Tangible Digital Manipulatives for Math Learning
Masters Project Proposal

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ABSTRACT
This project addresses student’s difficulty understanding abstract principles, even with the aid of physical objects. Teachers often turn to manipulatives to explain abstract principles to young students. However, students are unable to connect these physical representations with the symbolic representations they are meant to demonstrate. This problem begins early in schooling when students first begin learning about numbers and place-value, the understanding of how these numbers are organized. Additionally, Children in the U.S. struggle with this concept (Miura et al, Stevenson & Stigler 1986). We will build a tool designed to teach early place-value with symbolic and physical representations displayed simultaneously using physical blocks with a digital display.
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The Learning Problem

Math is a way to understand the world through language of symbols, abstract representations of phenomena. Gaining fluency in the symbolic notation of math—numbers, operators, equations and other symbols which represent the logic of the discipline, is crucial in accessing these concepts. It is the job of the math teacher to bring meaning to these symbols. This can be the simple task of helping children understand that the number 4 represents the amount of four individual items or it can be the complex task of explaining variables, imaginary numbers or other highly abstract concepts. Once students have an understanding of symbols, they learn to manipulate them to produce more and more complex ideas. However, the abstract nature of these symbols is often difficult for children to understand.

Cognitive psychologists like Jerome Bruner (1960) contend that we learn by recognizing these symbols and patterns: We “remember a formula, a vivid detail that carries the meaning of an event” (p. 25). Understanding symbolic notation is thus the first step in grasping mathematical concepts. As a child continues to understand a concept more deeply, he ascribes more layers of meaning to a symbol. Bruner (1960) views learning as a graduated process which “requires a continual deepening of one’s understanding of [ideas] that comes from learning to use them in progressively more complex forms” (p. 13). Thus, he argues that authentic access to a body of learning is crucial, regardless of the learners’ age and prior experiences. Rather, we must teach at the learner’s level of comprehension but continuously offer them chances of deepening their understanding.

Often as a first step towards understanding abstract principles, teachers use physical objects to represent concepts. These objects are most often referred to as manipulatives. Many elementary school classrooms are filled with many different types of these tools: fraction bars, movable clocks, tangrams, geoboards, and the popular, base-10 blocks. These tangible materials often help students understand underlying mathematical concepts. However, all too often, students are unable to transfer this knowledge to the symbolic representation in mathematical equations. For instance, a child may be able to add 7 plus 5 quite easily with individual blocks accessible for counting. However, when they see $7 + 5 = \_\_$ they are at a lost. Later on, the child may have developed a strategy for adding $7 + 5 = \_\_$ (counting on, counting all, etc.) However, this strategy has no link to the tangible counting from earlier. Thus, rather than the manipulative serving as a tool for problem solving, it has forced the child to learn two separate schemata, with no link between the two. In our project, we will address this problem that
children have of understanding abstract principles, even with the aid of physical objects by displaying the two simultaneously.

**Evidence of the Learning Problem**

Studies have **not** shown manipulatives to be effective on a consistent basis. (Sowell 1989, Freidman 1979). In a study conducted in response to the rise of manipulatives in the classroom in the 70’s, Friedman surveyed all of the studies on manipulatives. He cites four other studies, two of which found instruction using symbols to be more effective for learning multiplication than instruction using manipulatives. Of eighteen dissertations written on manipulatives between 1970 and 1978, ten found no significant difference between instructions with manipulatives. (Freidman 1979)

"Understanding does not travel through the fingertips and up the arm. And children clearly can learn from other sources—even from highly verbal and abstract, imaginary contexts...mathematical ideas really do not reside in cardboard and plastic materials." (Ball 1992)

Deborah Ball offers an enlightening anecdote about a student using fraction bars to compare fractions. The student guesses incorrectly every time as to which fraction is bigger. The same student can follow the teacher’s instruction in using the fraction bars to see that 4/4 is in fact bigger than 5/8. However, the child makes no connection from what he learns through the manipulative to the fraction itself. (Ball 1992) As a result, teachers may have incorrect views about the level of understanding their students posses.

Part of this disconnect between the manipulative and its symbolic counterpart stems from the difficulty children have with linking models to their physical counterpart. (Uttal) Uttal and Schneider demonstrated this difficulty in their study with 3-4 year olds. They built an exact replica of a room at a much smaller scale. They then showed the children where they were hiding a toy in the model room. When they brought the child into the actual physical room, they were often unable to find the toy. They did not understand that the model was a representation of the physical one. Although they were able to see the connection and locate the toy after direct explanations, they lost this link over time. (Uttal 1997??) This study among others (cite other examples??) show that students do not view models or symbolic representations in the same way that adults do. Even models that seem very direct to adults may be confusing to younger students.
Both Ball and Douglas Clements caution against the notion that abstract is always bad and concrete is always good. Concrete does not always need to be a physical manifestation, Clements argues. He offers a useful distinction between sensory-concrete and integrated-concrete knowledge. Sensory-Concrete Knowledge refers to need of the senses to make sense of an idea. For example, a child may need to actually see items to be able to count them. Integrated-concrete knowledge is built as we learn. Separate ideas are connected through a structure of knowledge, making them accessible and "concrete" to the user. 10 + 13 can be concrete, even without manipulatives, Clements argues. (Clements 2000)

Manipulatives are often touted because of their ability to make ideas “concrete, generally referring to sensory-concrete knowledge. However, in order for students to access and transfer mathematical concepts, students need integrated-concrete knowledge. While the affordances of manipulatives to bring sensory-concrete knowledge can be helpful to students, we believe other characteristics of manipulatives are more important: the opportunity for shared representation and embodied cognition.

**Manipulatives**

Eliot Eisner (1993) argues that a student’s understanding is built through various shared representations. Cognitive pluralists such as Eisner believe that these shared representations transform “the contents of [individual] consciousness into a public form so that they can be stabilized, inspected, edited, and shared with others” (1993, p.6). Shared representations, such as the symbols associated with math, become the foundation for discussing concepts and ideas and understanding them. Furthermore, Eisner (1993) argues that multiple modes of representing a single concept are necessary for grasping all its dimensions. “Since forms of representation differ, the kinds of experiences they make possible also differ. Different kinds of experience lead to different meanings, which, in turn, make different forms of understanding possible” (p.6). For example, using physical and visual representations in math may complement symbolic representations, offering students richer ways to understand underlying concepts.

Supporters of embodied cognition believe that physical engagement in particular can support learning by providing concrete anchors for theoretical concepts. Maria Montessori’s work in designing instructional materials is often regarded as a precursor to this idea. Montessori (1964) viewed learning as a physical act, and that the child’s senses must be trained by the teacher to perceive differences
through tangible experience. She created didactic material that she said provided “auto-education”, forwarding her belief that the child is meant to discover ideas on his or her own by interacting with the physical world.

One view of embodied cognition explains that physical interactions help one understand a concept because they afford opportunities for discussion and sense-making through language (Lakoff and Nunez 2001). Logical concepts that are already embedded in one’s grasp of language are made explicit as one talks about the physical object he is engaging with. Lakoff and Nunez (2001) argue that everyday mathematical understanding is part of embodied cognition because it is accessed through spatial language and metaphor, not necessarily through symbolic notation. For example, in understanding the grouping of numbers, we can use spatial-relational words such as “inside” and “outside” to posit the relationships among elements of a set; the terms we use to describe and categorize mathematical ideas are not specific to math itself. Hence, learning the symbolic notation alone is not enough to be able to access the deep concepts behind them: “The meaning of mathematical symbols is not in the symbols alone and how they can be manipulated by rule. Nor is the meaning of symbols in the interpretation...in terms of set-theoretical models that are themselves uninterpreted” (Lakoff and Nunez 2001, p. 49). Rather, mathematical symbols must be linked to the spatial relationships mediated by everyday language in order to make sense of the ideas behind them.

In conjunction with the verbal reasoning process, the rearrangement of physical objects themselves affords emergent understanding. Martin and Schwartz (2005) define physically distributed learning as a situation where one is able to adapt both their environment and themselves (or more specifically, their ideas) to facilitate the understanding of new concepts. The ability to move objects physically affords the opportunity to try different representations. These iterations do not just create new spatial relationships but also encourage the reinterpretation of one’s mental models. For example, grouping objects together provides a new framework for understanding certain mathematical concepts. Furthermore, Martin and Schwartz (2005) found that the ability to try multiple representations allowed children to understand a concept more easily when it was explicitly introduced to them later, even if they didn’t discover it themselves while they were originally manipulating the objects.

Whereas Martin and Schwartz (2005) posit that the manipulation of objects helped students understand new concepts by focusing on relationships, Dienes believed further that it was necessary to provide
multiple embodiments of the same concept in order to reinforce deep understanding (Olive 2008). For example, Dienes' designed the Multibase Addition Blocks commonly found in classrooms today to teach children about the structure of place-value. “Dienes’ rationale for using different grouping bases (rather than just base ten) was based on his theory of multi-embodiment: By grouping pieces using different numbers of blocks, but following the same grouping rules and forming similar structures at each level of grouping, the children would be able to more readily abstract the mathematical structure of the groupings and relate this to our base ten number system.” (Olive 2008, p.4)  

1 Following his belief of embedding the same content within different physical representations, Dienes also encouraged children to develop their own notation for mathematical concepts before introducing them to formal notation. He believed that creating personally relevant interpretations would allow the children to develop more sophisticated and efficient algorithms for understanding math (Olive 2008).

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1 Though it was Dienes’ intent to teach multi-base addition when he designed his blocks, only the base-ten blocks are still used in most classrooms today. One wonders whether the revision of Dienes’ rationale has inhibited students’ ability to grasp the concept of place value.
Design

The physical nature of existing manipulatives may give students a tangible way to understand mathematical relationships, but ultimately, these tools are only able to produce sensory-concrete knowledge. They fail to connect the physical learning to the symbolic language of math. The goal of math education, rather, is for students to have integrated-concrete knowledge of the concepts; students must understand the logic of math and the meaning behind mathematical relationships in concrete terms even without the use of physical representations.

To achieve the latter, manipulatives must be explicitly presented as a tool for understanding the symbolic language of math. They must become tools to think with—they must embody cognition, not just be viewed by students as a procedural formality that is unrelated to the equations they are asked to answer.

We propose to address the learning problem of providing a direct link between physical and symbolic representations by creating a math manipulative that is embedded with digital interactivity. Tools that combine physical and digital interactions, more widely known today as tangible media, provide immediate feedback that can display the relationship between physical manipulation and symbolic notation seamlessly and explicitly.

The specific mathematical concept that we have chosen to design for is that of understanding place value. Place value is a foundational system for organizing numbers that is commonly introduced through manipulatives such as Dienes’ blocks or similar counting objects. However, the meaning of our number system can easily be over-simplified into a procedural algorithm of using these manipulatives or by asking students to memorize sums. Because understanding place value is a crucial building block for arithmetic and number sense, this topic is a rich problem space for exploring the capability of tangible media to improve student understanding.

Our product will be developed for kindergarten and first grade, where students are just starting to learn the concept of “ten” as a basis for place value. To support a range of abilities and concepts, the curriculum designed to accompany the manipulative will advance from noticing ten as a group to adding up to teen sums. We believe that cultivating a solid understanding of place value from the beginning is most beneficial for contextualizing more complex mathematical concepts later on.
The following sections will discuss the rationale behind specific components of our design. We will first explain the benefits of tangible media in addressing our learning problem. Next, we will provide our rationale for focusing on place value. We will then describe specific design principles that inform our work. Lastly, we will describe the components of our proposed product.

**Tangible media: Combining physical and digital interactivity**

More widespread commercial use of computers has led to the emergence of digital or virtual manipulatives in the last decade. These onscreen tools often look similar to their physical counterparts, but they capitalize on the interactivity afforded by digital computing. According to Clemente, these digital manipulatives have practical/pedagogical implications for learning because of their ability to store and retrieve configurations, provide a cleaner and more manageable (because it is restricted to the screen) workspace, allow layering of multiple visuals onscreen, and allow students to record and extend their work (2000). Clemente asserts that there are mathematical/psychological benefits as well: Digital manipulatives add conscious awareness of mathematical process because they provide increased flexibility in manipulating objects onscreen (e.g. by changing its color and shape), allow composition and decomposition, allow the creation of units or groups, and are able to connect geometric learning to number learning. A computer program can also limit the student’s choices for interaction, forcing him or her to think about the underlying logic of the math concept the program is supposed to teach (Clemente 2000).

For example, a digital version of Dienes’ blocks can be found in the National Archives of Virtual Manipulatives. Unlike their tangible counterpart which requires students to “trade in” ten unit blocks for one tens block, the animated program shows the unit blocks combining to form a tens block. In effect, students are more likely to see that ten units are exactly the same as a tens block, instead of seeing the tens block as a replacement model for the units. Furthermore, the symbolic notation is written beside the pictures of the manipulatives, which may help provide a link for the student between the model and its symbolic representation.

However, though digital manipulatives can provide users with increased feedback and continuous guidance, students lose the physical interaction that tangible manipulatives offer. Having physical models, as mentioned in our description of the learning problem, does provide students with a foothold in understanding math concepts because they can easily engage with objects. Furthermore, theories of physically distributed learning and embodied cognition that were mentioned in the discussion of the
learning problem support the notion that physical objects can become tools for gaining understanding. Thus, tangible media, which incorporate the strengths of both digital and traditional manipulatives, holds some promising directions for addressing this learning problem.

The term tangible user interface (TUI) was proposed by Hiroshi Ishii in 1997 to describe physical interfaces that provide both representation and control of an internal digital system: “TUIs couple physical representations (e.g., spatially manipulable physical objects) with digital representations (e.g., graphics and audio), yielding interactive systems that are computationally mediated, but generally not identifiable as ‘computers’ per se” (Ullmer and Ishii 2001, p. 2). These interfaces are distinct from graphical user interfaces (GUIs) that are ubiquitous today, which are controlled by input devices such as mice and keyboards. Though these tools mediate human-computer communication just as tangible components of TUIs do, input devices do not provide physical representations of the computational system; “the physical form and position of the mouse hold little ‘representational’ significance. Graphical user interfaces (GUIs) represent information almost entirely in transient visual form” (Ullmer and Ishii 2001, p. 2). In contrast, the distinction between “interface” and “input” is rendered seamless by a TUI because one’s interaction with the physical representation (the traditional input) is equivalent to manipulating the interface.

Tangible media is a broader term that includes TUIs, as well as other media where physical and digital interfaces communicate but are not necessarily one and the same. For example, Eco-pods (Kikin-Gil 2009) are a set of physical controllers that affect a digital (onscreen) plant’s growth through user interaction. Each user is given a unique Eco-pod with a specific function and interactivity; shaking the water Eco-pod creates rain onscreen, blowing into the wind Eco-pod creates a nice day, and cupping the sun Eco-pod (akin to warming it up in your hand) dries up some of the water.

In our research, we discovered a few key trends in current designs of tangible media (Girouard et al 2007; Merril et al, 2007; Raffle 2008; Resnick et al. 1996, 1998; Ullmer & Ishii 2001) and some of their purported use in education. We summarize the benefits below, and discuss the trends and products we surveyed in more detail in our appendix.
Tangible media:

1. Affords manipulation through its physical interface
2. Teaches complex relationships/concepts that are difficult to grasp on a deep level by the senses through its digital interface
3. Is “system-aware”; Components are able to interact with each other and pass on information to change the nature of interactions
4. Affords open-ended learning or play
5. Affords independent engagement—and autonomous learning?

Because tangible media is a relatively new and diverse field, there are few long-term studies on the educational implications of most of these initiatives, especially on the ability of students to transfer concepts learned through them. However, Resnick and his associates at MIT Media Labs clearly articulate that they are interested in creating “Things to Think With” and that “[their] primary goal is not to help users accomplish some task faster or more effectively, but rather to engage them in new ways of thinking” (Resnick et al. 1998, p. 282). Most of their findings from preliminary tests in classrooms have been anecdotal for now. Yet the profuse stories of children’s creativity and engagement that many of the researchers (Raffle 2008; Resnick et al. 1996, 1998) relate from field testing seem to indicate that tangible media does present significant opportunities in education.

Place Value

We have chosen to focus on designing our tool for initial learning of place value. We chose this topic for several reasons: studies show that students in the United States have poor conceptual understanding of place value (Miura et al, Stevenson & Stigler 1986), Arabic numbers are the first mathematical symbols young students encounter and pave the way for future mathematical learning, and the most popular manipulative currently being used to teach place value offers several design opportunities.

Numerous studies have pointed to American children falling behind their Asian counterparts in mathematics. (Stiger & Perry 1988, Stevenson et al 1986,) While this disparity certainly is more prevalent in later grades, it begins in the youngest students as they learn place value. Many have identified the difference between Asian languages and English as a significant hindrance to conceptual understanding of place-value. (Fuson & Brian 1990, Stigler & Perry 1987, Murata 2004) In Asian languages, place value is explicit. For instance, the number 22 is translated, 2-ten-2. (table appendix 1) The language of these countries therefore may have explanatory powers, helping to connect a link between the symbolic notation and the underlying concept of place-value. The English language, on the
other hand, contains a disconnect between written notation and spoken words. Spoken English imperfectly represents the base-ten system (Fuson & Briar 1990). This is particularly glaring in the early teens, where the English language has no reference to place value. For instance, twelve contains no reference to either ten or two. As a result, students in the U.S. learn to count, not by recognizing patterns in the language, but by memorizing arbitrary words. This makes it difficult for students to connect the written numeral 12 to the concept of 1-ten and 2-ones. The tool we plan to create will do what the English language has failed to do, call attention to the pattern of place-value.

This failure to recognize patterns of place-value have consequences far beyond the early years of school. Students in the United States also have difficulty developing fluency in multi-digit operations. As a result, students rely heavily on the memorization of algorithms, without understanding the reasoning behind the steps. This can be seen in common mistakes made by students, such as adding 27+17 and getting an answer of 314. Here, the student did not recognize the need to regroup the sum of the ones digits (14) into 10 and 4. Similar errors continue in multiplication and division as well. (Murata 2004) One the authors observed this misconception in her own middle school classroom. Students struggled to understand place-value as they were learning about decimals. These examples show that understanding place-value has significant implications for further math learning.

**Manipulative for Place Value**

Dienes blocks, often referred to as Base-10 blocks, are often used to teach place value in elementary school. One major design flaw in base-10 blocks is that the physical activity does not always match the mental process. For example, when adding more than nine units students must trade in ten unit blocks for one ten blocks. Similarly, a student has to trade in a ten block for ten units when borrowing during subtraction. By trading in blocks, student may begin to see the amounts as separate, rather than different representations of the same amount. We observed this in a 3rd grade classroom where students were using Dienes blocks to solve double digit subtraction that required borrowing. The students told us that the blocks did not help them solve the problem. They viewed them as one more thing to do. They had difficulty explaining how trading in a ten block for ten ones blocks was related to borrowing. It was clear that they saw solving the problem using blocks, and solving the problems using written symbols as two separate processes, rather than aids to inform each other.
A newer version of base-10 blocks, called digi-blocks were released in the last decade. They offer a more authentic interaction as students pack units digits inside a tens digit block. They also relate to the symbolic notation more accurately than traditional Dienes blocks which do not have a consistent shape. The ones units in Dienes blocks is a cube, the tens blocks in a rod, the hundreds block a flat square. Digi-blocks have identical shapes for all units, however, the size is multiplied each step up in place value. This more accurately mirrors the symbolic notation where the 2’s in 222 in two hundred twenty two look identical but represent different amounts. However, these tools still do not offer a direct link between the physical objects and the numbers they represent.

**Design principles**

The specific implementation of the concept we propose in the next section is likely to change significantly in the course of the project, but the design principles below will guide the goals of our work. In creating our product, we plan to:

1. Provide explicit yet non-obvious links between the manipulative and its mathematical interpretation to enable students to see the manipulative and symbolic notation as one representation of the same math concept
2. Allow avenues for free play with the manipulatives to inspire authentic discovery of mathematical relationships
3. Emphasize activities and structures for “making ten” to embed the concept of “ten as a group” into the student’s vocabulary
4. Design manipulatives that allow the rest of the students to engage in independent learning to help the teacher focus on guiding one group at the time
5. Design manipulatives that encourage multiple conceptual representations to support and deepen different levels of understanding
6. Utilize interactivity and context-aware sensors to highlight places where student thinking breaks down
7. Design manipulatives which have minimal surface features to encourage a deeper understanding of the underlying concepts and the transfer of knowledge
8. Encourage individual and collective interpretations while engaging the manipulatives to form personally meaningful forms of understanding
9. Provide a concise guide that help teachers engage with the manipulatives in greater depth to allow them to teach students with deeper understanding

These design principles are described in more detail in Appendix B.
Current Design Concepts

Though this description of our idea is not final by any means, it gives an idea of the critical design issues we are thinking about.

Our system is composed of a ten-frame and an assortment of connectable blocks. The ten-frame is a rectangular frame that can only fit ten blocks. Ten-frames are vertically stackable up to ten (to make a 10 X 10 grid, or 100 blocks). There are single-unit blocks (representing “1”) and fused-unit blocks that range from 2 units to 10 units. Each kind of fused-unit block is a different color. The rationale for having both fused- and single-unit blocks will be made clear later on in the description of activities a student can accomplish with our product.

Every time a student puts a block into the ten-frame, a counter lights up, indicating the total number of blocks in the frame. If he adds a two-unit (fused) block into an empty frame, the counter shows the number “2”. If he adds the same block to a frame with already three units, the counter shows “5”. This connects the physical act of adding a block with the numerical addition. Because the fused blocks give the student the ability to put groups into the frame instead of units, the product slowly shifts student

2 We have yet to come up with a solution for limiting this stack to ten
thinking from a counting model of addition (i.e. adding discrete units) to seeing the effect of adding a group.

When the student has fit ten blocks into the frame, the entire frame lights up, and the counter displays the message “1 TEN”. This interactivity reinforces that the student has just created a group called “ten”, physically and symbolically. Rather than seeing “10” as a discrete unit, the design makes it explicit that it is a group of ten units.

As students gain familiarity with the concept of ten, the teacher could increase the complexity of the system by adding another ten-frame on top of the first. As the student fills up the second frame, its counter shows the number of units, while the first frame’s counter remains at “1 TEN”. Thus, the student can read the two counters together to say: “1 TEN and 4 units, 1 TEN and 5 units, etc.” until the complete the second frame, and the display on the second frame shows the message “2 TENS” instead. This way of seeing the relationship between ten-frames and unit-blocks is similar to the structure that the systems of Chinese/Japanese/Korean languages implicitly have.

Our proposed design can be used for a variety of scaffolded interactions, both on their own and in a teacher-guided group setting. These ideas will be described further in the curriculum accompanying our final product. To give an overview:
At the earliest stages of learning about ten, the teacher can invite the students to try inserting different fused-block combinations into the frame to get it to light up. For this free-play mode, the students have yet to focus on what the numbers mean.

Next, the teacher can introduce open-ended prompts that push students to think a little more. At first, it can be as simple as limiting students to one of each block so that they are forced to discover that a unit block and a nine-block complete the frame, a two-unit and an 8-unit, etc. Later on³, the students can be given an assortment of blocks and challenged to find all the ways to complete the frame: 1 + 2 + 7, 4 + 3+ 3, etc.

Once the students are familiar with pairs that make ten, the teacher can lead more guided sessions for finding missing addends and looking for patterns. For example, the teacher could ask the students to place blocks to complete the frame if there are already six blocks in it. Possible solutions could be a four-unit, 2 two-units, a one and a two-unit, etc. This reinforces the notion that math is not about memorizing pairs of numbers, but rather is about creating different patterns.

³ Based on our interviews of kindergarten teachers, we believe this will be more appropriate for 2nd or 3rd grade, because understanding more than two addends is a complicated concept.
When the student is ready for adding up to the “teens” and “carrying”, having a strong understanding of ten helps to find the sum. A similar scaffolding technique could be used: with one ten-frame already filled, students are challenged to fill a second ten-frame that is stacked on top of it. Eventually, the teacher can set two ten-frames next to each other, each partially filled, and ask the student to do the sum. Given the design of the frames, the student will be forced to move some of the blocks from the second frame to complete the first, before he can stack one on top of the other.

This act and the other “making ten” activities reinforce the “break-apart-to-make-ten” method of addition that Murata (2004) describes (see the figure on the next page).
<table>
<thead>
<tr>
<th>Steps</th>
<th>Representation of quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Seeing ten as one number + what number (10 = n + [m])</strong> [Pre-requisite 1]</td>
</tr>
<tr>
<td>6</td>
<td><img src="#" alt="6 4" /></td>
</tr>
<tr>
<td>7</td>
<td><img src="#" alt="7 3" /></td>
</tr>
<tr>
<td>8</td>
<td><img src="#" alt="8 2" /></td>
</tr>
<tr>
<td>9</td>
<td><img src="#" alt="9 1" /></td>
</tr>
<tr>
<td>10</td>
<td><img src="#" alt="10" /></td>
</tr>
</tbody>
</table>

Break-apart partners 10 = 9 + 1, 8 + 2, 7 + 3, 6 + 4

<table>
<thead>
<tr>
<th>2</th>
<th><strong>This step does not require 10 as a base. It requires finding an unknown addend for a break-apart partner for any number between 2 and 9.</strong> [Pre-requisite 2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Add n + m = 10 from step 1.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4</th>
<th><strong>Seeing 10 + another number to make a teen number (10 + n = [m])</strong> [Pre-requisite 3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td><img src="#" alt="10 3" /></td>
</tr>
<tr>
<td>14</td>
<td><img src="#" alt="10 4" /></td>
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<tr>
<td>15</td>
<td><img src="#" alt="10 5" /></td>
</tr>
<tr>
<td>16</td>
<td><img src="#" alt="10 6" /></td>
</tr>
</tbody>
</table>

Figure: Representation of quantities using 10 as a base used within the break-apart-to-make-ten method (Murata 2004).
Assessment

Our tool seeks to bridge the link between symbolic representations and their physical counterparts for young students learning about place-value. As stated earlier, the native language of Asian students helps provide this link through a direct-mapping between written and spoken numerals. Two separate studies Muira et. al showed that first grade students were able to use base-10 blocks to express an understanding of place-value where students in the United States were not. For instance, Asian students were far more likely to use 4–ten blocks and 2–ones blocks to represent the number 42. The large majority of students from the United States used 42–ones blocks to represent the same number. (Miura, I. T., Okamoto, Y. 1989, Miura et al. 1993). We plan to use the first task of the Miura study to see if students are able to produce canonical and non-canonical representations using base-10 blocks after spending time using our tool. We are aware, however, that the utility of the measurement will be limited, as the time frame allotted for the masters project is not sufficient to test a shift in conceptual thinking. However, if we are able to show some improvement, we plan to continue research into the effects on learning.

In addition to testing the learning goals of our tool, we also plan to evaluate the ease of use among students and teachers, using both student and teacher interviews and observations of prompted tasks. The goal of these assessments will be to evaluate the following:

Teacher

- How easily is the teacher able to integrate the tool into her current lesson plans?
- Is the teacher able to adapt the set curriculum to the needs of her individual students?
- Is the teacher able to correctly identify the goals of the activities?

Student

- Does the student engage easily with the tool?
- Does the tool give an appropriate level of feedback?
- Are the pieces easily manipulated? (correct size and shape)
- Is the student able to understand the goals of each lesson?
- Does the tool afford collaboration with others?
Although we plan to formally assess the project upon its completion, we also plan to conduct many informal assessments throughout the design process through prototypes of increasing fidelity. We will utilize look and feel prototypes for the individual pieces, for example, to ensure that young students are able to grasp and manipulate the tool easily.
Bibliography


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Appendix A: Survey of trends in designing tangible manipulatives

1. Affords manipulation

As evidenced by its name, tangible media add a physical dimension to a digital interaction, allowing one to engage the tool in non-linear ways. Though the functionality of the device is tied to its digital programming, the physical interface of tangible media can be engaged like any other physical object. For example, *Programmable Bricks* (Resnick et al. 1996) is a tangible media project that is made of joinable Lego blocks with sensors that can be instructed to do certain tasks. For example, using the Programmable Bricks, a group of schools in Rhode Island set up a “Robotic Park” exhibition, where the students created robots that mimicked the interactions of their living counterparts—designing Lego crabs whose pincers snapped when they hit something, Lego turtles that retracted their heads, and Lego dinosaurs that reacted to flashing lights (Resnick et al. 1996).

In their “inert” state, these units can be combined and interacted with like normal blocks. However, unlike regular physical objects, one can add actions to the blocks by sending instructions through a computer. In this example, the blocks must be programmed by a separate control device in order for them to move or react. However, in some of the other examples we will see later, interacting with the physical object is equivalent to sending a digital command.

2. Teaches complex relationships/concepts that are not grasped at a deep level by the senses

Most tangible media capitalize on sensors and computers that have the ability to quantify measurements and give the user immediate feedback about them. This ubiquitous computing power can be used to display patterns and relationships more explicitly. For example, *Thinking Tags* (Resnick et al. 1998) are a set of wearable badges that communicate with each other via infrared communication. When tags were in close proximity to each other, their displays changed based on the information they exchanged. Resnick et al. (1998) have used Thinking Tags with students to model spreading phenomena such as memes (ideas) or diseases, actively, person to person. The authors claim this provides a more meaningful model for understanding virality and exponential growth/decay than computer simulation.

3. Has an “awareness” of the system
Thinking Tags are one example of tangible media that are “system-aware”, where the components are able to share information among each other and adjust the interactions accordingly based on the (often physical) stimuli they receive. Using technology such as RFID chips, wireless or infrared communications, passive, physical objects are transformed into active, communicative devices. For example, Siftables (Merrill et al. 2007) are small, compact tiles embedded with LCDs screens and 3-axis accelerometers that cause the screen to respond when a tile is moved. Each Siftable also has infrared transceivers that can detect actions done to other Siftables, causing the inert tile’s screen to change as well. One of the small applications Merrill et al. (2007) have created is a “paint bucket” program, where the action of pouring the color from one tile into another colored tile results in the colors “mixing”.

4. **Affords open-ended learning or play**

Much of the tangible media we studied, such as Programmable Bricks or Siftables, were designed to be “toy-like”, or at least allowed for open-ended instead of goal-oriented interactions. Resnick, Martin, Sargent, and Silverman (1996) mention that their intention in designing the Programmable Brick was to support multiple activities “so that it could connect to the interests and experiences of a wide variety of people. While some people might use the Brick to create their own scientific instruments, others might use it to create their own musical instruments” (p. 445-46).

**Topobo** (Raffle 2008) is another tangible media example which allows for the user’s inventiveness in dictating the final design. Topobo is a construction system of blocks that can be assembled to produce toys with different types of motion. Some of the blocks, called “actives” and “queens” are motors that remember the torsional and rotational motion that the user applies to them. When these are connected to the “passives” (regular blocks that have some degrees of freedom) in different ways, different forms of movement are also produced. There are conceivably infinite configurations of the blocks that one can create, so each interaction with Topobo has the opportunity to be different.

5. **Affords independent engagement—and autonomous learning?**

Because tangible media respond to the user’s actions directly, the interaction can take place without a third party to mediate between the tool and the user. Some designers (Raffle 2008; Resnick et al. 1998; Ullmer & Ishii 2001) have argued that the richness of tangible media interaction provides opportunities for independent learning, through the discovery of complex phenomena: “In particular, we believe that children, by playing and building with these new manipulatives, can gain a deeper understanding of how dynamic systems behave” (Resnick et al. 1998, p. 282). Girouard et al. (2007) also mention that students
may form misconceptions when they are left unsupervised to play with non-interactive manipulatives whereas tangible media can offer real-time, guided feedback.

For example, *Smart Blocks* (Girouard et al. 2007) are designed for students to explore volume and surface area. The Smart Blocks system is a set of small cubes which can be assembled to form different shapes. Each cube has a unique RFID tag that allows an RFID reader to sense how many cubes are joined together and report the volume and surface area of the assembly. The reader can also read instruction cards telling a student to create a shape with a particular volume, and can tell him if he has successfully accomplished the task. Other tangible media have more gradated definitions of achievement; For Topobo and Programmable Blocks for example, a student’s success resides within getting the assembly to move or react as you want it.

Are these forms of feedback rich enough to constitute authentic learning? Or do even interactive toys require the guidance of an instructor for one to understand the underlying physical and mathematical concepts behind these media? Rather than replacing student-teacher interaction, perhaps tangible media can provide stimuli for enriching lessons that the teachers design. Raffle (2008) relates how many of the teachers whose classrooms he tested Topobo in suggested that he provide curriculum along with the Topobo set, which could guide students’ discoveries, or provide ways to connect the functionality of the blocks to concepts in biology, physics, and even poetry; one teacher suggested that students could write poem about the creature they create, matching the rhythm of the words to Topobo’s movement.
Appendix B: Design Principles

1. **Provide explicit yet non-obvious links between the manipulative and its mathematical interpretation**
   to enable students to see the manipulative and symbolic notation as one representation of the same math concept

Clemente (2000) emphasizes that manipulatives do not make concepts concrete just because of their physical nature. In fact, according to Uttal, Scudder, and DeLoache (1997), young children often fail to see that manipulatives are representations for something else and thus fail to interpret their significance in understanding mathematical concepts. Thus, the mapping between the physical objects and the underlying concept cannot be automatically assumed—it has to be made explicit to students through the design of the manipulatives and through the guidance of the teacher. Olive (2008) relates that while he was using Dienes’ Logic Blocks with third graders, “it was necessary for [him] to engage the children in an analysis of each game situation in order for them to understand the role of the logical connectives. When left to play the games with the blocks themselves, the children seldom generated logical sentences” (p. 2).

However, providing explicit links from physical to symbolic learning doesn’t mean that the manipulative should make relationships so obvious that the child doesn’t notice how important they are. Instead, Martin and Schwartz (2005) emphasize that “useful scaffolds should help a child find and work with critical aspects of a problem, without doing the work for the child” (Martin and Schwartz 2005, p. 622).

2. **Allow avenues for free play with the manipulatives to inspire authentic discovery of mathematical relationships**

Using manipulatives as tools for procedural learning-- for example, showing kids how to follow preset steps in solving a problem with them, does not build a deep understanding of underlying concepts. Ball (1992) emphasizes that it is the way in which the student interacts with the manipulative, rather than the use of the manipulative itself that builds understanding; "understanding does not travel through the fingertips and up the arm... [and] mathematical ideas really do not reside in cardboard and plastic materials" (Ball 1992, p. 47). Martin and Schwartz (2005) suggest that environments with supportive problem-solving structures (for example, where the manipulatives were given to students pre-grouped to make the solution more obvious) can lead to less learning than environments that required active adaptation and reinterpretation.

Rather, students must be given opportunities to understand the utility of the manipulative by actively engaging in free play. Martin and Schwartz (2005) also mention that even students who don’t discover the mathematical concept from interacting with the manipulatives benefited from them and were more prepared to understand these concepts when they were made explicit by the teacher. By allowing the
students to engage the manipulatives on their own, they were better able to appreciate the mathematical meaning of a good physical structure once it appeared.

3. Emphasize activities and structures for “making ten” to embed the concept of” ten as a group” into students’ vocabulary

Being able to see ten both as a collection of units and as a discrete group is critical for understanding place value. Murata (2004) describes how students who used “break-apart-to-make-ten” strategies based on seeing ten as a group had a better foundation for 10-based multidigit thinking later on. However, researchers (Miura & Okamoto 1989; Miura et al. 1993) have shown that English-speaking students are more likely than these Asian students to use one-to-one collections (i.e. using unit blocks) to represent a number rather than canonical base-ten representations.

Miura & Okamoto (1989) suggest that seeing ten as a group is more difficult for English-speaking students because language does not give them any scaffolds for understanding the concept of place value. In contrast, Japanese, Chinese, and Korean languages all share a number system where place value is implicit; eleven, twelve, thirteen would be translated into ten-one, ten-two, ten-three in these languages. Thus, our design must provide scaffolds that share a similar function with Asian languages in revealing the ten-based structure of our number system.

4. Design manipulatives that allow the rest of the students to engage in independent learning to help the teacher focus on guiding one group at the time

The teachers we observed would routinely break the class into heterogeneous small groups and have the students work on activities that were appropriate to their level. The teacher would then sit down with one of the groups and give them more guided instruction. One benefit of this setup, when it is running smoothly, is that the teacher can focus on building the understanding of a smaller group of students rather than an entire class. However, in practice, it was difficult to keep the groups truly autonomous, especially with younger kids. Questions that the groups had often diverted the teacher’s attention from the group she was working with. Maintaining a balance between drill worksheets and new material that demanded conceptual understanding was also a challenge. Thus, we need to create a product that is mentally engaging, yet straightforward to interact with even without the teacher’s constant supervision.

5. Design manipulatives that encourage multiple conceptual representations to support and deepen different levels of understanding

In any classroom, students will have a range of levels of understanding, yet the teacher must ensure that the needs of the high-performing and low-performing students are equally met. The components of our
design must be flexible enough to accommodate different learning levels while constantly challenging students to gain deeper understanding.

The process of understanding is a gradual process, where elementary models help students understand complex models. For example, in her study of teen-sums, Murata (2004) discovered new intermediate transitional methods that the students used in order to move from a more primitive model of addition (a counting model) to a more sophisticated one (a grouping model). Both of these intermediate models were made of combinations of counting and grouping, showing that the student had not made a full leap to using grouping as their primary mental model. These interesting transitional stages remind us that moving from a literal to symbolic model of addition doesn’t just occur in a single step; students do not just “forget” their original models and replace them with better ones. Rather, elementary models can help students understand more complex models if the relationships between them are made explicit through transitional models.

Furthermore, Martin and Schwartz (2005) show that the process of trying different models allows a child to discover new, deeper interpretations of a concept. Even an accidental discovery of “grouping” certain manipulatives together to solve the problem may lead to using “grouping” as a deliberate strategy later on. Thus, our manipulatives must also be designed to allow students to switch among different models as they build their understanding and choose better ways of representing the mathematical concept.

6. Utilize interactivity and context-aware sensors to highlight places where student thinking breaks down

Electronic tools and interfaces have the potential to increase the scaffolding of a concept because of the greater interactivity they afford; a digital manipulative can graphically show the student step by step what a concept means. In describing a few more benefits of digital manipulatives, particularly for math learning, Clemente (2000) says that they provide increased flexibility in manipulating objects onscreen by changing its color and shape, allow composition and decomposition, allow the creation of units or groups, and connect geometric learning to number learning. Tangible digital manipulatives provide both physical and electronic interactivity that could further reinforce understanding as well (Ulmer & Ishii 2001).

7. Design manipulatives which have minimal surface features to encourage a deeper understanding of the underlying concepts and the transfer of knowledge

Manipulatives with minimal surface features are tiles, blocks, shapes, dots etc.; objects with a lot of surface features include pictures and those with physical meaning such as pies and money. Some researchers (Martin & Schwartz 2005; Uttal et al. 1997) have suggested that using less concrete manipulatives can help children transfer the concepts they discovered through working with the manipulatives to other problems. Martin and Schwartz (2005) demonstrated that children who had to
adapt tiles and reinterpret them as groups and parts of wholes helped them handle new situations better than children who were using a pie manipulative. The pie materials more readily offered an interpretation of groups and wholes, but as a consequence, the children did not learn how to make and interpret new grouping and whole structures, and they could not handle new situations with different physical characteristics.

Dienes (Olive 2008) also believed in the theory of multiple embodiment: Students must be introduced to the underlying concept through multiple interpretations with the same abstract physical tools. For example, rather than teaching base-ten addition specifically, he sought to teach students multi-base addition through the use of manipulatives that could be reinterpreted to fit the “base” the students were currently learning. Olive (2008) observed that upon using Dienes’ method of teaching through his Logic Blocks, students went through cycles of building and reflection as they struggled to reinterpret their creations in light of the logical concepts. Later, Olive (2008) claims that these students were able to produce more sophisticated algorithms for solving logic equations than their peers.

8. Encourage individual and collective interpretations while engaging the manipulatives to form personally meaningful forms of understanding

Both Bruner (1960) and Eisner (1993) agree that understanding stems from meaningful learning experiences. Olive (2008) observes that “children should be encouraged to invent their own symbol systems for recording the logical relations before introducing any kind of formal system. Any symbol system should first be used to represent physical situations that can be analyzed meaningfully by the children” (p. 2).

Collective interpretations provide useful learning experiences as well. Murata (2004) relates a classroom episode where students were encouraged by the teacher to explain their procedure for adding the numbers, and the class had to come to a consensus about which method was the most efficient. She explains that this “was a subtle but important negotiation that occurred in their math discussions during Phase 2” (Murata 2005, p. 195) because it allowed children to transition to the more sophisticated “grouping” model of addition that their advanced peers advocated. As Murata (2005) suggests, students must be given models that will be meaningful to each individual learner, regardless of their beginning levels: “Students came to own the [break-apart-to-make-ten] method through their own learning paths” (p.195).

9. Provide a concise guide that help teachers engage with the manipulatives in greater depth to allow them to teach students with deeper understanding

Ball (1992) argues that some teachers do not fully grasp how a particular manipulative works themselves, and are thus unable to use it to solve difficult problems. For example, she gives evidence that many teachers were not able to model 1 3/4 divided by ½ using fraction bars, showing that they
were using the manipulatives with only a procedural understanding (Ball 1992). These teachers were not
given enough support to understand the design of the manipulative, and were hence unable to make
full use of their capabilities themselves.

Some of the teachers that Raffle (2008) worked with to test his Topobo construction system also
mentioned that they did not have the time to invest a deep enough understanding in the manipulative
in order to engage it in more complex ways. Raffle relates the experience of one of the science teachers
who wanted to relate the Topobo models his students were building to concepts like DNA, molecular
reactions, and geometry, but struggled to explain the links. This teacher suggested that a guide which
provided general design guidelines, not exact instructions, would help the instructor engage with the
manipulative in ways that could inspire learning in class as well.
Appendix C: Project Timelines

Project Timeline

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 18, 2009</td>
<td>Proposal draft submitted</td>
</tr>
<tr>
<td>April 24</td>
<td>Project proposal submitted</td>
</tr>
<tr>
<td>May 2</td>
<td>Build Alpha 1 and test with users</td>
</tr>
<tr>
<td>May 10</td>
<td>Build Alpha 2 and test with users</td>
</tr>
<tr>
<td>May 31</td>
<td>Finish Beta 1 (working prototype) and test; begin curriculum plan</td>
</tr>
<tr>
<td>June 8</td>
<td>Design Assessment Plan DUE</td>
</tr>
<tr>
<td>June 13</td>
<td>Build Beta 2</td>
</tr>
<tr>
<td>June 22</td>
<td>Begin evaluation of product 1</td>
</tr>
<tr>
<td>June 29</td>
<td>Finish Beta 2 (if necessary)</td>
</tr>
<tr>
<td>July 13</td>
<td>Evaluation of product 2</td>
</tr>
<tr>
<td>July 20</td>
<td>Write final curriculum</td>
</tr>
<tr>
<td>August 7</td>
<td>LDT Expo</td>
</tr>
</tbody>
</table>

**Time Budget**

We plan to have a minimum of one 2-hour meeting each week in the spring. On average, we meet about 5 hours right now, and spend about 5 hours more working on the project independently. In the summer we plan to have a minimum of two 2-hour meetings a week and about 3 hours a week for our research.

Some of the critical allocations of time are:

<table>
<thead>
<tr>
<th>Task</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needfinding/Interviewing teachers/ Observing classrooms</td>
<td>15</td>
</tr>
<tr>
<td>Prototyping</td>
<td>45</td>
</tr>
<tr>
<td>Familiarizing ourselves with electronic components</td>
<td>25</td>
</tr>
<tr>
<td>Testing prototypes with teachers</td>
<td>25</td>
</tr>
<tr>
<td>Building the final model</td>
<td>25</td>
</tr>
<tr>
<td>Writing the curriculum</td>
<td>25</td>
</tr>
<tr>
<td>Conducting learning assessment and analysis</td>
<td>45</td>
</tr>
</tbody>
</table>
Appendix D: Collaboration Plan

We will work together on most aspects of the project but have elected leads for each of the critical components. April will lead the pedagogical content and Larissa will lead the design content.

April’s major tasks to lead are to:

1. Research current curriculum on learning place value with manipulatives
2. Design an evaluation plan for assessing the learning
3. Create a curriculum to accompany the product

Larissa’s major tasks to lead are to:

1. Conduct needfinding interviews with teachers and initiate site visits
2. Design the product specifications and prototypes
3. Test products with users

The only component of the project that we will be leading together is the technology side. Larissa has prior experience programming in Flash and building analog circuits. April has experience working on tangible media in her Human-Computer Interaction classes. However, neither of us have the expertise in building digital circuits, so we will actively engage a community of collaborators who can help us develop some interactive components for our product.

Contributors

We plan to consult the following experts for advice throughout the process:

Dr. Aki Murata – content and curriculum expert
Dr. Daniel Schwartz- assessment plan and transfer tasks
Rajiv Patel- Product Designer, tangible and digital prototyping tools
Joel Sadler- Design Fellow/ Mechanical Engineer
Carly Geher- Designer in residence (prototyping expert)
Jonathan Edelman- Doctoral candidate in Design Research- Visualization techniques
Appendix E: Resumes

April C. Alexander
238 Ayshire Ln, #105
Stanford, CA 94305
aprilca@stanford.edu

EDUCATION

Stanford University 2008-2009
MA Learning Design and Technology
Relevant Course Work: Research in Math Education, Understanding Learning Environments, Topics in Learning and Cognition: Discovery and innovation, Human Computer Interaction

The George Washington University 2003
BA, International Affairs, International Economics

EXPERIENCE

Learning in Informal and Formal Environments (LIFE) Center 2008-Present at Stanford University
Research Assistant
- Recruited subjects for and assisted with interviews from families about ways in which families use math in the home, and how they see the school subject incorporate with aspects outside of school
- Examined database of past research in preparation for design work
- Prototypes mobile phone applications to be used in research designed to enrich everyday mathematics
- Conducts user-testing to refine and evaluate applications

Rodeph Sholom School 2006-2008
Mathematics Teacher
- Taught a demanding pre-algebra curriculum to middle school students.
- Developed a math enrichment and remediation program used by every fifth grade student in the school.
- Chaired accreditation committee on elementary math curriculum.
- Taught Spanish II to eighth grade students.
- Advised 6-8 students a year, helping them develop advanced study skills, and communicate with teachers.
- Facilitated Special Assembly and Events Committee that plans school-wide events.
Instituto Anglo Britanico 2005-2006

Seventh and Eight Grade Teacher

- Taught eighth grade History, Literature, and English and 8th grade Theater in a bilingual school in Monterrey, Mexico using
- International Baccalaureate and constructivism philosophies.
- Developed multi-sensory activities and projects to aid learning of native Spanish speakers.
- Developed inter-disciplinary projects with other subject teachers.
- Conducted parent conferences in Spanish.

Educational Services Inc. 2002-2005

Conference Assistant

- Planned meetings and conferences and provided logistic support for several Federal Agencies including: National Cancer Institute (NCI), The National Institute on Drug Abuse, and The Center for Mental Health Services (CMHS).
- Designed a corporate training with support manual and curriculum for registration database, Peopleware.
- Conducted site visits, prepared budgets and proposals.
- Drafted corporate logistics and client communication procedures in order to streamline division policies.
- Received letters of commendation from meeting participants and clients.

Suffolk University 1999-2001

Orientation Leader

- Guided rising freshman through college adjustment and registration process.
- Facilitated group discussions during and managed the orientation.
- Offered scholar position in recognition of leadership and accomplishments.

Activities

Hasso Plattner Institute of Design at Stanford University K-12 Lab, Co-Chair

Co-leads design committee focused on bringing design thinking to Afterschool programs. Coordinates course charged with creating the prompt for the Innovation Museum’s 2010 Tech Challenge

Team in Training, Triathlon Team

Mentored a team of eight in fundraising for the Leukemia and Lymphoma Society and training for the NYC Triathlon. Group raised over $20,000

Language Skills

Fluent in written and spoken Spanish
Larissa Co

(650) 3531950 PO box 14849, Stanford CA, 94305 http://ldt.stanford.edu/~lyco lyco@stanford.edu

Education

Stanford University, M.A. Education; Learning, Design and Technology, 8/09
Stanford University, B.S. Engineering; Product Design, 6/08
Relevant coursework in mechanical design and manufacturing; social entrepreneurship

Experience

09/08-present Project Intern, Stanford Teacher Education Program, Stanford University
design and develop a web-based curriculum sharing platform for current students and alumni

04/08- present Independent Designer/Engineer, Myanmar Stoves Project
design fuel efficient wood burning stoves for rural women in Myanmar
develop manufacturing plan in a low-cost, low-technology environment
identify business and marketing plan for creating a new industry

01/09-04/09 Course Assistant, Needfinding, Stanford Product Design Program
guided students in understanding the course material outside class
managed logistics for class activities, presentations, and sections

09/07-12/08 Teaching Assistant, Social Entrepreneurship Collaboratory, Stanford Urban Studies Program
coached students who are learning to develop business plans for their own social ventures
developed class content with instructor and invite weekly speakers for the speaker series
prepared course materials and readings for each week, facilitate discussions with speakers

06/07-09/07 Design Intern, Big Time Science, CA
designed and conducted user testing for early stage web-based game prototypes
improved game interface based on observations and testing
wrote teacher and student guides for using the program as a group

09/06-06/08 Head Peer Academic Counselor, Stanford University
mentored 85+ freshmen in a dorm setting about their academic decisions and future goals
organized workshops and events such as Majors Night and Faculty Night, which bring together
300+ student and faculty participants

01/06-08/07 Product Development Intern, Learning Friends Company, CA
designed and programmed an educational game that emphasizes innovation skills for kids
participated in strategy meetings for funding and company development
co-wrote and designed the company’s early stage business proposal for ESL software for China
and non-profit English learning software for the U.S.
Awards
- Ernest Chilton Memorial Award for Excellence in Product Design
- Hong Kong University of Science and Technology entrepreneurship competition, semi-finalist
- Stanford - Bases Social E-challenge business plan competition, semi-finalist
- William James Foundation Social Entrepreneurship Challenge, semi-finalist

Languages
- Native Speaker of English and Filipino, lived in the Philippines for 18 years
- Conversational knowledge of Mandarin and Fookien (Chinese dialect)

Computer
- Graphic Design: Adobe Creative Suite, including Illustrator, Photoshop, InDesign
- Skills - Interactive Design: Flash CS3 with Actionscript 2.0/3.0; some Java and HTML
- Engineering Design: Solidworks; Working Model