learning opportunities across the settings they spend time in by having tools that show them where there are gaps and surface new possibilities for learning. Such tools might help learners and educators develop meta-awareness of their broader learning ecologies. Finally we might ask that *our tools serve to enhance the ability of informal educators to advocate for their programs by communicating valued outcomes in their own terms while also enhancing their practice* (Emilyn Green, personal communication, February, 25th, 2014). Table 1 provides a summary of some of the stakeholders in the Informal Science Education system and how biographical and other complementary approaches might be of use to them. These purposes are aligned with the goal of helping all stakeholders sustain the support of funders and policy makers.

Table 1. Stakeholder assessment needs to advance STEM learning ecosystems

Who	**What information**	**For what reasons**
Informal educators	Informal educators can play roles as advocates for their programs and in the future, within these new learning ecology collectives, may begin to expand their roles beyond providing local experiences to taking on roles as brokers and resource providers to help connect young people and their families to new opportunities. To do this, they will need to understand the range of interests and preferences that a child has, as well as their personal constraints in terms of time, transportation, and financial resources.	Educators can help collect or facilitate the production of learning narratives. This can build the capacity of educators to document learning, can help educators communicate with confidence about what their work is offering, and can provide formative data that will help educators connect learners to the next opportunity. Knowing learner's interests, hobbies, school context, and digital resources can also help tailor informal experiences within a setting.
Learners	Children and teens also benefit from sharing their interests and values with adults and reflecting on them. The youth development research defines youth needs in terms of belonging, safety, caring relationships, sense of competence, and challenge.	Learning autobiographies can prompt reflection and facilitate the development of a meta-perspective that helps conceptualize and diversify one's own learning ecologies, building agency and social awareness.
Parents	Parents may like to know more about what their children find interesting and what possibilities there are for connecting them with low cost activities, free digital resources, and people who can support them.	Learning biographies can prompt reflection and help parents to better understand their child's interests and experiences and connect them to new resources. They can serve as a tool to develop meta-awareness of learning ecologies and pathways.
Researcher-designer	To make progress that is relevant to educational design, we need new conceptual tools that can help generate hypotheses, analytic categories, and theoretical accounts of how engagement is sustained. Types and sources of continuities between learning opportunities that are separated in space or time need identification as well as barriers and disconnects.	Narrative representations can help us imagine new types of connections between organizations, conceptualize new roles for educators, and develop ways for organizations to support them. Social network analysis can help track changes at the community level and eco-networks can chart the diversity of learning partnerships for an individual.
STEM ecosystem advocate	To secure funding and policy decisions that could support STEM learning ecologies, advocates need to develop a variety of forms of evidence. Narrative and biographical representations are one such compelling form. During the NRC/NAS session [Cite session?], it became clear that government leaders like to see images of engaged, curious, learners to complement quantitative metrics.	Learning biographies can help communicate the value of ISE experiences and the value of systemic approaches that create learning pathways, which will link experiences in discrete learning settings into developmental trajectories of participation. Incorporating stories of sustained learning in reports and grants can be more compelling than quantitative metrics of near term learning alone.
Funders	If hybrid, connected learning models take off, funders will want to know that learners take up the seeded pathways of engagement. They might be interested to know the types of consequential decisions that are made, such as choosing to take a science-related elective, join a science club, contribute to a citizen science effort or pursue a college STEM major or job in the longer term.	Learning biographies can complement other metrics to justify expenditures and contribute to the improvement of practice. Funders want to know that their investments in out of school science learning are paying off for learning in the short and long term.

Candidates for complementary forms of assessment

Complementary approaches to surveys and knowledge assessments that could be useful for multiple stakeholders include: 1) biographical data and narrative representations that focus on the development of interests and hobbies across time and setting; 2) indices and environments that can help surface sustaining learning choices; and 3) maps of learning partnerships within networks.

Biographical case study approaches

The usefulness of learning biographies can be seen in retrospective case based approaches (e.g. Bloom & Sosniak, 1985), life course and longitudinal studies more generally (Elder, 1994; Eccles & Wigfield, 2002; Gruber, 1981; Plath, 1980) and cross-setting ethnographies of STEM learning (e.g., Azevedo, 2013; Barron, Gomez, Pinkard, & Martin, 2014; Bell, Bricker, Reeve, Zimmerman, & Tzou, 2012; Calbrese-Barton et al., 2013, 2013; Crowley, Barron, Knutson, & Martin, in press; Polman & Miller, 2010; Leander & Lovvorn, 2006; Zimmerman & Bell, 2014). Learning biographies presented in narrative forms can include point of view, meaning making, and incorporate the words of the child, family, mentors, teachers, and friends. They can help researchers and educators see, map, and describe sustained engagement in activities for learning what Maehr (1976) called *continuing motivation*. They can help identify critical roles that parents, educators, and peers play in brokering and encouraging new opportunities. They can showcase some of the continuity and discontinuity dynamics suggested by a pathway metaphor and associated terms (e.g., roadblocks, on ramps, off ramps). As stories they have the potential to inspire designers to create activities and resources that may support learning across settings. If generated by learners and educators as a routine part of participation in a learning experience they could serve as a formative assessment tool to surface nascent interests and thereby help teachers, parents, and informal educators expand their own roles as brokers and collaborators

(Barron, Martin, Takeuchi, & Fithian, 2009). The generation of a self-narrative can support an articulation of learning preferences and desires that might help bring into focus new needs and opportunities. Finally, biographical case studies may serve as tools that help informal educators communicate program goals and provide examples of positive outcomes as well as identify ways to improve their out of school programs through the analysis of case studies they create.

From a practical perspective, tools and approaches need to be developed that can support data collection and representation. Interview protocols, electronic portfolio systems, and timeline database systems will be needed, designed with educators and learners in mind. Time and setting based visualizations can be combined with narratives to support reflection and communication. Given the heterogeneity of types of organizations, resources available for data collection, and range of relationships with learners, approaches would need to be tailored to the type of organization. The form, length, content of narrative representations could vary depending on their purpose and the capacity of the organizations to create them. An example of a research generated brief biography is provided in Appendix 2 (Crowley, Barron, Knutson, & Martin, forthcoming; see Barron, Gomez, Pinkard, & Martin, 2014 for detailed examples of longitudinal narrative portraits and accompanying visualizations of learning across setting and time).

Sustained engagement in activities for learning

The active choosing or creating of a new opportunity to learn following an organized out of school learning experience is an important marker of the value of that experience. Table 2 provides a set of categories of choices that have been documented in ethnographic case studies and that we commonly map in timeline visualizations (Barron, 2006; Barron, Martin, Takeuchi, & Fithian, 2009; Barron, 2010; Barron, Gomez, Pinkard, & Martin, 2014). For example, deciding to volunteer as an apprentice to an expert videographer would be an example of starting

a new learning partnership. Searching for a tutorial on a programming language would be an example of seeking out a learning resource. Digital technologies offer the possibilities for creating new tools for diary studies that might ask for daily, weekly, or monthly reporting of these markers of sustained interest. This would also pave the way for badge systems based on profiles of learning experiences (see Hickey, Kelley, & Shen, 2014). There have been some attempts to create survey instruments to measure continuing motivation. For example, a recent publication (Fortus & Vedder-Weiss, 2014), describes survey items that assess students' tendencies to engage in science related pursuits on their own time (e.g., "I browse Internet sites which deal with science, nature, animals, or environmental issues". Their response scale reflected agreement rather than frequency however. These authors report a study that contrasted tendencies to engage in these sustained learning activities among young people in Israel, and found that in general continuing motivation decreased with grade level and more so for students attending traditional schools compared to democratic schools. The PISA International Assessment also includes a subset of items that reflects elective science learning (see Suter, 2012).

What about using more behavioral markers of choices to keep learning as opposed to self-report? Again, digital environments could be designed to create and track choices to access resources that are connected to program activities. Some of these choice-based assessments have been developed as a way to assess learning (Schwartz & Arena, 2013) – these examples look at what choices are made within a tight set of options and in response to different types of feedback. However, one can imagine systems that provide pathways of learning resources and if the system is designed for it, the pursuit of these resources can be designed. One example comes out of the Digital Youth Network (Barron, Gomez, Pinkard, & Martin, 2014). Building on years

of ethnographic research the DYN team has created extensive online resources and is working on visualizations that can help track engagement over time, including use of resources (e.g. Nacu, Pinkard, Schmidt, & Larson, 2012).

Table 2. Candidates for a "Sustained Engagement in Activities for Learning Index"

- ☐ Creating personal projects beyond structured opportunities
- ☐ Choosing to participate in additional elective organized learning activities
- ☐ Selecting optional science courses at school
- ☐ Seeking out informational resources for learning such as books, magazines
- ☐ Watching science related media on television, or online
- ☐ Finding online tutorials, affinity groups, or other resources
- ☐ Playing games with STEM content
- ☐ Developing learning partnerships with guides, collaborators, or mentors
- ☐ Sharing expertise with family, peers, or community by teaching, consulting
- ☐ Contributing to online science communities such as Citizen Science projects
- ☐ Volunteering to help with environmentally focused community events

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Learning partnerships

To assess current and evolving learning networks, categories of partnerships and guides can be developed that would map onto mentor, peer, or expert roles made available in a particular science ecosystem. Appendix 1 includes examples of items that we have used with middle school students to assess their access to adults at home who serves as guides and partners. Techniques for generating and representing eco-focused and community based social network diagrams might also be used to chart opportunities and needs in the relational dimension of a learning ecology (also see Williams & Durrance, 2008). How might social network diagrams and associated analyses techniques be used? If the field takes an ecosystem metaphor seriously, in the future we might test hypotheses about whether regional STEM interventions are making a

difference for learners not only by tracking metrics, such as interest or learning, but also by assessing whether we can increase the breadth and depth of learning partnerships among STEM learners and among STEM educators. It might be of interest to know whether overtime we can increase the probability that a given community will develop a greater density of STEM learning ties with the intentional design of informal and formal learning pathways created through collaborative institutional partnerships.

Closing thoughts

New experiments are beginning that attempt to bridge school, afterschool, and online, spaces (Crowley, 2014; Falk & Dierking, 2014; Ito, et al., 2013; Barron, Gomez, Pinkard, & Martin, 2014). For example, LIFE Science of Learning Center researchers are attempting to coordinate students' participation in epistemic practices and conceptual learning of science across ten sites over the course of a school year using a mobile self-documentation platform (Stromholt, in preparation). New forms of collaboration and methods for design-based research will be needed to do this ambitious work well, including being able to follow learners over shorter and longer terms.

As researchers, to make progress that is relevant to educational design, we need new conceptual tools and research approaches that can help generate hypotheses, analytic categories, and theoretical accounts of how engagement in learning is sustained. We need work that helps identify types and sources of continuities between cross-setting learning opportunities as well as barriers and disconnects (Barron, 2006; Lawson & Lawson, 2013; Leander, Phillips, & Taylor, 2010; Hull & Shultz, 2001; Perry, Turner, & Meyer, 2006). At the same time, on the ground STEM eco-system advocates, funders, educators, parents, and learners themselves need tools that can help them document, reflect on, and design learning opportunities in the moment and across time. I have suggested that expanding our repertories of representations to include biographical

portraits, varied indices of continued engagement, and social learning network representations could help advance those aims. New expressive and computational tools and spaces for collaboration can support needed innovations and I close with a few ideas towards these ends.

1. *The value of collective work*. Shared databases for the informal science education community members are on the rise (Ellenbogen & Nelson, 2012). Common sets of biographical case studies chosen to highlight how STEM institutions can work together to support pathways for young people and families would be a powerful collective resource for case based professional development (Christensen & Hansen, 1987), theory building, and ecosystem designers.
2. *A need for tools*. Financial support for innovation in digital tools to make the work of collecting and representing cross-setting and time data could advance the capacity to do collective work. Interactive interfaces with relational database back ends could allow for both individual and cross-case analyses though interdisciplinary teams would be needed to create this kind of tool. Biographical methods are important for this kind of work but they are also costly. Self-documentation, the collection of digital traces of participation, and mobile platforms for multi-site ethnography are all pioneering attempts to characterize new, related forms of learning. There is a need for research on data collection tools, protocols, and in data representations that help us see and describe patterns in engagement, competence, and choices to learn (Schwartz & Arena, 2013; Schwartz & Gutierrez, in press). Multiple research designs at different timescales would also be needed to advance this agenda.

3. *Benefits of expanding roles of varied stakeholders*. Foregrounding learner, parent, and educator needs will help advance the design of useful tools that make visible funds of interests and possible next steps. These are formative assessment possibilities that can advance learning though they go beyond knowledge to include opportunities to learn. Research on the value of taking a broader meta-reflective stance on learning in and out of school would contribute to the design and specification of tools and representations.

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Appendix 1

Parents as learning partners for technology learning index

For each description, check if each parent has **EVER** played this role.	Mother or other female guardian	Father or other male guardian
Looked for technology-related activities for me to do and/or signed me up for them (*like classes, clubs, camps, etc.*)	☐	☐
Taught me how to do something on the computer (*like typing, how to create a Web page, etc.)*	☐	☐
Worked with me on a technology or computer-related project (*like built a robot together, worked on a Flash tutorial together*)	☐	☐
Bought me things to support my computer activities and learning (*like hardware, software, books, courses*)	☐	☐
Bought me entertainment related technology (*like games, console*)	☐	☐
Had things (*like books, equipment, software*) at the house that I use.	☐	☐
Gave me advice on non-technical issues that have helped me with my technology activities.	☐	☐
Paid me to do something technical or on the computer for her/him.	☐	☐
Let me watch how they do something *(like turn on the computer, set up the printer)* that I eventually learn how to do from observing them.	☐	☐
I have taught them how to do something with the computer.	☐	☐

Appendix 2

An example of a narrative representation of learning from Barron & Martin, 2012; Crowley, Barron, Knutson, & Martin, in press)

Catherine: Connecting personal interests and citizen science practice.

> *I like Vital Signs a lot but I am not espe—I don't really like science. I mean I guess I shouldn't say it because I have enjoyed it this year with all the interactive things, but I would never like see myself doing it as a career unless it was probably like art.*

Catherine was a gifted and talented student at a school in a community with many social and monetary resources. On the survey, both Catherine's interest in science and her interest in Vital Signs ratings were relatively high, falling into the top 25% ranking for both measures. Although doing well in school was important to her, she did not connect science as a field to her own personal passions. She was an avid fiction reader and was crazy about animals, with a particular fondness for pigs, dogs, and cats. She pursued music and artistic activities at home and during afterschool and community classes and clubs and had immediate and extended family members who were professionals or informal experts in the fields. Interviews with Catherine and survey measures about her future revealed that Catherine definitely did not see herself becoming a scientist "because I'd rather be a horse trainer, and if I was doing science I would want it to be science that interested me, like being a veterinarian." Although Catherine often used YouTube do-it-yourself videos for inspiration about her art and design activities, she reported that she did not seek out science information for fun on her own time on the Internet or through books or other material resources. While she reported that her friends think science is cool or okay, she also shared that she did not talk to them about science topics outside of school.

Vital Signs provided Catherine with a compelling pathway into science practice. Catherine enjoyed the hands-on experimental nature of the project and getting online feedback from experts. She was particularly drawn to sketching found species and photography during fieldwork. Catherine had ideas for similar investigations that would tie into her own interests, including tracking animals and the well-being of the animal populations, and thought that it would be helpful to have social networking features to interact with and learn about other participants and their investigations.

Through the Vital Signs project, her perception of the beach that is close to her house and that she frequents regularly during the summer shifted to a more informed understanding of the habitat. She was struck by the difference between reading about the invasive species and actually seeing them for herself on the beach:

> *When we like read how invasive species are all over, it was just kind of like "yeah, okay, whatever." But then we went out and like they were everywhere. And I just didn't ever realize it. And like whenever I go down to the beach, I see that orange goop all over and I just never really knew what it was. And then I read about it and then when I went again, I saw it everywhere again and I was like, "Oh no! What?!"*

Catherine talked about how doing the investigation has changed the way she looks at the beach near her house to a more informed understanding of the habitat. In the fall of 2012, we heard from Catherine's science teacher that she had been spotted on the beach over the summer babysitting a small group of kids and showing them how to identify the "orange goop," an invasive coastal species called Orange Sheath Tunicate, and to move it beyond the high tide line so it could not reproduce. Figure 2 shows a timeline representation of Catherine's engagement in these varied activities over time.

Figure 2. Catherine's timeline representation showing connections between informal and formal activities