Education as experience

The role of technology in science education

Ammar Halabi and Marisol Villacres

Studies confirm that instructional strategies to actively engage students in learning science can help them achieve greater levels of understanding, retention and transfer of knowledge than with the traditional lecture/lab class model (Handelsman et al., 2004, p. 521, Sandoval and Reiser, 2003, p. 345, Project Kaleidoscope, 2002, p. 4). In spite of these findings, evidence points out that introductory science courses for undergraduates are still being taught based on the transmission model of teaching and learning where "the professor lectures and the students take notes, read the text, memorize the material, and regurgitate it later on an exam"(King, 1994, p. 15).

The National Science Foundation (1996) warns about the negative unintended consequences of the current focus on teaching rather than learning in college education:

- By losing their opportunity to discover and construct a personal understanding of science and mathematics, students develop an unfavorable attitude towards science (p. iii). As a result, over half of the students who enter college to pursue a science-related education drops-out within two years of taking their first college science class (Seymour and Hewitt, 2000).
- On the other hand, it can also lead to the inadequate preparation of graduates who go out to work feeling poorly prepared to "solve real problems in a cooperative way, lacking the skills and motivation to continue learning" (National Science Foundation, 1996, p. iii).

If the goal is to shift focus from what instructors can "cover" to how students can achieve meaningful learning and transferable knowledge, science education in college needs to be approached with newer strategies. Several studies suggest that IT-based learning could support this reform movement (DeHann, 2005, p. 261; Roschelle, 2000, p. 78; White and Frederiksen, 2000, p. 321). The interactive and adaptive nature of technology can provide students with opportunities to explore and experiment with ideas and concepts that traditional teaching strategies cannot provide. In general, when effectively used, technology can enhance fundamental characteristics of learning such as active engagement, participation in groups, frequent interaction and feedback, and connections to real-world contexts (Roschelle, 2000, p. 76).

Studies related to he application of technology in science education have shown a strong emphasis on putting students in performance situations as real as possible, to encourage them to learn by doing. Science educators have long held that enhancing students' understanding of the strategies and logic of scientific inquiry can facilitate students' development of scientific literacy. Based on the research to date, technology's role in improving the

students' understanding and use of scientific inquiry has been explored from the following angles:

- The role of social interaction, collaboration and collective practices in productive inquiry-based learning environments. In his study of computer-mediated mathematics classroom, Enyedy (2003) explored "how students' mathematical activities, and thereby their mathematical understandings, change as a function of their participation in different social configurations" (p. 361). In the same line, Vahey et al. (2000) reported the impact of collaborative inquiry activities and student-controlled simulations in the development of probabilistic reasoning.
- The importance of providing epistemic support for inquiry learning. In that sense Sandoval and Raiser (2004) propose ExplanationConstructor, a software tool based on an explanation-driven inquiry approach. ExplanationConstructor was designed to support students' "(a) articulation of coherent, causal accounts and (b) use of the data to support causal claims" (p. 349). On the same line, several studies have focused on offering learners tools that simulate experts' knowledge organization (Koedinger and Corbet, 2006; Schwartz et al. 2007). The main goals have been to provide students with a context-based source of advice, to encourage reflection and to support them in learning by teaching.
- The exposure to complex and "nonlinear open-ended dilemmas with no clear boundaries" and the support to approach and reflect on them. Several studies have proposed embodied and immersive techniques such as participatory simulations (Colella, 2000), augmented reality (Klopfer et al., 2003) games and embodied modeling languages (Willensky et al., 2006), to allow students "dive into a learning environment and directly engage with the complex system at hand"(p. 191). Although every technique has a different way to approach embodiment, all of them are based in students becoming players in a either simulated or real world, where they are exposed to a "learning through failure" experience.

Although experts agree that "the widespread promotion and adoption of the elements of scientific teaching by university science departments could have profound effects in promoting a scientifically literate society and a reinvigorated research enterprise" (DeHaan, 2005, p. 253), very few of the approaches discussed above have been explored at a college level (Roschelle, 2000, p. 78). The challenges college science education faces push for the redesign of curricula that focuses on offering students "learning experiences that motivate them to persist in their [scientific] studies and consider careers in these fields" (Project Kaleidoscope, 2002, p. 1).

Toward a unified language for Educational Technologies

Upon the aforementioned efforts we can observe a group of values that researchers attempt to support. Which are mostly relevant to embodiment, participation, collaboration, sharing, situated action, reflection and

authenticity. These values share the drive towards giving authentic, meaningful contexts to educational activities, which goes against instructionist approaches where information is pipelined to students. On the individual level, this is linked to *experiential learning*, which views learning as a product of authentic interaction in real-world situations that give rise to meaningful experiences where action and reflection play a central role in meaningful learning (Dewey, 1938; Kolb 1984)**.** Also, carrying our values to a social level mainly supports a pedagogy that is rooted in *social constructionism*, which "places equal importance on the individual learner and on the role of social participation. Here, the individual, the artifact, and collaborative input of the community shape learning, participation, and sharing." (Peppler and Kafai, 2007). Thus, for socio-cultural constructionists, the individual and the community develop through “shared constructive activity that is resonant with both the social setting that encompasses a community of learners, as well as the cultural identity of the learners themselves” (Pinkett, 2000)

Peppler & Kafai (2007), reported that a constructionist approach is highly compatible with the requirements of modern education of new media. Design, creation, sharing, and social participation were key to achieve high-level understanding and critique of new media. That supported the development of Scratch; a visual programming environment which is sought to be flexible and accessible environment to enable novice programmers to create or incorporate existing images and sound files into their videogames, interactive art, and narrative video productions. In another study by Barab et. Al (2005). the authors/designers base on experiential learning to combine strategies used in commercial gaming and educational research in their design of Quest Atlantis. An educational gaming environment that “allows users at participating elementary schools and after-school centers to travel through virtual spaces to perform educational activities, talk with other users and mentors, and build virtual personae.” (p. 86)

Out of this review, a central unity floats which has the potential to encompass the values highlighted and supporting pedagogies. This unit is "experience", which, along with arguments made around experiential learning, can serve as an adequate unit of observation for education. In this paper we take experience a step further by arguing that "aesthetic experience" is central to successful education. We therefore base on various works, which are rooted in pragmatism, to build a language for speaking about the role of aesthetic experience in learning. This will further aid us to delineate a critical framework that is useful for analyzing educational technologies form a point of view that accounts for experience. Provided this unified language and critical lens, we hope that we can open the space for discussion on the potential of technology to support aesthetic experience in education which would prove valuable for researchers and designers.

What is aesthetic experience

Basing on the works of Dewey (1934) and Russon (2003), we can define experience as our continuous engagement in doing and undergoing the world through our senses, intellect, feeling, and action to make sense of our selves and the world.

We here emphasize the role of experience in our continuous sense-making. This understanding implies totality in the sense that we cannot "be" without experiencing due to our nature as sense-making creatures. Also, the works of pragmatists highlights a central characteristic of experience: subjectivity. This subjectivity arises from our crafting of our own experiences by interpreting them through our own perspectives. My understanding of a book I read is influenced by my history, knowledge and emotional state. I see the architecture in town through my own eyes that were trained to recognize beauty according to certain contexts and forms. As Bakhtin (1981) points out, we author our unique experiences due to our unique positions in the world.

Dewey primarily draws the distinction between what he calls experience and "an experience", or in other words "aesthetic experience". For Dewey, such aesthetic experiences are not restricted to those by encountering art or consummating what is conventionally dubbed as a creative work, but it extends to every experience that leads seamless, meaningful flow that concludes with consummation. For him, our continuous experience in the world lies between two extremes: meaningless succession and mechanical succession. In the first, we go through insignificant happenings that we overlook as if it were noise of a surrounding world. In the second, while events and actions are tightly connected, they lack meaning due to their mundane nature or repetition, such as walking down the road we used to take for so long. Between these extremes lies a sweet spot marked by strong, seamless succession and deep meaning of high personal relevance. They are experiences that we view as wholesome unities which we recount to others to share meaning. Such experiences are those that are accompanied by moments of revelation, distinct emotional flow, and meaningful resolution.

Justifying aesthetic experience

To establish an argument for examining education through experience we mainly draw on the several works on line with a pragmatist stance on being and the construction of self and identity. We base our vision on emphasizing the role of aesthetic experience in the construction of self and identity, which, in turn, creates the arena for learning.

Indeed, Hull and Katz (2007) take their project on the use of multiple-media, multiple-modality literacy of digital storytelling, which created a frame to foster agency, to illustrate "how conceptions of self have much to do with how and why we learn; the desire to acquire new skills and knowledge is inextricably

linked to who we want to be as people." (p. 43) Their framework is based on studies of performed narrative in its various forms (text, dance, music, etc.) as the means to engage in a social discourse governed by sign and value systems. Miller et. al. (1993) suggest that “the narrated self is a relational self” (p. 89) That is, if we believe that “narrative practices are social practices,” then implicitly, “the narrated self is constructed with and responsive to other people” (Miller and Goodnow, 1995, p.172). Narration is always performed in relation to the other to position ones own identity.

On the other hand, researchers have suggested that this construction, this authorship of self, draws upon and qualifies for aesthetic experience. McCarthy and Wright (2007) view that "for Bakhtin, the relationship of one consciousness to another consciousness, as an other, is constitutive of aesthetic experience." (p. 75) This implies that aesthetic experience essentially arises through engagement in a cultural discourse, or the interaction with the "other", which leads to deep realizations about one's self in its dialogical relationship with the discrete material world.

> *“From the perspective of the self, the other is rounded out that it is a consummated, self-sufficient whole. In contrast, the self cannot see itself in that way. It is tied up in the incompleteness of its own story, unconstrained by time and space, unsettled. It suffers from lack of vision with respect to itself. The excess or surplus of the other is required to make up for the self requires the other but also a return to self. It centers in the self, returning to itself to take advantage of its own surplus and outsideness. In this moment, the self is authored. Consummation of self entails a dialogue with the other -a meeting of two conciousnesses- that confirms the unique perspective and value of the self, allowing the self for a moment to experience unity and completeness”* (McCarthy & Wright 2007, p. 75)

This is a plausible depiction of aesthetic experience, for on the felt level we associate remarkable experiences with deep realizations and impact upon our understanding of ourselves and the other; the world of objects and people. This impact is accompanied by change in our views and relations through intricate dialogical interaction with the world. Furthermore, while Hull and Katz (2007) acknowledge that "one’s sense of self is continually recreated from moment to moment throughout one’s life," they report on Urciuoli as she claims that "some moments are more significant than others and take on a special intensity." She writes, “Any activity that coordinates action to create a unity from many selves—dance, ritual, religion, sport, even military actions—can generate performative moments” (Urciuoli 1995, p. 202]. It is this unity of aesthetic experience that marks its value in sense-making and separates it from mundane and casual ongoings. This perception of a wholesome synthesis is what we reinterpret and recount as the ways to make and narrate meaning while to author our selves. However, our notion of self-authorship is not restricted to active narration, but it also extends to Bakhtin's continuous dialogical engagement with the other - the world and its beings. That implies that all meaningful activity we engage in contributes to our continuously changing sense of self. This can be supported by Holland et. Al (1998) **.** who state that “If all sign systems have in common that they are indexically structured, then all meaningful action is concerned with the interactive construction of a person” (p. 192). Here, indexicality of sign systems (languages and discourses) means that all structures within these systems

refer to world states and matters. This entails that all action of sense-making through engaging in discourses that live in these sign systems contribute to the construction of self. Hence, the continuous dialogical construction of the self happens through our continuous experience which revolves around sense-making. In its prime, experience elevates to an aesthetic experience with wholesome unity, profound subjecive meaning, and deep change.

In Bruner's studies of narrative, these are "turning points":

> *"In his studies of narrative—in particular spontaneous, spoken autobiographical accounts by adults—Bruner commented on the universality of "turning points," moments when people report sharp change in their lives and demonstrate accompanying dramatic changes in their representations of self. Among the features of these turning points are vivid detail and great affect, a connection between external events and internal awakenings, and agentive activity. In Bruner's words, such turning points are "thickly agentive" (p. 50). Rather than viewing these accounts simply as true reports of past events, Bruner understands them as "preternaturally clear instances of narrative construction that have the function of helping the teller clarify his or her Self-concept. They are prototype narrative episodes," he continues, "whose construction results in increasing the realism and drama of the Self" (p. 50). These turning-point narratives may thus serve as emblems or tropes for how one thinks of one's life as a whole."* (Hull & Katz, 2005, p. 45)

This ties the argument back to education, as we perceive the prime role of aesthetic experience in leading to Bruner's turning points, which are the landmarks of changing the self, in other words: learning.

To summarize, we argue that experience, encompassing our sense-making faculties, has a prime role in education. This relationship becomes clear when we view education as a framework for constructing selves and identities, and when we further recognize the impact of aesthetic experience in shaping this construction of self - who we are and what we want to be.

On education of arts & humanities

As we position ourselves to consider the role of experience in learning and construction of self, we view education in arts and humanities as fertile grounds to inform education in science and engineering. This comes from inherent values that premise current education in arts and humanities; values which are intimately relevant to experience. This mindset encourages critical reading and participation in culture through appropriation of expressions in cultural discourses, aiming to bring individuals to realize their roles their contexts and to qualify for societies that are capable of reflection. Education in arts and humanities therefore highlights the importance of the construction of independent voices and social participation through subjective interpretation, critical appropriation, and production.

These values are shared across fields in arts and humanities, of which is new media production. Education of new media emphasizes on enabling students to develop their own languages to question and rewrite power structures in dominant texts (Peppler and Kafai, 2007; Bolter and Grusin,

1999). Black (2005) highlights the participation of youth in critical reading and authoring in digital media:

> *"… these youth refashion the pre-existing media tales by infusing them with social and cultural themes, multiple literacies, various forms of expertise, and concerns from their daily lives. Moreover, these mass-produced media become resources for and are integrated into fans' day-to-day interactions, activities, and the cultures of online fandoms."* (p. 173*)*

Here we can observe the explicit emphasis of education in arts and humanities on the appropriation, interpretation, and expression, which contribute to the construction of identity. These experiential values support a viewing of arts and humanities as bearing good potential for the appropriation of methodologies and frameworks to construct a mindset in science education that accounts for the role of experience.

Here, as we consider the role of technology in education of science and engineering, we appropriate a critical framework that accounts for experience to analyze the potential of the LilyPad Arduino and wearable computing in acquiring programming skills. This shall serve as an instance of how we can appropriate hybrid methods to account for the role of experience in education. Appropriating such a critical framework can also be supported by the work of Bardzell in their call for incorporating criticism in the design of technology (Bardzell and Bardzell, 2008). We further incorporate criticism to analyze the role of technology in educational experience.

THE LILYPAD ARDUINO

In order to clarify the value of a framework for analyzing the learner's experience with technology, we would like to take a closer look to an example of technology in a learning environment. The LilyPad Arduino is a set of sewable programmable electronic components that let schoolchildren and adults build their own soft, interactive fashion. Its creators have conducted a series of studies in the form of workshops to investigate the impact of the LilyPad's emphasis on fashion, aesthetics and creativity, on young learners' motivation and engagement towards science (Buechley et al, 2008; Buechley and Eisenberg, 2008)

The kit consists of a flower-shaped microcontroller and a group of sewable sensors and actuators. To build and e-textile, a person would sew the parts together using conductive thread to create both physical and electronic connections. The microcontroller can be programmed in C using the Arduino Integrated Development Environment (Buechley and Eisenberg, 2008)

The workshops employing the LilyPad Arduino were held with the intention of evaluating the kit's potential to engage learner's creative experimentation with computing and electronics while teaching them basic skills in these areas. At the start of each workshop students were introduced to circuits, electrical resistance, multi-meters, and sewing. Next, students were taught the basics of programming and they were instructed to experiment with the kit. Finally, after these exploratory activities, students were given the opportunity to design and

build their own e-textiles and at the end of the week, the class culminated in a fashion show (Buechley et al., 2008)

The LilyPad Arduino's relatively novel affordances make it an unusual technological device that presents programming and electrical engineering as tools to design and craft arts, thus becoming a medium to democratize human expression and creativity. By encouraging the integrated exploration of art, design and engineering, the LilyPad workshops have the potential to "support the learner's independent interests and motivation" and "foster new, creative, and contentful youth cultures" (p. 429).

The result of the workshops were very positive and indicated that several of the students became extremely engaged both in the class and in the use of the LilyPad Arduinio. The expressions students used to rate the workshop where "motivating", "engaging", "fun" and "awesome". Most interesting, that collected data indicated that the experience might have empowered and motivated some students to take more interest in electronics and computer science. One 15 year old student answered that after the workshop she discovered that programming was not as hard as she thought it would be and that now she felt more inclined to take future classes in computer science (Buechley and Eisenberg, p. 14).

Nonetheless, it is valuable to mention that not all students were passionately engaged and that students expressed frustration with programming and sewing (Buechley et al., 2008, p. 431).

With the goal of unpacking the experiential qualities of the LilyPad Arduino's workshops, we propose to use McCarthy and Wright's threads.

Introducing the framework

In an effort to present technology as experience through exploring the potential value, meaning and vitality of the relationship between people and technology, McCarthy and Wright (2004, 2007) characterize what they refer to as the four threads of experience. These are not necessarily fundamental elements of experience, separated from each other. Rather, they constitute a framework of four intrinsically connected parts that aim to help us talk about "the sense we make of experience in terms of our selves, our culture, our lives" (McCarthy and Wright, 2004, p. 42).

Based on McCarthy and Wrights' reading of the pragmatist literature, the four threads are: the sensual, the emotional, the compositional, and the spatio-temporal.

The sensual thread describes sensory engagement people have with a particular situation. It draws attention to visceral and palpable reactions being grasped as the immediate sense of a situation. It prompts the question of how the use of an artifact or one atmosphere makes us feel. For example, what sensual reactions trigger the look and feel of a cellular phone, or having a conversation with someone?

McCarthy and Wright (2007) explain that emotions “are the color shot through the experience that holds all aspects of the experience together and makes it different from other experiences” (p. 83). From that aspect, the emotional thread elicits analysis around the emotional quality of an experience, and triggers the question of “what emotions color the experience for us?” Complementing this description, they also report that Dewey, Bakhtin and Nussbaum give a dialogical interpretation to emotion when they argue “emotions acknowledge our need for others in our struggle to achieve emotional unity” (p. 84). In that sense the emotional thread describes the relationship between our emotions and our relation with others (persons and things).

In a novel, play or film, the compositional thread describes “the narrative structure, plausibility, consequences, and explanations of actions” (p. 87) . In general it refers to “the relationships between the parts and the whole of the experience”. The questions that this thread motivates are related the coherency of the elements of an experience: “what is this about? What has happened? Where am I? What will happen next? Does this make sense? What would happen if?” (p. 88)

All experience is affected by time and space. If we are experiencing an intense emotional engagement, we might perceive time in a different way. On the other hand, an overwhelming experience trigger a need for emotional space. McCarthy and Wright explain that in our search for constructing spatio-temporal aspects of an experience, “we may distinguish between public and private space; we may recognize comfort zones and boundaries between self and other, or between present and future” (p. 91). To try to uncover the space-time quality of an experience we can ask ourselves questions such as “what kind of initiative do people have?”, “what kind of creativity is possible?” “does social context change?”, “do personal identity and character change in response to events, or are they fixed?” (p. 94)

Experiential Analysis of the LillyPad Arduino Workshops

We here come to employ the critical framework in analyzing the experience of using of LillyPad Aurduino in science education. This should serve as an example on the kinds of insights that such analysis is capable of bringing.

Reflecting on the sensual thread, we here examine how we make immediate sense of our perceptions. This thread is concerned with pre-reflective visceral character of experience and which is maintained with novelty, primitive familiarity and engagement. The materiality of Lillypad leaves the impression of the manipulability of its electronic parts through hands-on experimentation through physical circuit design and programming of its behavior. As it incorporates lights, vibrators, and speakers, it provides tangible, visual, and auditory feedback which render the Lillypad as a highly flexible and interactive toy of use. This sense of a "toy of use" is novel for it incorporates two senses that challenge each other: the sense of complexity and awe that comes with

advanced electronics coupled with craft and sewing, which is in intriguing contrast with the sense of safe playfulness and experimentation. On the other hand, the incorporation of fashion brings a variety of materials, their colors, textures, smells, and manipulability which opens a vast space for sensual richness. Also, the primitive sense of what is considered pretty, attractive, and cool drives the design of interactive fashion pieces.

As for the emotional, this thread carries our reflection on the meaning we make in evaluation of our surroundings and happenings against our needs, goals, and values. For the LillyPad, as pupils keep craft and test the e-textile, their emotions flow, leading to mixtures of frustration, enjoyment, or fulfillment. Discussions and comments of peers in the workshop would also lead to self-evaluation and critique of others, which results in an continuously changing understanding of the work at hand as learners project their identity in their piece of e-textile.

This primarily highlights the emotional flow that is associated with social engagement. The presennce of peers, collaboration, and critique situates pupils in an interactive and hardly predictable settings, which, by bringing in cultural values about looks, aesthetics, and coolness, pollinates creative capabilities, such that pupils would often find themselves in continuous reflection, realization, and innovation. This encourages curiosity about the potential of Lillypad to empower people to reflect, express, and create through interactive wearable pieces.

Provoked by the compositional thread, we are concerned with the relationship between the parts and the whole of the experience. An aesthetic experience would maintain a plausible and consistent relationship that conserves its unity. By introducing LillyPad, its creators remediate activities and concepts relevant to circuit design, programming, fashion and crafts. This challenges the notion of rigidness of science and the separation between engineering and self-expression. Through fashion, a meaningful context encompasses the learning of technical concepts, and pupils are enabled to critique their culture and craft their personalized expressions in the form of fashion pieces. This would, as the creators hope, to the sense of active presence and achievement as pupils conceive complex technical skills and engage in cultural discourses with their peers and communities.

As tension and resolution are often inherent in aesthetic experiences, it is useful to underscore the tension in the composition of activity around LillyPad. Among the tensions we can identify, the tension between design ideas and materials is evident. This is resolved upon successful manipulation of material to reach a desired form an behavior of the wearable piece, or maybe the failure of manipulation which would leave an experience which is not complete that would inform future designs. Another tension is the between conventions of fashion and the pupil's struggle to re-appropriate these conventions to make pieces that are their own. It is noteworthy to mention that although tension is important in experience, balancing it is a delicate matter. If it overpowers the capacity of pupils to overcome the experience potentially

becomes frustrating. This was reported in some experiments with the LillyPad, where programming skills were hard to acquire for some which resulted in a break in the flow and engagement.

The LilyPad's workshops also highlight the learners' possibility exercising choice and control over the space. This creates a free and safe environment for self-expression, and for developing a genuine sense of "becoming". The technology they are introduced to, allows learners to quickly appreciate science and engineering as a means for self-expression, and change their perception of their capabilities and professional inclinations.

The LilyPad constitute a mean for learners to project in their creations, of all the elements that describe their identity. Every piece of clothing designed is grounded in the designer's cultural and social context, and affected by time and place.

Finally, by focusing the interaction on pieces of clothing, learners are introduced to a new type of social context based in play. Every piece of clothing is an invitation for other learners observe it and interact with it, there for, interacting with the person wearing the piece.

Conclusion

Our transition towards incorporating modern values in science education motivates the need for a unified language to speak about the composition of these values and how they relate to education. Taking experience to coin that unified language holds a promising potential: talking about [aesthetic] experience in education opens the space to reflect on how we can craft our educational compositions to aid students in science and engineering to understand their contexts, their roles, and the potential for action. Discussing aesthetic experience in education means discussing profound understanding and deep change. It also helps constructing identities of scientists and engineers that approach learning about the world through collaboration and sensible commitment to everyday life. Our proposal is therefore to consider the role of technology in promoting educational experiences.

Our natural source of inspiration was research and pedagogy in arts and humanities, which share the values of a mindset that accounts for subjective experience. This would not only help strengthening communication between the traditions of science and humanities, but would also contribute to a more authentic construction of scientists and engineers. In this paper we appropriated a critical framework to analyze the constituents of an instance of experience mediated by an educational technology. This analysis illustrates the potential of critique in understanding educational experience to qualify for informed appropriation of technology.

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