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Creative Design Process in Making Electronic Textiles

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ABSTRACT
This paper looks at the creative design process in making electronic or e-textiles. E-textile artifacts were first evaluated for creativity using the Consensual Assessment Technique. By comparing the design processes of artifacts with high and low creativity scores, we draw inferences about the creative design process. Deductive coding using themes from literature on design and creative processes showed the importance, and interaction between the following factors: attention; high degree of divergence before convergence during idea and solution finding; aesthetic and functional considerations; and designing to convey social themes. The paper concludes with a discussion on how to engage youth in creative design and future research directions.

Categories and Subject Descriptors
K.3 [**Computers and Education**]: Miscellaneous

J.4 [**Social And Behavioural Sciences**]: Psychology

General Terms
Measurement, Design, Theory

Keywords
Design process, creative process, creativity, electronic-textiles, consensual assessment technique, mixed methods

1. INTRODUCTION
Design is a process where an abstract theoretical concept is concretized into an artifact that can be experienced. The designer needs to decide on the right materials, the right proportion, and use the right set of tools to achieve a final desired outcome [11]. Problem framing [15] is used to describe how interpretation, inference and exploration occur throughout the process. Design is also seen as a reflective conversation with the materials of the design situation [15]. Part of this "conversation" involves an appreciation of the materials of design, and how they can be used to communicate and convey messages [7]. Not all design yields creative products or artifacts. For a design to be creative, it must be original. Additionally, it should also be effective: functional or even aesthetic [14]. The creative process is a "set of cognitive or mental processes that determine the production of ideas that are both novel and useful" [5, p. 191]. The creative process requires high openness or receptivity (*attention*) to both the environment as well as one's inner world of thoughts and ideas. In the process, attention shifts from external stimuli to internal ideational stimuli. These internal or complex ideas need to be transformed into creative products, and *motivation* is required. *Ability* is key, which is a distinct form of cognitive ability, enabling the reorganization and recombination of ideas [5, 10]. The creative process can also be seen as creative problem solving, and can occur in four phases: preparation, incubation, illumination and verification [17]. Divergence and convergence can take place through all stages of the creative problem solving process: fact-finding, problem finding, idea finding, solution finding and acceptance finding [9]. For divergent thinking, ideational fluency (number of ideas) and flexibility (number of themes in the ideational set) are important [13], whereas convergent thinking is usually judged by correctness.

Design thinking has been associated with creativity and innovation [3, 18]. However, little is understood with regards to the *creative design process*. Western psychology has focused more on creative products, measurement and personality, and less on the creative process [5]. This study takes a unique approach to understanding the creative design process by first evaluating artifacts created by participants for creativity. Next, the design processes of highly creative artifacts are compared with the less creative, and inferences are drawn regarding the creative design process.

2. PURPOSE OF STUDY
The study is guided by the following question: What can we understand about the creative design process by comparing the design processes of electronic-textile or e-textile artifacts with high, and low creativity scores?

The Consensual Assessment Technique or CAT [1, 2] is used for the evaluation of artifacts for creativity. A product is "creative to the extent that appropriate observers independently agree it is creative" (p. 1001). Appropriate observers would be experts in the specific domain. This assessment has been used in creativity writing, musical compositions and visual art, with high levels of inter-rater reliability among experts. The creativity score for an individual artifact is then taken to be the mean of the creativity ratings by the experts (on a scale of 1-5).

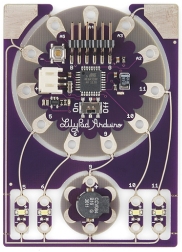

Figure 1. LilyPad Development Board Simple Kit consisting of the LilyPad, four LEDs, and a musical buzzer.

The materials for design are electronic-textiles or e-textiles, which are conductive materials made up of sewable electrical

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components like the LilyPad (a microcontroller), LEDs (light-emitting diodes), and buzzers etc., sewn together with conductive thread (Fig. 1). Projects typically involve a compositional assembly of these components, computation of component behaviors, and sewing of the circuitry with conductive thread. The process of crafting allows participants to customize both the form and function of their artifacts [4].

3. Methods

3.1 Setting, Workshop and Participants

This is part of a larger study of twenty participants including adults. This study focuses on youth, who signed up for the workshop as part of a library's "Maker Days summer program" in Summer 2014. The library is located in a Midwestern town. A total of nine youth participated (Mean age: 13; Range: 10 - 18.5).

The nine-hour workshop was spread over three days, and was facilitated by three graduate research assistants. The workshop content was modified based on curriculum developed for "soft circuits" [12]. On Day 1: participants were introduced to simple circuitry in e-textiles and sewed a practice project. At the end of the day, participants were briefed about the final project, with the aid of sample project pictures; Day 2: participants were introduced to the LilyPad Simple Development Board (Fig. 1). Participants used Modkit (http://www.modkit.com/micro), a visual computing software with a drag and drop interface similar to Scratch (https://scratch.mit.edu/) to program the components, and the code was saved in the LilyPad; Day 3: components of the development board were snapped apart before participants arrived to save time. Participants prototyped their project using alligator clips, before sewing the components together on the material of their choice. Materials provided in the workshop included different types of fabric (e.g., felt) and decorations (e.g., beads, sequins, fabric pens). Participants were strongly encouraged to bring personal items for the final project.

3.2 Data Sources

The design processes of all participants were captured through pictures of participants working on their projects; planning documents; close-up pictures and videos of the final artifact; daily observation notes; and audio-recorded, semi-structured interviews (15-20 min) conducted at the end of the workshop. Questions in the interview included: What do you like most about your design? Describe the process of making your e-textile. What kinds of difficulties or challenges did you face? How did you overcome them? If there were something you could change about your e-textile design, what would it be? The semi-structured interview questions made visible the thought processes behind participants' design actions or choices. It also provided background information of participants, which was important in the selection of cases for comparison. Of the nine participants, two were excluded from the analysis because of missing data.

For the Consensual Assessment Technique [2]: Two pictures and a video (10-15 seconds) of each artifact were included in an online survey to three expert evaluators, researchers in the domain of e-textiles with extensive experience with the materials. Video was included so the programming of the LEDs and musical buzzer could be visualized and heard. Each artifact was rated for creativity on a five-point scale with the following labels (1=low, 2= below average, 3=average, 4=above average, and 5=high). Following the recommendations for CAT [1. 2], the sequence of viewing the artifacts was randomized for each evaluator.

3.3 Analysis

We used a mixed method approach to data analysis [6]: findings from the initial quantitative analysis, i.e., the creativity evaluation by experts using CAT [1, 2] informed the selection of focal cases for in-depth qualitative analysis. For the CAT, a Cronbach's Alpha of 0.733 was obtained, indicating good reliability among our three evaluators (0.7 and above is recommended in creativity literature). Interviews for selected focal cases were transcribed. A concept-mapping tool Popplet (http://popplet.com/) was used to visualize each participant's design process by placing all relevant data on a timeline. The deductive coding process was guided by literature on design and the creative process (Table 2).

4. Quantitative Findings

4.1 Creativity Evaluation using CAT

The mean of the creativity ratings or creativity score ranged from 4.33 (highest) to 2.67 (lowest). Details of the ratings can be seen in Table 1.

Table 1. Means and Standard Deviations of Creativity Ratings

Pseudonym/Project Name	Mean	Std. Deviation
Lydia: Fireflies	*4.333*	*0.577*
Clarissa: Disney Princess	*4*	*0*
Item3	3	0
Item4	3	1
Item5	2.667	0.577
Item6	2.667	0.577
Caroline: Flower Brooch	*2.667*	*1.527*

NOTE: Gray highlighted cells indicate the focal cases selected for in-depth analysis of design process.

4.2 Focal Case Selection

We selected three focal cases based on artifacts with high and low creativity scores: Lydia (creativity score = 4.33) and Clarissa (creativity score = 4.00) were selected; Caroline (creativity score = 2.67) was selected because like Lydia and Clarissa, she enjoyed crafting and was skilled in sewing and music.

5. Qualitative Findings

5.1 Deductive Coding of Design Processes

Our codes include: ability and attention [5, 10]; the degree of divergence before convergence in idea finding, and solution finding [9]; as well as considerations to the effectiveness of the design: functional and aesthetics [14].

The creativity scores appear to be related to the age of participants. We acknowledge age to be an influencing factor in the participants' ability [5]. Ability is also interpreted generically as skills in music and computation. Such background information is provided in Table 2 for contextual understanding based on self-reported interview data, observation notes, and planning documents. Our key focus is more on the design process, and less the participants.

To explore variations between the focal cases, the degree of occurrence of each code/factor is indicated using a high, medium and low scale. In assigning the levels for *attention* (Table 1), *functional* and *aesthetic* (Table 2), we assign: high when there is strong evidence in our data sources, and/or when key ideas are self-generated; medium: when there is some evidence in our data sources, and/or when key ideas are taken up by emulating another;

and low when there is little or no evidence in our data, and/or key ideas are mainly suggested by facilitators. Assignment of levels for *idea finding and solution finding* (Table 2) will be explained in the focal cases.

Table 2. Deductive coding on the design processes, and degree of occurrence based on a scale of low, medium, and high.

	Creative process [5]		**Design to convey**
	Ability	Attention	
**Lydia	Age: 18.5 Music: not formally trained, but familiar Computation: programmed LED lights to sync with the buzzer tune	High	'Awesome fireflies' in summer
**Clarissa	Age: 15 Music: formally trained Computation: programmed LED lights to sync with the buzzer tune	High	Disney princess theme
*Caroline	Age: 12 Music: formally trained Computation: programmed buzzer tune and LED lights, but did not sync them together	Low	Flower (self-expression)

** = High creativity score; * = Low creativity score

Table 3. Deductive coding on the design processes, and degree of occurrence based on a scale of low, medium, and high.

	Idea finding:	**Solution finding:**	**Effectiveness** [14] Considerations of:	
	Degree of divergence before convergence [9]		Functional	Aesthetic
**Lydia	High	Medium	High	High
**Clarissa	Low	High	Medium	High
*Caroline	Medium	Low	Low	Low

** = High creativity score; * = Low creativity score

5.2 Design Processes of Focal Cases

5.2.1 Lydia: Fireflies

In *idea finding*, Lydia showed high divergence. She researched online (Flickr and Pinterest) for ideas: "I found this picture of a galaxy swirl skirt … but I wasn't sure the music to put with that. And I was thinking about music yesterday, I thought of Owl City's Firefly, and well I have LED blinking lights, so it was perfect." Lydia converged on the Firefly idea because of the 'Firefly' tune she had programmed onto the buzzer on Day 2.

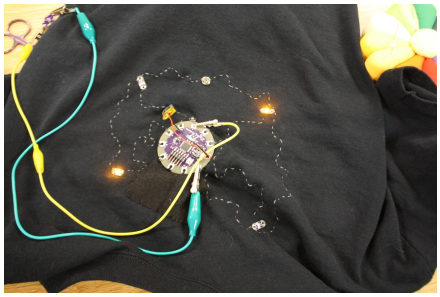

Figure 2. Lydia's project: Fireflies © Kylie Peppler

Her high *attention* or openness to both the environment and her inner world of thoughts and ideas [5] can be seen in how she coupled her inspiration from nature with her appreciation of the materials. She associated the orange LEDs to the 'bug', and used the black t-shirt for contrast. The *solution finding* is of medium divergence. Lydia wanted to use her stiches to represent the flight trails of the fireflies as part of her *aesthetic* design. She needed to make decisions on the placement of the components, ensuring her positive and negative stitching lines do not cross. In addition to positioning the components on her shirt, drawing on the planning sheet helped Lydia finalize the solution. Lydia was first to ask about the buzzer, which could be damaged on contact with water. She adopted a sewing strategy ('buzzer on snaps') that allowed the buzzer to be removed when necessary. Although Lydia adopted the facilitator's idea, the *functional consideration* was self-generated. Being a 'planner', Lydia talked about the ideal situation of knowing how the components worked in advance of the design project – she wanted to frame her 'design problem' with an understanding of the affordances and constraints of the design tools.

5.2.2 Clarissa: Disney Princess

In *idea finding*, Clarissa showed a low level of divergence. Her mind was fixed on the Disney Princess idea. In *solution finding*, Clarissa showed high divergence in the following ways: 1. she used multiple material and methods: she chose a white t-shirt and an iron-on applique, on which she printed the Disney graphic with Mickey's head; 2. she took steps to ensure the proportion of the print was right for her to fit the LilyPad over Mickey's head; 3. her placement of the components was guided by her consideration for the *aesthetics,* to make them 'well-hidden': her buzzer was placed on one of Mickey's ears and she sewed along the edges of the applique. Clarissa showed her *attention*, or appreciation of materials in the way she assembled the t-shirt, Disney print on the applique, LEDs and buzzer (Disney tune) to collectively 'communicate and convey' the Disney Princess theme. Clarissa's aesthetic design required careful planning - positioning the components on the material, and drawing on the planning sheet was a necessity. Seated beside Lydia, Clarissa also adopted the *functional* solution of 'buzzer on snaps' to prevent buzzer damage when washing.

Figure. 3. Clarissa's project: Disney Princess © Kylie Peppler

5.2.3 Caroline: Flower Brooch

In *idea finding*, Caroline had medium divergence: she brought a grey t-shirt, and doodled many flowers on her planning sheet. The "illumination" [17] took place when she was sketching flowers at home after Day 2 – she pictured the LilyPad in the center of the flower. The *solution finding* was straightforward and of low divergence: since there were four LEDs, Caroline decided her flower would have four petals. She chose her favorite red and yellow colored LEDs, then white and orange felt material for contrast. Her *aesthetic* considerations were in the color coordination; no attempts were made to hide or use her stitches. Caroline's idea materialized only on Day 3, so her "flower brooch" idea was unrelated to the tune (from the pop group R5) she programmed in the buzzer on Day 2. Caroline also did not sync the LED lights with the tune in her computation. In the interview, Caroline talked about using the flower as a brooch with a safety pin (suggested mainly by facilitator), and how it could be worn on multiple attires, and taken off when necessary. Caroline's

consideration of *functional aspects* developed through exploration and discussion with facilitators. In choosing her favorite tune and colors, her design was self-expressive, and the creativity is personal rather than social [14].

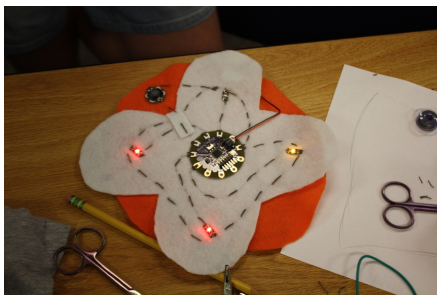

Figure 4. Caroline's project: Flower Brooch © Kylie Peppler

5.3 The Creative Design Process

Referring to Table 2, we see the importance of the degree of divergence for both idea and solution finding in the creative design process. For Lydia, the divergence in idea finding came from her search of projects online. A lack of divergence in the idea finding stage does not mean the process will not be creative - divergence can occur in the solution finding stage. This was the case for Clarissa, whose creative design process involved combining features from existing designs (Disney print) into a new combination or configuration (with LEDs and buzzers). A lack of divergence in both stages, as in the case of Caroline, is seen to be less creative.

Attention has been defined as high openness or receptivity to both the environment as well as one's inner world of thoughts and ideas [5, 10]. The attention levels were high in both Lydia and Clarissa, and both of them were able to use the appropriate materials, arrangement and computation to convey and express their design ideas, which were related to natural phenomena or popular culture. There is a unique interplay between internal and external stimuli. Caroline's attention to materials developed over time, through drawing, and her interaction with facilitators. Although Caroline's design resembles a flower, it is more personal and self-expressive.

The consideration of aesthetics is important in the creative design process, and drawing on planning documents for Lydia and Clarissa facilitates this thinking process. This form of planning is necessary to make decisions on the placement of components, and to hide or display sewing lines (depending on the design). For Caroline, she drew the sewing lines directly on the felt material and did not use the planning document.

6. Discussion

Based on the findings, we discuss ways to engage youth in creative design processes. We have seen how attention plays an important role in the divergence of idea and solution finding. In visualizing design as a conversation with the materials of the environment [15], we incorporate the poststructuralist view that considers the transformative agency of the materials. Materials interact with the participant's hand, body, eyes and imagination [16]. This view gives us new perspectives on engaging the attention of youth. They should be exposed to different types of materials or environment/nature, to touch, feel, imagine and connect to their ideas and imagination. This also has implications on the kinds of materials provided, and the design of the physical environment. Brainstorming [8] is another strategy to increase divergence in idea and solution finding. Specifically, brainstorming as a group can also help participants think beyond their immediate experiences, to consider design themes that are more social in nature.

Through our workshop, we see how youth will be more able to frame design problems holistically when they are aware of the affordances and constraints of the design tools. Time should be allocated to playful and in-depth explorations, and also for the incubation of ideas, to reach illumination moments [17]. Also, drawing was important for the participants in planning for aesthetics. In design, drawing is an important skill that connects the mind with the hand. Drawing can also serve as inspiration for idea finding, and lead to deeper considerations like functional aspects. More can be done to discover the role of drawing in creative design processes. Lastly, how can we challenge and scaffold youth to go beyond just creating a working artifact, to further consider aesthetics and functional aspects? Facilitation of creative design processes was not part of this study, and would be another area to explore for insights.

7. References

[1] Amabile, T. M. 1982. A consensual assessment technique. *Journal of Personality and Social Psychology, 43*, 997-1013.

[2] Amabile, T. M. 1983. The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology, 45*(2), 357.

[3] Brown, T. 2008. Design Thinking. *Harvard Business Review, 86*(6), 84.

[4] Buechley, L., Peppler, K. A., Eisenberg, M., & Kafai, Y. B. (Eds.). 2013. *Textile messages: Dispatches from the world of e-textiles and education*. New York: Peter Lang

[5] Chamorro-Premuzic, T. 2009. Creative design process. In B. Kerr (Ed.), pp. 191-194, *Encyclopedia of Creativity Vol. 1.* CA: Sage

[6] Creswell, J. W., & Clark, V. L. 2011. *Designing and conducting mixed methods research* (2nd ed.). LA: Sage

[7] Cross, N. 2006. *Designerly ways of knowing*. London: Springer-Verlag

[8] DeLisle , J. B. 2009. Creative classroom techniques. In B. Kerr (Ed.), pp. 174-175, *Encyclopedia of Creativity Vol. 1.* CA: Sage

[9] Firestien, R., & Treffinger, D. J. 1983. Creative problem solving – Guidelines and resources for effective facilitation. *Gifted Child Today*, *26*, 2-10.

[10] Guilford, J.P. 1962. Factors that aid and hander creativity. *Teachers College Record, 63*, 380-392.

[11] Nelson, H. G., & Stolterman, E. 2012. *The design way: Intentional change in an unpredictable world*. NK: Educational Technology Publications

[12] Peppler, K., Gresalfi, M., Salen, K. & Santo, R. 2014. *Soft circuits: Crafting e-fashion with DIY electronics.* MA: MIT Press

[13] Runco, M. A. 2009. Divergent thinking. In B. Kerr (Ed.), pp. 252-253, *Encyclopedia of Creativity Vol. 1.* CA: Sage

[14] Runco, M. A. 2009. Creativity, definition. In B. Kerr (Ed.), pp. 200-202, *Encyclopedia of Creativity Vol. 1.* CA: Sage

[15] Schön, D. A. 1983. *The reflective practitioner: How professionals think in action*. Basic Books: New York: Basic Books

[16] Taguchi, H. L. 2014. New materialisms and play. In E. Brook, M. Blaise & S. Edwards (Eds.), *SAGE Handbook of Play and Learning in Early Childhood* (pp. 79-90) LA: Sage.

[17] Wallas, G. 1926. *The act of thought*. London: Watts

[18] Wylant, B. 2008. Design thinking and the experience of innovation. *Design Issues, 24*(2), 3–14.