# Invent-abling: Enabling Inventiveness through Craft

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## ABSTRACT

Computationally enhanced craft items have created a new genre of educational toys and construction kits. Previous work shows that such activities increase interest in STEM particularly among female audiences [11]. However, there are few affordable kits for children, and current projects leave room for improvement. Many kits provide "cookie cutter" projects that call for blind following of instructions. Additionally, they market to girls with stereotyped branding (e.g. using colors like pink or activities like baking) and with preconceived ideas about their interests. We are working to expose these concepts in gender-neutral ways that encourage creativity and resourcefulness. The Invent-abling project, outlined in this paper, addresses gender inequality in STEM learning tools by exploring how aesthetics, materials, applications, and learning styles, impact girls' engagement with educational materials.

## Categories and Subject Descriptors

K.3.m Computers and Education (e.g. Computational Design Learning): Misc.

## General Terms

Design; Experimentation

## Keywords

Electronics, smart materials, construction kit, girl-centric toys, interactive learning

## 1. INTRODUCTION

Computational tools are becoming more ubiquitous and accessible with the rise of maker communities and DIY spaces. This mass production and simplification of hardware enables designers to embed sensors, actuators, indicators, and smart materials, into their products. Marketed and viewed as the latest trend, embedded computation is increasingly integrated into craft, DIY, and educational kits [3,4,5].

The LilyPad Arduino has brought embedded computation into the same commonplace realm of crafting as hot-glue, empowering diverse users to incorporate computation into their craft [5]. Expert research around the behavior of different materials has led to the invention of useful techniques for non-experts. Perner-

Wilson's "Kit-of-no-parts" provides a comprehensive encyclopedia for combining craft with computation [7]. We feel that even more could come of engaging beginners in the research process by introducing them to design thinking along with tangible tools. Additionally, much of this work attracts an older, skilled audience, already familiar with crafting techniques.

Hands-on learning provides outlets for children to expand their interests, and promotes growth of critical thinking [8, 10]. Projects from the Transformative Learning Technologies Labs addresses this problem through developing a variety of physical-to-digital educational tools for STEM [2]. Squishy Circuits adds a new dimension to the popular play material of Play-Doh® [9]. There are many approaches for simplifying and explaining a concept, and this gives potential to develop specific tools for smaller subgroup, such as our target audience of young girls. Reports on gender imbalances in STEM fields highlight the importance of engaging girls with these concepts in early education [6].

We use previous work, and the DIY mentality of making computation accessible, as a guide to design STEM toolkits that spark interest in young girls. Our project, "Invent-abling" invites children to learn about how computation and craft intersect through the act of "making". Invent-abling kits provide basic instruction and teach children to build upon example projects in inventive ways. Through exploring different materials and methods they can fashion their own style, empowering them to develop skills beyond those taught in the kit. This paper describes the development of the Invent-abling kit and discusses the outcomes of a series of pilot workshops with middle school girls. Feedback and experience from these workshops offers direction for further development.

## 2. A MATERIALS KIT FOR GIRLS AND BOYS

Invent-abling is a girl-centric design construction kit for "wearable electronics" targeted at children ages 5-15. The kit exposes children to an assortment of smart materials and electronic components for interactive craft projects. The kits are housed in toolboxes, with compartments for materials, tools, works in progress, and a guide/notebook. The materials have properties relating to topics including materials science, electronics, and architecture, and are organized in four categories. The focus of Invent-abling is to promote creativity and freethinking, encouraging children to integrate ideas and materials outside of the kit.

The categories of materials in the kit are (1) prototyping tools, (2) smart materials (3) passive electronic components, and (4) electromechanical actuators. The materials facilitate prototyping wearable electronics and other tangible interaction devices. Materials have the potential to generate novel sensory feedback. Smart materials have been investigated as new interfaces for

children's toys, for example the Spookies project, which uses a set of textiles to explore different interactions [1]. Additionally these materials may replace traditional electronics in toys, making them more environmentally sustainable to manufacture and producing less harmful waste [1,9].

The electronics provided in the kit and sample circuits are analog, but could easily be integrated with more advanced digital wearable circuits. We divide them into electromechanical and passive components. Though this distinction is not the primary focus, it gives the child a framework for further exploration. They were chosen to be in compliance with Restriction of Hazardous Substances (ROHS) regulations and common-sense child-friendly guidelines.

## 2.1 Guidebook meets sketchbook

Each kit includes an Invent-abling guidebook that contains: resources and ideas for researching parts and processes, tutorials for sample projects, descriptions of the contents of the kit, and a section for sketching ideas. The tutorials are designed based on research that defines methods for engaging girls through hands-on learning.

The guidebook is printed in black and white and all drawings are outlined for the children to color in. Coloring allows for personalization through a familiar mode, drawing the child's attention throughout the book.

The sketchbook section provides the following key questions, adapted from a children's museum survey, for children to answer before starting a project:

1) What steps do you need to make that?

2) What materials and tools do you need to put it together?

3) What will it look like when you are done?

4) How do you want someone to interact with it?

The guidebook leads them through design thinking and prototyping processes. The goal is that the child will have a concrete model to develop his/her personal making process.

## 2.2 Custom parts

The kits contain a few custom Invent-abling parts. Inspired by open hardware initiatives, we have designed and fabricated a coin cell battery holder for wearable electronics, a USB battery charger, and sewable LEDs. These parts were developed to brand and unify the components in the kit. We were not satisfied with existing sewable LEDs as a tool to teach children about e-textiles, since existing products are extremely small and difficult for novices to use. We will develop more custom parts in the future, while working to maintain an open-ended (in terms of hardware and parts) kit.

## 3.  PLAYTESTING AND WORKSHOPS

A pilot set of kits were play-tested with ten girls ages 10-13 over a five week period at Assemble, an open gallery and workshop space in Pittsburgh. Assemble provides volunteer staff to teach the workshop, additional materials and tools for the workshops, and a network of partner organizations. We chose to work with a group of girls from a local organization, Gwen's Girls, which provides gender-specific programming to improve the lives of young girls. The group completed four activities, including "activating origami" and "magnetic nightlight", with their kits and took them home after the final workshop.

Shorter "pop-up" workshops and presentations took place over a four month period at Children's Museum of Pittsburgh's (CMOP) MAKESHOP, The Carnegie Science Center, and the Society for Contemporary Craft in Pittsburgh. This allowed us to reach hundreds of children and teachers. We are currently talking with local schools about incorporating the kits in their programs.
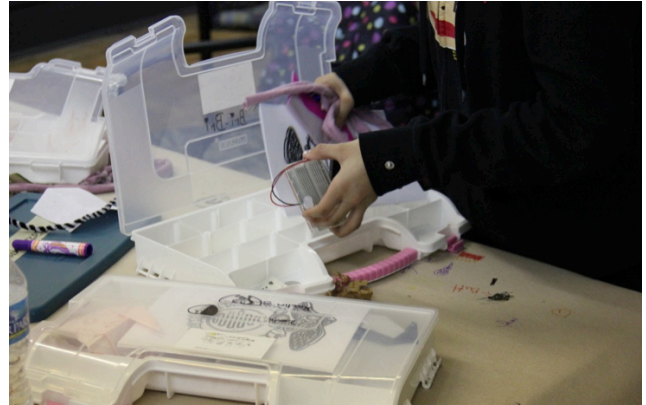


**Figure 1. Girl with Invent-abling kit**

The workshops gave us insight as to how to assess the difficulty level of our example activities. Resnick et al. present guidelines for designing educational construction kits [8]. They use the terms "low floor"—easy for a beginner to use—and "high ceiling"—having the potential for experts to use in sophisticated projects—as originally coined in relation to the Logo programming language. They also introduce a concept of "wide walls": designing tools that suggest and support a range of projects, which agrees with our goals for Invent-abling [8].



**Figure 1. Parents and children participating in e-textiles/smart fabric workshop at CMOP Makeshop**

## 3.1 Reactions

We asked the girls what they thought the point of the activities was. One girl responded:

*"Putting science and art together…to make it real fun…art and science go together totally"*

We asked what the projects were for. The girls responded:

*"Something you could give to your brother or sister or your mom or dad."*

*"Something you could show someone to make them amazed."*

Additionally, the girls expressed confidence in their understanding of electricity and feel they will be ahead of their classmates when these subjects are taught in school.

We observed that the activities attracted more young girls than boys (about 4:1), though boys showed interest when introduced to the project. The boys who wanted to participate in museum workshops would leave the table once outnumbered by girls. We speculate that the fact that workshop teachers were usually female, and that the museum offered alternative "boy-centric" activities (e.g. building model cars), contributed to this effect. We noticed this was less of an issue when the parents were present at the workshops with the children. Additionally, this occurred more often when the activity included sewing. We are taking this into consideration while choosing components for the next series of Invent-abling kits.



**Figure 3. Dad explaining tilt switch project to young boys at a museum workshop.**

When Invent-abling was presented in a show-and-tell format, boys would play with the parts for several minutes longer than girls. Girls would briefly look at example projects and shy away, while boys would immediately start putting components together and ask questions about how to integrate these parts with other toys they have at home. This suggests that girls are more interested in a focused learning session while boys are more interested in an open-ended format where they can remix and re-engineer familiar toys. We are working to develop a balance of sample activities in our guidebook that appeal to these different learning styles.

## 4. FOCUSING CONCEPTS: MINIKITS

With the large kits, we found that dividing the topics and materials into different workshop sessions did not work; children were often distracted by other parts of their kit not related to the current activity. To address this, we are developing a series of "mini-kits", expanding the accessibility of Invent-abling. These kits focus on a specific toolset in attempt to give children a deeper understanding of one concept.

We have presently developed three minikits. The "Materials Kit Explorer" includes materials with state-change properties such as thermochromic fabric, glow-in-the-dark tape, and shrinking plastic. The "Switch Kit Explorer" includes different types of switches (reed switch, toggle switch, etc.) and different materials that can be used as switches. The "Embroidery Kit Explorer" includes a piece of needlework cloth with a pattern printed on it in a "cross-stich by colors" style, and part of the pattern is an e-textiles circuit. Normal thread, conductive thread, and e-textiles parts are included.



**Figure 4. Materials minikit (left). Switch minikit (right)**

The mini-kits come with fewer components, and encourage users to add their own crafts supplies, giving each project a unique outcome. They present an option that is easier for teachers and other interested users to integrate due to their lower cost and time commitment compared to the larger kit.

## 5. STEM CONCEPTS FOR GIRLS

The need to attract and engage girls in STEM education continues to be a relevant challenge in designing curricula, toys, and games. A 2000 American Association of University Women (AAUW) report presents the results from interviews with high-school girls about their relationships with computing [11]. They find that girls dismiss the stereotype that boys are "better with computers" by saying that boys' obsessive nature with playing and taking things apart is immature. Girls prefer to work on more open-ended projects, empowering them to feel responsible for developing the final outcome. We observed similar behavior to this in our workshops. The image below shows a girl who chose to develop her own project in an "Activating Origami" workshop instead of following the example provided.



**Figure 5. Girl showing her LED flower (left). Zoom in on flower (right).**

Stressing social and cultural applications of computing makes the subject more approachable to girls [10]. In line with this, Invent-abling presents a social and function oriented approach in the provided sample activities, emphasizing the open-ended potential of integrating computation with new and traditional media.

## 5.1 Closing the gap

Numerous reports show the lack of women in STEM professions [6,10,11]. College statistics show that girls receive 20-40% of the degrees in these fields and that women make up only 20% of STEM jobs [6]. Addressing this problem at a younger age by exposing girls to STEM education initiatives has been shown to increase the number of girls engaging in STEM at higher levels of

education with a rise from 3% to 20% since 2008 [6].

As Kafai et al's comparative study shows, textile construction kits such as Barbie Fashion Designer have been instrumental in increasing the applications and usability of technology [5]. A number of recent toys such as Goldieblox have also successfully attracted young girls to science and engineering activities [6]. These initiatives share our theme of breaking the branding barrier of "boys only" around STEM toys, but not the theme of inventing. The parts in our kits readily suggest creative integration with other toys and crafting materials. Existing products do not convey the versatility of their components, and thus are limited in their ability to impart skills that transfer to other media and integrate with other methods.

## 5.2 Instilling maker attitudes

Participants often became discouraged if they thought a friend's project was more advanced or aesthetically pleasing than their own. To address this challenge, we found it best to compliment them on parts that they understood quickly. Sometimes it was better to suggest a different activity that did not depend a specific skill like sewing, reminding them that it takes time to define one's unique skillset. We would like the variety of materials and methods in each Invent-abling kit to allow users to find and play to their strengths. We are interested in different approaches to instilling the DIY, maker attitude, and empowering students with the ability and wherewithal to explore the creative potential of new media.

Previous work with materials kits provides excellent techniques for embedding computation into crafts. Invent-abling strives to teach children how these different methods can be combined, thus fostering inventiveness.

## 6. FUTURE WORK

Based on feedback gathered from this initial phase of the project we plan to continue developing Invent-abling minikits and hosting pop-up workshops. More research and play-testing will establish methods for promoting curiosity through gender-neutral media and determine which toolkits are appropriate for different concepts and age-levels. We are currently working with a local middle school to create e-textile kits for their Home-Ec department. This will provide a robust opportunity to test the kits in a school setting and develop a sample curriculum around the kits.

We have not finalized the contents of the large kit and are working to design versions with various tools and difficulty levels based around different age groups. The Invent-abling kit series will provide a system for advancing through topics and techniques. Future work will integrate Invent-abling with digital embedded programming, as well as other unconventional programming environments.

## 6.1 Online Gallery

The current Invent-abling website functions as a blog for project updates, tutorials, and resources. We plan to rebuild the website and establish a platform for children to showcase their projects and ideas through an online gallery and profile section. Select projects will be featured based on their ingenuity and applicability. We will also feature the work of enthusiastic users who consistently submit to the gallery. We are considering giving achievement badges, which may help with integration of the kits into groups who use badges, like Girl Scouts. A forum and support section of the site will allow users to post questions and ask for

feedback about their projects. We hope to attract cyber schools to build Invent-abling into their curriculum. The tangible and digital system of making a project and sharing it through the website, provides a dynamic tool for this type of learning environment. Increasing the online presence will give Invent-abling a larger, more diverse network.

## 7. CONCLUSION

Invent-abling has succeeded in motivating children, particularly young girls, to investigate materials and methods in STEM. We found that careful choice of materials and activities can establish gender-neutral aesthetic. This, combined with girl-centric activities, makes the kit attractive to girls. Similar projects have introduced many women and girls to a new world of making, allowing them to enhance traditional methods with modern tools. We draw from research studies and personal observations about designing projects that appeal to girls, rather than using concepts that feed into gender stereotypes. We believe there is more work to be done, especially in the effort to educate children about concepts and processes of inventing.

## 8. ACKNOWLEDGMENTS

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