Motivating and Broadening Participation: Competitions, Contests, Challenges, and Circles for Supporting STEM Learning

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Abstract. National and local competitions have become popular venues to inspire students in K-16 to excel in math, science, engineering and computing. In recent years, online versions—such as the National STEM Video Game Design Challenge, Globaloria Awards, and Make-to-Learn Contest—have joined the portfolio. While competitions, contests, challenges, and circles are theoretically open to all, it is unclear to what extent they are not only motivating but are also broadening participation. The goal of this symposium is to better understand the dimensions of four different type of public events by reviewing (i) the design of the public event model, (ii) implementation of activities, and (iii) evaluation of participation and learning that amplify levels of youth participation in sharing design-based projects and increase opportunities for STEM learning for all.

Overview

National and local competitions, such as Coding Wars, Google Science Competition, FIRST Robotics, Hackfest, Microsoft Imagine Cup—to name just a few of the ever-growing list—have become popular venues to highlight STEM accomplishments. While science fairs have a long tradition, starting with the first National Science Fair in Philadelphia in 1910, the number of these public competitive events has increased with recent efforts to inspire more students in K-16 to excel in math, science, engineering and computing. Online versions, such as the National STEM Video Game Design Challenge, Globaloria Awards, and Make-to-Learn Contest, have recently joined the portfolio. The goal of this symposium is to better understand the dimensions of these public events that amplify levels of youth participation in sharing design-based projects and increase opportunities for learning, online and offline.

Public STEM events, where students prepare, display, and share their artifacts, are widely believed to be a valuable learning experience (e.g., Abernathy & Vineyard, 2001; Grote, 1995; Yasar & Baker, 2003). Participation, often encouraged with support from teachers or parents, is highly correlated with later career choices in STEM majors (Forrester, 2010). At the same time, little is known about which aspects of these events motivate and sustain youth participation. Although actively engaging many youth, to date large-scale competitions have often encountered difficulties attracting and sustaining participation for students in groups traditionally under-represented in STEM careers (e.g., FIRST LEGO League, 2008-9; Greenfield, 1995). Research on achievement motivation suggests that an emphasis on performance and competition may be most motivating to students who already have high confidence in their ability (see review by Kaplan & Maehr, 2007).

While competitions, challenges, and contests are theoretically open to all, it is unclear to what extent they are not only motivating but are also broadening participation—an issue central to any STEM effort. One solution to address this concern has been to focus more on collaboration than on competition in the design of public events. For example, Rusk and colleagues (2008) present examples of organizing robotics exhibitions as an alternative to robotics competitions. Other solutions have been also used to leverage more collaborative models of production. For instance, in the *Connected Messages* project, conducted in the Summer 2013, hundreds of youth in public library branches designed and assembled message boxes that resulted in large public electronic displays. In this type of collaborative design event, rather than focusing on individual projects, the compilation of individual contributions completes the larger public design. Although differing in focus from competitions, exhibition-focused events still retain the idea of addressing an authentic audience (Magnifico, 2010), but they focus more on sharing of ideas than selecting a winner. While an array of approaches has emerged, to date little is understood about how to design features of public events, with or without competitive dimensions, to successfully engage broader participation of K-12 students as well as community members attending the events.

In this symposium, we bring together a first set of recent designs and studies that have implemented and evaluated different types of public competitive and collaborative events. Our goal is to understand how these events can be designed not only to support and motivate STEM learning but also increase diversity in participation. Online competitions such as the 2012 National STEM Video Game Design Challenge (http://stemchallenge.org) invite students to program games with STEM content and upload them, whereas the 2013 Make-to-Learn Youth Contest invites youth to share and explain physical rather than virtual designs for the possibility of garnering one of the prizes in different grade levels (http://m2l.indiana.edu/make-to-learn-challenge/). The 2011 Scratch Collab Challenge initiated collaborations between online members to program a Scratch project by using three different elements (http://info.scratch.mit.edu/collabchallenge). By contrast, the 2013 eCrafting Circles (http://ecrafting.org) include a hybrid of online calls that bring local community groups together in making physical artifacts for Halloween and end in local celebration of designs. Taken together, these four projects occupy different places on the continuum of collaboration versus competition, physical versus virtual designs, and individual versus collaborative productions, all of which can be key dimensions in the design of productive and meaningful STEM learning activities.

The chairs will introduce the theme and issues raised in symposium followed by 20 minute presentations that review the (i) the designs of each public event model, (ii) implementation of activities, and (iii) evaluation of participation and learning. Our discussant Alicia Magnifico, will review findings addressing issues of motivation and audience and discuss implications for future initiatives designed to increase and broaden youth participation in design-based STEM learning initiatives.

Feeding Competitive Streaks and Fostering Collaborative Determination: Grounding STEM Coursework in a National Video Game Challenge

Quinn Burke, College of Charleston & Chad Mote, University of Pennsylvania

Recent reviews of making games for learning (Burke & Kafai, 2014; Hayes & Games, 2008) outline a number of reasons why making video games exemplifies important learning, including the potential to reinforce traditional academic subject learning (Dickey, 2005), to introduce children to computer programming (Kelleher & Pausch, 2005), and to expose children to more authentic audiences as producers and not merely consumers of digital media (Peppler & Kafai, 2010). Yet despite the merit of each of these goals individually, what is lacking is a particular "forum" within schools in which all these learning principles can collectively take root.

In this presentation, we argue the *game design competition* can represent such a forum. In an arena once solely occupied by robotics competitions, game design competitions have recently emerged on both local and national fronts as a way to attract a wider variety of children to STEM learning. Among the growing number of annual competitions are Globaloria's "Globey Awards", Advanced Micro Devices (AMD) "Changing the Game" contest, the Games for Change Awards, and Microsoft's longstanding "Imagine Cup". A more recent addition to this group is a competition issued by the White House itself, the National STEM Video Game Design Challenge. Developed in order to inspire K-16 students to learn STEM-based skills through direct application, this contest is now in its third year. It awards each of its winners in the middle school category with a personal laptop computer plus $2000 for their respective schools. Over the initial year of the challenge, a total of ten middle school students were selected as winners from a total pool of 600 entries.

With no shortage of excitement, our classroom entered the competitive-fray. Using Scratch (scratch.mit.edu), we team-led an elective course around making one's own STEM-based video game at an urban public middle school in which more than half of the student population qualifies for a free or reduced lunch. It was to be the school's first elective around gaming, and we were offered the 2-3 PM time slot over the school's Winter trimester (late October until mid-February) which met twice a week. Our elective attracted the most participants that term—a total of 17 students, 6^{th} through 8^{th} grade. The group was representative of the racial and ethnic diversity of the school with approximately 40% of the group describing themselves as "white", 35% as "African-American", and 25% as "Asian" or of "Mixed" race/ ethnicity. We designed the three-month elective around three goals: First, to support middle-schoolers' math and science content knowledge with hands-on activity; second, to introduce children to the potential of computer programming as a vehicle for personal and creative expression; third, to expose children to more authentic audiences by becoming the actual producers of digital media and fostering a wider ethos of collaboration through sharing such media. Based on the these three goals, we structured the elective course around both discussing and sampling games rather than simply teaching the class the basics of Scratch and then leaving them to their own devices. To this end, every class would open with a "roundtable" discussion in which students would discuss games and gaming, brainstorm potential ideas for their own ongoing designs, and sample and share examples of other STEM-based games from the Scratch website. These round table discussions were paired with a series of “gallery walks” over the second half of the course in which students would play each others’ games and offer written feedback on game play and STEM integration; last, the course culminated with an in-class arcade in which the rest of the middle school was invited to come play the completed games before their final submission.

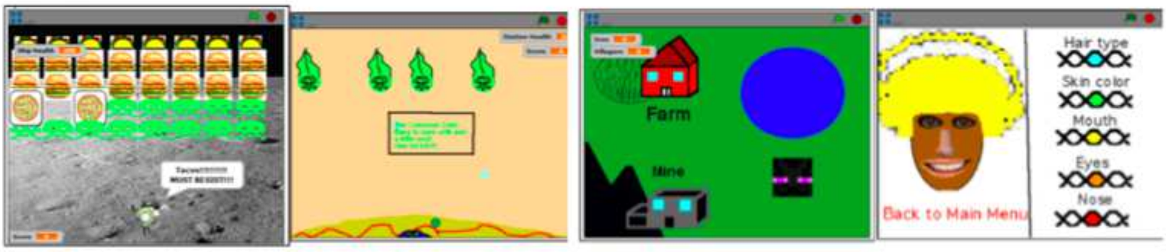


Figure 1. Screen shots of the completed games from the STEM Video Game Challenge. From the left: “Food Invaders”, “Lysosome Attack”, “Ender Build”, & “Genome Face”.

Out of the 17 students who participated in our Challenge elective course, 16 submitted fully working STEM video games by the mid-March deadline. Returning to our initial three goals for the course, it was clear that there had been considerable success. In terms of (1) STEM integration, over a third of the 16 participants (38%) developed their individual STEM video games “endogenously” focusing on a particular scientific phenomenon and/or mathematical relationship and developing a game around these learning principles for game-play. The other ten participants developed their games “exogenously”, starting with a particular type of gaming genre (e.g., a “platform game” or “first-person shooter”) and then subsequently “tacking on” the STEM theme into game play, extrinsically. In terms of (2) utilizing programming for creative an personal expression, all projects effectively integrated a wide range of essential programming concepts: 69% of projects used coordination and synchronization as well as loops; 63% used event handling and conditional statements, and variables, and 19% used Boolean logic. In terms of (3) peer-collaboration and finding authentic audiences, this is perhaps where the course had the greatest measure of success. In the post-workshop survey on who or what served as their strongest influence, 57% of participants reported their fellow classmates, 36% reported us as instructors, and 7% listed the National STEM Video Game Challenge. Altogether, the class seemed to genuinely appreciate feedback from their peers, particularly when their classmates played drafts of their games.

Discussion will center upon potential future iterations of this model for reinforcing STEM learning and delve further into some of the unique challenges of using video games as a way to attract more children to STEM learning, including attracting a greater number of females to such elective coursework, pushing for more endogenic (rather than exogenic) integration of content, and ensuring that fostering a spirit of competition among students also leads to utilizing each other as resources for more authentic audiences and peer-to-peer collaboration.

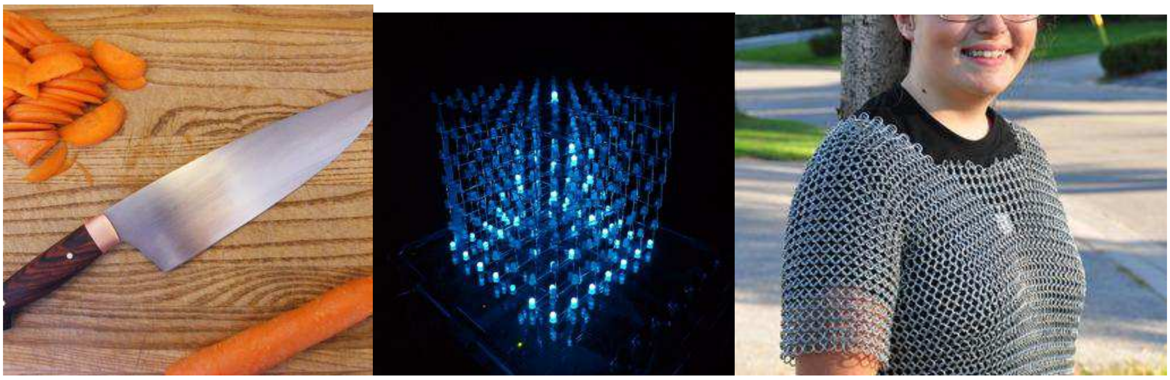
The Make-to-Learn Youth Challenge: Gaining Youths’ Perspective on Learning Through Making

Kylie Peppler, Indiana University

The maker movement consists of a growing culture of hands-on making, creating, designing, and innovating. A hallmark of the maker movement is its do-it-yourself (or do-it-with-others) mindset that brings together individuals around a range of activities, including textile craft, robotics, cooking, woodcrafts, electronics, digital fabrication, mechanical repair or creation—in short, making nearly anything (Peppler & Bender, 2013). Despite its diversity, the movement is unified by a shared commitment to open exploration, intrinsic interest, and creative ideas. And it’s spreading: online maker communities, physical makerspaces, and Maker Faires are popping up all over the world and are continually increasing in size and participation (Dougherty, 2013). Moreover, there is a growing national recognition of the maker movement’s potential to transform how and what people learn in STEM (science, technology, engineering, and mathematics).

While we know from theory and prior research that making can be particularly beneficial in the learning process (e.g., Catterall, 2009; Peppler, 2013), most of what we know about in this area comes from studies within schools and after-school programs (e.g., Kafai, Peppler, & Chapman, 2009), and less from makers and maker culture at large. In the interest of developing a grounded understanding of youths’ own conceptions of learning from the process of making, we launched an online competition for young makers (between the ages of 13 and 18) to share and discuss their “makes” for the chance to win prizes ranging from gift cards to mini iPads. To increase visibility for the competition, we hosted the challenge on the preeminent DIY portal, Instructables.com, an online community for makers of all ages to document their original work, connect with others, and gain inspiration. Challenge entrants were tasked to post one or more images and brief description of their make, which could be anything from a pinewood derby car, to a short movie, to science fair project. In an effort to uncover (a) the range of locations where youths' making was taking place (e.g., at home, in school, in afterschool clubs, etc.), (b) the range of practices involved in youth's making (e.g., working independently or collaboratively, etc.), and—perhaps most importantly—(c) what learning took place in the process of making, entrants had to answer the following questions in their submissions: (1) What did you make? (2) How did you make it? (3) Where did you make it? (4) What did you learn?

The Make-to-Learn Youth Challenge went live on Instructables.com in February 2013, with the entrance period closing 9 weeks later. At that point, a judging panel of 13 luminaries in the field of learning and making selected 20 projects (from over 300 submissions) to award with prizes. Submissions ranged from a "'French' style" kitchen knife made using a homemade grinder, propane forge, and milling machine; to homemade bracelets; to an Arduino-powered Analog VU meter that doubles as a clock (see Figure 2 below). Submissions fell into the following categories of project types: Arts and Crafts (48%), Electronics and Programming (14%), Shop projects (e.g., metal, wood, plastics, PVC, etc.) (12%), Fashion (7%), Mechanics/Engineering (7%), Digital Media (5%), Cooking (2%), and Other (5%). Over half of these projects were made at home (56%), with the remainder of projects being made within youth-serving organizations (28%), schools (9%), and hackerspaces (3%).



Figures 2: An array of projects submitted and reflected upon for the Make-to-Learn youth contest (http://www.instructables.com/contest/maketolearn/).

In terms of what youth felt they learned in the process of making, careful thematic analyses of youths' written reflections revealed that youth were less likely to state that they learned anything about subject-specific STEM content (17%) than they were likely to note general insights into the techniques for using tools and materials (e.g., how to use an exacto knife, raise fire temperature for forging metal, types of stitching) (33%), general habits of mind cultivated while making (e.g., perseverance, need for iteration, patience, setting reasonable goals, etc.) (28%), and observations of personal growth and social connections (e.g., "I learned that I liked…", "I learned that I could…") (19%). A small minority of youth (3%) reflected on learning about general entrepreneurship skills as they marketed and sold their makes. While implicit STEM content could still be taking place, it's clear that a sole focus on making as a STEM endeavor eclipses an important part of the learning that is happening in these spaces—and may neglect major genres of making which are important for preserving the broader maker ecology valued by young makers. In other words, by forcing an explicit STEM focus (particularly with electronics, programming, and, at times, shop projects placed central in this conversation), we may be overlooking the majority of young maker interests in the arts and crafts, fashion, and cooking, and digital media.

These findings suggest that the Maker movement can be inclusive of a diverse range of makers and leveraged to broaden STEM pathways. However, as we begin to think about leveraging maker culture in the learning landscape, how do we do so in a way that preserves the broader maker ecology and yet makes the potential connections to learning more explicit? How might the types of projects we promote in our educational workshops mutate the maker culture and constrain and enable the authentic learning goals? Lastly, there are some things that this data set cannot reveal to us, such as the extent to which this range of making is representative of non-dominant youth. Despite its promise, since most of this making occurs in homes and outside of any formalized context, how can we be sure that we are inviting youth from non-dominant communities to participate? Moreover, most of these projects require access to specialized tools, materials, and social networks to support such making that may have been prohibitive for youth to participate.

Leveraging Online Design Challenges for Local Collaborations: Collab Challenge and Collab Camp

Deborah A. Fields, Utah State University; Ricarose Roque, MIT Media Lab

Studies of massive online communities tend to focus primarily on those online participants that are at the core of the community. But in truth, only a small percentage of youth demonstrate the fluency to participate online in ways that are the most educationally beneficial (Hargittai, 2010; Grimes & Fields, 2012). Given known barriers to participating online (e.g., Kafai, Fields, & Burke, 2010), we argue that online community events can provide unique opportunities for local groups to come together and work toward an authentic goal at the same time that they engage online participants with opportunities to deepen their participation. In this presentation, we discuss one such type of event, an online design challenge issued in the Scratch online community that we leveraged both locally and online to provide opportunities for deeper learning and broader participation in Scratch. As the largest online programming community for youth, deepening participation in the Scratch web community has strong potential for strengthening youth participation in programming.

In 2011 we sought to create a series of online events in Scratch that would bring kids together to program, learn, and collaborate beginning with Collab Challenge. With nearly 4 million projects shared since its public launch in 2007, the Scratch website is a vibrant online programming community for youth, with over 1,000 new projects being uploaded every day. Yet only a small percentage of online Scratch participants regularly engage in practices like commenting, downloading, and networking around projects (Fields, Giang, & Kafai, 2013). The Collab Challenge thus provided an opportunity to engage both online participants and students from locally organized workshops in productive practices they otherwise would not likely access in the larger, interest-driven online community. The online challenge had four key features intended to engage youth in deeper processes of computing and participating: external feedback, creativity within constraints, open spaces, and authentic audience (see Figure 3). Below we consider these design features in light of online and local participation in the challenge.

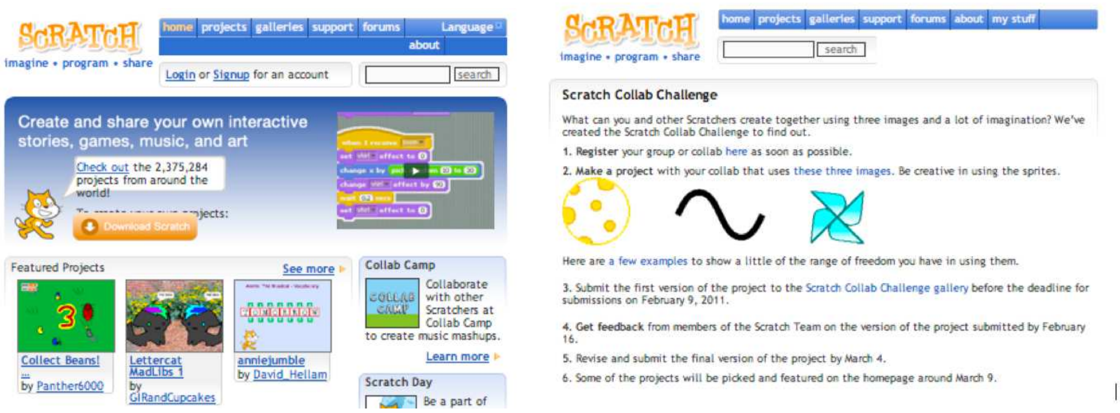


Figure 3. Scratch Collab Challenge: Call on main screen (left) and call details (right).

While most competitions (including those featured in this symposium) focus on a single endpoint of design, Collab Challenge and Collab Camp required two submissions: a draft and a final project. All submissions received *external feedback* from the Scratch Design Team in addition to goodwill comments left by other participants to help users improve their designs. Half of the 52 teams with 139 participants submitting projects online took the opportunity to resubmit their projects, most of them going deeper in programming in the second version. In addition, many participants left comments on others' projects, though not as many as we had hoped. Participants also submitted a range of projects, demonstrating that even within a shared task (design a project using three pre-chosen images: a pinwheel, a swirl, and a beachball), users were able to use *creativity within design constraints*. Participants submitted a wide range of stories, games, and interactive animations. Further, based on the number of comments and views tallied on Collab Challenge projects at both the draft and the final stages, the Challenge provided an *open space* with a wide horizon of observation (Hutchins, 1995) for participants to see others' projects, download them, and get ideas from them. Finally, the Challenge provided highly desired visibility on the Scratch website. This was instantiated in two ways. First, 14 of the best projects were "featured" on the front page for a week at the end of the Challenge. Participants strongly sought out this verification of their quality participation as it gained them a wide audience for their work. Second, simply by posting projects in the Challenge gallery, projects culled far more views than normal for projects submitted on the Scratch website. Thus the Challenge provided a means for online participants to have a wider audience for their Scratch work.

Locally we organized a workshop for students from a local high school to engage in the Challenge. Twenty-one high school freshman aged 14-15 participated in the 8 week (2 hours/week) workshop, forming six small groups. All students had prior experience with Scratch but none participated in the website regularly. In this way the Collab Challenge drew in students who otherwise did not feel very engaged in the Scratch website. According to even the most involved Scratch students (who played Scratch in their free time and helped to mentor others), they rarely logged on to the Scratch website unless requested by a teacher. Yet the *external feedback* left on their projects online had a strong influence on students' projects, particularly because it came from people seen as outside experts. As Jacob described about his group, "They took all of the criticism to heart and all the praise, and they worked hard to make their project more interesting." Individual students and groups as a whole read the feedback and make specific changes in their projects in response. We suggest that the external feedback from members of the online community held more status for local students because of the perceived expertise and authenticity the members. All local groups improved their projects substantially between the first and second submissions. In local workshops *open spaces* took two forms. Online, students could view many other groups' projects, download them, and open them to see how they worked. This gave them a wider perspective on how their work fit in with others' creative ideas and sophisticated programming. In addition we created hourly sharing times in the local workshops where students showed their in-progress project to the larger workshop and received praise and constructive feedback. This not only encouraged the individuals who shared their projects, it also created an open space where students could learn from each others' work, get ideas, and see different programming strategies.

The Collab Challenge provided a structure for students to work creatively and an audience that changed students' visions for who saw their work and how their work was perceived. Although *audience* is most often discussed in literacy studies (Magnifico, 2010), we found that it played a key role in students' programming. While all students in local workshops had their peers as a local audience, knowing that their project would be viewed online by other participants in the Collab Challenge "was helpful because it gave them perspective on their works," according to one student Sam. "It kind of made them realize that other people were going to see this too and it motivated them to put more work into it." Thus locally, the online audience gave students a wider perspective on their programming and they made more efforts to put in instructions and improve their projects. Online participants responded positively to the feedback that others left and Our experiences of leveraging and building on key features of online design challenges suggest further ways to build on opportunities normally taken up by only a small percentage of online participants.

In future iterations of the Collab Challenge we anticipate making several design changes to better facilitate Scratch users' deepening participation in key programming and online media practices. For instance, we hope to better understand the ways in which a broad audience and constructive feedback affect students' actual learning of specific programming concepts. In particular, user interaction and initialization are two key areas that we suspect could be improved through such design challenges since they depend on projects running consistently without a person present to guide and direct users through a project. In addition we plan to promote constructive criticism amongst all participants in the Challenge, not just the Design Team. This should encourage users to create a more open space to view others' projects as well as critique and encourage others. Overall, the Collab Challenge showed good potential for engaging both online and local youth in going deeper into programming while also encouraging stronger engagement with a key interest-based community that could support their programming practices.

eCrafting Circles: Rethinking Celebrations in Online and Offline Communal Makerspaces

Yasmin Kafai, Orkan Telhan, University of Pennsylvania, and Karen Elinich, The Franklin Institute

Much attention has focused on designing makerspaces either as physical spaces such as fablabs and museum spaces that provide access to 3D printing and other devices for manufacturing computational artifacts, or as online spaces such as Instructables, diy.org, or make2learn that allow for sharing of designs and instructions, or as public events such as Maker Fairs or online competitions that bring together groups and celebrate local productions (Honey & Kanter, 2013). Far less attention has focused on creating hybrid models that allow for local fabrications but also provide global connections. In our presentation, we describe the design and implementation of such a hybrid model called eCrafting Circles (see Figure 1) that bring together these different efforts by providing local communities and workshops with an online home, or circle, in which they can share designs of their artifacts and by providing access to a larger community that can offer support and feedback. Rather than focusing on competitions as a model for incentivizing making, displaying, and sharing handmade artifacts, eCrafting Circles leverage traditions of sewing circles which are themselves built upon the collaborative model of quilting bees that produce shared artifacts and celebrate diversity in accomplishments.

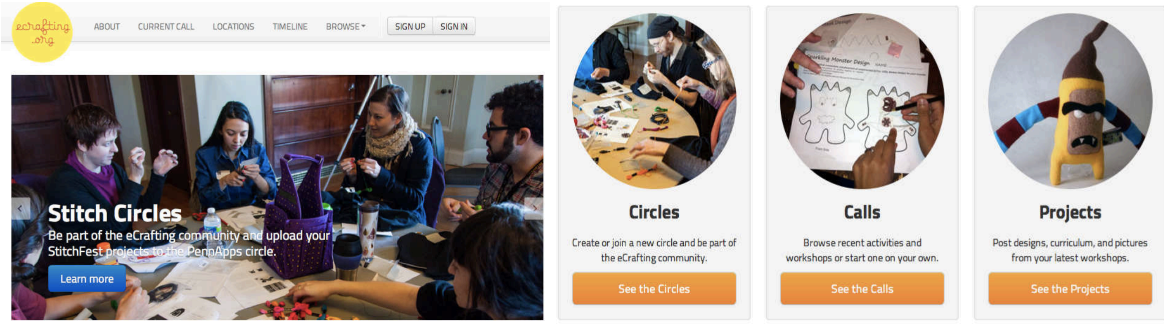


Figure 4. eCrafting.org: Main screen upper part (left) and lower part with different activities (right).

The design of the eCrafting Circles platform provides basic features for individuals and groups to sign-up and create their local activity groups. A location map, an activity timeline, and project archive let activities, calls, and projects be browsed freely by everyone. Online visitors can comment on the projects, ask to be invited to join circles where they can either work remotely with circle members on existing projects—during or after workshops—or join upcoming events and workshops to be part of new activities. Unlike most online communities that are geared towards the creation, display, and archival of individual projects, eCrafting Circles intend to motivate a social learning experience through organizing activities tied to public events. As the website allows individuals, groups, maker spaces, and institutions initiate their own circle and form their own calls, such groups can structure their own curriculum and pursue different types of learning objectives such as making socially integrative projects—such as designs that foster parent and child interactions—or commemorative artifacts, and memorabilia. Circles are supported by providing teaching aids, templates, instructions, and materials for a set of predefined themes—such as Monsters and Masks for Halloween, T-shirts for Astronomy night—and allow the circles customize the material for their own events.

In our first local implementation we issued two calls, *Monsters & Masks* in Fall 2012 coinciding with celebration of Halloween night and *Astronomy Night in Philadelphia* in Spring 2013 connecting to an annual city-wide event during the Philadelphia Science Festival to bring eCrafters and their families together. Several workshops at The Franklin Institute, in different branches at the Free Library and other community organizations and schools had students and adults stitch circuits with LEDs and switches on masks, monsters (abstractly-shaped stuffed creatures), t-shirts and interactive hoodies. In addition, we organized a meeting in a centrally located public park that also provided portable telescopes as part of Astronomy Night. Dozen of parents participated in making simple circuits with their children while a small group of eCrafters had brought their interactive hoodies and linked their hands while touching conductive patches to form a human circuit that lit up their LED designs. Our analyses of pre-post surveys found success in that the over 100 participants ranging from 10 to 50 years of age broadened their views of computing and increased their interest in searching out more activities in computing while also significantly improving their understanding of simple circuits and electricity concepts. We also learned that attendance at local events is not guaranteed, even when connected to initiatives such as Astronomy Night that receive widespread advance publicity.

These experiences and evaluations prompted us to rethink the role of public events in reaching out and connecting to local and online community members. Rather than using public events to celebrate final accomplishments, we will use them as a launch pad to generate interest and showcase designs. An intense 48-hour local event, called PennApps, will serve as anchor to engage 100 undergraduates in generating new applications with the LilyPad Arduino while across the city children and their parents at The Franklin Institute as well as youth in participating branches of the Free Library will engage in simpler designs but joining the larger community online all the same. Our aim is to support the activities both during and after the workshops, so that the learning and sharing experience can be sustained after the initial contact among the circle members. Here, circles can continue to grow with non-local participants and continuously be in dialogue with other circles. The website provides also a visual interface through which circle members can upload pictures and videos of their individual projects and share code, craft and design techniques with each other. They can also embed annotations, comments and explanations to their own designs and mix their content with different elements they appropriate from other designs. By participating in eCrafting Circles, all participants can bring local funds of knowledge and experiences to bear in the design of their artifacts and find access to local and collaborative communities of practice, further suggesting that the eCrafting Circles model may have broad potential impact for the informal science learning community.

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