BuzzBits

A Robotic Construction Kit for informal learning of electronic and technology in underserved communities

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BuzzBits is a robotic construction kit (RCK) consistent of elementary and cheap electronic pieces, that combined with elements from the user's environment, can be assembled to create an electronic insect. The kit is designed for children from 8 to 14 years-old located in underserved communities across the globe that have little to no previous interaction with technology. The kit will be distributed in rural, marginal, or displaced communities to be used by kids outside their schools. A typical learning context would be the street, at home, or in any recreational environment they may use. The ultimate learning goal of the kit is to enhance in these children a proactive and challenging attitude toward technology that can be synthesized in the expression: – I can make technology! –.

1. PROBLEM DEFINITION

Technological changes have shaped our notions of literacy; active and successful participants in the 21st century global society must be able to navigate proficienciently and fluently with the tools of technology (Resnick, 2001; National Council of Teachers of English, 2013). Technological literacy can eventually increase and improve career opportunities, but more important it can offer countless creative opportunities through multiple learning and expressive affordances. In our digital age, being digitally fluent means not only knowling how to use digital technology, but also knowing how to create things of significance with it (Resnick, 2001). Increasingly nowadays, children are expected to develop technological fluency despite wide variability in the quality of learning opportunities schools provide (Greenhow & Robelia, 2009). Technology integration in schools is taking more time than expected to transform education (Resnick, 2001; Fullan, 2016) and children around the world are missing the opportunities that technology, as a creative tool, can bring to their lives. According to Michael Resnik (2001), "there is a real risk that only a small handful will be able to use the technology fluently" as a tool for learning and creating. Every child should become aware that she/he can participate in our technological world, not only as a consumer but also as a creator. For this purpose, we need to rethink the technology that we provide to children (Resnick, 2001). Technology needs to be not only accessible but also understandable, transparent and "makeable" from the perspective and interests of kids. The interaction with the powerful idea of *technology as a makeable artifact* could be a first step to encourage children to explore its multiple affordances and use it in personally meaningful way to create and transform the world around them.

2. LEARNING OBJECTIVE

The ultimate learning goal of the kit is to encourage a proactive and challenging attitude toward technology: – I can make technology –. In addition learners will be able to:

- Figure-out how to build something with limited elements, non direct instruction, and ill-structured guidance.
- Recognize the value of household elements and practices of their environment for technology creation.
- Collaborate and share their creations with other kids from their communities.
- Understand the basic components of electric circuits; how they work and how they do not work.

3. THEORETICAL BACKGROUND

For the purpose of this project, a Robotic Construction Kit is defined as a set of elements with the potential to build machines capable of carrying out actions automatically. These kits could include structural elements, mechanical and electronic components, sensors, and controller boards. Depending on the availability of such items within the kit they can be divided into three categories: complete kits, assembled kits, or incomplete kits. The first ones can be purchased as a whole package with all the necessary elements to build robots or machines; examples are Lego Mindstorms, Lynxmotion, Tinkercrate, or LittleBits. The second ones can be assembled using individual parts that are sold separately by companies such as Arduino, Gogo Board, Raspberry Pi, Chibitronics, or Sparkfun. Finally, the third ones are kits that intentionally do not include some elements to provide the users the opportunity to use their own; for example, Tin Can Robot, that consists of all necessary components except the body of the robot that can be made using a soda can. The price of these kits can vary from around 500USD for complete packages to 15USD for a basic assembled kit.

In general, RCKs are conceived for people to construct with open-ended results guided by their interests or needs. This way, learning with a kit can be framed from a constructivist theoretical perspective in that it aims for learners to build the understanding of the ideas embedded in the creation of personally meaningful artifacts (Papert, 1993). These learning experiences are based on the premise that constructing external physical artifacts can facilitate knowledge construction (Wilkerson-Jerde, Wagh & Wilensky, 2015). "The argument is that by constructing such artifact, using primitive rules that connect to the learners' existing ways of navigating the world, learners' prior knowledge can be reorganized, debugged, and built upon to generate new ideas" (Wilkerson-Jerde et al., 2015). The ideas that can be explored in this open-ended construction process can be divided in two groups, domain-related ideas and learning-related ideas. On one hand, for the domain-related ideas children will explore the basic components of electric circuits and how they work together. They will also understand how sources of natural energy, as the sun, can be used as a source of power for their projects. On the other hand, for the learning-related ideas, children will learn about their own capacities to create with technology and they will develop learning skills, such as tinkering and debugging to figure-out how to build the artifacts and make them work.

However, the extent to which the experience of constructing a robot may lead to such learning experiences will be determined not only by the artifact itself, but also by other factors such as the learner and the learning context, that will be analyzed from a theoretical perspective in the next section.

4. THE LEARNERS

A clear focus on who learners are shapes the pedagogical design and practice of making in consequential ways (Vossoughi et al., 2016). The target audience of this project are children aged between 9 and 14 years old that live in remote, marginal, or displaced communities. For the purpose of this analysis, learners will be considered from a constructivist theoretical perspective, in which "the knowledge is not apprehended or discovered but it is created by the learner" (Smith & Ragan, 2005). The learning affordances of the kit will be highly affected by learner characteristics such as cognitive, affective and physical states (Tessmer & Richey, 1997; Smith & Ragan, 2005). Among the variety of learner characteristics, we will briefly analyze how learner cognitive development, role perception, and previous knowledge can affect the implementation of the kit.

4.1 Learner cognitive development. According to Piaget's stages of intellectual development, learners in this age group are going through the end of the stage of concrete operations and the beginning of the stage of formal operations. During the stage of concrete operations, learners acquire skills such as "classification, seriation (ordering), reversal of operations, reciprocity, and identity" (Smith & Ragan, 2005, p. 67). Learners "can think logically but require concrete objects to support this thought process" (Smith & Ragan, 2005, p. 68). The kits aims to leverage logical skills and support that process through the construction of external artifacts.

4.2 Learner role perception. The role that learners play in the environment determines what they learn and how they learn (Tessmer & Richey, 1997). When learning with open-ended technology such as RCKs, students must see themselves as nonlinear and exploratory learners (Tessmer & Richey, 1997). An environment that allows learner autonomy (McCombs, as cited in Tessmer & Richey, 1997) may be desirable as well. According to Papert (1980), digital technologies, such as computer and robotics, can empower students by embracing different learning styles and epistemologies. The adaptability of technology can create environments in which students can find their own voice, consolidate their ideas and projects with motivation and engagement (Blikstein, 2008).

4.3 Learner previous knowledge. One of the most relevant factor to be considered is specific prior knowledge (Smith & Ragan, 2005). What learners already know about robotics and technology should guide the design of the implementation of the RCKs learning experience. This perspective also has cultural implications, especially when working with technology in underserved communities. In Paulo Blikstein's (2008) research on the implementation of expressive technologies in underprivileged settings in Brazil, he described how the students perceived technology as a "foreign and rare artifact, an extravagancy consumed by the upper classes. This attitude, together with the fact that many of the student's parents had lost their jobs to technology, was a barrier for students' interactions that, in the beginning, were permeated with caution and suspicion" (Blikstein, 2008). Nevertheless, Blikstein also uncovered another aspect of students' prior interaction with technology that reverted this problem; the particular technological culture of the community characterized by inventive practices of repurposing and fixing, improvising, and re-constructing using what was at hand (Blikstein, 2008). Recognizing the value of their knowledge and expertise was the key for Blikstein's increasing success in the introduction of technology. Similarly, learning-by-making initiatives such as the implementation of RCKs should never discredit the expertise and previous knowledge of the learner communities. Assembled or incomplete RCKs like BuzzBits facilitate this process by allowing learners to incorporate recycled and household elements into their projects.

5. THE LEARNING CONTEXT

The environment where the construction of robots takes place can largely affect the learning experience. The RCK BuzzBits are designed to be distributed across a wide diversity of environments characterized by low access to quality education, technological resources, and connectivity. Distribution will reach rural, marginal, and displaced populations where kids have had little or no previous experience manipulating technology. Because of the range of different environments we cannot assume that the children will receive the kit with guidance from an adult. For this reason, the kit will be designed to be explored and constructed with only the guidance of the printed materials included. On another hand, children in these communities are frequently accompanied by friends, brothers, and sisters, and the kit aims to provide the means to facilitate and encourage collaborative work and sharing. In addition, there are children in these environments throughout the world which implies that the design of the support material should omit written language and display the information through visual means to provide universally comprehensible information. Finally, the learning affordances of the kit should not be determined by economical access to the kits themselves and the tools required to assemble them. For this reason, kits will be distributed at no cost and the complementary elements that they need to incorporate are going to be basic, reusable household objects. Furthermore, there should be minimal need for replacement parts, such as batteries or glue.

6. IMPLEMENTATION AND SUSTAINABILITY

Because of the diversity of learning context where the kit is aim to be used, implementation is one key consideration in the design of this project to ensure the continuity, scalability and sustainability of the initiative. To reach rural, marginal, and displaced communities we can give new purposes to current practices that reach those environments, such as traveling and volunteering.

According to The United Nations World Tourism Organization, there has been an increase in young people travelling in developing countries which can boost tourism and has potential to contribute to global development. "These young travellers are environmentally-aware and tend to stay longer and interact more closely with the communities they visit than the average tourist. As such, youth travel has emerged as one of the most promising paths towards a more responsible and sustainable tourism sector" (Rifai, 2012). In addition to their interest in the communities they visit, young travelers are digitally connected and can be reached through social media and other online communities for traveling. We can take advantage of the potential of this group to reach the communities we are targeting and their willingness to transform travel into a source of good. This way, the kits could be acquired at a low price by young travelers as something meaningful to carry and distribute in the communities they visit. Because of this particular method of distribution, the design should consider a simple and easy to carry packaging that could maximize the number of kits that each person can carry to these places.

Another possibility of distribution is through international ONGs that deliver basic supplies to refugee camps and other underserved communities. These organizations have already the logistic infrastructure to make an effective distribution of basic supplies and other educational elements.

7. DESIGN SPECIFICATIONS

BuzzBits is a robotic construction kit (RCK) consistent of elemental and cheap electronic pieces, that combined with elements from the user's environment, can be assembled to create an electronic insect. The physical appearance of insects, how they move, and the sounds they emit can be easily represented using electronic pieces. In addition they are a common element in the life of children across the world and a great variety of them can be found almost everywhere. Because some children, especially girls, may be afraid of insects, the visual design of the kit invites their exploration in a friendly and attractive way for both girls and boys.

7.1 Components:

The packaging of the kit is contains two essential parts: a set of electronic components and a set of guiding cards. In addition, in order to make the electronic insects, children will have to add a third group of components: basic and recyclable elements that they can easily access in their environment.

a) Set of electronic pieces. Each electronic kit has all the necessary components to generate a basic closed electric circuit made up of one energy source, conductive wires, and three output devices. Children can activate a working closed circuit with these elements. The elements are designed for intuitive comprehension on how to put them together in order to make the circuit work and appreciate the activation of the output as a learning feedback. For instance, each power unit and output unit has two wires with two distinctive colors for the negative and the positive and the learner will intuitively connect together the wires with matching color. Similarly, only the power source has a female header connector and all the outputs has male header connectors, this way the learner will only be able to connect the outputs to a source of power and not with other not intended pieces. The durability of the electronic elements need to be considered in order to allow the children to connect and disconnect the elements multiple times without breaking the components. In the final product, a solar panel will be the source of power of the circuit in order to ensure long life and multiple explorations without the need for battery replacement. In addition, the solar panel provides an opportunity to explore physical concepts related to the transformation of natural energy into a source of power for other purposes. Finally, avoiding single-use batteries will ensure that the kit will not contribute to pollution and undesirable effects in some delicate natural environments where they may be distributed.

b) Set of guiding cards. As adult guidance is not guaranteed to be around, the cards enhance the key function of scaffolding the explorative learning process. Each kit has a set of fifteen cards of three different types: three guided cards, nine inspiration cards, and three open cards. a) Guided cards has on the front face an illustration of an insect and on the back face a graphic depiction of the resulting artifact and its components. Each insect use a different output and has a specific function that is going to be the main goal of the construction process, for instance, light-up, make sounds, or move around. Using the graphic representation children will have to figure out the process of construction using both electronic elements from the kit and household elements from their environment. b) Inspiration cards only display the illustration of the insect on the front face as inspiration for the possible look and functions of the insect. The back face of these cards are completely blank except for a small icon that indicates the children to design their own depiction of the insect. One important purpose of inspiration cards is providing variety of options to incentivize trading of cards with other kids. c) Open cards are going to be blank on both faces of the card except for a small icon that indicates the children to design their own depiction of the insect's components and their own illustration of the insect. The objective of blank cards is encouraging children to observe and design insects that are part of their environment. Cards are designed only using only graphic language in order to access a diverse audience of children with different languages and even without reading literacy. The development of a graphic language that can be easily interpreted and that can scaffold an explorative learning process is a significant design challenge that is worth considering for this project that aims to embrace diversity and equity.

In order to scale and broaden the possibilities of the kit there will be three types of boxes with different assorted cards inside. This way, children from a same community that receive different packs can trade their electronic pieces and cards in order to generate new creations. This process can enhance collaborative and peer-learning among children which can be essential to support the challenging process of construction, specially with no adult participation. Furthermore, games based on cards can easily connect with practices that they may currently engage in, such as trading and playing cards.

The illustrations of the cards are the result of a collaboration with Tano Veron, an argentinian artist that designed the project "biomechanics" which consists in a collection of 45 different insect's illustrations with mechanic characteristics. The variability of illustrations will provide enough material to have three different types of kits.

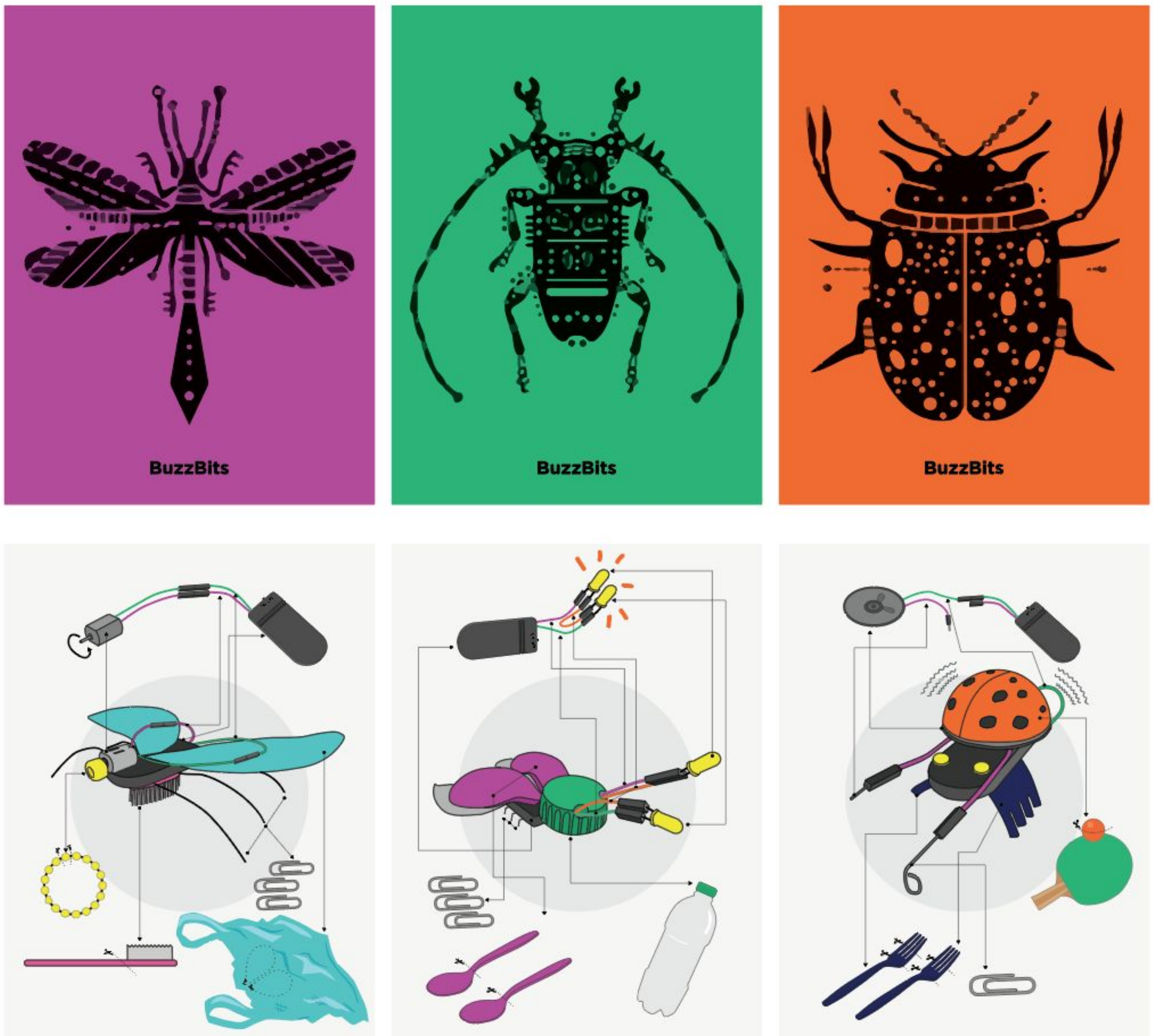

Fig 1. Guided cards have an illustration on the front face and a graphic depiction of a possible result on the back.

Fig 2. Inspirational cards (first row and first three of second row) have an illustration on the front and they are blank on the back for the children to design their own interpretations of the insect using electronic and local elements. Open cards (last three of second row) are blank on both sides for the children to design their own illustrations and graphic depictions.

c) Local elements. The elements that children incorporate are essential for the construction of the insect but not for the functionality of the electronic circuit. This way we will make sure that every kid will be able to effectively assemble a working an electronic circuit. However, local elements will be required to create the insects suggested in the cards and to create further insects designed by the children. The elements suggested can be replaced for other elements with functional equivalence. The set includes glue dots to assemble and disassemble the elements are incorporated to the electronic pieces.

In the following table one kit is depicted into its components:

Cards	**Source of power**	**Outputs**	**Local elements**	**Other components**
Shield bug	Solar panel	-2 LED -Extra wire	-Plastic spoons, -Wire or clips -Chocolate folding paper	-Pencil -Glue dots
Mosquito		-Miniature DC Motor	-Toothbrush -Wire or clips -Plastic bag -One bead	
Humbug		-Speaker -Extra wire	-Ping-pong ball, -Plastic fork	
9 extra cards with assorted images of insects		Any output can be used	Any local element can be used	

7.2 Task Analysis

In this section we provide a description of the intended learning process that the kit is intended to generate. This analysis is based on several assumptions of how the kit will be distributed, received, interpreted, and assembled by the children. Further research is required to test these assumptions and make sure the components are used as intended or in other unexpected but meaningful ways.

- The children will receive the kit from a traveler or volunteer. The participation of the traveler, volunteer, parent, or caregiver is ideal but cannot be assumed, for this reason the functional description of the kit will not consider their eventual involvement on the construction process.
- The children will open the small packaging and find the electronic pieces and the cards.
- The children will explore the pieces and reach for more clues in the cards which will have a depiction of how to put the pieces together to create an insect. The children will observe that some pieces are missing but that they can be found somewhere around them.
- The children will try to find the missing pieces. This process may take time, ingenuity, and reaching out to family or friends. This may be a good opportunity to find collaboration for the construction process as well.
- After having all the components the learner will use the cards as a guide to put the pieces together starting with the electronic pieces. Guided by the different colors and forms of the wires the children may connect them in such way that the circuit is closed and the electronic circuit works. This process may involve tinkering, debugging, and several processes of trial and error.

- Using the glue dots the children may add the local complementary elements to create the insect.
- The children will make one insect work. We assume that the children will be willing to build new insects if the construction process was a positive experience. Similarly to what occurs with LEGOS where children build something and after a while they dismantle it to create something new.
- The children will dessamble the insect.
- The children will make an insect from another card or will design a new insect using the blank cards.
- If the children decide to design a new insect will use the pencil and the blank cards to plan and draw her idea, before, during, or after the construction process.

7.2 Prototypes

7.2.1 Minimum Viable Product: A first approach to the idea was developed using one battery and one miniature DC motor. Those elements were complemented with a toothbrush and some wires to create the first bug. The elements were pasted together using glue dots and hot-glue after the first ones proved to be insufficient. This rudimentary bug was shared with three children that were very surprised with it despite the simplicity of the product. As they started to discuss how to create more bugs, we decided to narrow the project, which at the beginning was intended to generate any kind of robot, solely to the design of insects.

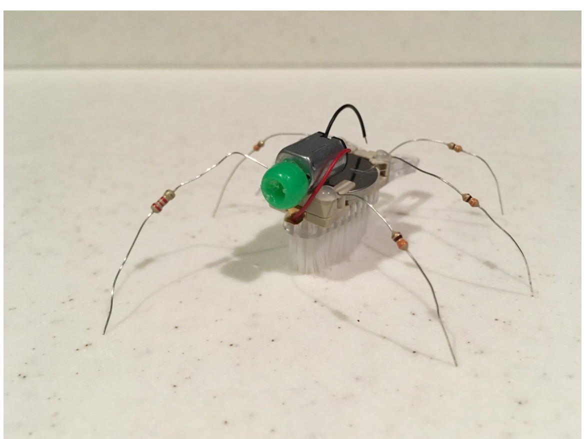

Fig 1. First functional bug made up of a battery, a DC motor, a bead, some resistors as legs, and a toothbrush.

7.2.2 Pre-Alpha: A second approach aimed to generate the largest quantity of insects using only a battery holder with two batteries and a DC miniature motor. The battery holder and the motor were solded with colored wires for children to identify how to connect them in order to appropriately close the circuit and make it work. This test resulted in two functional but similar bugs and one insect that did not look like an insect. After this approach we decided to incorporate new outputs to diversify the range of possibilities and exploration of electronic components.

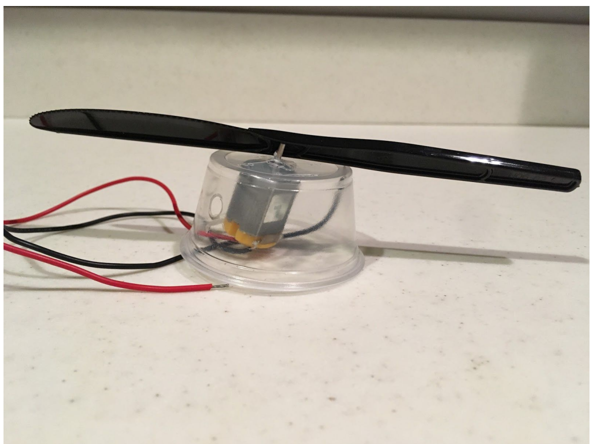

Fig 2. Insect that was functional in that the propelled spinned around but it did not look like an insect

7.2.3 Alpha: A third approach aimed to generate at least one insect for each of four possible outputs (motor, LED, vibrator, and speaker) and one battery holder. The battery holder and each output were solded with colored wires. Four children informally participated in the ideation process. After several prototypes the result was one different and functional insect for three outputs: motor, LED, and speaker. Each insect also was able to make one different action such as move around, light-up, and make sounds. This insects were used to create the cards and the packaging.

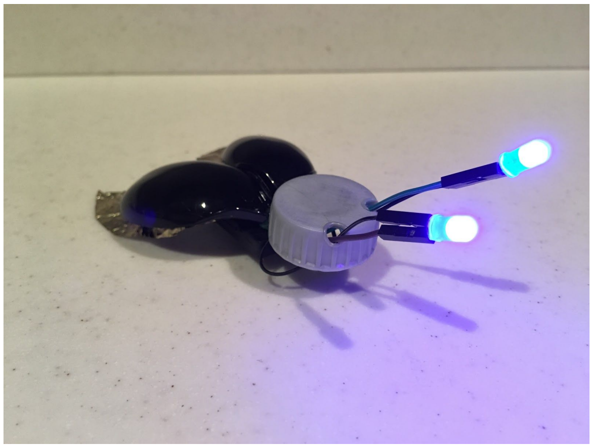

Fig 3. The lightning bug incorporate a circuit with two LED outputs.

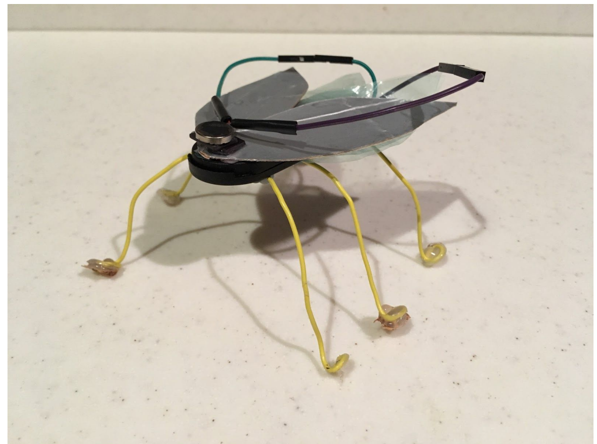

Fig 4. The pond skater bug went through several tests in order to find a good material for the legs to support the bug in the water. This prototype after many trials did not work consistently and was removed from the kit.

Fig 5. The humbug uses the simplest way to create sound using a speaker, it does so by manually closing the circuit using the two metallic heads of the wires.

Fig 6. The mosquito is a more advanced version of the first Minimum Viable Product.

7.2.4 Alpha 2: An additional test with one kid was made in order to see if the cards were enough to enhance the construction process. The kid was able to assemble and light up a bug in twenty minutes of deeply engaged work.

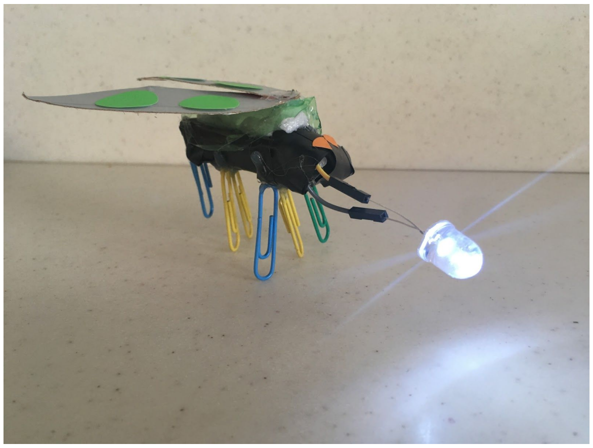

Fig 7. Insect made by a children using the electronic elements and the guidance of one card.

7.2.4 Beta: A fourth prototype will be required to test an alternative glue product that can be strong enough to hold the pieces together and flexible enough to take them apart without damaging the components. Other solutions to this problem can be also tested, such as incorporating more than one source of power and a permanent glue that can be utilized for many insects. This prototype should also test the power and feasibility of the solar panels. In addition this prototype may be a good opportunity to test the cards and the graphic language.

8. DISCUSSION

8.1 Foreground and background design decisions

The project aims to provide transparent access to the technology provided in the kit. Every electronic piece is presented in its most elementary way for the children to connect them together and see how they work as an electronic circuit. The components inside each electronic piece are backgrounded because they do not concern to the learning goals. For instance, we do not expect children to understand exactly how a motor, a wire, or a solar panel work so their internal components are not accessible. Another piece of information that was purposely omitted in the design is the step by step instructions on how to assemble the insects. The children will be able to see the intended result and the structural components in the cards but they will have to figure out how to put them together. This way we aim to encourage tinkering and trial and error processes that precede discovery. Furthermore, we expect that this more ill-structured approach will encourage the design and creation of new insects without any instructions which is the purpose of the blank cards.

8.2 Assumptions and further research

The project is based on several assumptions that need to be tested before the project is formally implemented. In the following section we analyze six important assumptions that guided design decisions that are subject to change depending on the outcomes of further analysis.

- *Assumption 1: Children in rural, marginal, and displaced communities have all similar needs in relation to technology and they will interact similarly with the kit*. The project is, for the moment, open to children in rural, marginal, or displaced communities but probably will be required to narrow it down to one of those environments in order to be properly tested and effectively targeted to one of the audiences.
- *Assumption 2: Distribution and financial support can be found in communities of travelers that can be reached on the internet*. This is a possibility that can bring renewed purpose to the project by integrating an outsider actor: the traveler. We can leverage the traveler's interest in contributing to the communities they visit and take advantage of their capacity to reach remote places. This distribution strategy can be explored and tested as well as other possibilities of distribution that can ensure the sustainability of the project.
- *Assumption 3: Children will understand graphic instruction without words or adult guidance.* While prescinding from written words can certainly broaden the audience it is a significant challenge to generate guidance based only on visual language. The graphic support will have to overcome several testing processes in order to ensure that it is not misleading.
- *Assumption 4: Children will be willing and able to dessamble their insects to create new ones.* We assume that children will be willing to pursue further exploration and new open-ended creations using the blank cards. This assumption need to be tested because it is a key aspect of the explorative affordances intended. Furthermore, the prototype demonstrated the need for a better glue solution that allows this process. Glue dots are occasionally not strong enough to hold the pieces and be re-utilized.
- *Assumption 5: Children will use the cards as a means to trade and collaborate.* We are assuming that the cards are going to incentivize collaboration, trading, and sharing among the community of kids. Other ways to encourage this fundamental aspect of every constructive learning process need to be explored as collaboration and sharing are key to any constructionist learning environment.
- *Assumption 6: Meaningful interactions with technology can transform their perception on it.* Finally, the main hypothesis of the project is also subject to test and analysis. The ultimate goal of the project is to encourage a renewed attitude on children toward technology. The assumption is that after a small but meaningful interaction with technology in which they participate as creators and not only consumers, children will be empowered to pursue further explorations and will perceive technology as something handy rather than foreign. The confirmation of this hypothesis

can encourage the development of more projects along these lines and contribute to further research exploration in underserved communities.

9. CONCLUSION

While technology is changing everything around us, as educators we must work to ensure that every kid has access to the tools of power that are transforming our world. Constructionist toys such as BuzzBits aim to provide scalable ways to reach children in environments where technology integration in their schools is unlikely to occur. The project aims to provide small but meaningful interactions with technology outside formal education with the objective of transforming their perception and attitude toward technology. The process of discovery and exploration embedded in the construction of personally meaningful artifacts can open a scope of possibilities for children as they start to perceive technology as something "makeable" and subject to transformation and creation. The implementation of a project like this requires careful consideration of the learner characteristics and the learning context of the intended communities of implementations and further research is required to test the assumptions on which this project relies.

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