The Optimization and Packaging of Materials Safari Science Educational Tool for K-4 Grade Levels

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ABSTRACT

An interactive materials-based learning kit for K-4 grade levels was refined to effectively be used in outreach and after-school programs. Different safari animals made of different materials are packaged in the kit, along with different activities to explore physical properties. An optimized number and variety of animals and materials were determined. The volume and weight of the Materials Safari learning kit was optimized to meet the user's needs. One way the product was optimized was reducing the number of animal pieces in the product. Also, two of the testing stations were reduced in size by about fifty percent to fit in the new, sleek packaging design. The packaging of Materials Safari was designed in ArtiosCad and resembled a regular slotted container style with a tuck and tongue made of microflute, also known as E flute. The prototype package was constructed on a Kongsberg cutting table and assembled with hot glue. The volume and weight of the Materials Safari was reduced by fifty-three and thirty-seven percent, respectively. The graphic design, which embodied a safari adventure theme, was designed in Adobe Illustrator. Interactive and educational activities were created and tested to assist with children's conceptualization of weight, magnetism, and density. A sorting chart, instructional children story book, and guided instructions were developed for the educational activities. The final packaged product will be tested with children who are in K-4 grade levels to further research on child psychology of science concepts.

Keywords: Informal Science, Materials Safari, Optimization, Packaging

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1. Introduction

Informal Science Education is a voluntary participation of activities outside the classroom environment. Informal science can be structured to meet academic objectives, influence attitude or behavior of a course subject.[1] Materials Safari science education tool is a set of informal science activities that are designed and developed for children in kindergarten to fourth grade levels.

1.1 Stakeholders

Materials Safari Learning Kit can be utilized in different informal science settings. One stakeholder for the educational tool is a facilitator for after-school programs. Facilitators will work with children and guide them through the testing stations. The facilitator will answer questions that children may have about the physical science concepts. Facilitators may also volunteer at educational outreach events. During the outreach event, facilitators as well as chaperones can engage in demonstrations to help children observe and discover science concepts. Another stakeholder for Materials Safari Learning Kit is the Child Development and Psychology department at Cal Poly. Materials Safari Learning Kit can be a research tool to help teachers evaluate how children at Cal Poly's Child Development Lab engage with self-directed activities.

1.2 Background

Informal science education is voluntary based and is sparked by investigation and curiosity from the individual. Informal science education varies vastly to a formal learning setting, such as a classroom. The formal classroom environment can present the curriculum and instructional material in way that does not cater to each student's learning style. Informal science education can be explored at a museum, after-school program, outreach events, aquariums, television, etc. Informal and formal science educations have different features that help or hinder an individual's academic competence (Figure 1). It is important to recognize that informal science education can emerge from both formal and inform learning environments. [1]

Features of Formal and Informal Science Learning

Informal learning - field trips	Formal learning - school
Voluntary	Compulsory
Unstructured	Structured
Unsequenced	Sequenced
Nonassessed	Assessed
Unevaluated	Evaluated
Open-ended	Close-ended
Learner-led	Teacher-led
Learner-centered	Teacher-centered
Out-of-school context	Classroom context
Non-curriculum-based	Curriculum-based
Many unintended outcomes	Fewer unintended outcomes
Less directly measurable outcomes	Empirically measured outcomes
Social intercourse	Solitary work
Nondirected or learner directed	Teacher directed

Figure 1. Features that contrast Formal and Informal Science Learning.[1]

Informal learning is facilitator-led; the inquisitiveness of the user in an informal learning environment may not be addressed fully depending on the facilitator's background and guided instructions. This can be seen a drawback or inclination to a child's development of cognitive skills. The child may voluntary seek out the answer to any questions he or she developed from an informal learning experience or lose curiosity to new subject learned.

Deborah Perry created a model that designs a motivating museum exhibit. Six components her model incorporates are Curiosity, Confidence, Challenge, Control, Communication, and Play.[3] However, the six components are not limited to museum exhibits. It is important for every informal learning environment to encompass Curiosity, Confidence, Challenge, Control, Communication, and Play. Curiosity encourages voluntary participation; Confidence gives a sense of academic competence; Challenge motivates user to engage and solve activity; Control assists in self-determination and learning pace; Communication allows for social and behavioral development; and lastly, Play invites excitement and enjoyment to the informal learning experience.

Another factor that influences informal learning activities is the presentation and aesthetics. Younger users, especially children, respond to colorful, interactive objects. Individuals will read and look at well-designed interpretative labels. Interpretative labels can refer to titles, label, sections, or group labels.[3] The user's perception of the interpretative label and design, surprisingly, influences the engagement and interaction of informal science activities. Thus, the informal science activities need to be highly noticeable and enticing to encourage self-directed learning.

Informal science education and experiences influence the development of cognitive skills for young users. The children, who spend more time engaging in informal science activities, build knowledge in science and technology related fields. Informal science learning is an attribute to an individual's informal education. An informal education is a lifelong learning process in which an individual gains knowledge and cognitive skills to develop values and beliefs that ultimately influences personal and professional decisions; the informal and formal education prepare individuals to be competitively competent in their future profession and lifestyle.

2. First Prototype of Materials Safari Learning Kit

The original prototype of the educational tool was designed and developed by three Cal Poly Materials Engineering students, Thomas Agasid, Santiago Caceres, and James Woodhead, during the 2011-2012 academic year. Materials Safari learning kit was proposed as an exhibit, but eventually evolved into a set of testing stations to illustrate three physical science concepts that are objectives for the California Science Education Standard for Kindergarten.

2.1 Testing Stations

A testing station was designed to illustrate one of the three physical science concepts: buoyancy, magnetism, and weight. The Watering hole is a testing station that demonstrates the physical science concept of buoyancy. The user will interact with, but not limited to, materials such as ABS, clear cast acrylic, aluminum, balsa, oak, rosewood, and alder. The capacity of the container used to hold the water and animal pieces was one gallon (Figure 2a). The mud pit is another testing station in Materials Safari Learning Kit and focuses on the concept of magnetism. Seven pounds of pinto beans were used to simulate mud in the testing station and placed in a blue container with dimensions of fourteen inches by eleven and half inches by four and half inches. Various animal pieces and material were buried in the blue container to help children investigate magnetic properties with the magnetic wand (Figure 2b). The last testing

station allows children to observe the weight of materials. The balance tree is a weight balance that has tree shrub attached to the top to illustrate a safari tree (Figure 2c). Children can place different animal pieces in the pouch that is attached to either side of the beam. Users will observe that the mass of different materials vary despite the same volume animal size.

(2a) (2b) (2c)

Figure 2. a) Watering Hole demonstrates buoyancy. b) Mud Pit demonstrates magnetism. c) Balance Tree demonstrates weight.

2.2 Challenge Cards

Four instructional questions were designed as challenge cards. Three of the four cards help children investigate the specific science concept at one of the testing station. One challenge card investigates if animal pieces made of same material have the same density. Other challenge cards investigate if metals are magnetic, quantify the difference between different materials on the weight balance, and lastly sort the various materials into categories (Figure 3).

Figure 3. Four challenge cards were included in learning kit to help children investigate physical science concepts.

2.3 Packaging

Materials Safari Learning Kit was stored in a clear plastic storage bin with dimensions of twenty three and quarter inches by sixteen inches by six and three-fourths inches (Figure 4). The total package weighed 16 pounds. Although the package did contain and protect each component, the learning kit was bulky and heavy. It was difficult for one person, such a facilitator, to carry the learning kit to different informal science settings. Lastly, there was no graphic design for the science educational tool, which can make it less appealing to the user.

Figure 4. The first package design of Materials Safari Learning Kit.

3. User's Needs and Optimization of Materials Safari Learning Kit

The design and development of the initial prototype includes testing stations and manufactured the animal pieces. However, the prototype needed to be optimized, such as re-package the product and create guided instructions, to make it an effective tool for children to conceptualize density, magnetism, and weight.

3.1 User Personas

User personas are profiles of potential users that show their type of gender, personality, and background. The user persona is a great tool to assess how different users can interact with a product, such as Materials Safari Learning Kit. Three user personas, two children and one adult, were created to conceptualize the user interaction with learning kit and refine the product to meet their needs (Figure 5). User personas were a key to defining the user's needs and dictate the additional design requirements for learning kit.

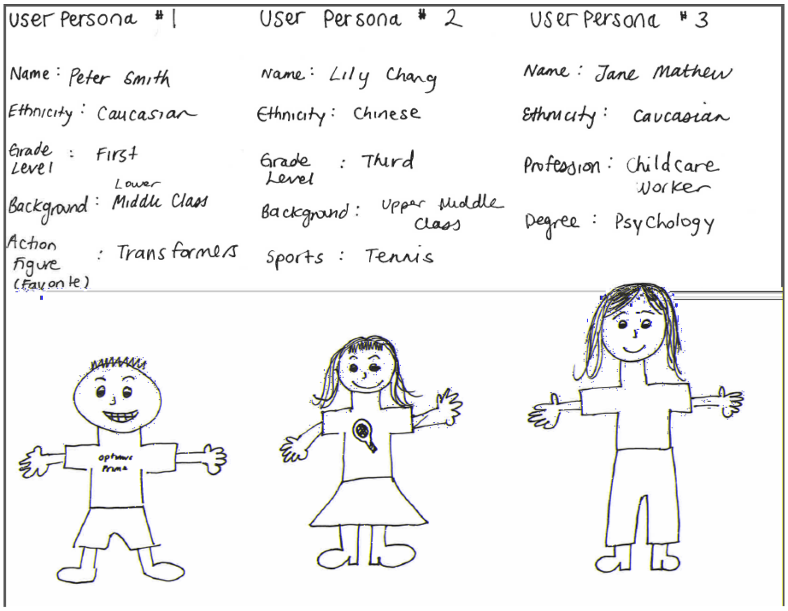

Figure 5. Three user personas were created to optimize Materials Safari Learning Kit.

3.2 Design Requirements

Each user had a different interaction with the Materials Safari Learning Kit. The two children users illustrated that the learning styles may vary between users. Thus, multiple instructional activities needed to be created to cater to different users. Also the appearance and graphic design affected the children's perception of the product. As for the childcare worker/facilitator, the instructional activities needed concise explanations about each physical science concept for each testing station. Also, the size and weight of the educational tool can be a limiting factor for both children and facilitator. A table was created to categorize the different materials into different attributes as well as determine optimal number of pieces (Table 1). The result of the chart emphasized a need for a clear cast acrylic alligator to be added to the collection of animal pieces.

Table 1. A chart designed to optimize and manufacture animal pieces

	6061-T6 Aluminum	a-36 mild steel	360 alloy brass	Clear cast acrylic	ABS	Rosewood	Balsa	Alder	Oak
Weight	X	X	X	X	X	X	X	X	X
Density	S	S	S	S	F	S	F	F	F
Magnetic		X							
Shiny	X	X	X						
Elephant	X			X					X
Lion		X							X
Alligator				O		X	X	X	
Giraffe			X		X				

X= Available; S=Sink; F= Float; O=Manufacture

4. Realistic Constraints

The optimization process of Material Safari Learning Kit resulted into a few realistic constraints. The first realistic constraint of this project was manufacturability. Only two types of corrugate fiberboard were readily available to design the package design due to the budget. Also, an industrial machine called the printer slotter would be the appropriate equipment to complete the graphic and package design for the learning kit. The machine prints the graphic design on the corrugate fiberboard then cuts and scores the material. The graphic design will not tear or rip off the corrugate fiberboard. Another realistic constraint was social. The instructional activities were designed to meet a broad group of users and cater to their learning needs. It was hard to determine and categorize each learning style for individual users. The last realistic constraint was health and safety. The Materials Safari Learning Kit graphic design needed to be in compliance with Child Safety Protection Act. Also the animal pieces cannot be a choking hazard to users.

5. Package Design and Development of Materials Safari Learning Kit

The new package design was stressed as a new design requirement for Materials Safari Learning kit. The package design needed to incorporate the functions of packaging and have an attractive graphic design to market the product.

5.1. Functions of Packaging

The first function of packaging for Materials Safari Learning Kit was containment. The new package design must contain and avoid vibration damage to the testing stations, animal pieces and instructional activities. The next function of packaging was protection. Materials Safari Learning Kits package ensured functionality of each component and prevented any environmental degradation. An important packaging function that was heavily focused on for the learning kit was convenience. The package design needed to be light-weight and easy to open for users. The last packaging function was communication. The package needed to illustrate a safari-theme and display a warning label due to the Consumer Product Safety Act.

5.2 Manufacturing of the Package for Materials Safari Learning Kit

Corrugate fiberboard was the material selected to create the package design. C-flute is the most common grade used in packaging industry and has good cushioning and stacking properties; however, E flute was a lightweight fine flute with excellent crush resistance. The thin flute thickness is space saving due to the reduction of box size.[4] Thus, E flute, also known as micro flute, was the materials selected for Materials Safari Learning Kit. The next step was to design the box style for the package. Materials Safari Learning Kit closely resembles a regular slotted container (RSC), but has a tuck and tongue (Appendix A). The combination of RSC and tuck and tongue style was designed in ArtiosCad, which is a structural packaging design software.

After the design of Materials Safari Learning Kit was created in ArtiosCard, the file was uploaded to the computer to be cut and scored on a Kongsberg table located in Cal Poly's Industrial Technology Lab (Figure 6).

Figure 6. Kongsberg table that cuts and scores Materials Safari Learning Kit package design.

5.3 Graphic Design for Materials Safari Learning Kit

The vision of the graphic design was to present a fun, exciting game to the children's perception. The graphic design was an isotropic view of a jeep. There are four different types of animal in the learning kit. Each animal was animated to become passengers of the jeep. After a survey with five people, the isotropic view of the jeep was favorable among the individuals.

The jeep was created in Adobe Illustrator and resembled a Jeep Wrangler. The square and circle tools in Adobe Illustrator created the box shape with car features. Next the animal pieces were hand drawn and scanned into the computer. The sketched drawing of each animal is pixelated; thus, the live trace tool was used for vectorization of the drawing. The artwork for the graphic design needs to be vector drawing to ensure high quality printing. After each animal was a vector drawing and juxtaposed in the car, the file was saved as a Press Quality PDF. The front view, back view, right and left view, and top view were printed and adhered to the cut and scored microflute (Appendix B). Lastly, four blank, white sheets were adhered to the inner flaps to add to aesthetics of graphic design. A spray glue was the adhesive used.

6. Assembly and Results of Materials Safari Learning Kit

The graphic design was adhered with a spray adhesive to corrugate fiberboard. Hot glue was smeared on the manufacturer's tab, which is protruding trapezoid shape in ArtiosCad file, to adhere to the opposite end of the fiberboard. The fiberboard will no longer look flat and will have a square shape. The bottom flaps were adhered with hot glue to construct the box.

6.1 Instructional Activities

The user profiles helped conceptualize that users may have different learn styles. Three types of activities were created to meet help facilitator guide children with each testing station. A guided instruction was created for each testing station to assist with process and explanation of the physical science concept observed (Figure 7).

Materials Safari
A Science Learning Adventure

Exploring Buoyancy – Watering Hole

Try This!

1. Fill the bowl with water (around 3/4th full).
2. Find the aluminum elephant, acrylic elephant, rosewood alligator, balsa alligator, oak alligator, alder alligator and ABS giraffe.
3. Place each animal piece into the water.
4. Observe which animal pieces sink or float. Why does that happen?

What is going on?

Buoyancy is scientific phenomenon, which a material has the ability to sink or float in a specific medium. In this context, a medium is defined as type of environment, such as liquid, solid or gas. For the watering hole, the animal pieces will either sink or float in tap water.

The density of water, which is the weight of water displaced in the volume of the bowl, equals 1 gram per cubic centimeter. If an animal piece floats in beta drum bowl, that means the animal piece has a density, or the mass of the material in respect to its volume, less than or equal to 1 gram per cubic centimeter. However, if an animal piece sinks, or is not buoyant, the density of the animal piece is more than density of water.

How does this relate to Materials Science and Engineering?

Buoyancy of a material is based on Archimedes principle. If the weight of the medium displaced is more than weight of material, then the material will float. Otherwise, the material will sink if it weighs more the weight of water displaced. The densities of different materials are incorporated in the design of products, like airplanes, boats, to maintain its functionality.

Figure 7. Guided Instruction for Watering Hole

Another activity called the Sorting Chart was design to conceptualize the properties of material. The user can sort the different animal pieces after using them at each testing station. A sorting chart was created for K-1 grade levels that simply categorize the animal pieces. The terms “white/plastic”, “natural”, and “shiny/metal” will help younger user categorize the materials and property (Figure 8). As for the older users in 2-4 Grade Levels, each material was listed to challenge the user and learn the name of materials used for various applications.

	SHINY/METAL	WHITE/PLASTIC	NATURAL
LION			
ELEPHANT			
GIRAFFEE			
ALLIGATOR			

Figure 8. A sorting chart for different materials for K-1 grade levels.

Lastly, an instructional story book was written and created to present the physical science concept in a fun, interactive way for users in K-2-grade levels (Figure 9). The story book catered to children who prefer a facilitator to guide and help user interact with each testing station. It promoted a more facilitator-user engagement.

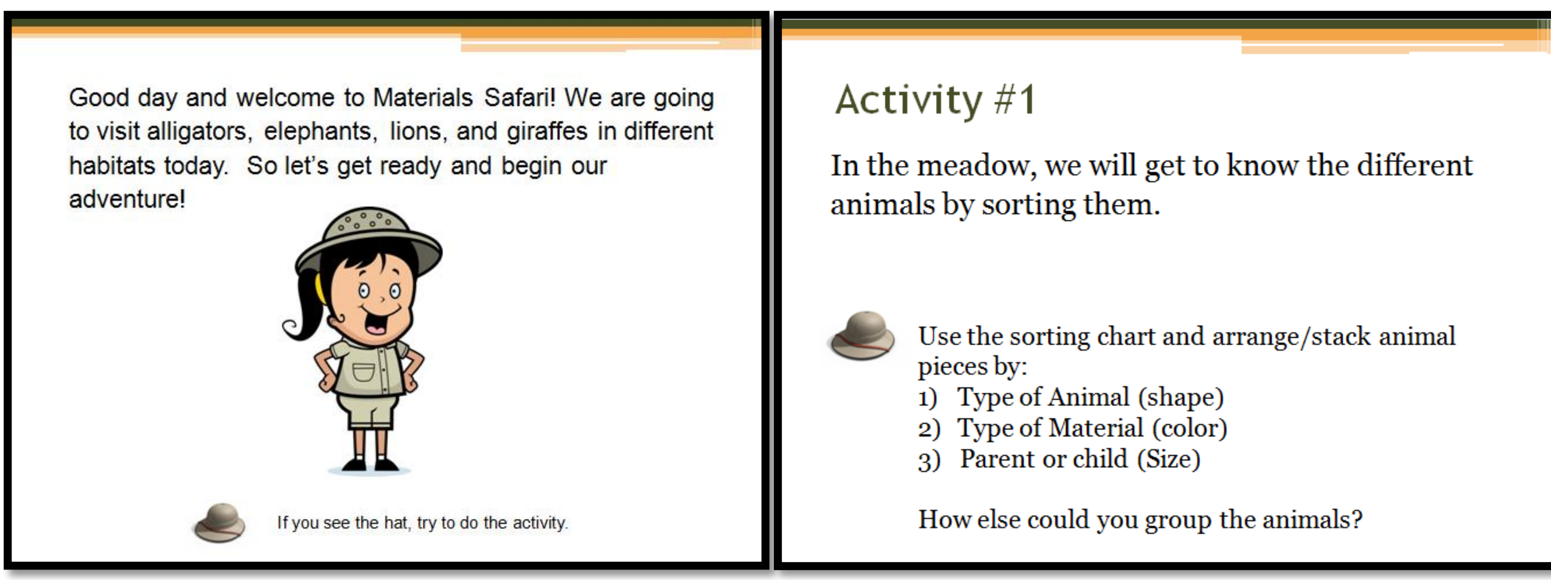

Figure 9. Pages from instructional story book for users.

6.2 Optimization of Testing Station and Overall Package

The testing stations, animal pieces, instructional activities were all the components in the Materials Safari Learning Kit. The testing station for Watering Hole and Mud Pit were each reduced in size by fifty percent. The number of pinto beans used to simulate was reduced for the testing station. The optimization of the aforementioned testing stations still demonstrated the same physical science concept in the first prototype. The volume and weight of final prototype was reduced by fifty-three and thirty-seven percent, respectively (Table 2).

Table 2. Optimization results of Materials Safari Learning Kit Package

	Original Prototype	**New Prototype**	**Percent Reduction(%)**
Dimension (in)	16 x 23.25 x 6.75	12 x 14 x 7	53
Weight (lb)	16	10	37

7. Future Work and Recommendations

The manufacturability of the alligator pieces will be required to complete educational tool. The laser cutter in Mustang 60' shop will cut the animal pieces out of the two inch by two inch by three-eighths clear cast acrylic sheet. The laser cutter requires an Adobe Illustrator file of the animal silhouette. The machine settings will be used to control power, speed, and cuts of material (Table 3).

Table 3. Laser cutting settings for acrylic alligator

Material	**Power**	**Speed**	**Number of Passes**
Acrylic	80%	3.0	3: z height move of +0.05" per pass

It is recommended that Materials Safari Learning Kit be tested with Child Development Lab to analyze the concept of informal science with K-4 grade level students. The six strands of learning are objectives that can be used to evaluate the voluntary participation of scientific activities. The six strands of learning will help gauge whether the prototype has successfully introduced basic materials concepts to user or help children gain tactical experience.

8. Conclusion

Materials Safari Learning kit is a scientific educational tool that can be used with users in informal learning environments. The self-directed learning encourages users to predict, observe and measure three physical science concepts: buoyancy, magnetism, and weight. Materials Safari science educational tool promotes science discoveries as well as help users gain tactical experience due to user interaction with animal pieces. The user profiles were beneficial to determine the design requirements for the new prototype for Materials Safari learning kit. The optimization and packaging of product met the user's need. The volume and weight for package of the educational tool are reduced by 53% and 37%, respectively. The sorting chart, instructional activities and story book were created to promote various interactions with Materials Safari Learning Kit.

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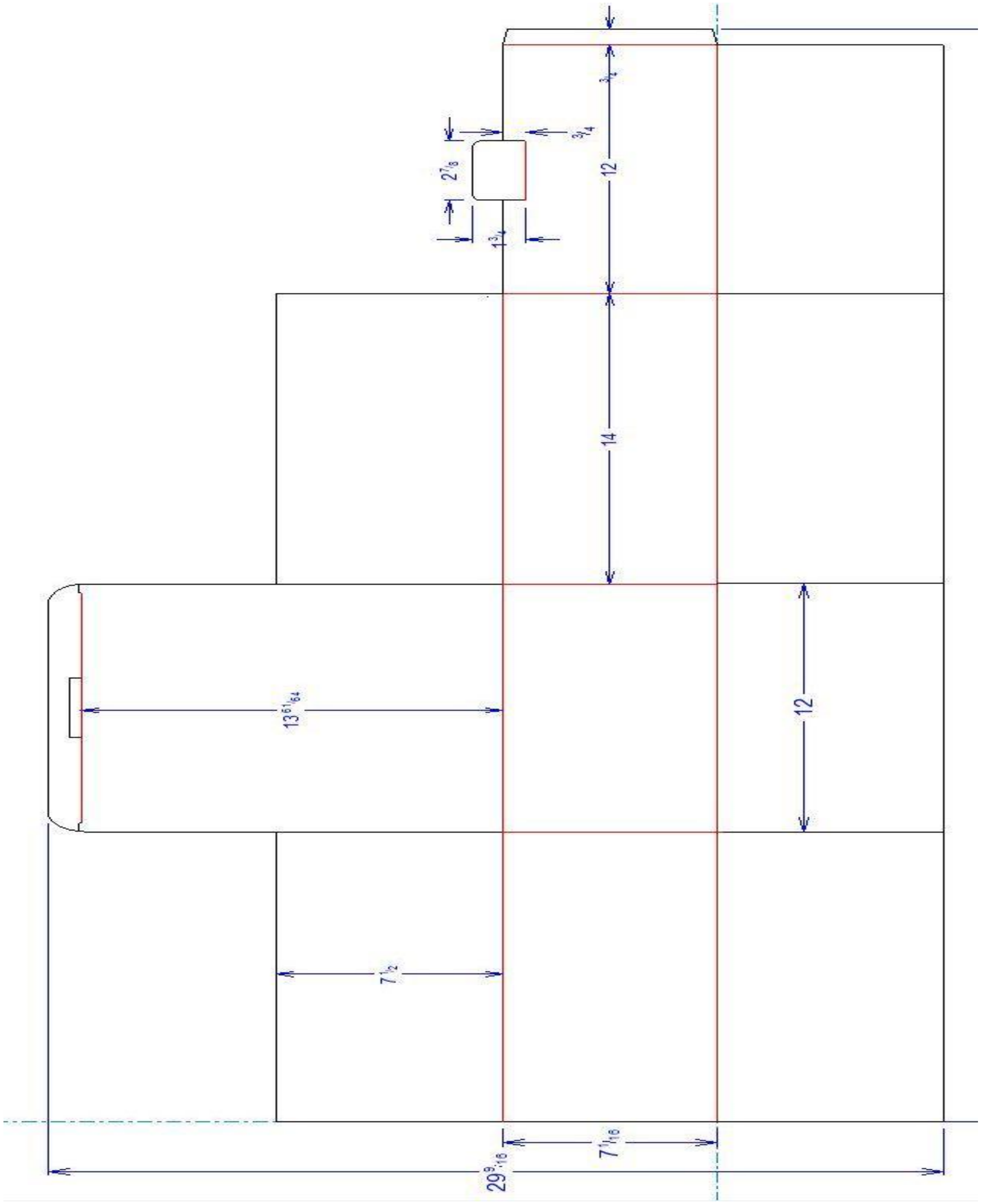
Appendix A



Appendix B