July 4, 2001

Ms. Fabiola Rodríguez
P.O. Box 10303-1000
Calle 4, Avenida 9
Antigua Penitenciaria
El Museo de los Niños
San José, Costa Rica

Dear Ms. Rodríguez:

Enclosed is our report entitled Mechanics Exhibit Design for El Museo de los Niños. It was written at El Museo de los Niños in San José, Costa Rica during the period from May 14 through July 4, 2001. Preliminary work was completed in Worcester, Massachusetts prior to our arrival in Costa Rica. Copies of this report are being submitted simultaneously to Professors Elmes and Salazar for evaluation. Upon faculty review, a copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the help that you and the other museum staff have given us.

Sincerely,

Adebayo Adeyinka

Lee Fisher

Mark Liffiton

Report Submitted to:

Professor Michael Elmes and Professor Guillermo Salazar

Costa Rica, Project Center

By

Adebayo Adeyinka ____________________

Lee Fisher ____________________

Mark Liffiton ____________________

In Cooperation With

Fabiola Rodríguez, Executive Director

El Museo de los Niños, San José

MECHANICS EXHIBIT DESIGN FOR EL MUSEO DE LOS NIÑOS

July 4, 2001

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of El Museo de los Niños or Worcester Polytechnic Institute.

This report is the product of an education program, and is intended to serve as partial documentation for the evaluation of academic achievement. The report should not be construed as a working document by the reader.

Abstract

This report, prepared for the Museo de los Niños (Children's Museum) in San José, Costa Rica, outlines procedures for the design of an interactive, educational exhibit area about mechanics. Fabiola Rodríguez, the museum's director, commissioned our team to aid in the design of the new area. This report contains our research and analysis, as well as recommendations in the form of multiple exhibit options, material lists, costs, a possible floor plan, and general guidelines for the design of interactive exhibits.

Authorship

Adebayo Adeyinka, Lee Fisher, and Mark Liffiton prepared this report. Initially, the group developed the ideas to be included in each section. Individual members then wrote specific sections of the report, which were edited and revised by all members. During this process, each person's ideas and suggestions were applied to make the report representative of the group. We would like to acknowledge that each member had certain sections that they were in charge of. Adebayo Adeyinka researched information on children's education and developed the list of possible sponsors for the displays. Lee Fisher designed and built the prototypes used for the project along with developing the drawings for each display. Mark Liffiton wrote the introduction and administered the worker survey and teacher interviews. Other sections of the report are to be considered the work of the entire group.

Acknowledgements

We would like to thank the following individuals for devoting their time and energy to help us complete this project. We are very grateful for all they have done for us.

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The entire staff of El Museo de los Niños
Last year's Museo IQP team

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Executive Summary

The primary goal of the Museo de los Niños in San José, Costa Rica is to provide a fun and educational experience for children that supplements their academic curriculum. Though the museum once had exhibits about mechanics, they have mostly been removed and it now requires new displays. Our team was commissioned to design interactive and educational displays that would allow it to fill this need.

To accomplish this task, we needed to learn more about the qualities that make an interactive children's museum display successful. We researched literature on children's education. We interviewed experts on exhibit design. We surveyed museum guides and visited the displays they felt were the best to see what qualities made them successful. We also interviewed elementary school teachers to determine how the children who visit the museum learn best. From this research, we learned that there are different stages of cognitive development that affect the learning process in children of different ages; interactivity and physical involvement in exhibits increases children's enjoyment and learning; and simplicity is a key characteristic of successful exhibits.

To further our understanding of how children interact and learn at a children's museum, we built and tested prototypes of two potential displays in the museum. To investigate how much children learned from the prototypes, we administered a simple knowledge test to children before and after they interacted with the prototypes. We also observed the children to see how they interacted with the displays and whether they enjoyed playing with them. We found that approximately 30% of the children did not give the correct answer to the test question before playing with the displays. However, after being allowed to play with the prototypes, a full 100% knew the correct answer and

some even understood the concepts. Also, the children were very excited to play with the displays and appeared to have fun with them.

By analyzing all of our data, we determined the most important qualities of a successful children's museum exhibit. Because the main goal of the museum is to educate the children, an exhibits's educational value is of paramount importance. Interactivity and fun are also critical to the success of an exhibit because children will not learn if they are not interested in playing with it. Exhibits must also be self-explanatory and easy to use. A guide will not always be available in the exhibit area to explain what each exhibit is teaching or how it works, and we want the children to always be able to play and learn from them. Finally, financial aspects such as construction and maintenance costs are important because the museum has to fund and build these exhibits.

To create our exhibit recommendations, we needed a list of exhibits from which to chose those most likely to succeed in the museum. We gathered ideas from other museums, exhibit design experts, and brainstorming sessions. Then, using the important exhibit characteristics, we developed a value analysis test to determine which exhibits were best. We gave each exhibit a score for each attribute, and calculated a weighted average of those scores, with a different weight for each quality, as a final score for each exhibit. All three members did this and a group average was used to determine which displays to recommend. The displays that scored above the median were considered worthy to recommend to the museum. However, individual group members wanted to include some displays that did not fit in this category, so an additional five displays were recommended for reasons other than their raw scores.

We have given the museum detailed descriptions of each display, including those we did not recommend. Each description includes a general idea of how the exhibit is constructed, the concept that it teaches, and various advantages and disadvantages. We have supplied illustrations of each exhibit to further help others understand how we envision them. To assist the museum in funding the construction of the exhibits, we created a cost estimate for each and identified possible sponsors. We also created a possible floor plan for the area to provide the museum with one possible option for the layout of the area in which the mechanics exhibits will be built.

In addition to determining the best displays for the mechanics room, we also have recommended methods for the museum to determine if the displays are educating the children. These include periodic random testing of the children and conducting surveys. These methods are applicable to other exhibits in the museum and we feel that they will be very beneficial in obtaining information about their educational value.

We further recommended that the museum use our value analysis system to determining which displays will be most successful for future exhibits. This consists of creating a weighted scoring of important qualities to rate and rank proposed display ideas. We feel that this is important because it provides the museum with a systematic technique for selecting designs that will be most successful.

1 Introduction

1.1 Subject

The earliest incarnations of science museums were little more than exhibitions of curiosities. They consisted of rooms filled with displays containing various specimens such as fossils, preserved remains, and other things that were interesting to the general public but did little to educate the museum visitors. Since the time of those early examples, science museums have grown in size, popularity, and, most importantly, educational value. Modern science museums have mostly abandoned the old "look but don't touch" glass displays, replacing them with interactive exhibits that actually involve the visitors. People now go to science museums both to be entertained and to be educated.

Children's museums, a specific subset of science museums, grew in popularity in the 70's and the 80's, when many children's museums such as the Exploratorium in San Francisco (Online: Exploratorium, 2001), the Chicago Children's Museum (Online: Chicago Children's Museum 2001), the Children's Museum of Manhattan (Online: CMOM, 2001), and the Capital Children's Museum in Washington, DC (Online: CCM, 2001) all opened their doors. Children's museums are geared toward children and their specific educational needs. As centers for "informal learning," they supplement the children's traditional school education, emphasizing an interactive and hands-on approach that can be hard to implement in a classroom.

One such museum is the Costa Rican children's museum, El Museo de los Niños, located in Costa Rica's capital, San José. The museum opened in 1994, and it is now more than 7 years old. Its goal is to be a source of knowledge that might not otherwise be available to Costa Rican children and to shape the children into more critical and creative persons. Through its various exhibits, it provides an opportunity for the children to have a better understanding of the world in which they live. The intent is to create a better future for Costa Rica.

1.2 Goals and Importance

The Museo de los Niños currently has over 32 exhibition rooms covering a wide range of topics including biology, music, history, and the universe. However, despite the great number and variety of exhibits at the Museo de los Niños, it does not have anything dedicated to mechanics. It once had a large area dedicated to the topic, but the exhibits have mostly been removed. Some of them were not designed with children in mind and elements either weighed too much or were not accessible to small children. Others simply broke due to poor design and parts of inadequate quality. They have not yet been replaced. Furthermore, though this subject is on Costa Rica's national education agenda, schools are inadequately equipped to teach it due to the economic limitations of a developing country. Although they may be able to teach mechanics with textbooks and lectures, Costa Rican schools do not have the resources to complement that learning with the experiments and physical demonstrations that are so important to learning about mechanics. The museum feels that it should be able to provide resources that allow children to experience this hands-on learning. Our project's goal was to fulfill this need by designing an interactive and educational exhibit area about mechanics for the museum.

1.3 Methods

Our methods consisted mainly of research into background information useful for designing exhibits and data collection about the current state of things in the museum and Costa Rica. Mostly before coming to Costa Rica, we researched topics such as children's education, exhibit design, and principles of mechanics through books, magazine articles, visits to other museums, and interviews with experts. While in Costa Rica, we administered a survey to the museum guides, conducted interviews with teachers and experts on various aspects of exhibit design, and built and tested prototypes of some exhibits with children in the museum. The information that we collected was analyzed to make the recommendations and design the exhibits in this report.

1.4 Audience

This report is intended for the administration of the Museo de los Niños, as well as those in charge of designing and building the exhibits. While these people are the primary audience, other organizations may find the report useful as well. One such group is the Costa Rican teachers and school administrators. If they learn about the project, they may be more interested in bringing school children to the museum, or they may implement parts of the exhibits as experiments in their classrooms. In addition, the project may be used by other museums in Latin America and the world as a model for creating similar exhibits. One other result of the creation of these exhibits is an increase in Costa Ricans' technical knowledge. As Costa Rica is in the process of expanding its economy into the high-tech area, skilled workers knowledgeable in the sciences are in great demand. This exhibit will play a small part in preparing today's children for tomorrow's high-tech jobs by teaching them important scientific concepts and hopefully sparking an interest in science in general.

1.5 Results

This report presents the museum with many different options for mechanics exhibits, as well as a possible layout of the designated area showing how the exhibits might be arranged. Each exhibit recommendation includes a general design, a picture, a cost estimate broken down into individual components, its advantages and disadvantages, and possible sponsorship opportunities for some. The museum can review the options and decide what will work best to fulfill its goals. The report also includes general recommendations that apply to all of the exhibits. Through our research and design, we have provided the museum with the ability to make informed decisions on what steps need to be taken to create these mechanics exhibits.

1.6 IQP

Finally, as an Interactive Qualifying Project, this project is designed to illustrate the connection between society and technology. By accomplishing our goals, we have helped bring science, namely the concept of mechanics, to the children of Costa Rica. This education will empower them with knowledge, benefiting society by making them more informed and possibly encouraging them to pursue a career involving science and technology.

This report was prepared by members of the Worcester Polytechnic Institute Costa Rica Project Center. The relationship of the Center to the Museo de los Niños and the relevance of the topic to the Museo de los Niños are presented in Appendix A.

2 Literature Review

In creating this proposal, we have called upon knowledge from many different areas and have done research into these areas to prepare for our work. This chapter contains the results of that research. The first section includes some details about the Museo de los Niños itself. The second section deals with children's education and learning. The next section more specifically looks at concepts of museum design and ideas relevant to creating exhibits for a children's museum. Following this are some overviews of similar museums that provide good models and examples of how others have done similar work. Next is a section on the fundamental concepts of mechanics and the basic ideas that children will learn from the exhibits. After that, we investigate a variety of specific displays that could be used in the exhibits. Finally, we look into some of our methods for collecting and analyzing data.

2.1 El Museo de los Niños

In designing and proposing exhibits for El Museo de los Niños, it is important to know how it functions with respect to its exhibits. The museum is continuously changing. There are always new exhibits in planning, under construction, or undergoing maintenance and upgrades. The museum tries to keep the exhibits as "fresh" as possible by removing old exhibits and replacing them with new ones. The administration chooses to remove exhibits when they are no longer serving their purpose, which is indicated by children spending very little time in an exhibit or entirely passing it by (Rodríguez, personal communication, 6 June 2001). For example, the current Hydrocarbon exhibit is mostly ignored by children, and so the museum is in the process of replacing it with a new exhibit about dinosaurs. The previous exhibits about mechanics broke rather quickly, because they were made from poor-quality components, and so it is being replaced as well.

Ideas for new exhibits are chosen in a number of different ways (Rodríguez, personal communication, 6 June 2001). They are generally conceived by various members of the museum administration or staff as brainstorms and then discussed and reviewed in more detail. Some exhibits are included because they are considered necessary for the museum. These deal with topics of great importance to Costa Rica or to children in general. For example, the Seres Vivos (Living Beings) exhibit is considered necessary to teach children the importance of the great diversity of living creatures that Costa Rica possesses in its rainforests. Other exhibit ideas come from other museums. Mechanics, for example, is a topic covered in most children's museums, and El Museo de los Niños believes it is very important to include such exhibits. Finally, some exhibits are created simply because they cover topics known to interest children. The new dinosaur exhibit is being built because the museum knows that children love dinosaurs and they are the best selling items in the museum shop. A few exhibits are actually proposed by outside corporations and businesses that wish to have a presence in the museum. The business initiates relations with the museum and controls most aspects of the design, though the museum of course has the final say, with the ability to reject ideas if they are too commercial or otherwise unsuitable.

Often, after an exhibit idea has been created, bids on actual design and construction of the exhibit are solicited from about four or five different contractors (Rodríguez, interview, 6 June 2001). The administration then reviews the bids and chooses the one it likes best. If the exhibit has a sponsor, the sponsor has input into the choice, as well. Upon winning a bid, a company either builds the exhibit itself or subcontracts another company to do it. The construction takes approximately half of a year after the funds are collected, though it depends on the size and complexity of the exhibit.

2.2 Children's Education

The main goal of any exhibit in a children's museum is to educate a child. When designing such an exhibit, it is necessary to understand how children learn so that the exhibit may accomplish this goal to the greatest degree possible. Some excellent work has been done in this field by notable psychologists like Jean Piaget, who pioneered the theory of cognitive development in humans, and John Holt, who wrote numerous books on children's education. According to Piaget, cognitive development is the acquisition, organization, and use of knowledge from infancy to adulthood, otherwise known as learning (Kearsley, 2001). Piaget categorized this dynamic process into four distinct periods in a human's development in which similar specific mental actions are obviously identifiable (Baltes, 2001).

The first stage is known as the sensorimotor period, which usually lasts from birth to about two years of age (Boeree, 2001). During this period, infants acquire basic knowledge of objects, causes, space, and time. Children in this stage use their senses and motor abilities to understand and interact with the world around them, beginning with simple reflexes and ending with combinations of sensorimotor skills. Also during this stage, their memory functions poorly, so anything out of sight is effectively out of mind. Infants should be provided with a rich and stimulating environment with ample objects to play with.

The next stage is the preoperational stage, which occurs between approximately 2 and 7 years of age (Boeree, 2001). During this stage, intelligence is intuitive in nature. Children's thinking and behavior are illogical in that they tend to see only their point of view and cannot imagine another perspective. They start to develop a clear understanding of past and future.

The third stage is the concrete operational stage (Boeree, 2001). During this stage, between ages 7 and 11, thought is far more logical and organized. Children start to acknowledge the concept of conservation and they are able to reverse their thinking. They develop logical operations on principles for solving problems and are able to manipulate things better within the context of concrete situations. Children in this stage should be provided with learning activities that involve problems of classification, ordering, location, and conservation using concrete objects.

The last stage is the formal stage, which occurs from about 11 years of age. In this stage, abstract thinking and logical reasoning appear (Boeree, 2001). Abstract thinking involves ideas that are entirely within the mind. In the concrete operational phase, children are mostly constrained to thinking about and working with things that exist in physical reality, whereas people in the formal operational stage can think about entirely hypothetical situations. Children are able to think of all possibilities whenever faced with a problem, and they are able to make viable decisions on their own.

In the past works of John Holt, he has focused more on the general ways children interact with their environment and their attitude toward learning. He believes that children are normally cheerful, energetic, and enthusiastic in their early ages. They tend to learn better than adults do because they use their minds in a special way different from most adults (Holt, 1967, p.vii). However, most children dislike being taught, unless under their own conditions (Holt, 1967, p.46). For this and other similar reasons, the task of children's education is not an easy one.

To educate a child, one must first be able to capture his or her attention. Otherwise, all effort is wasted because there will be no interest in learning. It is normally said that children have a very short attention span relative to adults (Holt, 1967, p.4), because they tend to be easily distracted by their surroundings. Therefore, much research must first be done on their likes and dislikes (i.e. what interests or bores them). Usually, children do not like to be forced to do things, otherwise known as compulsory fun. Instead, they prefer to be allowed to improvise their own fun, e.g. form their own games or compose their own songs (Holt, 1967, p.6). Through these forms of independence, learning tends to occur rapidly.

Various methods for attracting children's attention exist. Children in general will enjoy games that make them seem more powerful and in control of a situation (Holt, 1967, p.12). For instance, driving a toy car around the house gives them some sort of control because they are the one behind the wheel. Also, there may be a certain desire to imitate an adult that the child might have seen driving. A colorful moving object is more likely to catch the attention of a child as opposed to something dull and stagnant. This particular strategy is applied in today's amusement parks, with the merry-go-round and other sorts of colorful, fast-moving rides. Another method employed by the amusement park to lure children, which has proven to be very viable, is their ability to mix fantasy and reality. This tends to stimulate children's curiosity; Disney World is a good example of this.

Another way of attracting a child is to create a tempting target (Holt, 1967, p.20), for example, making your cheeks into a swollen ball filled with air will most naturally lure a child to want to slap it in order to release the air. This is otherwise known as a cause and effect game (Holt, 1967, p.33) and is always bound to attract the attention of children. However, while providing children with these dynamic toys, it is important to be careful not to scare them away by exposing them to devices that make very loud noises or move very quickly, as these often tend to stunt the child's learning process by making them less curious.

In conclusion, there is no point in getting a child to learn something today that will be forgotten tomorrow. Therefore, it is always important to provide interesting activities in which they can independently participate and with which they have somewhat deferred success (Holt, 1967, p.26). This simply means that even though the task is simple enough, it should not produce an immediate answer. The harder a child works at a task, the more knowledge they tend to retain. Retention is also increased by using multisensory approaches to learning, in which information is obtained through more than one sense. When information takes these multiple paths into our brains, it is retained better. For example, when something is both seen and heard, it is retained far better than if it is only seen or only heard (Setley, 2001). Therefore, it is advisable to keep in mind that, whenever working with children, the easiest way to help them learn is to engage them in vivid, vital, and pleasurable experiences (Holt, 1967, p.ix).

2.3 Museums and Exhibits

Of course, at a most fundamental level, our project involves a museum. In our literature review, we have researched many aspects of museums, including their general purposes and how these purposes are accomplished, as well as many concepts involved in exhibit design.

2.3.1 Fundamentals of Museums

Science museums are learning institutions. They exist as places that educate people and facilitate self-education. Children's science museums comprise a specific subset of science museums that aim to provide such a resource for children. Specifically, they try to focus on topics that children can both enjoy and understand. Furthermore, such museums often attempt to foster a general curiosity about science and nature in children so they may be motivated to learn more beyond the walls of the museum.

Another goal of museums is embodied by "New Museology," a movement towards viewing museums as tools for societal change, with education as a means of social-improvement (Hauenschild, 2000, section 1). In children's museums, this can be manifest in exhibits that seek to promote knowledge about public issues. These exhibits allow children to become better equipped to make informed decisions about such issues in the society around them (Schauble & Bartlett, 1997, p.782). Another way for a museum to focus on society in addition to pure education is to relate its exhibits to its specific locale. The Stephen W. Hawking Science Museum in San Salvador, for instance, has exhibits on flora and fauna native to El Salvador as well as inventions and other displays specific to the country (Komar & Buechner, 2000, p.144).

Museums often have to strike a fine balance between entertainment and education. Both are necessary for a proper, functioning museum. Without entertainment, the museum will attract few visitors, and it will fail to accomplish its goals to any large degree. The opposite extreme, an entertaining museum that lacks any educational value, fails similarly. There is often a conflict between museum curators' viewpoints and those of the visiting public. Museum professionals often view entertainment as far less important than the education, while the visitors themselves come mainly to be entertained (Belcher, 1991, p.64). Belcher also points out that some people are entertained by the act of learning itself, though they are probably a minority. Maximizing both entertainment and education is best, but it is difficult to create exhibits that combine the two.

2.3.2 Exhibit Design

One of the primary focuses of modern exhibit design is interactivity. Two phrases used to describe this are "hands-on" and "minds-on" (Russel, 2001, "Designing for Play"). The most effective education occurs when people are actively involved and taking part in their learning, instead of passively learning by simply listening or reading. Geoff Nelson (telephone interview, 12 April 2001) advocates "learning by playing" and "learning by doing." He emphasizes that learning should happen on its own, a consequence of the children's interactions with the exhibit as opposed to a forced activity. He gives an example of a child playing in the streams and puddles on a rainy day. By splashing around, channeling streams, and otherwise having a good time, the child is inadvertently learning about fluid dynamics and various properties of water. The value of interactivity is best captured in the old adage: "I hear and I forget. I see and I remember. I *do* and I understand" (Belcher, 1991, p.66).

Nelson (telephone interview, 12 April 2001) also places a lot of emphasis on making exhibits "open-ended," or approachable from many different viewpoints. One can maximize the value of an exhibit by leaving it as open to the visitor's interpretation as possible. This makes it possible for someone to learn multiple things from one exhibit, and it allows people of different ages to interact with it in different ways. For example, a pendulum exhibit that traces its path using dropping sand is a source of intriguing patterns and motion for young children. Older children and adults, however, will attempt to affect the pattern by varying parameters of the pendulum's motion or they may time the pendulum's swings and make observations about that.

Exhibits that are simple are much stronger than complex ones (Nelson, telephone interview, 12 April 2001). Simpler exhibits are less expensive, more robust, and easier to repair. This all translates to lower costs for the museum. Simple exhibits are also easier to use. If an exhibit is self-explanatory, a visitor can simply walk up to it and start using it. Nelson (telephone interview, 12 April 2001) states that hardly anyone reads signs, and Lynn Corona (personal communication, 13 April 2001) recommends against verbose labels, saying they may scare people away. If an exhibit is self-explanatory, it needs little labeling, if any.

Related to the idea of simplicity is that of using familiar objects in the exhibit (Nelson, telephone interview, 12 April 2001). An example is the funnel used in a sand pendulum exhibit. Funnels are common items, available from any hardware store. They are far less expensive than custom-machined parts, and it is very convenient to be able to make a trip to the local hardware store instead of ordering a part from a machine shop if a part needs to be replaced. Familiarity also helps engage children. A child may see a funnel and think, "We have one of those at home!" They will feel more comfortable with familiar objects and may even be inspired to create something similar at home.

One of the most important things to consider while designing an exhibit is safety (Nelson, telephone interview, 12 April 2001). Each child's innate creativity, multiplied by the large number of children who may visit an exhibit each year, leads to children inevitably discovering new, unintended "uses" for exhibits. It is hard to predict how children will interact with an exhibit, so changes must be often made to the exhibit after observing children using it for a while. Some things can be considered and avoided in the early design stage, however. Sharp edges and corners should be minimized, for example, and if they are necessary, one should be sure to place them in low-traffic areas and away from areas where children may run or otherwise be more active. Simple things such as magnets and lasers have well-known risks that can be minimized by limiting how an exhibit may be manipulated and by placing prominent warning signs to inform visitors of simple precautions they should take.

Cost must also be taken into account. Nelson (telephone interview, 12 April 2001) says that most of his exhibits cost about $500, on average. This value includes all parts and materials, but not his time and labor. A similar exhibit ordered from a catalog could cost two to four times as much. Corona (personal communication, 13 April 2001) states that exhibits may cost from $125 to $450 per square foot, depending on the level of computer technology, materials, and general complexity of the exhibit.

A topic of more general importance is the layout of the floor space. It is important to remember that there is a limited area to work with. Not only does it need to contain what is being presented, but also it needs to allow the visitors to easily move through the area. One of the best ways to explore this is to create a layout of the area either on paper or in a scale model and consider what might happen as people pass through (Witteborg, 1991, p.5). Using this technique, a display designer will be better able to create the best visual arrangement and visitor flow plan.

Also important to the flow of visitors is considering if any of the displays will draw extra attention. If so, they should be given adequate space so that passageways around them are not blocked. As a general rule of thumb, it is a good idea to leave at least 8 feet of open space between displays to allow free circulation (Witteborg, 1991, p.10). Due to the audience that we are expecting, specifically children, we need to consider that they might be running or gathering around a display. For this reason, it is especially important to allow a good amount of space between the displays.

For many exhibits, it is important to consider the position of the power supplies. These are important when lightning is needed or if the actual displays need electricity. Fortunately, due to the excellent natural lighting of the room, we will most likely not need to have any additional lighting. Secondly, because the exhibits are mechanical and generally simple, most will not need power supplies at all.

Lighting and color are important aesthetic elements of successful exhibits (Witteborg, 1991, p.15). While there are no rules to follow when choosing colors, it is important to try to set an appropriate mood. For children, it is generally better to use bright colors to attract their attention and create a pleasant environment. Likewise, bright lighting may be necessary to bring out the colors and to adequately illuminate any labels for reading.

Once people are drawn to a display, they should be learning something if it is intended to be educational. To accomplish this, the displays must have explicitly labeled objectives. This is best accomplished using 72 point font for the display signs to maximize visibility (Witteborg, 1991, p.88). While this will minimize the number of words that can be used, it will also make it more likely that the sign will be read. So if an important concept can be communicated in a few words, large font should be used. It should also be noted that often times people will not fully read long display signs, especially if they are in small print.

Finally, the actual materials used for construction of the exhibit must be considered. Though it will depend on the funds available, it is strongly encouraged to use good materials for the displays, even if at greater cost (Witteborg, 1991, p.30). This will enable the exhibit to last longer and require less maintenance. On the other hand, using less expensive or already available materials will help reduce the cost to the builder. This is an important decision that needs to be considered by the institution building the exhibit. In the case of the interactive mechanics exhibits, however, durability is an extremely important issue, and high quality, industrial-strength components are recommended.

2.4 Specific Museums

2.4.1 Children's Museum of Indianapolis

One specific example of a children's museum is the Children's Museum of Indianapolis (Schauble & Bartlett, 1997, p.781). The ScienceWorks gallery is devoted to educating children about science. The museum staff employed some innovative ideas in its design. The first of note is the "Funnel Approach" to gallery design. This approach to layout results in a wide variety of small "entry-level" exhibits that cover a broad range of topics. Following those are areas with successively more in-depth and more focused topics. The deepest and narrowest levels are "discovery labs" where children can work hands-on with the concepts that may have been touched upon by the broader displays. Another part of this plan suggested that the entry-level material should be cumulative in nature. It should add slowly onto existing knowledge instead of presenting entirely knew ideas, as this will be more easily learned.

2.4.2 Museum of Science, Boston, Massachusetts

Another example of a science museum is the Museum of Science in Boston, Massachusetts. Specific to our topic, mechanics is displayed at the Boston Museum of Science in the "Science in the Park" exhibit, a large area themed as an outdoor, park-like space. The various displays deal with mechanics, forces, motion, etc. The layout is somewhat haphazard; some displays are located freestanding in the middle, while others are flush against the wall. However, they are far enough apart that movement between each is not difficult. None of the displays is static; every single one involves its audience (generally a single person or group) in some way. This fulfills the entertainment aspect of the exhibit quite well, as children are seen enjoying themselves as they run, swing, jump, or even just build, at all of the sites. Some displays involve more activity than others; a lever demonstration has children pulling on ropes, while a "build your own mobile" display is more intellectual. They all have important concepts to convey, with clear labels located prominently near each.

Some displays do not appear to be educating the children, however. One in particular involves running at a constant pace with a light and bell that moves along a wall. Children run back and forth, clearly enjoying themselves, but they pay very little attention to the cues, and it was clear that they did not know the point of it at all. This is a fine example of how one must be careful of entertaining at the expense of education.

One positive feature about the Science in the Park exhibit is that it does not need to be supervised by museum staff. Each display stood on its own with no need for direction or guidance by a museum worker. Some were entirely self-explanatory, such as the pressure-sensitive pad on which children could jump and see the pressure spikes immediately displayed on a computerized graph. Most others were clearly labeled and simple enough that a child could understand what to do with simple direction from a parent or chaperone.

2.5 *Mechanics*

Because we designed an exhibit to educate children about mechanics, it was important to determine the main ideas contained within that broad label. These ideas, covered in any introductory physics book, include such basics as the concepts of force, momentum, and energy. These fundamental concepts are then used to build up others such as gravity, friction, and the various conservation laws. Another essential topic of mechanics is the basic devices humans have created to simplify mechanical work, often called simple machines. David Macaulay (1998, p.7) lists the following: inclined planes, levers, wheels and axles, gears and belts, pulleys, and screws. In the next section of our literature review, we have found many excellent examples of demonstrations of these principles of mechanics.

2.6 *Specific Exhibits*

One demonstration of conservation of angular momentum is given in *Making Things Move* (Ardley, 1989, p.27). One holds a bicycle wheel upright with the axle in both hands and someone else spins the wheel. Once it is spinning, rotating the axle of the wheel in various directions will appear to push or pull the axle in strange directions. The unusual force that is felt is caused by conservation of angular momentum, which causes the force on the axle to act at right angles to the direction that it was rotated.

Making Things Move (Ardley, 1989, p.26) also has another example of conservation of angular momentum. A person starts by sitting in a revolving chair while a friend spins her in a circle. She keeps her arms and legs sticking out while being spun. Then, she pulls her arms and legs toward her body and feels how she starts spinning faster. This happens because the speed at which an object rotates is dependant on its diameter. The smaller the diameter, the faster she will spin.

A screw can be used for many purposes, but one of the most interesting is its use as a pump (Vogel, 1998, p.288). A device generally referred to as Archimedes' Screw can be constructed by coiling a tube around a pipe in a spiral shape. When one end of the pipe and tube are placed in a liquid, rotation along the pipe's axis will cause the liquid to be carried up the tube. It uses simple rotational energy to move liquid up an incline.

The mechanical advantage of levers can be easily demonstrated on a Teeter-Totter (Gardner, 1999, p.100). This idea consists of a beam resting on a pivot with multiple places to sit on each side of the beam. Depending on where the people are sitting on either side, it will be easier or harder to lift the weight on the opposite side. The closer a person is to the end of their side, the easier it will be to lift something on the opposite side of the pivot.

Tryggvason (personal interview, 3 April 2001) suggested an exhibit utilizing a hydraulic lift. Hydraulic lifts work by transferring a force applied to a large area of liquid to a smaller area, effectively amplifying the force. An exhibit could be constructed with two plates of different size, each above a reservoir of liquid. The reservoirs could be connected with clear tubing. Pushing down the larger plate would cause the smaller plate to move further, though with less force. Likewise, children could lift large objects by placing them on the large plate and applying a small force to the small plate.

Keil (personal interview, 12 April 2001) had many excellent suggestions for possible exhibits. One involved the use of a pendulum. Visitors can use pendulums to time oscillations, observe the direction of the oscillations and how they change, and learn a little about how the Earth rotates about its axis. Variations on this idea for children would be to have the actual swinging object be filled with sand and a small hole in the bottom to release a steady stream of the sand. As the pendulum moves back and forth, the children can make designs with it. This exhibit can promote learning through experimentation by allowing the children to vary the distance that the pendulum swings among other things.

Keil (personal interview, 12 April 2001) also suggested the topic of collisions. In addition to the fact that children love to watch collisions, they can provide a good learning experience about force and momentum. A simple exhibit would consist of cars on a single track that is about 5 feet long. The cars could be made heavier or lighter with the addition or removal of weights. Also, the cars could have interchangeable bumpers made of rubber, wood, or metal. The children could then slide the cars at each other and see what happens during the collision. They could also learn about how different masses and contact surfaces affect the result of the collision.

Keil (personal interview, 12 April 2001) suggested another exhibit involving collisions, Newton's Cradle. In this exhibit, a number of balls or other material could be hung from strings in a manner that they all line up with their sides touching. If an object on the end is pulled back and released, the momentum would transfer through the objects when they collide and the last object on the other side would be pushed in the air. An advantage of this exhibit would be that it is very interactive, and it could further explain the concept of collisions.

Keil (personal interview, 12 April 2001) also had a great idea about the use of springs. He said that in the San Francisco Exploratorium museum, there is an exhibit consisting of a chair suspended by a large spring. A child can sit in the chair and swing not only up and down, but also side to side. In this way, the children might learn about how springs bend and stretch as well as investigate concurrent oscillations in more than one dimension.

Pulleys were another idea mentioned by Keil (personal interview, 12 April 2001). A good exhibit from the Exploratorium has a chair that a child can sit in with a rope attached to it. This rope can be passed through a system of pulleys and back down to let the child lift him/herself and the chair a few feet off the ground. Another setup without the multiple pulleys could be right next to it, displaying the mechanical advantage that pulleys provide.

The use of levers was a topic that Keil (personal interview, 12 April 2001) felt was important to teach. He said this might be done using the nuts and bolts of a car tire. Wrenches with different length handles would be provided and the children could try to tighten or remove the bolts. This would help to demonstrate the advantage gained through levers. It is also a concept that they are likely to remember as they see family members or others change a car tire.

2.7 Methods

2.7.1 Surveys

Surveys are used to determine the characteristic behavior or opinions of a particular population (Salant & Dillman, 1994, p.10). In most cases, the purpose of a survey is to obtain information from a small portion of a population and to use that information to describe the characteristics of the entire population. The accuracy of the results is improved by surveying a larger percentage of the population. It is important to make sure that the survey is well distributed among the entire population and not concentrated in a particular sample. The sample must be as random as possible to avoid any sort of biasing of the results.

Before doing a survey, it is important to determine what the problem is and what new information is needed to solve the problem; this will help in creating the right type of questions in a survey. However, if the questions are not precise about what information is required, the responses can turn out to be vague, biased, or not really critical to solving the problem. People are also turned off by long and time-consuming surveys, so it is essential to keep the number of questions small and the length of the questions short. Questions should be checked carefully to eliminate any elements of bias that could influence the respondent's answer. In addition to checking each question for these elements, surveys should be tested with a small group of people to test their efficiency and catch typos or other small errors.

There are three types of surveys: mail surveys, telephone interviews, and face-to-face interviews (Salant & Dillman, p.33). Factors that affect what type of survey to use are the number of people available to work on the survey, how much time they have to produce results, and, most importantly, the budget.

2.7.2 Interviews

Interviewing is the process of conversing in order to gather information (Berg, 1989, p.66). As with surveys, interviewers should go into the interviews with a clear understanding of the purpose of the interview and what information he or she is trying to obtain. This should also be communicated to the subject of the interview before it begins. Whenever interviewing, it is always important to take notes while the information is being conveyed, so as to avoid forgetting the core of what was said during analysis of the interview. If the interview is to be conducted over the telephone, it is in the interviewer's best interest to ask the subject specific questions that are simple and short in order to avoid getting negative responses (Berg, 1989, p.83).

The interviewer should always be properly dressed for a face-to-face interview. He/she should be aware of his/her audience and have respect for them at all times by not interrupting their sentences and allowing them to speak fully. The interviewer must assess the way a subject tends to answer questions and adjust his/her pace to best match it (Berg, 1989, p.98). The interviewer should never show up late to an interview and always thank the subject when it is over.

Interview data is often analyzed with various techniques of content analysis, applying coding schemes to notes or other data to make them more compact and easily comparable (Berg, 1989, p.238). Essentially, the researcher chooses a type of textual element and counts individual elements of the chosen type as they appear in the data. The elements can be of many types, including words, sentences, paragraphs, themes, or concepts. For example, a researcher may chose to count concepts in interview notes, which would involve tallying how many times certain concepts appear in those notes. Once the data has been tabulated, patterns and relationships are more apparent and it becomes easier to test hypotheses. The success of this method increases with the verbosity of the notes being analyzed, how detailed the notes are, and how close they are to exactly what was said. Because of this, verbatim interview notes transcribed from an audio or video recording are best.

2.7.3 Observation

There are no pure observations (Rachel, 1998, p.85). Every observation made is biased in some way, because people's perceptions depend on the theories that they already hold in their mind about what they are observing. Therefore, it is always a good idea to have different people observe the same object, person, or thing. "Triangulation" is, as its name implies, the use of multiple lines of sight to get a better fix on the object of study (Berg, 1989, p.4). With observation, for example, this can be accomplished by having multiple observers for a single subject. By comparing and contrasting the results of multiple observations by different people, their individual biases can cancel out, leaving a more unadulterated record. There is no way to know which biases are stronger, so the best one can do is take an average of the results of the different points of view. However, if the magnitude of the discrepancies between observations is too great, they should be examined closely to determine why that is the case, as that indicates possible errors in data collection.

Berg (1989, p.155) lists four general steps one should take while observing: Taking in the physical setting; Developing relationships with inhabitants; Tracking, observing, eavesdropping, and asking questions; and Locating subgroups and stars. Learning about the physical setting involves wandering around the area in which the observation will be done, generally to get an idea of how to best cover it. Developing relationships with the inhabitants is often best accomplished with the help of "guides," people who are familiar with the area, and in the case of the museum this will be done with the actual museum guides. The actual observing, the main focus of this method, is relatively self-explanatory, and consists of following guides, watching, listening, and asking questions. Finally, it may help to find individuals who seem to have more access to others, the "stars" of the group, as access to them often implies easier access to the rest of the group.

The observer should always be fully alert during the time that he/she is observing and should record and take notes while observing. There is no single way to take notes, however (Berg, 1989, p.158). One can wait until after the observation and immediately write complete notes then or take simple notes during observation to be written more completely later. Notes can be spoken into a tape recorder, recorded with a video camera, written on notepads or quickly jotted down on note cards, or even typed into laptops. One thing that is especially important is that notes must contain the date, time, and place of observation. Berg (1989, p.160) gives five simple guidelines for effective note taking: record key words and key phrases while in the field, make notes about the sequence of events, limit the time you remain in the setting, write the full notes immediately after exiting the field, and get your notes written before sharing them with others.

The observer should try not to intimidate any live specimen that he or she is observing whether it be a small animal or a person. It is always best to carry out an observation without the live specimen knowing to avoid what is known as the "Hawthorne effect." This states that if a subject knows it is being observed, it may become self-conscious of its behavior and thus act differently than it would otherwise. Berg (1989, p.147) gives many strategies for "becoming invisible." The most relevant to this project are "Disattending: Erosion of visibility by time," and "Misrepresentation: Masking identity as ethnographer." The first, disattending, involves being around subjects for long enough that one becomes "part of the scenery." This may work best with children, as they have short attention spans and may quickly lose interest in the observer. The second strategy, misrepresentation, can be accomplished by pretending to be visiting the museum and not overtly watching the children and taking notes.

3 Methodology

3.1 Project Verification

Our very first task, completed during the first few days of work at the museum, was to verify that our thoughts about the project matched those of our liaison and sponsor. We met with our liaison on the first day to discuss our general plans. Later, we gave our formal presentation of the project proposal to communicate those plans in more detail, obtaining valuable feedback from our sponsor in the process. This was vital to ensure that we started out on the right path.

3.2 Physical Survey of Museum

One of our initial tasks was to acquaint ourselves with the museum itself. We took a brief guided tour of the entire museum and later explored it individually at various times. By doing this, we learned more about the general style of the museum, how exhibits are laid out, what sort of labeling is used, the materials and construction of the exhibits, color schemes, and much more. This helped us design the new exhibit to fit into the current museum as much as possible.

Also included in our physical survey of the museum was a detailed inspection of the area designated for the new exhibit. Most importantly, we appraised the overall shape and dimensions of the room both by direct observation and by looking at floor plans. This information was essential to the design of the exhibit, as we needed to know how many individual displays could fit in the area. We also made note of installed lighting, the locations of windows, existing furniture or other structures, and the current state of the floor, walls, and ceiling. This was necessary for determining how much pre-existing material (lights, paint, flooring, etc.) could stay and what had to be changed or replaced.

3.3 Museum Visits

We visited a number of other museums in San José, namely the Gold Museum, the National Museum, and the Museum of Criminology. By visiting these museums, we learned more about museums in general and got additional ideas for the presentation and layout of our exhibit. It was useful to note any differences between museums in the United States that we are familiar with and museums in Costa Rica. Because of the non-interactive nature of these museums, our data collection was limited to passive observations. During the visits, we slowly walked through each area and recorded what was observed. By having multiple people record information separately, we were able to obtain a more comprehensive list of observations at the museums. We looked for a variety of topics that could help in designing the layout of the mechanics exhibit or to generate new ideas. One thing we looked for was how displays sharing a topic or theme were clustered. We were interested in the amount of space between displays and how well it accommodated the number of people there. Also, we wanted to see how the displays were labeled. We wanted to learn more about what are the best methods to present information effectively and briefly, through labels. To accomplish this, we tried to read the labels and see if the information was short and informative. We also watched other visitors to see if they bothered to read the display labels at all. In general, we looked for any more ideas that could possibly be used for building or creating a floor plan for the mechanics displays.

We each recorded our personal observations about the museum on notepads. Before starting, we decided to take notes on as many features of the museum as possible and then compare notes afterwards. In this way, we would be more likely to have data or ideas that could help our project. We checked for similar notes on the previously noted topics and tried to find useful information. We looked over each other's notes to remember what we saw or did not notice and to generate useful feedback about the museum visits. Anything contained in our notes that pertained to the topics of interest was considered important. We discussed what was found and tried to generate links to how it could be used when designing the mechanics exhibit. This was done in an open conversation regarding the contents of the notes and through brainstorming.

3.4 Survey of Museum Guides

To learn more about the current exhibits in the museum, we administered a survey to the guides. The guides work in the museum with the exhibits and the children together, so they were an excellent source of information about both. The survey consisted of five open-ended questions, asking them to tell us which exhibits attract children the most/least, at which exhibits do the children spend the most/least time, and which exhibits require the most maintenance. In addition to simply requesting the names of exhibits, we asked for explanations of their responses, as well. We also provided a space for any additional comments and asked the respondent to write his or her name if he or she were willing to be interviewed by us later. This format enabled the respondents to give us recommendations we had not thought of, stimulated creative thinking, and left room to obtain more information than simple multiple-choice or more limited questions alone could gather. We used a survey because it would be the best way to gather the information we were looking for from such a large group of people.

We drafted and finalized the survey in English, but we had to translate it into Spanish, as the majority of the guides spoke no English. We tested the questions by showing them to our liaison, who gave us helpful feedback that was incorporated into the survey. Our liaison told us that there were approximately 42 guides, so we printed fifty copies. With arrangements made through her, we administered the survey during the guides' "day off" to a group assembled in a very informal meeting. This was a day on which they still came to the museum, but it was more relaxed, and they did not have their regular duties. We first briefly introduced ourselves and explained our project and the purpose of the survey through a translator. We then handed out the survey and a few pens and pencils for those who had none. They filled out the surveys immediately while we waited. After they finished and we had collected everything, we thanked them and left. We ended up with 44 completed surveys.

We tabulated the data by counting how many times each specific exhibit showed up in a response to each individual question. We could then see what percentage of the respondents thought that each exhibit was most attractive, least attractive, and so on for all five questions. This allowed us to focus our attention on these specific exhibits to determine why they either succeeded or failed.

Any explanations given by the respondents were noted. Ideas were roughly weighted by how many times they showed up in the responses to indicate trends and patterns. These were all kept as suggestions to be considered when designing the exhibits.

See Appendix B for the full survey, including the Spanish translation that we gave the guides.

3.5 Interview with Head of Maintenance (Leonardo Sánchez)

One of the main problems with designing exhibits for a children's museum is that they will face a level of abuse and misuse that is not typical at other types of museums.

Because we proposed highly interactive displays for children, we wanted to ensure that they were constructed with strong materials in a manner that ensured long lifetimes. To assist in deciding which materials we should use and which to avoid, we interviewed Leonardo Sánchez, the head of maintenance at the museum. Mr. Sánchez has been working at the museum for 9 years, since 1992. He was originally an assistant to the chief engineer during the renovation and remodeling of the site, and when the museum opened in 1994, he became the chief of maintenance. As he has been at the museum for the entire time it has been open to the public, he is the most knowledgeable person with respect to the maintenance and upkeep of the exhibits.To conduct this interview, we used a semistandardized approach. We used this method because it allowed us to prepare questions beforehand that could open the discussion to the topics we wanted to cover, while still allowing us to ask for more detail and further explanation of anything he might have brought up. We also finished the survey with a general question asking for any more information he believed might be useful to us, as a way to be sure that we got as much information as possible. We asked him about what, in his experience, has proven itself to be most durable, as well as what has been least durable and required the most maintenance. We asked about both materials and exhibit designs and mechanisms. In addition to this, we asked about how exhibits are currently repaired and how parts are obtained. The full list of questions is available in Appendix C. The interview was analyzed by comparing and contrasting the ideas gathered with those from other sources. It was used mostly when analyzing exhibit materials and construction, though other topics were touched upon as well.

3.6 Interviews with Teachers

A very large portion of the visitors to the museum is comprised of schoolchildren between the ages of four and twelve years old, brought by their teachers. These teachers are a valuable source of information about how their students learn and what they know. We determined that it would be easiest to interview them when they visited the museum with their students. However, for most of the time that they are in the museum, they need to be watching the students. For this reason, we interviewed them while the students were in the Children's Rights exhibit, which is a video that the children watch in a small theater. This gave us approximately ten minutes during which the teachers were free to be interviewed.

Due to the time constraints, we decided to use a standardized interview. The interview protocol is contained in Appendix D. With each teacher, we simply explained our purpose, and then went through the list of questions, recording their answers. If we had more time, we could have gone into more depth, but this was out of the question, due to the logistics of the interviews.

With the help of a translator, we interviewed five teachers with students from ages 3 to 11. We took simple notes of each answer given. As with some of our other data, we did no systematic analysis of the responses, but simply read them over and looked for any new ideas. Most of their responses were ideas we already had, which helped reinforce what we already knew. The few new ideas were kept in mind for the design and recommendation stage.

3.7 Prototypes

To better understand what would make the most successful exhibits for the museum, we created and tested exhibit prototypes. They were used to examine three important guidelines of designing an interactive, educational display for children. The first guideline is that the material being taught has to be presented in a manner that a child can understand. The second is that the learning should be done in a fun and interactive way. The third is that the exhibit has to be self-explanatory. By testing several prototypes of our display ideas, we were able to see if what we were designing would be consistent with these guidelines.

The first step of building the prototypes was to decide which principles we desired to teach. We wanted to use very fundamental mechanics concepts, but we also needed to be able to build the prototypes. This meant that we had to consider practical constraints, specifically time, money, and materials. We reflected upon the poor success of the museum's old mechanics displays about pendulums and angular momentum and decided not to use these concepts for the new prototypes. We then thought about some of the displays that we had seen in the Boston Museum of Science and discussed what Professor Keil had said about children loving collisions. From these factors, we finally decided upon two concepts to teach and designed prototypes to teach them. One involved using the mechanical advantage of a fulcrum to show how levers make lifting heavy objects easier. The other design showed conservation of momentum through toy car collisions. Detailed descriptions of the prototypes are given in Appendix D.

In addition to using prototypes that we built, we also incorporated the museum's two remaining mechanics exhibits into the same investigation. We did this to broaden our base of exhibits in the study, offering some exhibits that we knew had failed as counterexamples to our more successful designs. In this way, we could further explore the characteristics that make a display a success or failure.

One of the failed exhibits consisted of a rotating chair mounted on a platform. A bicycle wheel, with handles on the axle, is spun quickly. The spinning tire is then passed to the person sitting on the rotating chair. As the axis of the tire is changed, the chair is supposed to rotate. The second existing display is based upon the effect of weight on a pendulum. This is a more complex exhibit that requires the visitor to read the labeling to understand how it works and what it teaches.

The methods that we used to test the old, failed exhibits were different from those we used for the prototypes. Over a period of two days, we had six groups of children and two groups of adults, totaling approximately 185 people, gather at the old displays. We then asked them to play with them as they would other museum exhibits. We allowed a few minutes for them to explore the displays and recorded what they did during this time. We were specifically looking to determine if the children knew how to properly interact with the display. By observing their interaction and taking notes, we could determine if they were following the directions given on the display labels. We assumed that they would not read the label, and we wanted to verify that this was correct. By doing this, we could learn how important it was to make a display self-explanatory. Next, we showed the children how to properly use the display and then gave them another minute to play with it. We felt that one more minute was enough time to adequately interact with the display. We then asked them about what they thought the display was about. We expected no answers, but we waited a minute to see if any volunteered information.

Next, we asked them if any understood what the display was teaching. We finally recorded their expressions and responses, or lack thereof. If no children responded, we assumed that the old displays failed to educate them. This would also verify what we have already been told by our liaison and other staff members regarding those displays.

When building our prototypes, it was important to remember that we were designing them primarily for children. Though teachers and parents might also have interacted with the exhibits, our primary concern was to be sure that the children learned. Because of this, we needed to consider factors such as their height and weight. The children that we observed at the museum appeared to be between about 3 and 4 feet tall and weigh between 50 and 100 pounds. These factors were important for the design and construction of each prototype.

We were told that the museum does not want to have any guides in the mechanics area, if possible, due to budget constraints. Because of this, we wanted to make our displays require as little supervision as possible. This meant that the displays needed to be self-explanatory, so that no staff member was needed to explain them. Another requirement consistent with the policy of minimal supervision is that each display must be as inherently safe as possible, even if used in an unintended manner. Therefore, we needed to keep the prototypes self-explanatory and safe in addition to fun and educational.

After setting up the exhibits in the museum itself, we stopped groups of children as they came through our area. As they initially approached the prototype area, the guide had them all sit down in front of the lever display. He told the children that we were testing out a new display and wanted their help to determine if it was "good." He asked them which of the levers with blocks of equal weight would be easiest to lift. He then asked them to raise their hands for the correct answer as he pointed at the two levers, one at a time. We counted their raised hands for each answer. We would like to mention that we previously discussed with the guide the risks of leading children to an answer by the way a question is asked and the tone of voice used. He said that he understood and would make sure to ask the questions in an unbiased manner.

Though children will sometimes raise their hands in a group regardless of the answer, our guide did tell the children to make sure that they raised their hands for only the answer that they thought was right and not what their friends thought. We checked to see if this was effective by having the guide randomly question a child from each group about why he or she raised their hand for that choice. This was done to ensure that they were not just going along with the crowd. If the child gave a reason, regardless of if it was correct or not, we could be confident that they answered honestly. If they responded that they were not sure, this might imply that they had just answered like their friends. The guide then asked a few children to come up and play with the display. He did not explain how to use it, but we simply watched as they interacted in front of the other sitting children. While this did not allow every child to play with it, the guide told us that this method was used at some other displays in the museum and the children were used to it. The reason he gave for this method was time constraints.

The museum works by having the children follow a set path through the different exhibits, and if we allowed time for each child to play, we would be disrupting that flow. Therefore, we watched the selected children interact with the display to see if they used it properly. If so, we knew that the exhibit was sufficiently self-explanatory, an important characteristic of successful exhibits. If they did not know what to do after a minute, we would tell the guide to help show them how to use it, though this was not needed. We then observed them while they were using the display. We noted how much they were enjoying it, indicated by smiling, clapping, cheering, and obvious attempts to get to the exhibit to play with it. In observing their reactions, we watched as many individual children as possible, as well as the general reaction of the group. One possible consideration was that the children might have seemed to be enjoying themselves due to the reactions of other children or that they liked the guide. While we could not discount these factors, we do not think that they invalidate the point. We wanted to see if the children were having fun while playing with the prototypes. Though we could not distinguish between if the children were having fun with friends or due to interacting with the exhibit, we were primarily concerned that the displays created a fun environment to learn in. We could check to see if this happened by looking for consistency between the different groups. If most or all the groups of children were having fun, we felt that would mean we were successful in creating that environment. Another method we used to gauge their interest was to look for how attentive they were. We did this by noting how much they were talking to their fellow students or looking at the exhibit itself. The more they stayed focused on the display, the more successful it was in entertaining them. Finally, we watched for any unforeseen safety issues that might arise.

In addition to observing the children interact with the exhibits, we wanted to know if they learned the mechanics principles involved. We did this by repeating the initial test, administered by the museum guide. We performed the test on the same six groups of children and two groups of adults that took the test before interacting with the display. In total, approximately 185 people were tested. Once again, this short interaction time was necessary to allow the children to continue going through the museum. We did not feel that a longer time period would change the results, except that more children would get to directly interact and have more fun. The question for the lever exhibit simply asked which lever they thought would be easier to lift. The question for the collision likewise asked which truck the children thought would move the most after a collision between the two. If the children learned something about mechanics, then a higher percentage would answer the question correctly the second time. This would indicate that we were successful in designing an educational exhibit. To combat bias of pressure to answer like their friends, the guide randomly tested individual children to be sure they were not just going along with the crowd. This was done by randomly asking one child from each group to explain why the display worked the way it did. In this way, we were able to check if that child had answered honestly. If we found that the randomly selected children had answered honestly, we feel that it reflected that most or all of the children did the same.

Now that we have mentioned what we are looking to learn from the prototypes and existing exhibits, we want to briefly mention some things that we were not interested in. First, we were not concerned with the durability and maintenance of the prototypes. They were made simply to see if they were successful in educating and entertaining the children. It should be noted that the final recommendation of exhibit designs to the museum includes information about durable materials and construction that will stand up to interaction with children. Another area that we were not very interested in was the visual appeal of the displays. While they were painted and made to look somewhat attractive, the final designs recommended to the museum have much more detail and are very colorful. These attributes make the designs look professional and also help to attract the children to interact with them. The main reason that we could not make the prototypes meet these standards was time constraints.

In summary, the main areas that we wanted to learn from the prototypes were: are the designs self explanatory, do they educate and do they entertain the children. As mentioned before, it is important for a design to be self-explanatory just by looking at it, because children will often not read signs to learn how to use it, nor will guides be present to explain it. Through the prototypes, we were able to see if at least some of the displays that we recommended were fulfilling this requirement. The displays need to educate the children to be of real value to the museum. By testing to see if the children were learning, we were able to see if we were designing exhibits that would satisfy this goal. While the project's main purpose is to educate the children, this will only work if they are attracted to the exhibits and are interested in them. We looked to see if the prototypes stimulated interest in the children to interact with them and if they liked playing with it. In this way, we tried to make sure that we followed the concept of teaching the children by letting them play. While we could not create prototypes for all the exhibits, we believe that the information \ obtained from the two prototypes and the two existing displays will be reflective of how we designed all of our recommendations. This is because we have tried to keep the same principles in designing them to be interactive, educational, and fun.

3.8 Collection of Exhibit Ideas

Developing a list of possible exhibits was an important part of designing our recommendations for the mechanics exhibit area. We used various research techniques to create this list. It was created with the aim of collecting as many ideas as possible, and so ideas were included without regard to whether they would be included in the final recommendations. We visited the Boston Museum of Science in Boston, Massachusetts and went to the Science in the Park exhibit where they have displays about mechanics for children. We recorded a description of all the displays present to start our list. We researched ideas in books about mechanics and children's museums. To find as many ideas as possible, we searched the Internet for children's museums to see of their websites listed exhibit ideas. We checked museum exhibit discussion boards. Our team also continuously brainstormed as we worked on the project to think of new ideas or expand on existing ones. From this list, we thought of variations of the displays to create even more ideas. The result of this collection was used throughout the project and is available in Appendix H, which is a list of all exhibit ideas.

3.9 Cost Determination

Our final recommendations include cost estimates for each individual exhibit. These allow the museum to estimate a budget for the construction of whatever exhibits they choose and provide them with some preliminary cost information to give to possible sponsors.

To determine the cost of each exhibit, we first needed to know what materials and parts went into its construction. To determine this, we enlisted the help of Jorge Chica, an exhibit designer recommended to us by our liaison. He is currently working for the museum, designing exhibits such as the new Dinosaurs exhibit. He previously worked at a children's museum in Colombia, and he has a great deal of experience in the field. We helped him understand how we envisioned each display by showing him sketches that we had created and answering any questions he had about them. Once he understood the design of each display, he developed the list of materials that we needed.

To determine the cost of each component, we took the list to Leonardo Sánchez, whom we had interviewed earlier about materials and durability. As the chief of maintenance at the museum, he has experience with purchasing parts and materials and was able to provide us with prices for the entire list we showed him. He also gave us estimates of the cost of labor for the construction of each exhibit. The full list of materials and costs is in Appendix J.

3.10 Value Analysis of Potential Displays

Because we had many potential displays for the mechanics room, we used a weighted value table to determine which were the very best. Essentially, this means that we chose a set of distinct qualities important for an exhibit and assigned each exhibit a score for each quality. We then calculated an overall score for each exhibit as a weighted average of its individual scores, giving more weight to the more important attributes. These scores were used to rank the exhibits and identify those that are more likely to be successful.

We determined the qualities used to score the exhibits as well as the relative weights assigned to each by referring to our literature review and analyzing the data collected in our research. From these, we established the following as the characteristics important for a successful exhibit: educational, interactive/fun, self-explanatory, low construction cost, low maintenance cost, and safety. In addition to scoring each exhibit on the basis of these criteria, we subtracted a small amount from the final score if the exhibit required a museum guide for proper operation. Furthermore, the analysis led us to settle on a set of weights for these attributes, shown in Table 3-1. This analysis is described in the Analysis chapter of this report.

Table 3-1: Relative Weights of Exhibit Characteristics

Educational	40%
Interactive/Fun	25%
Self-Explanatory	15%
Construction Cost	10%
Maintenance Cost	5%
Safe	5%
Guide Required	-1 from average of others (out of 10)

While ranking the exhibits, each quality was scored from 0 to 10, with 10 being the best score. To keep the scoring consistent in this respect, the two cost criteria were scored backwards, with higher scores indicating lower costs. As noted in Table 3-1, if an exhibit required a guide for proper operation, 1 point was subtracted from the weighted average of the other criteria.

To check to see if the value analysis was robust, we changed the weights. "Educational" became 55 percent, and 5 percent was taken from each of "interactive/fun," "self-explanatory," and "construction cost." We did this to see if the scores changed significantly if we placed more emphasis on education. If the overall scores did change a lot, we would then explore why changing the weight had such an impact. If little change was noticed, we could be confident that our analysis was robust and the weighting of the qualities was appropriate.

To minimize the effects of any personal biases for or against particular displays, we decided to use triangulation in scoring the displays. Specifically, each team member assigned scores independently, and those were then averaged to obtain final scores. In the cases where the individual scores differed by a few percent, we simply used the average as our final score. For exhibits that we disagreed on, when our scores varied greatly, we discussed our reasoning behind the scores. We did this to attempt to reconcile scoring differences that might have originated in a misunderstanding of the display when originally assigning the scores. If the original scores held, we still used the overall average, as this was the fairest method.

Finally, after we had settled on a set of final scores, we chose the exhibits that would be included in our recommendations. We decided to set a cutoff point at first. Exhibits above the cutoff score would be included in the recommendations, while those below would not. (All exhibit ideas have been included in Appendix H, however.) We chose to use the median score as the cutoff, at first. This automatically placed half of the ideas above the cutoff. We chose this point because it left us with an adequate number of exhibits for the final recommendations and because we agreed that it matched our own feelings about what should be included rather well.

We then investigated any exhibit within a few percent of the cutoff, both lower and higher. We wanted to see if there were any "injustices" in the scoring; that is, we knew that the scoring method was not perfect and it might exclude a few exhibits we felt were worthy of inclusion in our final recommendations. We could not incorporate every possible exhibit attribute in the scoring, nor could we find a perfect set of weights, so some fine-tuning was necessary. Reasons for any of these inclusions or exclusions are discussed in the Analysis section.

4 Results

4.1 Physical Survey

4.1.1 Museum

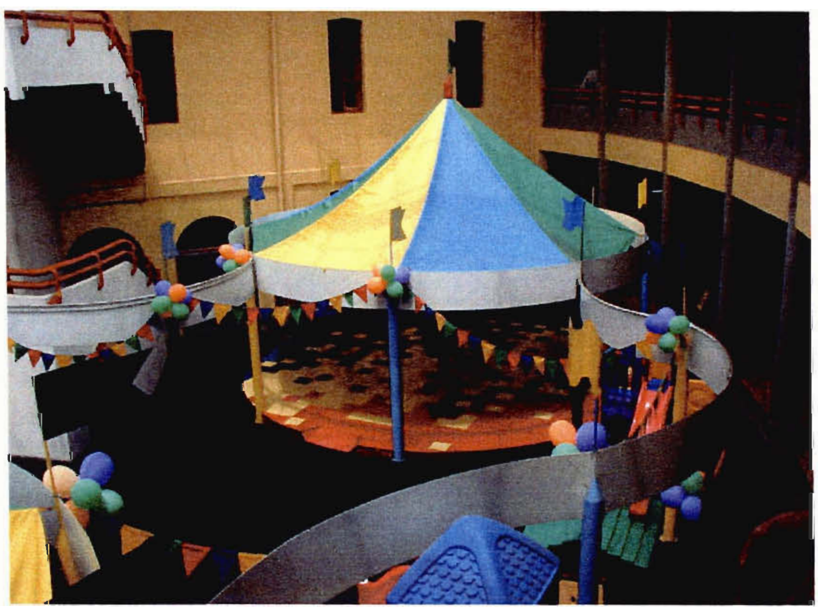
Our survey of the museum covered many of its aspects, including the size, layout, and exhibit specifics. During the tour of the museum, we realized that it is quite big. There are more than thirty exhibits spread out in different areas connected by long and spacious hallways. The actual exhibit rooms are separated into themes such as space exploration or the human body. This allows each display area to focus on educating the children about one specific topic. There is also a certain atmosphere present in each room. For example, the space room is very dark and has planets hanging from the ceiling. This creates the feeling of being in space and exploring the universe. The signs that explain the exhibits are usually brief with just a title and a few words. A few signs are longer with more information. The displays are always spread out so that they do not block the flow of traffic. In general, there is usually at least 6 feet of space between the different exhibits. The displays are mostly colored in bright, bold colors such as red, yellow, blue, or green. One observation worth noting is that there are guides present in each room. They explain how exhibits work, actively run several such as the earthquake table, and help teach the children about the material.

4.1.2 Assigned Room

One of the special features about the room for which we are designing the mechanics exhibit is its location. It is directly adjacent to the very center of the building and right at the entrance to the museum. For this reason, it will be seen by every child who enters the museum. Because of this, it will be of great importance to the museum. The space is currently rented out as a party room.

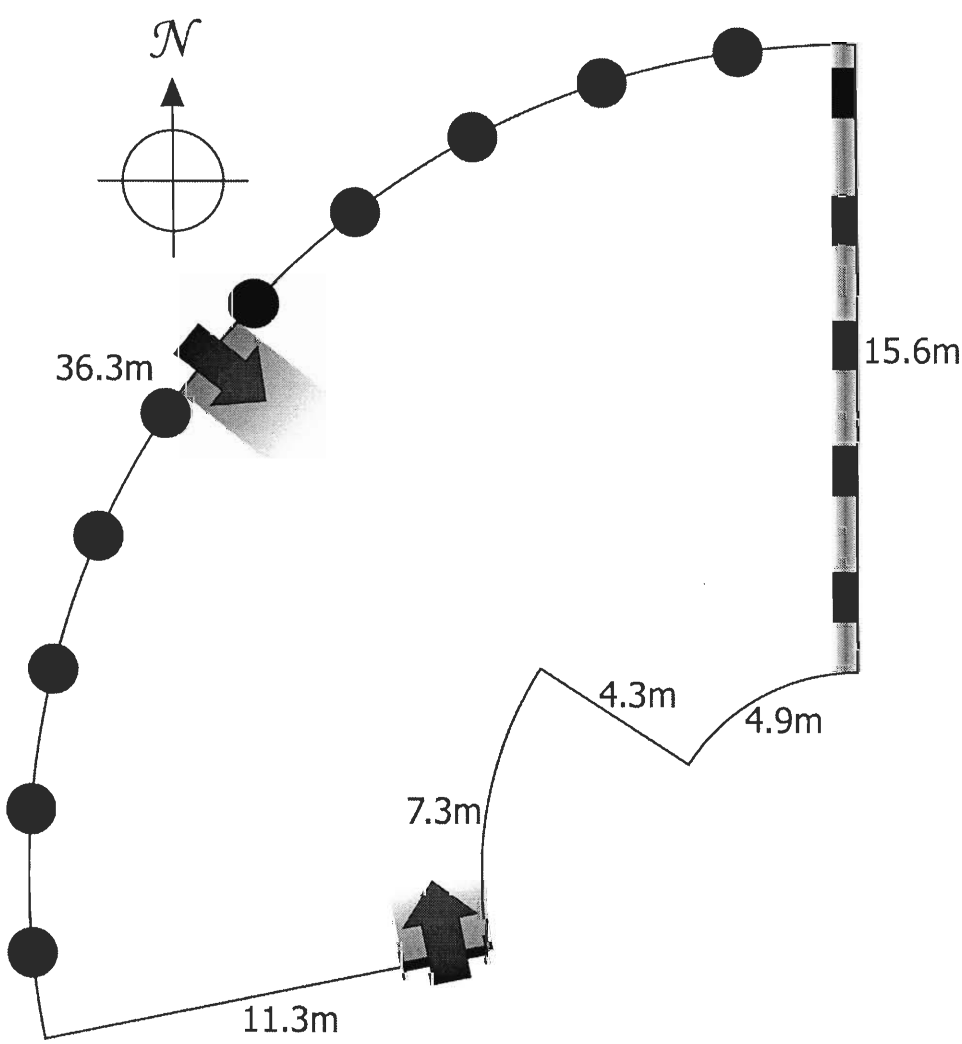
The room is currently in good condition. There are some structures present, pillars and tents shown in Figure 4-1, but we were told they could be easily removed if so desired. They take up floor space in a way that severely restricts placement of exhibits, and so their removal would greatly ease designing the layout and placement of exhibits. The floor is a simple rubbery plastic that appears to be standard in most of the building and should present no problems. The surfaces of the walls and floors are all kept clean and relatively unmarked.

Figure 4-1: View of Assigned Room from Above



The room is one of the biggest in the museum, and the floor plan (Figure 4-2) is somewhat atypical. The outline of the room consists of two straight walls to the south and the east connected by two circular arcs, a small one towards the southeast and the other along the outside to the north and west. Against the inner arc is a stairwell that cuts into the corner of the room. The outer arc is not actually a wall but a step up onto a walkway, and it is marked with 10 columns approximately 3.3 meters apart strung with rope that acts as a simple barrier. The eastern wall is a remnant of the building's original construction, made of brick, with buttresses sticking out 60 centimeters approximately every 3.4 meters and a gutter along the bottom. Two meters of the southern wall are taken by doors and a ramp. There are approximately 325 square meters of available floor space and the room is more than two stories high. The ceiling is constructed of sloped steel I-beams from which pieces of exhibits could be hung if required. To the northwest, the ceiling is about 8 meters high, while towards the southeast it is 10 meters high.

Figure 4-2: Outline and Dimensions of Designated Room



Other points of interest:

- The lighting is all natural from a translucent ceiling and appears to be acceptable. Even on overcast days, there is suitable lighting, though signs and labeling may require a few additional light sources.
- There are few sources of electricity, especially if the existing structures are removed.
- The ceiling does not connect with the wall on the southern side of the room, and the entire area is open to the outside air. Birds are often flying around the room.

4.2 Museum Visits

In our visits to other museums, we noted four aspects of interest, namely the complete lack of interactive exhibits, bilingual labeling, exhibits with encompassing atmospheres, and clustering of exhibits with similar themes. By encompassing atmospheres, we are referring to components of exhibits that allow the visitor to feel like they are in a different environment. Ambient audio, scents, and props are examples of things that can be used to simulate a different environment. Clustering is simply the grouping of exhibits with similar contents in one place. For example, in the Gold Museum, all of the gold frogs were together, the gold birds were together, and so on. Table 4-1 compares the three museums we visited in terms of these four aspects.

Table 4-1: Comparison of Museums

	Gold	National	Criminology
Interactive	No	No	No
Bilingual Labeling	Yes	Yes	No
Atmosphere	Some	Yes	Some
Clustering	Yes	Yes	Yes

4.2.1 Gold Museum

The first museum that we visited was the Gold Museum. It is located under a park in the center of San José. Upon entering the lobby of the museum, it becomes apparent that there is something of value inside, due to the large number of armed guards. After passing through a metal detector, the first exhibit area is the coin area. In there, the history of Costa Rican coins is traced. There are many displays, all in cases under the watchful eye of a guard. Each case has a brief explanation of the contents in Spanish and English. This room was very small and the tour is only a few minutes.

After going downstairs and passing more guards, the next area that you come to is an exhibit about the original inhabitants of Costa Rica. There is a three dimensional scene with sculpted people and a thatched roof hut to help create an historic atmosphere. Pottery from the period is displayed in glass cases. Further into the displays are many more cases filled with gold ornaments that the natives used to wear.

In general, there was not very much to learn from this museum. The non-interactive nature of the displays was not pertinent to the exhibit designs for the children's museum. The atmosphere that was created from the different scenes was very pleasant. The only other thing of value to us was that the signs in the gold museum were in both Spanish and English. This was very helpful, as not everyone on our team was fluent in Spanish.

4.2.2 National Museum

The findings from the National Museum were very similar to those of the Gold Museum. There were no real interactive displays and the guards became angry whenever they saw anyone touching anything. The signs were in both Spanish and English, which was helpful in understanding the displays. The museum has different areas, each with a different theme, such as animals or coffee. This was helpful because it separated the material being taught in a logical manner.

4.2.3 Criminology Museum

The last museum that we visited was the Criminology Museum. This museum was extremely small, and we saw no one else in it. Everything was in a display case, so no interaction was possible. The most interesting display contained mannequins dressed as robbers and tactical police. A sign explained how the Costa Rican banks were being robbed frequently and how that led to the creation of a tactical police force to help prevent future robberies. Many displays were too graphic for children. For example, there were human body parts preserved in jars from industrial accidents and criminal acts. Because this museum was inappropriate for children, our target audience, this museum was not very useful to our research.

4.3 Survey of Museum Guides

4.3.1 Survey Data

The raw results of our survey consisted of 44 responses totaling 88 pages. Each answer included the name of one or more exhibits, and some guides provided explanations of their choices. The numbers of times each exhibit was mentioned in response to each question have been counted and tabulated in Appendix F. In this section, we present some of the more outstanding results and explanations.

Figure 4-3: Question 1: Which Exhibit Initially Attracts Children Most?

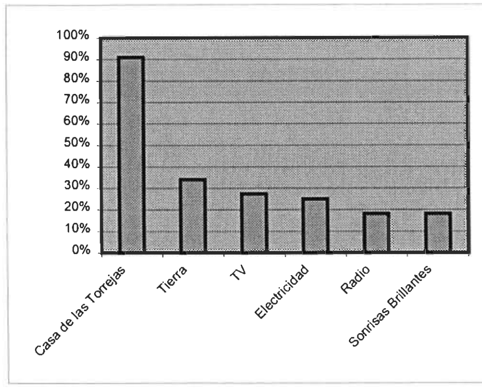
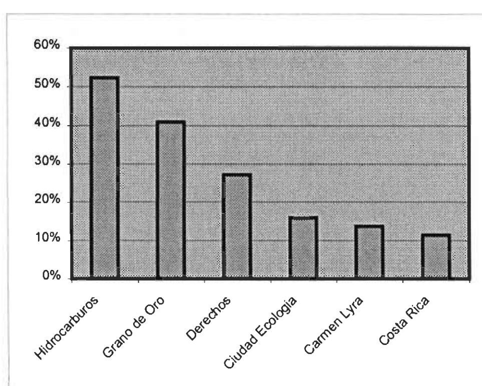


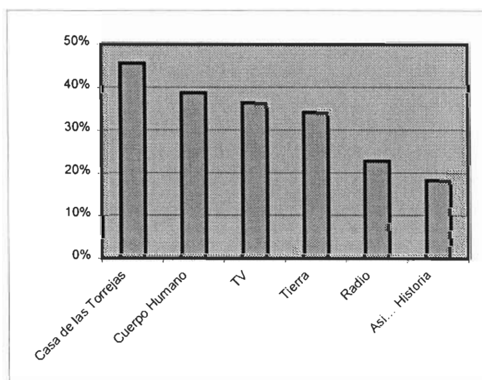
Figure 4-3 shows the percentage of responses mentioning specific exhibits in question 1, about which exhibits attracts children the most. The Crooked House was mentioned in 91% of the responses to this question, far more than any other exhibit. Explanations given by the guides in their responses indicated that children like feeling or doing new things. Also evident from the responses is that children like to actually be a part of the exhibit. Above simply interacting with exhibits, they enjoy becoming involved in them. Often mentioned by the guides was the fact that, very often, only a certain part of a room attracts children. The earthquake table in the Earth room and the giant mouth in the Brilliant Smiles exhibit were both given as examples of this.

Figure 4-4: Question 2: Which Exhibit Initially Attracts Children Least?



Popular responses to the second question, about which exhibit attracts children the least, are shown in Figure 4-4. The Hydrocarbons exhibit was noted as the least attractive to children, mentioned by 52% of the respondents. According to the guides, these exhibits were "boring" for the children. One reason given for this was that some of the exhibits cover concepts that are too "deep," "profound," or "heavy" for the children. Another reason given was that the exhibits lack interactivity or even movement. For example, the Carmen Lyra exhibit "is very boring, and always is the same," and the Rights exhibit is simply a video for which the children must sit still for 10 minutes to watch.

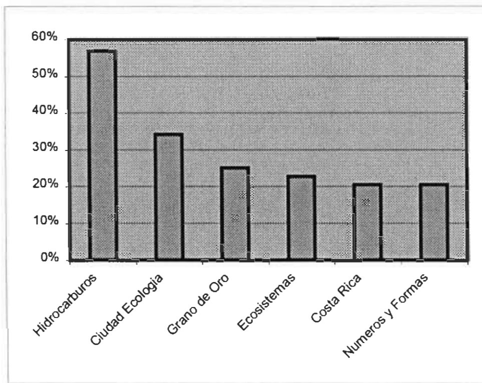
Figure 4-5: Question 3: At Which Exhibit do Children Spend the Most Time?



Responses to the third question, about which exhibit children spend the most time in, are shown in Figure 4-5. The guides' explanations fell into two categories. The first type of explanation stated that children spend a lot of time at these exhibits because the children like them. For example, many guides stated that children repeat the most popular response to this question, the Crooked House, multiple times in one day. The second explanation said that children spend so much time in the exhibits simply because the exhibits are so large. The second most popular response to this question, the Human

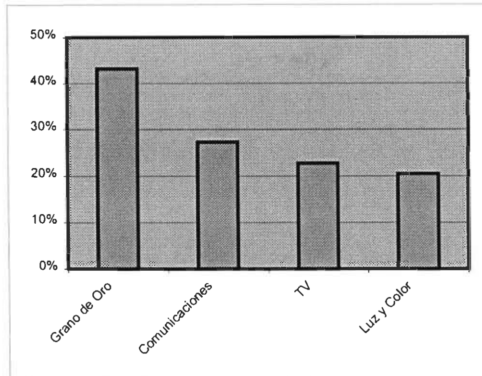
Body exhibit, was mentioned many times in this category. The guides said that it is a very large room with many displays, so the children have to spend a lot of time just to see all of them.

Figure 4-6: Question 4: At Which Exhibit do Children Spend the Least Time?



The fourth question, about which exhibit children spend the least time in, gathered many of the same responses (Figure 4-6) as the second, about which exhibit attracts children least. Once again, Hydrocarbons was the most often mentioned, showing up in 57% of the responses. The reasons given were also very similar to those given in response to question two. One new response was that the children do not enjoy the coffee exhibit, while adults do. Also noted was the fact that the Numbers and Shapes exhibit has activities that are so simple that they can be easily done at home, and so there is nothing new to hold children's attention.

Figure 4-7: Question 5: Which Exhibit Requires the Most Maintenance?



Exhibits mentioned in response to the final question, about which exhibits require the most maintenance, are shown in Figure 4-7. The Coffee exhibit is apparently in most need of maintenance, mentioned by over 40% of the guides. Among the reasons given for these responses is the fact that electronic equipment (such as in the Communications and TV rooms) often requires a lot of maintenance. Also mentioned is the fact that many of the mechanisms in some exhibits such as the Coffee exhibit are very delicate and simply break easily. One respondent noted that the Human Body exhibit breaks often because there is so much that the children can touch.

4.3.2 Discussion

It should be mentioned that one of our questions failed to gather very useful information. The third question, asking in which exhibit the children spend the most time, was less effective than we had hoped, due to the fact that some exhibits require that more time be spent in them than others. In their responses, the guides themselves noted that there were two different ways to approach the question. Some explicitly separated their choices into those exhibits that are popular and those that simply take a long time. Therefore, the third question is not a good measure of either popularity or how long children actually spend in an exhibit due to the fact that we do not know how all of the respondents interpreted the question. That question's counterpart, about the exhibit(s) in which children spend the least time, did not suffer the same shortcoming, however. Children will spend little time in exhibits they do not like regardless of the size of the exhibit, so it is still a good measure of the least popular exhibits.

Also of note is the fact that the guides may have influenced each other's answers. When the survey was administered, they were all sitting together in a very jovial and talkative atmosphere. Many surveys were received together, thus probably from the same group of people, and had very similar, if not exactly the same, answers for some questions. While it is doubtful that the respondents would "cheat" and simply copy down each other's answers without believing them, they may have seen what their neighbors wrote and simply taken that as "good enough" without thinking about it further. This may have effectively reduced the number of actual respondents, but the data is certainly still valid. The validity of the results is not harmed, because the survey is exploratory in nature, and we are not doing any statistical analysis or hypothesis testing.

4.4 Interview with Head of Maintenance (Leonardo Sánchez)

Our interview with Leonardo Sánchez, head of maintenance at the museum, mostly covered ideas related to durability and maintenance, though he touched on a few other aspects of exhibit design as well. The key points of the interview are shown in Table 4-2. A full summary of the interview is available in Appendix G.

Table 4-2: Key Points from Interview with Head of Maintenance

Good Exhibits	Musical Scale Orchestra
Poor Exhibits	Bank (the piggy-bank) Brilliant Smiles (the large door mechanism) Coffee
Good Materials and Components	Animatronics Industrial-strength Parts Motion-sensing Pads
Poor Materials and Components	Electronics Glass Particleboard Plastic Push-buttons VHS film Wiring
Other Points	Safety: "Think like a child." Children find innovative ways to use exhibits. There have been some bad accidents in the past. Repairs: Most are done on-site, but all electronics and some metal pieces are done elsewhere. Simplicity: Clear explanations and simple exhibits are important, otherwise they will be ignored.

The first four rows of Table 4-2 all deal with durability and maintenance requirements. The "good exhibits" are exhibits that were mentioned as requiring very little maintenance. For example, the orchestra room has not broken often, mostly because it contains no moving parts. "Poor exhibits" are those that have had many problems requiring maintenance. The Coffee exhibit is a good example of this; it was poorly designed and most of the components broke within three months of its completion. The components in parentheses for the Bank and Brilliant Smiles exhibits are those pieces that break most often and cause the most trouble for those exhibits. Good and poor materials and components are things that were mentioned at various points in the interview. The good materials and components are those that are the most durable and have broken the least in the past. Those considered poor are those that cannot be used for safety or other concerns, such as glass, and those that have a history of failing repeatedly, like the VHS film in the Children's Rights exhibit.

The final row, labeled "Other Points," are things brought up in the interview that were not the main focus of the interview but proved to be useful. When discussing safety, Mr. Sánchez gave many examples of how children have been hurt, some quite badly, by exhibits in the past. The part about repairs covered the logistics of the process and differences between their repairs of various components. Finally, Mr. Sánchez mentioned simplicity as a very important characteristic for exhibit design in general, relating his personal observations of some of the more complex exhibits.

4.5 Interviews with Teachers

We interviewed five teachers. For each teacher, we first asked how old the children were and then moved on to our other questions. The ages ranged from 4 to 13 years old, specifically one group of 4-5, two of 5-6, one of 9-10, and one of 10-13 year olds.

In response to us asking if their children had ever had any classes about mechanics in the past, 4 of the 5 teachers said no or only very few, and one said yes, but only the most basic concepts.

When asked what they thought the children should learn about mechanics, three presented simple concepts such as velocity, movement, friction, and action/reaction or simply said they should learn the basics. Two had no ideas. In general, the teachers did not have many ideas, and did not seem to be very knowledgeable of the topic.

They had more to say when asked how they thought the children should learn about mechanics. One said that, because the concepts are so abstract, the children need to see or touch things presented in a simple manner. Another said that the children should manipulate things, participate in and actually make the movements themselves. Two teachers explicitly mentioned experimenting. One said that disassembling and constructing things helped the children learn. All five mentioned participation or experimentation in some way.

One very interesting point brought up by one teacher was that of learning disabilities. She said that over half of her children had learning disabilities, and so they needed visuals. They also needed concepts to be broken down into very simple, concrete steps.

We asked them if they do many hands-on activities in class to determine how familiar both the teachers and the children are with such an approach. One said that they do quite a bit, with music and body movements, using props, sharing, etc. Two teachers said that their classes spend half of the day interacting and playing and the other half in more formal class sessions. The two other teachers said that they do not do much hands-on learning at all, because they teach at "traditional" schools, with no "labs." One mentioned that they come to the museum to experiment.

Finally, we asked the teachers if they had visited the museum in the past. If they had, we asked which exhibit was their children's favorite, to complement the data collected in our survey of museum workers. Of the three that said they had visited in the past, all three said the children liked the earthquake table and two also mentioned the crooked house.

4.6 Prototypes

4.6.1 Observation and Testing Results

Over two days, eight groups of people interacted with the prototypes, totaling approximately 185 people. Two of the groups were comprised entirely of adults, while six of the groups were entirely children. The children who participated were between the ages of five and eight years old, while the adults were around thirty to forty years old.

Table 4-3: Results of Initial Prototype Knowledge Tests

	Levers			Collisions		
Age	# Wrong	Total	% Wrong	# Wrong	Total	% Wrong
5	15	23	65%	9	23	39%
7	10	23	43%	4	25	16%
8	7	33	21%	5	32	16%
8	7	32	22%	0	31	0%
8	8	24	33%	4	28	14%
8	7	23	30%	9	25	36%
30-40	6	12	50%	4	12	33%
30-40	7	15	47%	5	10	50%
TOTALS	**67**	**185**	**36%**	**40**	**186**	**22%**

We tested the groups' knowledge before they played with the prototypes, and the results are shown in Table 4-3. We found that 36% answered the question incorrectly for the levers and 22% incorrectly for the car collisions. The youngest children, five years old, had a higher percentage of incorrect answers than the other groups. After playing with the prototypes, they were tested again, and 100% from all groups gave the correct response.

Our random sampling indicated that the children randomly surveyed did answer honestly. When we asked them to explain their answers before interacting with the prototypes, we received various responses. Those that had raised their hands for the correct answer for the levers said that was the one that seemed easiest to lift. One smart child even said that it was because the lever was longer. The children that had given the wrong answer said that they raised their hands because it seemed easier to lift. We had the same findings for the car collision test, and the children could explain their answers. Due to the randomly tested children supporting their answers, we felt that the majority of the responses were honest.

We then conducted the same random sampling of the children after they had played with the prototypes and taken the second test. Once again, all the children supported their answers. Because all the children had raised their hands for the correct answers, the children all gave us reasons why they said the correct lever was easier to lift. We found a variety of explanations ranging from "because it was easier to lift the block with" to "because the lever was longer." The results of the car collisions were the same. The children all answered correctly, so their explanations reflected their knowledge of the right answer. Some just said that "it bounced back more" while others said "because it was heavier." From the random sampling responses, we felt that the majority of the children were honest.

We also observed the children while they were interacting with the exhibits, noting to the best of our ability how much they were enjoying, paying attention to, and understanding the exhibits. We observed that the children had big smiles on their faces and that they were very anxious to play with the displays. As soon as they sat in front of the displays, they stopped talking to each other and paid attention. They really loved it when the boys could not lift the difficult lever and the girls could lift the easy lever. In fact, they enjoyed it so much they clapped their hands and cheered. Many had big smiles and quite a few laughed or giggled.

When the children were able to crash the cars, they became even more excited. Some jumped up and down, and many strained to get a closer look. They loved loudly counting down "Three, Two, One" right before the cars were pushed towards each other. Some of the boys pumped their fists in reaction to the car crash and a few girls giggled. When they saw the results of the car crash, many yelled "Yeah" and smiled. One more thing we noted was a safety concern. At one point, the children collided the trucks with a great deal of force, and a small plastic piece broke off of one and became a projectile.

In addition to observing the children react to the displays, we also asked a few from each group if they enjoyed the prototypes. The children responded that the displays were "great" and "neat." The adults said that they were "fun" and "interesting."

We were also interested in determining whether the displays were self-explanatory. Because we had a guide interacting with the children, we had limited success in this area. While the guide did tell the groups what to do, such as pull down the lever, he did not tell them how to do it. Almost all the children pulled the levers down in the correct places. A few children tried lifting the lever from below, which we had not anticipated. The children seemed to know exactly what to do with the car collision display. As soon as they went near it, they grabbed the trucks and prepared to crash them.

4.6.2 Discussion

It is important to discuss a few unexpected findings. First, the number of responses that we received from each group of children was not always the same between the different prototypes. This could have occurred if a child raised their hand for multiple answers for one display, or they raised their hand for one display and not the other.

Regardless, what is most important is the overall consistency that we found in the responses.

Also, the fact that 100% of all those tested knew the correct answer after interacting with the exhibits is quite remarkable, and it warrants further investigation. The children were all asked the same question at once and asked to raise their hands to indicate their answer while they were counted and recorded. It is very likely, especially with children, that many felt peer-pressure to answer the same as their friends. Conformity is a powerful social force, and studies have shown that, in similar situations, even adults will give a response they do not believe. Thus, we cannot reasonably expect that every single person knew the correct answer after using the prototypes. However, the fact that people from all but one group answered incorrectly in the initial tests indicates that there was some change. Most likely, a much larger percentage of those tested knew the correct answer afterwards, so those with the incorrect answer were outnumbered far more than before, at which point conformity kicked in. In addition, the children selected randomly from the groups supported their answers and had explanations, indicating that they had thought about them. Thus, it is reasonable to assume that learning did occur and that a significant majority of the children who answered incorrectly at first knew the correct answer after interacting with the prototypes.

4.7 Value Analysis

Appendix K contains tables of scores given to each exhibit by each individual team member as well as overall averages.

Though each member scored the exhibits separately, the scores for each display were very similar. Bayo's average score for the displays was 7.58, Lee's was 7.92, and Mark's was 7.28. From these, the overall average for the group was 7.59. Even after changing the weights to emphasize education, the overall average score only changed 1%, from 7.59 to 7.49. There were no large deviations in individual scores, as all were within 3 points. Many scores differed by only one or two points between the group members.

The gear, pulley, and lever lifts were among the highest scores with all being above an 8 and many being over 9. The highest overall scores were for the Pulley Lift - Self, which received a 9.20 and 9.25 with the different weights. The lowest scores were for the Hydraulic Lift, 6.02, Archimedes Screw, 6.07, and Carnival Ladder, 6.18. These scores dropped in the second value analysis, because they all had low educational scores. The lowest individual score was given by Lee for the Hydraulic Lift, 5.00. The highest individual score, 9.55, was given by Lee to four displays. Three of them were very similar, being the gear, lever, and pulley lifts with a car. The other was the Pulley Lift - Self display.

5 Analysis

5.1 Exhibit Guidelines

The first step of our analysis was to develop a series of guidelines pertaining to exhibit design in general. We drew from the information gathered in our research to determine all important aspects of children's museum exhibits and to learn how to best design the exhibits around these aspects.

5.1.1 Educational Value

The main goal of these exhibits is to educate children, so educational value is of paramount importance. It is an abstract concept, however, and measuring it or designing exhibits around it is difficult. It is very important that the children interacting with the exhibits learn, though, so we have tried to ensure that this will happen.

While we were observing the children interact with the prototypes, we saw that the adults and eight year olds were more inquisitive, in that some asked questions relevant to the displays after interacting. This was not the case for the younger children, as they seemed content with simply playing and seeing the result. This can be attributed to the different levels of mental capacity in Jean Piaget's theory of cognitive development. For children in the early stages, their reasoning is intuitive. This means that they see only one point of view and cannot imagine another perspective. The older children and the adults, being in a later stage, are more logical and organized in their thinking. This means that they can manipulate and reverse their thinking, which allows them to come up with a series of relevant questions pertaining to a problem. This holds true more for the adults than the older children, as they have developed these skills longer.

Furthermore, in our survey, it was often noted that some exhibits cover topics that are too complex for most of the children to understand, and thus are unsuccessful. In some cases, this may be due to the fact that the children have not yet learned the preliminary concepts necessary for understanding those presented in the exhibits. In the case of mechanics, the official Costa Rican primary school curriculum introduces simple machines and very basic ideas about force and movement in the third year, so the older children will have some background in the basics. A more formal education in physics does not occur until the seventh and eighth years, however, so many of the concepts will be new to almost all of the children. Because of this, exhibits should only present the most basic concepts, as most children will not have sufficient foreknowledge to understand anything very advanced.

Some of the concepts may simply be too complex for the children to understand at all, however. According to Piaget, abstract thinking and logical reasoning do not appear until approximately 11 years of age, and the concept of conservation and similar concepts useful for understanding mechanics do not develop until around 7 years old. So, as the visitors are between 4 and 12 years old, only some will have developed enough to fully understand the concepts.

Despite the fact that some of the concepts may be inaccessible for some children, that does not mean that these children will get nothing out of the exhibits. Nelson (telephone interview, 12 April 2001) introduced us to the idea of making exhibits "open-ended," which means that they can be approached from many different levels. While the younger children may not learn concepts in the way that the older children do, they still can get a lot out of the exhibit. For one thing, by playing with the exhibit, the children can see how it works and remember what they see. Later, when they learn the concepts in school, they can remember the exhibit, apply their newfound explanation to it, and thus reinforce their learning.

In addition, children can get immediate benefit from an exhibit by simply learning the rule it teaches, even if they do not understand it. For example, a child can learn a concept such as "pulley systems make it easier to lift things" without necessarily understanding why it works. The child can then apply the concept in his or her life even though he or she does not know the principles behind it.

Finally, younger children may derive an education from the exhibits that have very little to do with the concepts at all. Simply by playing in such an interactive, stimulating environment, they can further their cognitive development. For example, if a very young child plays with an exhibit about collisions, she might not learn anything about the mechanics of collisions, but rather she could gain more experience with simple cause and effect relationships.

5.1.2 Interactivity and Fun

As part of the project specification, it is extremely important that the exhibits be interactive. While we have not been actively investigating the importance of interactivity, due to the fact that it is a requirement, it has been appearing repeatedly in our research. Interactivity is a subset of the larger aspect of fun, which is just as necessary.

First of all, interactivity and fun are necessary for attracting and holding children's attention. In their responses to the survey, museum guides mentioned the interactive elements of various exhibits as one reason they were so popular with the children. In addition, in our observations of children in museums, we have seen that children are far more interested in interactive exhibits than in static displays. Holt also mentions that holding children's attention is a difficult task, but it is necessary for them to learn.

Secondly, it is clear that interactivity is very helpful to the learning itself. Many experts advocate learning through experimentation. Teachers visiting the museum with their students emphasized it as the best method for teaching mechanics, as well. Nelson spoke of "learning by accident," in which children learn without actively seeking to do so. If a child has fun with an interactive exhibit, he or she may learn the concepts even without consciously realizing it.

While observing children interact with the prototypes, we identified some differences in the various age groups. One was that the children were eager to crash the trucks and see what happened, while the adults needed to be told to play with them. The children's eagerness can be attributed to how they like to be actively involved in cause and effect reactions as described in the works of John Holt. In contrast, the adults seemed to logically analyze the displays and preferred watching others interact with the prototypes. These differences are further described by Jean Piaget's theory of cognitive development. Specifically, in the later stages of development the individual is able to reason logically and think of possibilities when faced with a problem. This means that the adults were able to conceptualize from abstract ideas and come up with rough predictions without direct interaction.

We also noticed that when the five year olds crashed the cars, they did it has hard as possible each time. While they did this, they did not care about possible damage to the trucks. They were only concerned with the joy of the crash. John Holt described this as the luring power of a tempting target on children. The adults were more reserved and after being told to crash the trucks, they still only crashed them with moderation. One explanation for this is that their logical and organized thinking enabled them to comprehend more clearly possible damage to the truck from a sharp collision.

How to achieve good interactivity is another matter, and various approaches to it exist. From the exhibits chosen by the museum guides as the most popular, it is obvious that children most enjoy feeling or doing new things. For example, they enjoy new sensations such as the disruption of their equilibrium in the Crooked House or the current running through their bodies in the Electricity exhibit. They get to do new things in TV, Radio, and Computer rooms, which all house technologies that are otherwise not available to most children. Also evident from their responses is that children like to actually be a part of the exhibit. Above simply interacting with exhibits, they enjoy becoming involved in them, as with the earthquake table in the Earth exhibit.

The visiting teachers mentioned experimentation as well, and gave ideas such as hands-on manipulation of displays. They said that it helps children to actually participate in movements themselves and disassemble and reconstruct objects.

5.1.3 Simplicity

Simplicity is a concept that, when implemented, helps many other areas of the design as well. It has been emphasized by nearly every one of our sources, from the experts on exhibit design to the children's teachers. Simplicity applies to the concept being taught, its presentation, and the construction of the exhibit. A simple concept is one that does not build upon others or have other requirements to be understood.

Concepts are presented simply when they do not have long, difficult instructions or explanations. Simple construction involves few moving parts and few pieces in general.

When the concept taught by an exhibit is simple, it will be easier for children to learn. Even more importantly, if it is presented in a simple manner, it may be self-explanatory. This is of great importance for many reasons. First, people rarely read labeling. If they come up to an exhibit and see a long, complex instructional label, they may simply bypass it. Secondly, simplicity is important because we have been told that the museum would like to avoid having guides in the mechanics room. Visitors will be on their own when interacting with the exhibits, so they need to be as self-explanatory as possible to facilitate that. Visitors should be able to walk up to an exhibit and start interacting with it in the intended manner without much thought or excessive reading.

Simplicity also applies to the construction of the exhibit. First, simply constructed exhibits have fewer points of failure, and thus are more durable. Also, if they do break, they are much easier to fix if they are easily disassembled or made from simple parts. Secondly, simply constructed exhibits are safer. Exhibits with fewer moving pieces or less complex mechanisms are less likely to cause injury to a child. Likewise, broken exhibits can cause injuries; so simpler, more durable exhibits are safer as well. Finally, less complex exhibits are cheaper, with fewer parts and thus lower construction costs.

5.1.4 Durability

Durability is an issue that has also been mentioned by all of our sources that work with exhibits in children's museums. It is a fundamental issue. If an exhibit breaks, it no longer serves its purpose. Maintenance also increases the cost of an exhibit. The two aspects of exhibits that contribute to its durability are the materials and the components from which it is constructed.

Exhibits in children's museums are subjected to great amounts of stress from the children's interactions, according to experts on exhibits in children's museums. This was evident from our observations, as well. Small children have little concept of the possibility of an exhibit breaking or simply do not consider it, as they do not hold back when interacting with exhibits. Children of all ages tend to enjoy seeing how far they can push exhibits and often interact with them in ways that are obviously unintended. This can be even more of a problem with teenagers, who are much stronger than the smaller children. For these reasons, exhibits must be built very sturdily.

We have more information about poor materials than good materials. We have been told that wood is a poor choice because it breaks often. Plastic and glass have been noted as poor, also, because they break easily when hit. Glass is especially bad, because when broken it can be very dangerous. Most of the exhibits we have seen in various museums are made of metal, and this seems to be the best choice for general construction. Plastic appears to only be used in exhibit construction when part of the exhibit needs to be transparent, otherwise metal can be used.

There are many different types of components, but some are more prone to wear and tear than others. Electronics are bad, because they are so sophisticated; there are more opportunities for them to break, and they are much harder to fix when they do. Items such as computers, VHS films, and wiring are all vulnerable. Even push buttons are a poor choice, due to the fact that they can break or even be stolen.

It has been stressed numerous times that industrial strength parts are required for exhibits in children's museums. Heavier, thicker parts, especially for those pieces that move a great deal, are best. The design is important, as well, and "home-made" designs often fail.

5.1.5 Safety

Safety is of prime concern when dealing with children. Injuries must be avoided at all costs. Both Geoff Nelson and Leonardo Sánchez have said that children will find new, unintended ways to interact with exhibits and can hurt themselves even when precautions have been taken.

It is difficult to guard against this, but there are some things that can be done. First, one can limit how children can interact with an exhibit to try to keep them from using it in an unintended manner as much as possible. Also, care should be taken to prevent pieces from breaking off or even becoming projectiles, as we noted while testing our prototypes. Children can be hurt on exhibits even when not using them, simply by colliding with them when running around or interacting with other exhibits. Because of this, edges and corners should be kept as smooth as possible, and the proximity of the exhibit to areas where children might run should be taken into consideration. We have seen that many exhibits are made with rounded corners or constructed from round pipes, which can help minimize any accidental injuries.

5.2 Value Analysis Criteria

From those characteristics that we decided were important, we constructed a set of criteria for actually scoring our exhibit ideas and gave them relative weights. We also decided on a general definition for each, to ensure that we each scored the exhibits with the same criteria in mind.

As it is the most important attribute, educational value was included and given 40% of the final score. Educational value relates to the concept each exhibit is trying to teach. It includes how well the concept is presented, how accessible it is to children, and how much it teaches about mechanics overall.

The next characteristic chosen for the scoring criteria is the interactivity and fun of an exhibit. It was given 25% of the total, as it is less important than educational value, though still very important. This category includes ideas such as feeling and/or doing something new, being a part of the exhibit, and simply doing or creating things oneself.

"Self-explanatory" was the third criterion, worth 15% of the total. This was only concerned with how obvious the intended use of an exhibit is. This is important because there will most likely be no guides in the area, so visitors must be able to walk up to an exhibit and use it without help. For this rating, exhibits with complicated instructions and labeling requirements earned low scores and those for which its intended use is visually apparent scored higher.

The construction costs and maintenance costs of each exhibit counted as 10% and 5% of the final score, respectively. The construction cost was estimated based on the complexity of each exhibit and any special parts they required. The score for maintenance costs was based on the durability of an exhibit, affected by the number of moving parts, required lubrication or other scheduled maintenance, and general toughness. Also considered in the maintenance cost score are any replacement costs. For example, exhibits with sand that would need to be replaced routinely scored slightly lower due to this added cost. In addition, exhibits with items that might need to be replaced due to theft scored lower.

The last scored attribute was safety, worth 5%. It was given a low percentage of the final score because, although safety is of extreme importance for the exhibits, it is assumed that the exhibits will be designed and built safely. This score takes into account any problems that cannot be prevented through proper design and construction. For example, any exhibit in which a child physically moves while interacting with it holds the possibility that the child will fall. This problem can be made less severe with proper padding, but the exhibit is still slightly more dangerous than an exhibit where the visitor interacts externally, without becoming physically involved to any great degree.

Also of extreme importance in choosing exhibits was whether they required a guide to facilitate the visitors' interaction. There is no way to assign a score to this, however, as each exhibit either requires a guide or it does not. For this reason, it was decided that it would simply count against the final score, removing 10% of the total possible score if an exhibit requires a guide.

5.3 Value Analysis

With our value analysis chart, we were able to systematically determine which exhibits were the best to be recommended to the museum. We decided that the best method for choosing these was to use the median of the exhibit scores as a cutoff point. By finding the median score, we were able to distinguish the better half of the displays from the worse half. All scores above this point, 7.53, in first value rating were considered of enough value to recommend to the museum. We only used the first value rating, because it was generated with the weighted percentages that we initially agreed upon when designing the value analysis method. The second value rating was primarily to determine the robustness of our system. Table 5-1 lists the 19 displays chosen from 37 possible and their value analysis scores.

Table 5-1: Exhibits Above the Median Score

Exhibit Name	Score
Build Your Own Mobile	7.68
Car Collisions	9.07
Car Race with Gears	7.78
Climbing Slopes	7.77
Decaying Motion	7.65
Exercise Bike Generator	7.53
Friction	7.77
Gear Lift – Car	9.02
Gear Lift – Classmates	8.17
Hanging Bicycle Gyro	7.55
Lever Lift – Car	9.08
Lever Lift - Classmates	8.23
Lever Lift – Weight	8.62
Merry Go Round	7.73
Pulley Lift – Car	9.08
Pulley Lift - Classmates	8.23
Pulley Lift - Self	9.20
Rotating Tube	7.55
Teeter-Totter	8.35

These 19 displays were not the only ones that we wanted to recommend to the museum. Because there are multiple variations of the lever, pulley, and gear lifts, there are really only 14 unique display ideas above the median. To provide the museum with a more diverse list of good selections, we decided to consider some of the displays that were below the median score. These were decided on a case-by-case basis during a special group meeting. We all agreed that the best way to do this was to allow any member to recommend a display regardless of its score. The main reasons that we chose this method was to allow a member to recommend a display if he felt strongly for it, even if the other two did not like it. The condition was that the member or members would recommend the display on a personal basis separate from the group. In this way, we were able to reach a compromise regarding these displays. Table 5-2 lists the displays that were included by personal recommendation along with their value analysis scores, the group member or members recommending them, and why it was recommend.

Table 5-2: Personally Recommended Exhibits

Exhibit Name	Score	Recommended By	Reason
Ball Drop	7.35	Lee and Mark	Educational
Jump-pad	7.50	Lee and Mark	Fun and Interactive
Kangaroo Shoes	6.77	Bayo and Lee	Fun
Newton's Cradle	6.95	Mark	Simple and Educational
Velcro Wall	6.43	Bayo and Lee	Fun

The Ball drop was recommended due to its high educational value. It lets children explore how gravity makes heavy and light objects fall at the same rate. This principle surprises many people and it can also be fun to watch. The Boston Museum of Science had this display in the Science in the Park room and we feel that is a strong indication of the value of the display. For these reasons, Lee and Mark feel that this would be an excellent addition to the mechanics room to educate the children.

The Jump-pad was selected because it is fun and highly interactive. The display lets children jump on a pressure sensitive pad, which constantly sends the current pressure to a simple computer. The computer then displays how the pressure changes over time in a manner similar to how hospitals use a screen to display a patient's heart rate. This display was also present in the Science in the Park exhibit in Boston, Massachusetts. While we were there, we observed how children enjoyed stomping on it to change the moving pressure cursor on the screen. We also noticed that most of the children loved to jump on it as hard as they could to make the cursor spike off the screen. The direct correlation between their actions and the graph on the screen make it easy for children to understand what it is displaying. While this is part of the fun and interactivity of the display, Lee and Mark feel it is worth emphasizing that the pressure sensor pad must be industrial quality and able to withstand the abuse. It is also the only display that was recommended that deals with the concept of pressure, which makes it worth further consideration.

The Kangaroo Shoes are recommended primarily to entertain the children. While they do have some educational content regarding how springs work, Bayo and Lee feel that the most important aspect is how they present a unique opportunity to jump around on springs. This can be connected to how astronauts walked on the moon or how a kangaroo hops around. To allow children to put on these shoes will let them experience a sensation that they have likely never felt before. Because of the nature of the display, it will be necessary to have a dedicated guide to hand out and collect the special shoes and to keep the children within the designated area. It is also suggested that each shoe have four springs to provide more balance. This is similar to how roller skates are easier to stand on than roller blades. The display is sure to be popular among children and Bayo and Lee believe that it is worth considering for the mechanics exhibit.

Mark recommends the Newton's Cradle exhibit because of its simplicity. It is extremely easy to build, it is cheap, and it should not require much maintenance. The educational content is also quite good, as the concept of conservation of momentum is well presented and easy to understand in this form. It scored poorly because it is not as interactive or fun as the others are, but it might as well be included due to its low cost and space requirements.

The Velcro Wall was recommended by Bayo and Lee due to how fun and interactive it is. Children and adults get into Velcro suits and use a trampoline to jump against a wall. When they hit the padded wall with a Velcro cover, they remain suspended in the air. This is due to the large amount of "friction" from the Velcro. While the Velcro Wall does not truly represent friction, the concept and visual effect are similar enough to help teach the concept. This and the fact that a guide needs to be dedicated to the display are the only drawbacks. However, the display will be one of the most popular displays in the museum due to how interactive and fun it is and the unique experience that it provides. For these reasons, we feel that it deserves to be recommended.

5.4 Layout

We investigated the positioning of exhibits because part of the final recommendations is a possible floor plan. There are many factors that need to be considered when deciding where each display goes in a given area. Many museums use a method referred to as clustering. This involves keeping all of one type of display or theme in one area. The main reason that this is done is to thematically link similar displays together in an area that focuses learning on that specific subject. Due to the project specifications, we followed this practice by keeping all the mechanics displays in one room. The clustering and ordering of displays can be much more organized, though. Sequential learning must be taken into consideration where appropriate. This means that if one display builds upon the concepts developed in another display, the museum should attempt to make sure that they are visited in that order. Because each of the displays we have proposed teaches a different principle of mechanics, we do not need to consider the sequential learning approach.

Of particular importance to any room design are the entrances and exits. The mechanics room has two entrances that are used and another that is kept locked. It is best to have the most exciting and interesting exhibits closest to these entranceways, if possible, to initially interest the children as they enter the room. In this way, they immediately create an atmosphere that promotes learning by stimulating the children to interact. This is not to say that the other displays will not also be of great interest to the children. It is just that they should see the most interesting first.

We also needed to design the spacing of the room for the type of groups that use it. We observed that many of the school groups visiting the museum consisted of between 20 and 40 people. To accommodate this number of people, there must be enough space between exhibits for them to move freely and to interact with the displays. Approximately 8 feet should be left between each exhibit to meet these needs. This figure was obtained through research found in the literature review.

Other points of consideration involve the physical construction of the exhibits. Certain displays require placement against a wall, while others must be hung from the ceiling. The limited wall-length in the room caused us to limit the number of exhibits that require a wall, and the height of the ceiling played a role in designing and placing any hanging exhibits. In addition, for safety, maintenance, and aesthetic reasons, it is important to minimize the number of electrical wires running across the floor. While almost none of our displays need power, it is best that the few that do be placed close to a power supply on a wall or have the power supplied directly from below if possible. Furthermore, there are currently two canopied party tents and various colored pillars in the mechanics area. We were told that these could be taken out if necessary. Their placement and size is such that placing exhibits with them in the room would be very difficult, if not impossible. For this reason, we recommend that they be removed, and our floor plans have been created under the assumption that they will be.

Safety is also important when positioning exhibits in a room. Sharp edges and extended bars should be turned away from high traffic areas or places where children tend to run. Where this is not feasible, we recommend padding the corners and edges.

While we do not want long and boring labels cluttering the room, it is important to have some basic information conveyed regarding the displays. Our research indicates that long labels are hardly ever read, so it is extremely important to keep them as brief as possible. The most important information should be contained in one phrase or sentence, in very large type, with any other important information below in smaller type. While bilingual labeling can be useful, we do not feel that there are enough foreign visitors to warrant the extra cost.

The positioning of the labeling is also important. It should be in a conspicuous place on each display, facing the direction from which people approach, so that everyone will read it. People reading the labels can be any age, from children just old enough to read to adults, and they will all need to be able to read the labels. For this reason, the labels should be no more than a few feet off the ground, most likely tilted up to be readable by children and adults alike.

6 Conclusion

By completing the various aspects of our methodology, we were able to meet all project requirements. We have proposed a design for an educationally rich and interactive exhibit area to teach children about mechanics. This was accomplished through generating a list of display ideas and determining the best ones to recommend by performing a value analysis. We also obtained a list of materials required for each display and the cost to construct them. A possible floor plan for the mechanics room has been created using the best displays and presented to the museum for consideration. In addition to fulfilling the project requirements, we have proposed a systematic method that can be used to determine the quality of current and proposed exhibits. This will prove to be a useful tool in the future to improve the overall quality of the displays at the museum. As a final contribution, we have recommended testing methods for determining if children are learning from the displays. This is of great importance, as the primary goal of the museum is to education Costa Rican children.

7 Recommendations

7.1 Exhibits

The most important part of our recommendations is the list of exhibits. This list, shown in Table 7-1, contains the exhibits that we believe are worth constructing.

Table 7-1: Exhibit Recommendations

Build Your Own Mobile	Gear Lift
Car Collisions	Hanging Bicycle Gyro
Car Race with Gears	Lever Lift
Climbing Slopes	Merry Go Round
Decaying Motion	Pulley Lift
Exercise Bike Generator	Rotating Tube
Friction	Teeter-Totter

Table 7-2 lists exhibits that were recommended only by specific members of the group. A detailed explanation of why these displays were selected can be found in the Value Analysis section of the Analysis chapter.

Table 7-2: Personally Recommended Exhibits

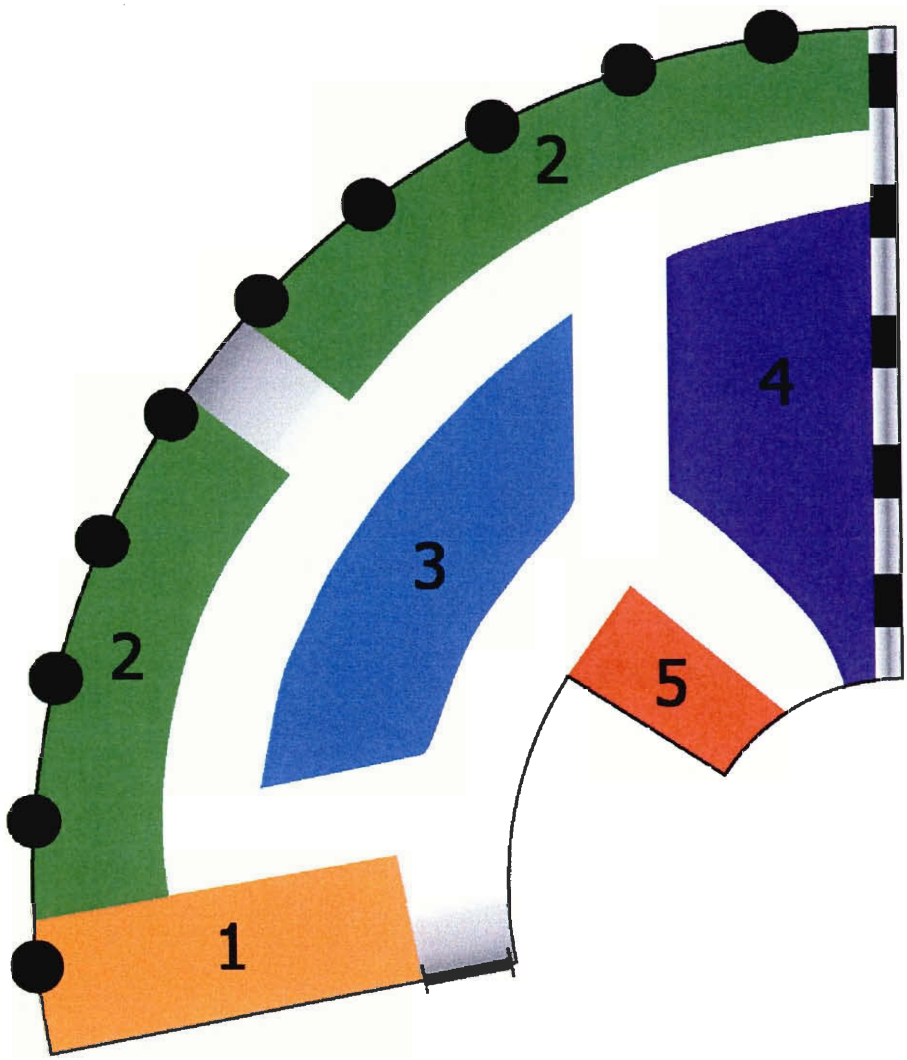
Newton's Cradle
Jump Pad
Kangaroo Shoes
Ball Drop
Velcro Wall

Detailed information about all of these exhibits as well as those that we did not recommend is contained in appendices. Appendix H contains descriptions of each exhibit, including its physical construction, the concept it teaches, its pros and cons, and possible sponsorship ideas for some. Illustrations of the exhibits are in Appendix I. Lists of materials and costs for each exhibit are contained in Appendix J. Finally, the value analysis tables used to rate and rank the exhibits are in Appendix K.

7.2 Floor Plan

As there are so many exhibits and the room is so large, there are very many possible layouts that can be proposed. Because of this, we created a single general layout, as one option that contains many, but not all, possibilities. This floorplan can be seen in Figure 7-1. Essentially, it splits the room into different areas, numbered from one to five in the drawing. The exhibits all have characteristics that make them better or worse for each area.

Figure 7-1: Proposed Floor Plan



One such attribute is whether an exhibit requires a wall. Of the exhibits we recommend, only the Climbing Slopes and the Velcro Wall require a wall against which they must be placed. These both must be placed in area 1 in the layout, as it is the only section with a consistant, flat wall. In addition to those that require a wall, many exhibits are used only from one direction and thus have a rear side which might as well be placed against a wall. These can go in any of the areas 1, 2, 4, or 5. They could also be placed back-to-back in the middle of the room, but there is a lot of area around the outside of the room where they would be placed best. The exhibits that we have recommended that would best be placed against a wall are listed in Table 7-3.

Table 7-3: One-sided Exhibits

Ball Drop
Car Race With Gears
Friction
Gear Lift
Jump Pad

The center of the room, area 3 in the diagram, is best saved for those exhibits that can be accessed from multiple sides. These consist of all of the recommended exhibits not yet mentioned. If they are placed in the center of the room with adequate space on all sides, they can be used by as many people as possible, thereby increasing their interactivity.

Finally, one must consider where to place exhibits relative to the entrances. We recommend that the most exciting exhibits be placed nearest the entrances to entice the children as they are initially entering the room and put them in an excited mood. Also, we recommend that the less interesting displays not be placed in corners or too far from the entrances, as they may then simply be ignored by the children. Instead, the less exciting displays should be placed near or between some of the more exciting displays so that children may use them as they pass by.

7.3 Value Analysis

We found the value analysis technique we used to rate and rank our exhibit ideas to be very useful. It provides a simple way to determine the relative quality of many exhibits. In addition, it shows exactly why some exhibits are better than others, because it essentially takes one's thoughts and feelings and puts them on paper in a quantitative, numerical format that is easy to analyze.

We recommend that the museum consider using this technique for its own exhibits. First, the museum could use it on the existing exhibits. The technique can be used to rate the current exhibits to determine which should stay, which should go, and perhaps which should receive more funds than others. Also, the museum could rate and rank any proposed exhibit ideas they have. This provides a simple way to compare and contrast ideas that can act as a supplement to the current decision making proccess.

The technique we used is outlined in the Value Analysis section of the Methodology chapter. While the museum could use the same categories and weights that we did, it is also free to create its own, as it is the technique itself that we feel is most valuable to the museum.

7.4 Educational Value

While we are confident that the displays we have presented here will be educational and fun for the children, we recommend that the museum test their educational value after they have been implemented. The museum should determine how much children are learning from each exhibit. We feel that this is important because education itself is such an important aspect of the exhibits. The testing may reveal ways in which the exhibits could be improved as well as suggest methods for designing better exhibits in the future. We recognize that major changes to the exhibits after their completion is most likely impossible, but small changes can still help.

Several methods could be used to determine if the children learned the concepts taught by the exhibits. One is to individually question random children before and after playing with the displays. This can be done by a guide asking children simple questions about certain exhibits. Another way is to create a questionnaire that can be filled out after playing with the exhibits, essentially a quiz of the visitors' knowledge. The method that is perhaps the best builds upon a technique that the museum is currently developing. This involves giving out workbooks to the children to fill out while they are in the museum. This allows them to apply the knowledge that they learned, can be treated as a school assignment to increase participation, and gives the museum a method to determine what the children are learning. The main reason that we recommend this technique is that it will simply build upon what the museum is already going to do, and it would be more likely for them to use this method than adopt a whole new system. To obtain even more feedback, we feel that it would be advisable still to randomly test a few children from several groups periodically. This would help to complement any chosen method and create a more accurate determination of what the children learned.

In addition to testing, the museum could develop packets of information for teachers. These packets could contain activities for their students to do either before or after their visit to complement and extend the learning from the visit. By presenting some of the concepts in class with these packets before visiting, the children will be better prepared to learn from the exhibits themselves. Likewise, if they learn more about the concepts in class after they visit, the students can reinforce their learning and retain the knowledge better.

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Appendix A – Project Sponsor

In 1991, the then First Lady of Costa Rica, Gloria Bejarano de Calderón, formulated the concept of the Museo de los Niños (Children's Museum). Under the direction of the Fundación Ayúdenos para Ayudar (Help us to Help Foundation), the project was undertaken with the support of various individuals, corporations, and the government of Costa Rica. The museum is part of the Costa Rican Center for Science and Culture (CCCC), which in turn is managed by the Help us to Help Foundation.

The old, abandoned Central Penitentiary was chosen as the home of the CCCC. It was saved from demolition at the hands of the government and was rebuilt and remodeled over a period of a few years. Located in the heart of San José, the Penitentiary was considered an ideal location for the Center. From the building's previous purpose came the museum's motto: "Educate the child to avoid punishing the adult." The museum hopes to provide children with knowledge and understanding about the world around them to prepare them for their future as adults in Costa Rican society.

During the conceptualization of the museum, the founders wanted to incorporate ideas from the best museums in the world. Their main goal was to educate children in innovative and exciting ways, specifically by using interactive exhibits. The museum also wanted to supplement the children's classroom education. By making the exhibits fun and hands-on, children would be more inclined to participate actively and learn more. This interactive education began when the museum opened on April 27, 1994.

The museum's budget comes from three distinct sources. Most funds, approximately 60 percent of the budget, come from museum revenue such as entrance fees, room rentals, and the museum store. Another 5 percent comes from sponsorships from large corporations, in which a corporation funds the construction and maintenance of an entire exhibition room. In return, the corporation gets some control over the design of the exhibit, which often features the company's brand name or products. The museum sets limits on how much advertising a corporation can include in an exhibit, however, and will refuse a design if it contains too much.

The other source of money, comprising approximately 35 percent of the budget, is the government. Due to the nature of Costa Rican politics, the amount of money received from the government depends on the current party in office, which changes with the presidential elections every four years. The two major parties are the Partido Unidad Social Cristiana (PUSC) and the Partido Liberación Nacional (PLN). Mrs. Calderón, former First Lady of Costa Rica and founder of the museum, is a member of the PUSC. Because of her party affiliation, it is easier for the museum to obtain help when the PUSC is in power. As the controlling party switches from term to term, so does the museum's budget.

The museum is run by a three-level hierarchy. The museum workers form the first level, called the Museografia. They work under Ms. Rodríguez, who manages the day-to-day operations of the museum. The workers give her ideas and tell her what they need. Ms. Rodríguez and Mrs. Calderón discuss the issues and present them to the board of directors. The board of directors sets the policy for the museum, which includes approving exhibit ideas. The board meets only once a month, so if a decision is time-sensitive, Ms. Rodríguez and Mrs. Calderón will act on it themselves as necessary. However, they still present their actions to the board, so everything does go through the board of directors at some point. Due to her busy schedule, Ms. Rodríguez was often unavailable to meet with us. Because of this, we worked mostly with her assistants, Karla Camacho and Brenda Rodríguez, making occasional reports to Ms. Rodríguez.

Our project, designing interactive exhibits about mechanics, is part of the museum's continuing effort to expand and improve its ability to educate Costa Rican children and other visitors. This project is of particular importance to the museum because it currently lacks mechanics exhibits. By completing our project, we will enable the museum to fill this void by implementing our proposal.

Appendix B – Museum Guide Survey

English

This survey is being administered to gather information relevant to the design of a new exhibit area about mechanics. Please fill it out to the best of your ability. Give as much detail as you can in your responses, as it will all be very useful to us. If you cannot answer a certain question, feel free to answer "N/A" or "no answer." The survey applies to all of the exhibits in the museum. If you have more experience with certain exhibits than with others, please indicate which exhibits you focus on in the "Other Comments" section.

1) Which exhibit initially attracts children best:
2) Which exhibit initially attracts children least:
3) At which exhibit do children spend the most time:
4) At which exhibit do children spend the least time:
5) Which exhibit requires the most maintenance:

Other Comments:

If you would be willing to be interviewed to help us further, please write your name here:

Thank you for taking the time to help us design better exhibits.

Español

Hemos preparado esta encuesta para reunir la información que nos permitirá diseñar una nueva sala de exhibición en el tema de mecánica. Por favor conteste a la encuesta en la manera que le sea posible. Le agradeceremos que nos proporcione tanto detalle como usted pueda y explique el porque de sus respuestas por que esto es muy importante para nosotros. Si usted no puede responder a la pregunta, simplemente indiquenos que "No hay respuesta." La encuesta se aplica a todas las salas de exhibición del museo. Si usted tiene más experiencia en particular con alguna sala por favor haganoslo saber e informenos cual es esa sala en la sección titulada "Otros Comentarios" al final de la encuesta.

1) Cuál sala las llama más la atención a los niños:
2) Cuál sala las llama menos la atención a los niños:
3) En cuál de las salas de exhibición los niños pasan la mayor parte del tiempo:
4) En cuál de las salas de exhibición los niños pasan la menor parte del tiempo:
5) Cuál sala requiere el mayor trabajo de mantenimiento:

Otros Comentarios:

Por favor dejenos saber si usted podría ser entrevistado por nosotros en otra ocasión para darnos más información al respecto. Si es así, escriba su nombre en el espacio siguiente:

Muchas gracias por su valiosa contribución. Sus puntos de vista nos será de mucha ayuda para diseñar la sala de exhibición de mecánica.

Appendix C – Interview Protocol for Head of Maintenance

- What types of mechanisms and exhibits break most?
- What types of mechanisms and exhibits break least?
- What materials are best?
- What materials are worst?
- How do you fix and maintain the current exhibits?
- How do you obtain parts?
- Are there any other things we should keep in mind when designing the exhibits, in terms of making them durable or anything else?

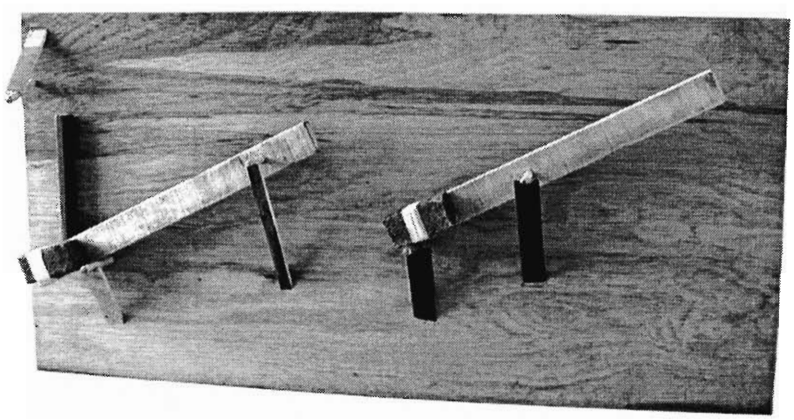
Appendix D – Interview Protocol for Teachers

- How old are your students?
- Have your students had any classes about mechanics?
    - If so: What have they learned? How?
- What do you think they should learn about mechanics? Are there any concepts that you think are most important?
- How do you think they should learn about mechanics?
- Do they do many hands-on activities in class?
    - If so: Of what sort?
- Have you ever visited the museum with students before?
    - If so: Which exhibit is their favorite?
- Do you have any other information that might be useful to us?

Appendix E – Prototype Designs

We designed and constructed two prototypes of exhibits to test with the children in the museum. This appendix contains detailed descriptions of each prototype, including the concept that it teaches and its physical design.

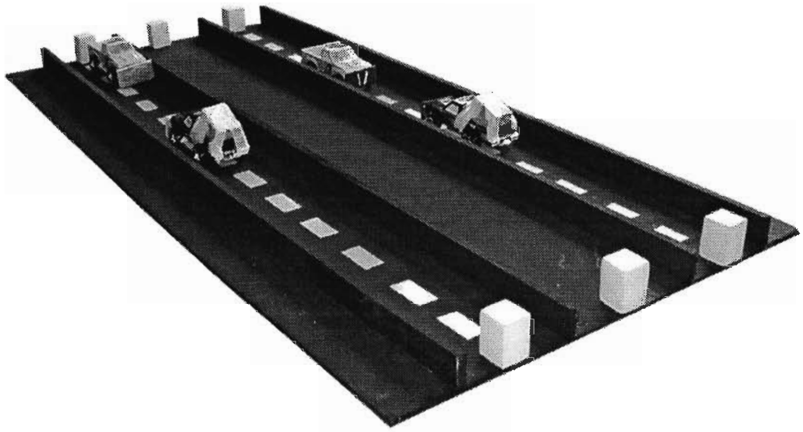
Lever Prototype



The first prototype, shown above, is about levers and fulcrums. The main goal of this display is to teach children that the difficulty of lifting an object with a lever depends on the location of the fulcrum along the lever. More specifically, the closer the fulcrum is to the weight being lifted, the easier it will be to lift. The display consists of two levers mounted on a piece of wood. Each lever is the same length, and each has a similarly-weighted brick on one end. The only difference is the location of the fulcrum, or pivot point. One one lever, the fulcrum is very far from the brick, while on the other, the fulcrum is approximately in the very center of the lever. Children will be able to feel that it is much easier to raise the brick using the second lever than it is using the first. This illustrates the mechanical advantage of a lever.

This prototype was constructed entirely with wood. It consists of a vertical standing display approximately 3 meters wide and 1 meter tall. Cylindrical pieces, specifically broomstick handles, were built sticking out perpendicular to the plane of the display. Each piece supported a beam approximately one meter long by passing through a hole in the beam. These were the levers, so the holes were in different locations on each beam. An identical weight, in the form of a large brick, was placed on and attached to the end of each beam. There were also wooden pegs in place to limit the movement range of each lever and support the weights when the levers are in their "resting" positions. The display was setup so that the beams were next to each other and could be tried sequentially. The display was simply propped against something to stand it up vertically. The levers were placed at a height such that small children could reach them and possibly hang from the harder lever to pull it down.

Collisions Prototype



The second prototype, shown above, teaches children about collisions between two objects of different masses. It allows children to propel two toy trucks down a track toward each other. The trucks are identical but for an extra wooden block placed on one. When the trucks collide, the truck with the weight rebounds much less than the lighter truck. This shows heavy objects have more inertia and move less during collisions, concepts related to conservation of momentum.

This prototype was also built entirely of wood. Vertical guide rails a few inches high were placed on a horizontal sheet of wood, creating two tracks the length of the display. The end of each track was closed off by a wooden block, to keep the trucks from falling off of the end. Four plastic toy trucks were purchased at a local toy store, and a heavy wooden block was placed in the bed of two of them, making them considerably heavier than the others. The display was placed on cinder blocks, raising it a few feet off the ground, at an appropriate level for even the small children.

Appendix F – Museum Guide Survey Results

The museum guides listed many exhibits in their responses to each question. The following tables list how many responses mentioned specific exhibits for each question both as a raw number and as a percentage of the total number of responses.

Question 1:

Which Exhibit Initially Attracts Children Most?

Accident Prevention	1	2%
Brilliant Smiles	8	18%
Communications	1	2%
Crooked House	40	91%
Electricity	11	25%
Human Body	3	7%
Land	15	34%
Light and Color	2	5%
Means of Transportation	1	2%
Musical Scale	1	2%
Orchestra	3	7%
Radio	8	18%
Space	4	9%
Thus Begins My Story	1	2%
Train	1	2%
TV	12	27%

Question 2:

Which Exhibit Initially Attracts Children Least?

Bank	3	7%
Carmen Lyra	6	14%
Coffee	18	41%
Costa Rica	5	11%
Ecology City	7	16%
Ecosystems	3	7%
Games	2	5%
Human Body	1	2%
Hydrocarbons	23	52%
Light and Color	2	5%
Newspaper	3	7%
Numbers and Shapes	2	5%
Recycling	3	7%
Rights	12	27%
Thus Begins My Story	2	5%

Question 3:

At Which Exhibit do Children Spend the Most Time?

Bank	2	5%
Brilliant Smiles	2	5%
Communications	6	14%
Costa Rica	2	5%
Crooked House	20	45%
Electricity	6	14%
Human Body	17	39%
Land	15	34%
Light and Color	2	5%
Magic Dreams	1	2%
Musical Scale	1	2%
Numbers and Shapes	1	2%
Orchestra	3	7%
Radio	10	23%
Recycling	2	5%
Robots	1	2%
Space	3	7%
Thus Begins My Story	8	18%
TV	16	36%

Question 4:

At Which Exhibit do Children Spend the Least Time?

Bank	1	2%
Carmen Lyra	8	18%
Coffee	11	25%
Communications	1	2%
Costa Rica	9	20%
Dr. Picado	2	5%
Ecology City	15	34%
Ecosystems	10	23%
Games	7	16%
Human Body	1	2%
Hydrocarbons	25	57%
Light and Color	2	5%
Mirror	1	2%
Musical Scale	1	2%
Newspaper	1	2%
Numbers and Shapes	9	20%
Orchestra	2	5%
Recycling	2	5%
TV	1	2%

Question 5:

Which Exhibit Requires the Most Maintenance?

Accident Prevention	4	9%
Bank	1	2%
Brilliant Smiles	6	14%
Coffee	19	43%
Communications	12	27%
Ecology City	1	2%
Electricity	1	2%
Games	2	5%
Human Body	6	14%
Land	1	2%
Light and Color	9	20%
Living Beings	1	2%
Numbers and Shapes	1	2%
Radio	6	14%
Thus Begins My Story	4	9%
TV	10	23%

Appendix G – Interview with Head of Maintenance (Leonardo Sánchez)

We learned a great deal during our interview with Leonardo Sánchez, head of maintenance at the museum. One of the things that we wanted to learn about was what breaks most often in the museum. Leonardo said that the first thing that came to his mind was the push buttons. Not only do they break easily, but also the children sometimes steal them, particularly in the solar system room. Because of damage and theft, many of the displays that needed the buttons no longer work. It should be noted that the museum designed the newer orchestra room without the push buttons for these reasons. Instead, they installed movement sensors. While initially more expensive, they have not needed to be replaced in the few years the exhibit has been open.

He also mentioned that the VHS film in the Children's Rights Room is falling apart and frequently needs repair. Leonardo also added that we should try to minimize any wiring that we use, as it can be a problem to repair.

A material that Leonardo said broke often was plastic. He said that it cracks when children hit it very hard, which they sometimes do. For example, the orchestra room has been damaged in this way on occasion. He also mentioned that glass cannot be used, because it becomes very dangerous if a child breaks or cracks it. These materials are mainly used as clear covers for either labeling or display cases.

Leonardo said that anything made of wood needs to be constructed well. He said that if it is not, the display will be damaged and usually cannot be fixed immediately. An example he gave was the Brilliant Smiles exhibit. The giant wooden toothbrush has been broken and has yet to be repaired.

Next, we asked if the museum has any problems with displays that have moving parts. He informed us that many things with mechanical parts have had problems. For example, the door at the Colgate room was poorly designed, and the hinges broke. This was because it was not intended for a heavy-duty job. He said the coffee room was ruined because all the mechanics were designed poorly and strong materials were not used. The electronic components in the coffee room are also broken. Because of this, it needs to be rebuilt with stronger materials and a sturdier design. Yet another example of problems the museum has had with exhibits is The Bank of Costa Rica room. The little pig children can put money in has completely failed due to an inferior design not able to stand up to interaction with the children.

We also asked Leonardo about what types of mechanisms and exhibits break the least. The first thing that he came up with was the animatronics. In the seven years that the museum has had animatronics, only two parts have failed. One was a piston, which was easily repaired. The other was a microchip for the Frankie Chan robot in the solar system room. The microchip that sent data to the computer to control movement failed. The part was hard to find, so Leonardo ordered five extra chips in case it broke again in the future. He said that it was also worth mentioning that the orchestra and musical scale room have not broken often.

We then learned from Leonardo which materials are best for building exhibits. He immediately said that we should use sensor pads instead of any buttons that we might require. He then mentioned the importance of the type of wood used in construction. For example, particleboard should not be used, as it is very weak and will not stand up to the abuse of children. Instead, we should use solid wood pieces. He also emphasized that anything we use should be industrial strength if possible. As an example of how industrial strength materials are important, Leonardo talked about the solar system room. He said that there were scales that would tell visitors how much they would weigh on different planets. Originally, they were commercial quality, and they broke within three months. The scales were then replaced with industrial scales, which have been working for 3 years without problems.

When we asked Leonardo about what materials are the worst, he said that anything with electronics made in Costa Rica is bad. The reason he gave was that the electronic parts tend to be of poor quality, which means they frequently need to be replaced.

Leonardo also told us about how they maintain the current exhibits. He said that any problems with electronics are not fixed at the museum. This means that they have to be sent out and repaired by an outside source, since the museum does not have manuals or a person trained to fix them. Because the parts need to be sent out, it takes longer and can be expensive. Besides electronics, most everything else is fixed at the museum. The only real exception is that, at times, metal pieces need to be brought to a machinist to obtain a new one. He specifically noted that wood repairs stay within the museum maintenance staff.

To conclude the interview, we asked him if there was anything else that he could think of that might help our project. He started off by saying that we should think like a child. He said that they do strange things with the exhibits and that we need to ensure that they cannot get hurt. He recalled how in the past some children have been hurt at exhibits. For example, there was a car engine that had moving pistons. A child put his hand behind a protective sheet of plastic and his finger became caught in the piston. The piston then cut off the tip of his finger. Another example is the color wheel in the Light and Color exhibit. A chain that makes the wheel spin came off the gear. A child then opened an unlocked protective door and attempted to fix it. While he was doing this, another child spun the handle at the front of the exhibit. This turned the gear and cut the hand of the child trying to repair it. The cut was bad enough to need stitches.

Leonardo finally reemphasized the need to build the displays using strong materials and to keep in mind that children are very curious. He also thought that if we use a display with toy trucks, we should make sure that the trucks are somehow tied down to the display. This would be important so that the children do not take the trucks away from the area that they are supposed to be in. He then talked about how he felt that the explanation of an exhibit is highly important and that the learning needs to be interesting. One way he suggested was to keep the displays simple. He said that the children come here to play and that there have been unsuccessful exhibits in the past due to being too complicated, such as the pendulum display. The instructions are too long and the display is not self-explanatory. In addition, there are parts of the display that are broken. He has personally seen people walk up to the display, hit the pendulums, and then walk away.

Appendix H – Exhibit Descriptions

This appendix contains detailed descriptions of all of the exhibits we collected. This includes those that we recommended as well as others that were not included in the rest of the report but still may be of interest to the museum. The descriptions give a general idea of how each exhibit is constructed, the concept it teaches, its advantages and disadvantages, and possible sponsorship opportunities. While we thought of sponsorship possibilities for many of the displays, we could not generate ideas for all of them. This was primarily due to some displays being in areas that we could not locate businesses with similar interests.

Archimedes Screw

Archimedes Screw shows how water can be pumped using a screw. A child turns a handle that spins an attached cylinder. The cylinder is set at a slight angel with the lower end immersed in liquid. Around the cylinder, a clear hose is wrapped like the windings on a screw. When a child makes the cylinder spin in one direction liquid starts to flow up the clear hose and pour out the other end. The liquid should be colored so that it is easy to see it moving up the pipe. From the display, the children will be able to see the use of a screw to perform an unusual function. It should be noted that this display would be of more interest to the older children and adults that visit the museum. It is also relatively inexpensive to build and maintain.

Due to only turning a handle, this display is not highly interactive. The concept taught is somewhat complex and may not be understood or enjoyed by younger children. In addition, the screw only works if spun in one direction. To ensure that the children turn the handle the correct way, arrows show be placed on the rotating disc the handle is attached to. The water will also need to be replaced on occasion and colored dye added. In summary, due to a low level of interactivity, the limited amount of fun the children can have, and a relatively complex concept, we do not feel that this is one of the better exhibits to build.

Ball Drop

An interesting and often misunderstood property of gravity is that when objects fall in Earth's gravity, their acceleration does not depend on their weight. This display allows children to clearly see that light and heavy objects fall at the same rate. The display is a clear, tall tower that has a pulley mechanism that is used to pull up a box that can contain objects to drop. The objects will drop in a clear tube that prevents them from falling on the children. Children can put an object in the box through a small opening at the bottom of the tube. As the rope is pulled, it raises the box. When the box reaches the top, it touches a trigger device that opens the bottom of the box. The objects that the children placed in the box then fall and reach the bottom at the same time, regardless of their weight. A possible option is to use an electronic timer and sensor pad to display the actual time that the objects fell on an LED display.

The display will work as long as the objects dropped have about the same air resistance. For example, if a feather is dropped with a rock, they will not reach the bottom simultaneously. However, a light ball and a heavy ball will reach bottom at the same time. Due to the more complex interaction of the display, it is intended to be used by older children and adults, though younger children would still have fun playing with it.

A possible variation has two boxes to raise objects. They need to be synchronized to drop the objects at precisely the same time, however, this adds to the complexity. This will separate the falling objects, which prevents any interaction between them during the drop and thus reinforces the concept. They have to be constructed well so that the objects can drop simultaneously. If the mechanism is off, the display will not work as intended. A solution would be to mechanize the lift and have an electromagnetic trigger to drop the weights. While this adds to the cost, it will make the device perform better.

Bicycle Wheel Gyro

A less explored concept of mechanics is that of gyroscopic action. This is an effect of the conservation of angular momentum. When objects spinning on an axis are turned, they exert a force perpendicular to the motion. To feel this force, a child can hold a bicycle wheel on handles attached to the center hub. The child sits in a chair and the tire is spun quickly. When the axis of the spinning tire is changed, the child will feel the chair rotate. The motion generated is unusual in that it is unexpected. This strange force is one of the non-intuitive attributes of gyroscopes. Though this is a very inexpensive display, it still might be sponsored by a local bicycle shop.

The museum currently has this exhibit from a previous mechanics exhibit, but we feel that there are few problems that should be addressed. One problem is that the bicycle wheel currently used is too heavy for the children to hold. It also has too large a diameter, which causes the tire to touch their chest even if held out. This is not how it was supposed to work, so we recommend considering these factors if this display is chosen. The tire should be lighter and smaller to allow children to properly use it. In addition, the chair should be at a height easy for the child to sit on. It should also be on a low friction, ball bearing pivot that easily turns. The chair that is currently used does not spin freely, which detracts from the effect of the display. Other potential problems for the display are that the concept of gyroscopic action is not easy to understand. Therefore, it will be difficult to have children learn from it. In addition, the display is not self-explanatory in how to use it. Due to the diverse negative aspects, we cannot recommend the museum build this display. If the concept is still desired to be taught, we suggest referring to the hanging bicycle gyro.

Build Your Own Mobile

Exploring the principles of balance and center of mass can be an interesting endeavor. Every object has a center of mass that it can balance on. Using this knowledge, children can build complex, free hanging structures by balancing pieces with different weights from one another. The display consists of a hook attached to the top of the display and various pieces with hooks with which the children can create their own mobile. Each piece can have two more pieces hanging off either end. In this way, the original piece hanging from the hook can hold many more balanced pieces below it. Children are able to explore the center of mass by expressing their creativity in how they design their mobile from pieces of different lengths and shapes. This display allows children to construct something themselves and be creative while learning about the concept of the center of mass.

There are a number of possible downsides to this display. Due to the complex nature of hanging pieces, this display is mainly geared towards the older students, though younger children would be able to use it. Another possible issue that should be addressed is the time spent at the display. Because the children need to keep flowing through the museum, the display might slow them down enough as they take time to build their mobiles to cause a problem. These factors should be considered when determining whether this display should be built.

Car Collision

This display promises to be another great exhibit idea. It was tested in the museum as a prototype and proved to be greatly enjoyed by the children. The children's attraction to the display draws from their interest in seeing objects collide. It teaches the concept of conservation of momentum in a simple manner that even young children have proven able to understand. When a heavy object and a light object collide, each going approximately the same speed, the light object will bounce backwards more due to the conservation of momentum. Children create this effect by pushing cars simultaneously from two ends of a track towards one another.

By allowing the children to crash cars, a highly interactive and stimulating environment is created. An additional feature of the design is that we have already created and tested a successful prototype. Strong and durable trucks have already been bought, so all that is needed is an area to crash them. While the prototype crash area could be used, we recommend building a more aesthetically pleasing area to interest the children. One important comment is that it is necessary to somehow fasten the cars with a strong lightweight string to the display to prevent them from being stolen or removed from the exhibit. Another possibility is to use more sophisticated tracks and cars. The tracks can be made of metal, with special cars riding on ball bearings attached to the tracks. This will be very smooth and keep the collisions in one line, but it will probably be more expensive as well. A possible sponsors for this display are toy truck manufacturers, such as Nylint.

One possible downside to this display is that there is the potential for a child to have his or her fingers pinched between two crashing cars. This should not be a concern if the cars have rubber bumpers in the front.

Car Race with Gears

In this exhibit, children learn the effects of different sized gears. Two cars are on an inclined ramp and each is attached to a rope. A child would turn a handle that turns the gears, which causes the ropes to wind around the drive shaft. The rope attached to the large gear will result in the car moving up the ramp slowly, while the car attached to the small gear will move quickly up the ramp. This is because a small gear attached to a larger one causes a smaller force to be applied over a greater distance. In this way, the children will be able to see how gears can be used to change the distance an object moves for the same applied force. A possible connection to normal life would be to have a picture of a bicycle gears next to the display with an explanation of how they are similar.

Potential sponsors for this display would include any toy truck manufacturer, such as Nylint.

This display is less interactive and educational than some of the other suggestions, because the children only turn a handle. However, we still felt that it was worth mentioning. It should be noted that it is necessary for the gears to be enclosed in a clear case to prevent children from getting hurt while allowing them to see what is going on.

Carnival Ladder

The carnival ladder is designed to teach children about center of mass. It consists of a ladder constructed using metal bars held together with rope on each side. The ladder is widest in the middle and becomes quite narrow at each end where it is anchored. The distance between the high and low anchors should be approximately 3 meters. Children climb the ladder to ring a bell at the top, which is about 2 meters off the ground. The display is fun for children because it is challenging to get to the top. It requires the child to climb with their legs and arms spread out. If their center of mass moves away from the middle of the ladder, it will flip and they will fall onto the thick cushion below. Children enjoy challenges and this will provide an educational one. Potential sponsorship could come from the fire fighters.

Although it is fun and highly interactive, the display is not as self-explanatory as others are. A few graphical instructions and brief labeling could explain how to use it and what is supposed to be learned, however a guide would be preferred. One way to make it easier to climb would be to widen the distance between the anchor points at each end. This would widen the area in which the children need to keep their center of mass.

Climbing Slopes

The climbing slopes are by far one of the easiest and least expensive displays to build. They involve children attempting to climb up two ramps with different slopes to ring a bell. In this display, the children will learn how inclined planes can be used to make a difficult climb easier. This directly applies to how the roads in the mountains wind and do not go straight up. The steep slope will be hard enough to climb, approximately 70 degrees, that the children have difficulty climbing it. The other slope will be about 30 degrees to show how easy it is to climb, though the ramp is longer. This helps to emphasize the concept of the mechanical advantage obtained by using inclined planes. The older children are likely to notice that while the 30-degree ramp is easier to climb, it is longer to walk up. This reinforces that it is easier to apply less force over a longer distance compared to great force over a short distance. It is very self-explanatory, interactive, and simple to use. In addition, the materials required are inexpensive and it can be entirely built at the museum. Possible sponsors include commercial airlines flying in and out of San Jose. The display could either be painted to look like a runway or have their company logo on it

One drawback is that it needs padding around it in case the children fall. This is easily fixed by using the same thick padding as the Velcro wall around the sides and base of the ramps. Another possible safety feature is to put railings on the side of the long ramp. It would not make sense to put them on the difficult one, as the children would most likely use them to climb it. The display also requires use of the limited wall space, though we feel that it is worth it. The last possible downside is the simplicity. While it aids in teaching the children, it display does not hold the same excitement level as the Velcro wall or lever lifts.

Decaying Motion

While many pendulum displays simply move back and forth, decaying motion puts an interesting twist on the topic. In this display, a swinging pendulum pours sand onto a white, moving conveyer belt. As the sand pours out, it creates repeating patterns that exponentially decrease in size on the conveyer belt. The decrease in the size of the pattern is due to the dampening of the pendulum swing. Using the display, children will be able to draw oscillating patterns such as a simple sine wave or more complex, overlapping patterns. We feel that by deviating from the standard sand-pouring pendulum and using a conveyer belt, a more exciting and stimulating situation is created. Children love to interact with displays and express themselves artistically. These qualities help to make this one of the better displays to include in the mechanics exhibit.

There are a few minor concerns regarding this display. The motor that turns the conveyer belt needs to be enclosed so that no child can get into it. A tray should be under the display to catch the sand and a shovel should be included so that the children can fill the pendulum as necessary. The sand used should be very fine so that it is pleasing to the touch. It will also need to be replaced periodically due to being spilled on the floor and sticking to the children's hands.

Elastic Shooting Gallery

Another principle of mechanics is elasticity. What this means is that objects such as rubber can bounce and be stretched. This display helps children explore the stretching property of rubber in the form of a shooting gallery. The children try to hit swinging targets with tennis balls using rubber slingshots. These are attached to the display and the children can put the tennis ball in the sling and pull back. When they release, the ball will shoot forward. We recommend that various strength slings be used so that the children can explore how they shoot differently. Children are also taught about projectile trajectory and how pendulums swing. While the pendulums could be started moving by pulling a rope, we feel that it might be better to use a small motor to swing them. This would make the display much more exciting, while minimally increasing the cost. We think that this will be an exciting display that the children will want to play with. Due to the highly interactive and fun environment this presents, the children will enjoy playing with this display.

We feel that it is important to mention a few issues regarding this display. First, it is critical that netting be used around the display to prevent balls from being shot out of the designated area. Second, it is important to consider that children might want to steal the tennis balls. Using more complex shooting mechanisms that are fully enclosed and employ a plunger can prevent this, because the visitors are prevented from directly touching the balls. In addition, the rubber slingshots will need to be replaced over time as they age. These factors might cause the display to have a higher maintenance cost than other choices.

Exercise Bike Generator

One interesting aspect of mechanical energy is that it can be turned into electrical energy. This principle is used in such places as steam turbines that generate power. In the display, a child pedals an exercise bicycle that is hooked to an electric generator. As the child pedals, the light bulb will start to illuminate. The faster the child pedals the brighter the light bulb will become. When he or she stops pedaling, the light will quickly dim. This lets children actually see the results of their conversion from mechanical into electrical energy. The generator itself can be enclosed in a transparent casing to give the visitors a glimpse of its internals and how it does the conversion, as well. We believe that the children will be interested in how this concept works and will like the opportunity to use a familiar object, a bicycle. It is also worth considering having multiple bikes and light bulbs next to each other to have the children compete against each other to see who can make light bulb illuminate the most. Possible sponsors include any electrical company or bicycle company, especially those in San Jose.

One possible safety concern is if children try to put their fingers into the bicycle spokes. Using solid hub wheels easily prevents this. Another concern is that children might play with the gear that moves when pedaled. The gear and chain should be contained as much as possible inside a protective housing. The light bulb used will also be important. It should be selected so it will not burn out when a child pedals fast. It also will have to be replaced periodically, though this is a small expense.

Friction

While movement is a large part of mechanics, friction also needs to be considered, as it is a factor in all motion. For this reason, it is an important concept that should be taught to the children. In this display, three different types of materials allow children to explore differences in friction. The materials are rubber, smooth plastic, and cloth. These represent a diversity of the amounts of friction present. Blocks covered in various materials are attached to the display so the children can explore the friction created between two similar or different surfaces. Children could even use objects they bring with them to see how much friction they have with the materials in the exhibit. We believe that this display encourage the children to explore the concept of friction in a very interactive manner. It is extremely safe and does not require any supervision. In addition, the materials are inexpensive and it can be entirely built at the museum.

Sponsorship for this display could be obtained from a shoe company or plastic company in Costa Rica.

Due to the simplicity of the design, the display is not as exciting as many other displays. For this reason, we believe it should be placed between the more exciting displays so that the children can explore friction as they pass by. In addition, the surfaces will be subjected to a great deal of rubbing, and may need to be replaced frequently.

Gear Lift

This is the same concept as the lever and pulley lift, except this time the mechanical advantage of gears is shown. The same weights: a heavy block, classmates, or a car can be used for the gear lift. The children turn a handle that spins a small gear. This gear turns a much larger one, thereby amplifying the amount of force applied. The axle of the large gear is then attached to a pulley hung from the ceiling to allow a heavy object to be lifted. If a car is lifted, potential sponsors include all major car dealers in San Jose.

We feel that the lever and pulley lifts provide sufficient opportunity for children to lift heavy objects, so the gear lift would be recommended mainly as a possible alternative to either. This is because, while the gear lift is equally as educational and fun as the other two, it also poses potential safety issue. If the children are turning a handle to raise a weight, when the handle is released, the heavy object will fall. The distance the object can be lifted can be easily limited, but the handle that turns the gears will most likely spin very fast as the weight is lowered. It is this spinning handle that concerns us, and it is why we chose the lever and pulley lifts as primary choices, while the gear lift is a alternative.

Hamster Wheel Generator

One property of mechanical energy is that it can be turned into electrical energy. This principle is used in such places as steam turbines that generate power. In the display, a child stands inside a human-sized hamster wheel. As the child starts to run, the wheel turns faster and faster and an electric generator turns the motion into electricity, which starts to illuminate a light bulb. The faster the child spins the wheel, the brighter the light bulb will become. When he or she stops running, the light will quickly dim. This display lets children actually see the results of the conversion from mechanical to electrical energy. We believe that the children will be interested in how this concept works and will love the opportunity to use the human hamster wheel. Because this is something that most children would have never seen, it will entice them to explore what it is and to try to use it. The best sponsors would be electrical companies in San Jose.

Several issues must be addressed when considering this exhibit. One is that it poses a possible risk if the children fall in the wheel while it is turning. To make the display safer, we feel that it is important to use a high resistance wheel so that it is hard to turn. This will also prevent the wheel from being spun so fast as to hurt a child if they feel inside of it. We think it is also important to mention that the hamster wheel itself must be a solid hoop and not just bars to stand on.

The light bulb used will also be important. It should be selected so as it will not burn out when a child pedals fast. It also will have to be replaced periodically, though this is a small expense. This display could potentially use supervision, but we feel that is not required.

Hanging Bicycle Gyroscope

Another interesting concept of mechanics is that of gyroscopic action, an effect of conservation of angular momentum. This means that when objects spinning on an axis are turned, they exert a force perpendicular to the motion. To feel this force, a child holds a bicycle wheel on handles attached to the center hub. One of the handles is attached to a rope hanging from the ceiling. The wheel is spun quickly and the child releases the handles. This results in the tire to spin wildly in unexpected ways. It seems tire should just spin around in one direction, but it instead moves in many. This is because when the axis of the spinning tire is changed, it will create a force perpendicular to the movement. This creates an unexpected sight. This strange force is one of the non-intuitive attributes of gyroscopes. This exhibit is not only the one of least expensive to build; it also is a great way for children to interact with a gyroscope. This display removes many of the problems that the bicycle wheel with rotating chair has. The wheel should be light enough for a small child to reasonable hold. It should also have a diameter that does not allow the tire to touch the child's chest when held. It presents a simple and fun interaction with a gyroscope that should prove much more successful than other methods.

One potential problem for the display is that the concept of gyroscopic action is not easily understood. Therefore, it might be difficult to have children learn from it. Instead, it will primarily provide children to experience the phenomenon to apply it later on in their education.

Hydraulic Lift

One topic of mechanics is that of fluid dynamics. This display presents children with one concept in this area. A hydraulic lift works because the amount of pressure created by an applied force is proportional to the surface area. This means that when a small force is applied over a large area, then it can be transferred to a large force over a small area. Auto mechanics use this effect to help lift cars to work on their chassis. The display consists of a hydraulic lift that has a large area for children to stand on and a small area to lift a heavy object. The more children stand on the large area, the higher the heavy object will lift. This is interesting because the children are raising something heavy without any real effort.

This display has many drawbacks. It is expensive and has to be special ordered. It also might be difficult or impossible to obtain a transparent hydraulic lift that will allow the children to see inside. If it is not possible, it might be harder for the children to understand what is going on. In general, the difficulty of the concept poses a problem for the implementation of this design. This combined with a high cost and the fact that it is not exciting leads us to not include this display in our recommendations.

Jump Pad

This display provides children with a highly interactive and fun way to learn about exerted pressures. An electronic pressure sensor rests on the floor on which children are allowed to jump. A video display, similar to a heart monitor in a hospital, simultaneously shows the current force applied on the platform. This prompts children to jump up and down, as they can see the resulting pressure spikes appear on the screen. Many times, the children liked to jump and land as hard as they can to make the spike go off the screen. Also, some children tried running in place to see the bouncing spikes on the screen. This display proved to be highly successful at the Boston Museum of Science because it was so highly interactive. We feel that it will be will similarly successful at the Museo de los Niños by stimulating the children's interest and providing an excellent learning tool.

Potential sponsors include any computer manufacturer in Costa, such as IBM or Intel.

If this display is built by the museum, we recommend that the Boston Museum of Science be contacted regarding the computer system and pressure sensor used for their setup.

One drawback to this design is the cost. Because of the special sensor pad and the computer required for displaying the graph, the display has a higher price tag. However, this exhibit will justify the expenditure by providing a stimulating way for the children to explore contact forces. No supervision is required, and as long as a high quality, industrial pressure sensor is used, it should provide years of fun with little maintenance.

Kangaroo Shoes

Kangaroo shoes are sure to provide a great time for the children as they hop around like the animal. Another possible theme could be to jump like an astronaut. They are simply sneakers with three or four springs attached underneath and a wood platform in between. The children can put on the shoes and jump around to feel the unusual sensation. The display will be inexpensive, easy to build, and self-explanatory. We feel that it is a great way for children to explore how springs work and have a fun time doing it. In addition, it is great sponsorship opportunity for shoe companies like Nike, Adidas, or Reebok to advertise to children. This could be done by simply providing shoes of various sizes with their logos on them.

One concern is that a guide is required to keep track of the shoes to ensure that they are not stolen. One possible way is to have children trade their shoes in for the kangaroo shoes. There is also the potential for sprained ankles and the children falling over. For this reason, the shoes should provide additional support to the ankles. A variety of sizes will need to be created, so that everyone can use the display. The shoes should be replaced periodically as they age. This increases the cost of maintaining the display over time. Furthermore, the exhibit requires a great deal of floor space to give children adequate room in which to jump around. Despite these shortcomings, we feel that that the excitement and unusual feeling of hopping around on springs would be popular enough to warrant considering the display.

Lever Lift

This display presents children with the opportunity to lift very heavy objects that could not normally be raised. With the mechanical advantage of a long lever, a child can appear to have super human strength. In fact, a small boy or girl will be able to lift several classmates, a heavy weight, or even a car. This is accomplished by having a long beam suspended in the air on a support structure that acts as a fulcrum. The beam has the heavy object attached to one end, while the longer end has several ropes attached for a child to pull down on. These ropes are attached along the length of the beam so that a child can try each separately and discover which one makes the heavy weight easiest to lift. This will teach the children that the length of a lever is what provides the mechanical advantage. Specifically, a longer lever can lift more weight with the same ease.

One of the strongest points of this display is that it creates a high level of interaction by allowing multiple children to be involved simultaneously. The fact that a small child can lift several friends or even teachers will provide much of entertainment. It is even likely that the children will talk about how much they lifted when they return to school or go home. Another advantage is that it has a mid-range price for what could be considered a showcase piece. It also presents the perfect opportunity for sponsorship by an automotive company. For the great privilege of advertising their corporate logo on the car, they could sponsor the display or even the entire exhibit room. Once this display is constructed, it should require very little maintenance and last many years, which is another important feature. If a car is used for this display, any major car dealer in San Jose would be a potential sponsor. Otherwise, Caterpillar, which is a construction company, might be considered.

There is one possible safety issue that should be taken into consideration. The lever must be prevented from lifting the object too high. This is especially true if children are the weight being lifted. There are two methods that easy solve this problem. One is that the lifted object be attached to a short chain bolted to the floor. The second method is to have a brace that stops the end of the beam the child pulls down on from going too low. The second method is ideal if the display is placed so that a wall can be used for the brace. The first method is preferable if the display is not located near a wall.

Merry Go Round

Not referring to the amusement park namesake that has children riding moving horses, this display consists of a large rotating disk. The disk is free to spin as the children run around the outside pushing it. There are handles on the display to help the children push it and to help the children on it hold on. As the large disk starts moving faster and faster, it becomes very hard to stay on the outside of the disk. Meanwhile, it is quite easy to sit at the center of the disk. This is because of the properties of rotational momentum. Objects further from the center are moving much faster as the disk rotates, and they require a much larger force to keep them on the disk and moving in a circle. Children will be able to experience this effect on their own terms as they spin the disk or try to hang on. After playing with it for a little while, they will know how much harder it is to stay on the outside of the spinning disk versus the inside. This display creates an exciting and highly interactive environment that allows the children to truly learn by having fun. For these reasons, it will be a popular display among the children. Possible sponsors include any company who wants to maintain a fun image. One example is McDonalds, which could have their golden arches be the handles on the merry go round.

There are a few concerns that need to be addressed. As this display has the potential of children falling off the spinning disk, there needs to be thick padding to prevent injury. Also, the surface of the metal disk must not be smooth, but rather it should be slightly ridged so as to allow proper friction to keep children from sliding off. The display should make use a heavy-duty ball bearing device to ensure that it spins easily. While not required, it would be at least advisable to have a guide nearby to make sure children are not doing anything dangerous on the exhibit.

Newton's Cradle

Newton's Cradle is a famous way to show how objects can transfer energy and momentum. This display consists of five metal balls hanging from strings. They are positioned in a single line with the balls all touching. When a ball on the end is pulled out and released, it will swing into the four balls. This will cause the ball on the far end to move away from the center three balls and the ball that just collided. This process is repeated back and forth with the outside balls alternately swinging while the center balls remain motionless. Because this experiment is usually done on a small scale with golf ball sized balls, we feel it important to address the size of the metal balls used. The smaller the balls, the less interested the children will be with the display. However, if the balls are too large it can pose a potential danger of pinching a child's hand in a collision. For these reasons, we think that baseball-size, metal spheres be used. The display is somewhat interactive, very low cost, and educational. For these reasons, it should be considered as potential display for the mechanics room.

Due to the specific properties to make the display work, it is critical to use solid, metal balls. If another material is selected, the display may not perform as intended. Because this display is not very large and does not carry the excitement of the larger displays, it may not keep the children's interest for very long. For this reason, we recommend that it be placed between the bigger exhibits. This will allow the children to play with it and learn as they pass by.

Pulley Lift

Similar to the lever lift display, the pulley lift provides a child with another technique to lift exceptionally heavy objects. This time it is with the mechanical advantage of pulleys. A heavy object is attached to a steel plate connected to a rope and a system of pulleys. A child can pull on the rope to discover that he or she can lift a very heavy object. Once again, possible objects to lift are a heavy weight, a car, or classmates. A new possibility is for a child to lift herself. The pulley system can be attached to a chair in which a child sits and pulls on the rope at the same time. If a car is lifted, any major car dealer in San Jose would be a possible sponsor.

As with lifting any heavy object, there are potential safety issues. Specifically, a dangerous situation arises if the heavy object raises too far off the ground. Besides roping off the area, the weight should be attached to the floor with a chain that prevents it from being raised excessively high.

Rotating Chair

This is another display that teaches children about rotational momentum. Specifically, if a spinning object has some of its mass pulled inwards, it will spin faster. In this display children sit on a chair that can swivel. As classmates or personal effort spins the child, he or she can put legs and arms out to slow the rotation. If their arms and legs are pulled back in, they start to suddenly spin faster. This is a highly interactive way to teach children about rotational momentum. It is relatively low cost and does not require supervision. As an alternative, the chair can be replaced with a rotating disk in the floor with an attached handle a few feet off the ground. A visitor can stand on the disc and spin while holding onto the handle.

There are downsides to the display. Because of the low cost and the advanced concept taught, it is intended for older children to play with, as they are more likely to understand how it works. However, the older children are not likely to want to play with this simple display when so many more stimulating choices are available. In addition, the museum currently has an old version of this same concept that few if any people use.

Rotating Tube

Originating from an amusement park fun house, this display challenges a person's ability to stay upright while providing an exciting and different environment. It emphasizes the fact that gravity always pulls down and teaches how rotation works. A long hollow tube tall enough to stand in acts as a tunnel for children to crawl or walk through. The challenge is that a motor turns the tunnel, which makes it difficult to walk through. The idea is similar in nature to the highly popular Crazy House at the museum, because it manipulates a persons sense of balance. However, this display not only teaches about gravity always pulling down, but it allows children the opportunity to pin their hands and feet firmly to the floor to spin full circle. A good opportunity for sponsorship exists by putting advertisements on the rotating tube section. For example, Coca Cola might make the tube look like a soft drink can.

There are several safety concerns that should be addressed regarding this display. First, a special motor must be used to turn the tunnel, and it must be kept in a locked compartment. Second, the outside of the tunnel should be kept off limits. This is to prevent children from attempting to climb on it or have their fingers pinched as the tube turns into the base. However, no direct supervision is required for this display.

Sand Pendulum

Similar to the Decaying Motion display, a swinging pendulum pours sand onto a smooth drawing table. As the sand pours out, it creates repeating patterns that exponentially decrease in size. The decrease in the size of the pattern is due to the dampening of the pendulum swing. Using the display, children will be able to draw oscillating patterns that can be simple or complex. The children can fill up the swinging pendulum, called a bob, with sand using the provided shovel. There should also be a small handled broom to clear of the table between pictures and a tray to catch the sand at the edge of the table. This display creates an interactive display that allows children to express themselves artistically. These qualities help to make this a good display to include in the mechanics exhibit. There are no safety concerns with this display and it does not require any supervision. However, we believe that the Decaying motion display might prove more stimulating due to the conveyor belt. This is a factor that should be considered when determining whether to build this display.

There are just a few minor concerns regarding this display. The shovel and broom should be attached to the display to ensure that they are not stolen. The sand used needs to be very fine so that it is pleasing to the touch. It will also need to be periodically replaced due to being spilled on the floor and sticking on the children's hands.

Spring Platform

This display presents children with how different types of springs react differently. In technical terms, it shows the effect of the spring constant. This means that springs with a higher spring constant, basically thick springs, do not compress as much as thinner springs. Two types of identical length springs of different strength are used to support two small platforms. Each type of spring supports one platform. The two types of springs should be noticeably different. As a child sequentially steps on one and then the other, he or she will be able to see how one of the platforms will go lower than the other. Through this interaction, they will learn how springs of different strengths compress under the same applied force. An additional feature is that it will be very inexpensive to build and will take up little space.

Although the display is not as exciting or stimulating as other displays, it does teach the children about springs in a simple manner. This is a hard task to accomplish, as springs are not one of the easiest topics to understand. It should also be mentioned that there are no safety concerns regarding the display, and no supervision is required.

Swings

Another way to teach children about pendulums is by letting them play with swings. In this display, they are able to become part of the display while they learn about some properties of pendulums. One principle of pendulums is that the period of the swing only depends on the length of the pendulum. This means that even if big and little children use the same swing, the period of their swings will be identical. It is also true if one swings for a greater distance than the other. The swing display will allow children to explore these properties by providing them with multiple length swings. They are free to just have a great time playing, but they can also time the swings on the attached LED display timer. By timing various swings, they will be able to learn through direct interaction. It will not cost much to construct and it requires no supervision. The displays strong qualities are that it is highly interact and fun.

A few minor safety issues should be addressed. First, the swings need to be spaced far enough apart so that the children do not hit each other when swinging. It is also important to keep the area that each swing moves in free of people walking by. Providing plenty of space around the display can accomplish this. From what we have learned about the push buttons at the museum, we suggest the museum use another form of starting, stopping, and resetting the timer. One possibility is a sensor pad similar to that used in the orchestra room.

Teeter Totter

A popular playground toy, the teeter-totter is based upon the mechanical advantage of a lever and fulcrum. It is another display that can teach children about how they can lift more weight than normal, but it also allows them to just have fun. The teeter-totter will have three seats with handles on each side of the fulcrum along the length of the beam. Depending on where children sit, children might be able to lift people much heavier than they are or none at all. In general, it is likely that they will want to just rock back and forth enjoying the stimulating feeling. It is a highly interactive display that promotes learning through interaction and fun. It is also not very expensive to construct and does not require supervision. For these reasons, we highly recommend this display. Possible sponsors include any company who wants to maintain a fun image. One example is McDonalds, which could have their golden arches be the handles on the merry go round.

There is only one minor concern regarding the display. That is if two children are on opposite ends and the one on the low end gets off quickly. This will cause the bar to drop quickly and the child might feel the impact through the bar. To prevent this, we feel the ends of the bar should rest on rubber or a padded cushion. This will help dampen a fall if it occurs.

Tin Can Telephones

Another topic of mechanics is oscillations. Oscillations occur when an object moves back and forth repeatedly. In this display, a thin string connects two tin cans. The cans are attached to boards so that the string in between can be very tight. Two children can then talk back and forth using the tin cans. This is because the tin can will transfer their sound waves down the string. The other can then vibrates the same as the string and replicates what the original person said. Because of the children being able to become part of the exhibit, it is very interactive. It teaches children a little about how waves can travel and a primitive method of talking on the phone. It is extremely inexpensive, requires no guide, and is very safe. Potential sponsors for this display include ICE and Motorola de Costa Rica.

However, it only works if children are on opposite ends simultaneously. The success will depend greatly on how the cans are attached to the wood boards and if the string is tight enough. Also, it will not keep the children's attention long and is one of the less interesting displays. This might be a great classroom experiment to recommend to the teachers, but is less appropriate for the museum.

Turntable

The turntable is another great way to teach children about rotation. A table with balls and other rolling objects surrounds a center circle that is spun by a motor. As the objects are rolled across the static table onto the rotating circle, the children will see how they change direction and speed. This will teach children how rotation can change the way an object is moving and the speed that it was traveling at. It is very educational in addition to allowing children to interact on their own terms. This combination in addition to being fun will prove make a successful display. In addition, it is also moderately inexpensive to build and does not require any supervision. We feel that this would be a great display to consider for the mechanics room.

There is one safety issue that needs to be mentioned. As with any motor driven device, the children have to be protected from being able to touch the motor. This is easily fixed by enclosing the motor in a housing unit. Because the balls and other objects that are rolled on the table should not be attached to the display, they might be periodically stolen. For this reason, they should be cheaply made or bought in bulk. We highly recommend using wooden pieces, which would be less likely to be stolen than bouncing balls.

Velcro Wall

This exhibit was recommended because of a high level of interactivity and the fun the children will have while using it. Different size Velcro jump suits that allow children and adults to jump on a trampoline and stick to a Velcro wall. The display conveys the concept of how large amounts of friction can prevent two surfaces from sliding. In short, the people will stick to the wall. One reason this display is so attractive is that it is likely something the children, or adults, have never seen before. It also shows an interesting phenomenon, as there is not enough friction on normal walls to prevent a person from sliding back towards the floor. It is such an enticing activity that people pay to use them at parties and other events. The concept of magnifying the amount of friction to keep somebody suspended against a wall will be a sure favorite of all ages at the museum. A great sponsorship opportunity would be through the Velcro USA company, which has a branch in Costa Rica.

One of the drawbacks to this display is that it requires that supervision be present at all times. Also, safety precautions should be taken by thickly padding the floor around the Velcro wall, as well as the wall itself, to prevent possible injury. We feel the excitement and unique opportunity this display will bring to the museum and the mechanics room may justify the need for supervision.

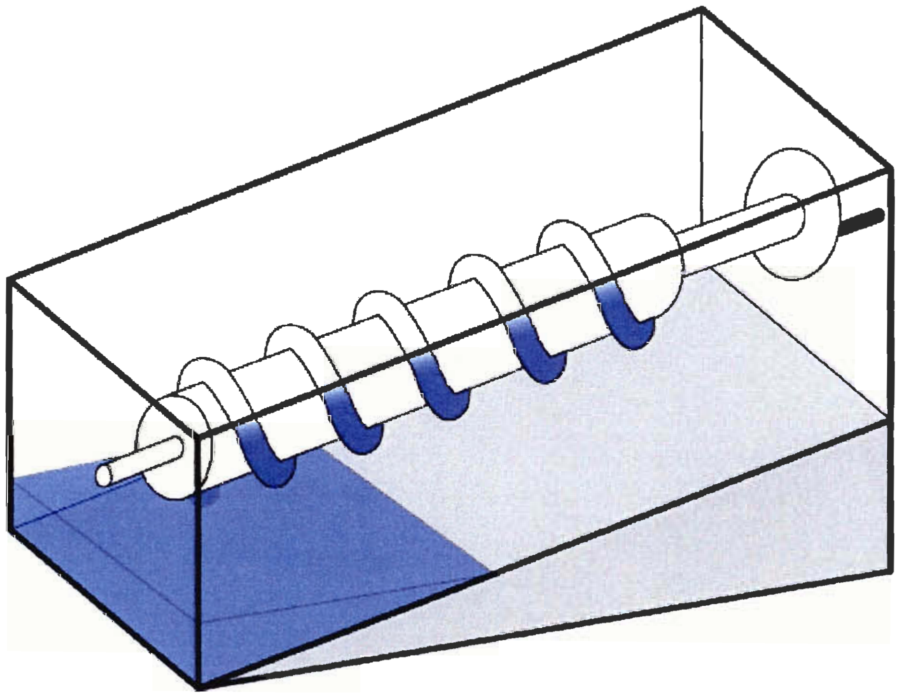
Wobbly Table

This is one of the simplest and least expensive displays. It consists of a 6-inch metal tube about two feet high connected to the center of a 1-meter diameter disk. The tube and disk are connected by a ball and socket joint that allows it to easily pivot. If the children try to step on the disk, they will realize that it is very hard to keep it stable. The ball and socket joint causes the plate to slant if the child does not keep their balance centered. As the children interact with it, they will be accidentally learning about their center of mass. This is a principle of mechanics that one's balance is dependant on. The display is very low cost, highly interactive, small, and somewhat challenging. It also does not require any supervision, which is an important feature.

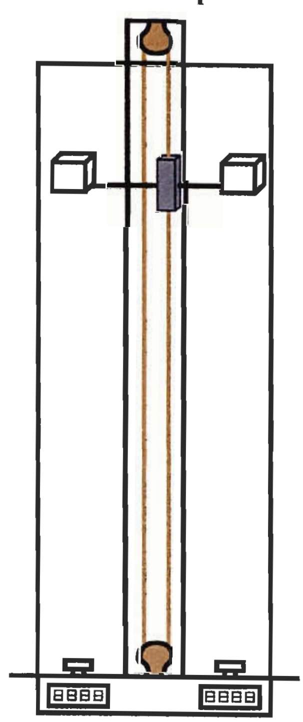
However, due to the low cost and simple nature of the design, the display does not have the same excitement that more complex displays do. This means that it will only hold the children's attention for a short period of time. Therefore, it might best be put between more exciting, and expensive, displays to allow the children to explore it as they pass by. It also should have padding around it to prevent injury if children fall.

Appendix I – Exhibit Illustrations

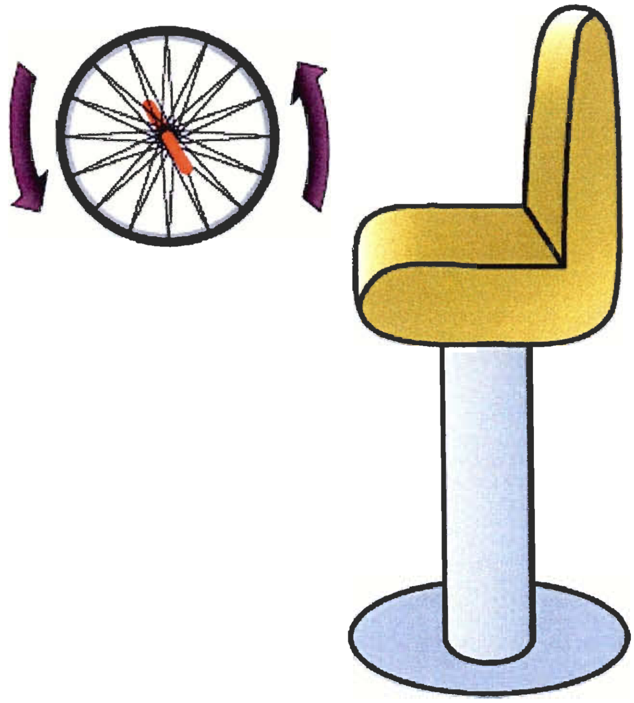
Archimedes' Screw



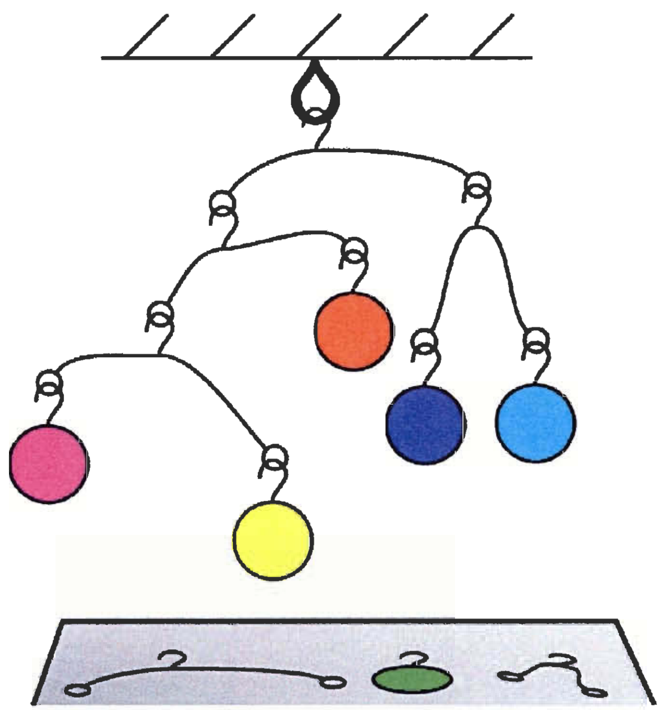
Ball Drop



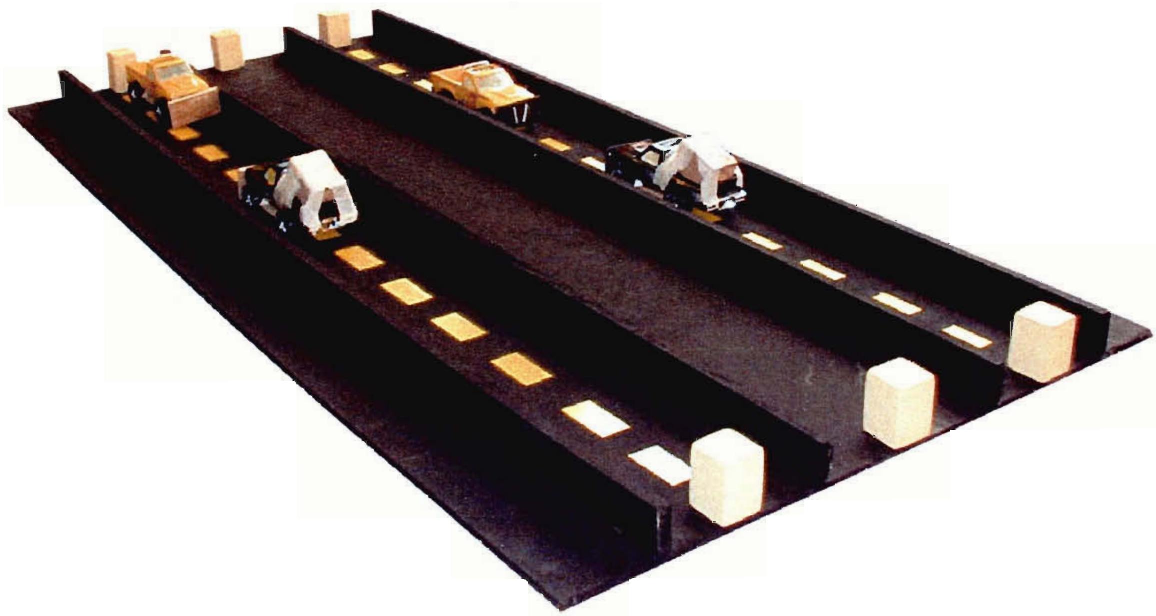
Bicycle Wheel Gyro Chair



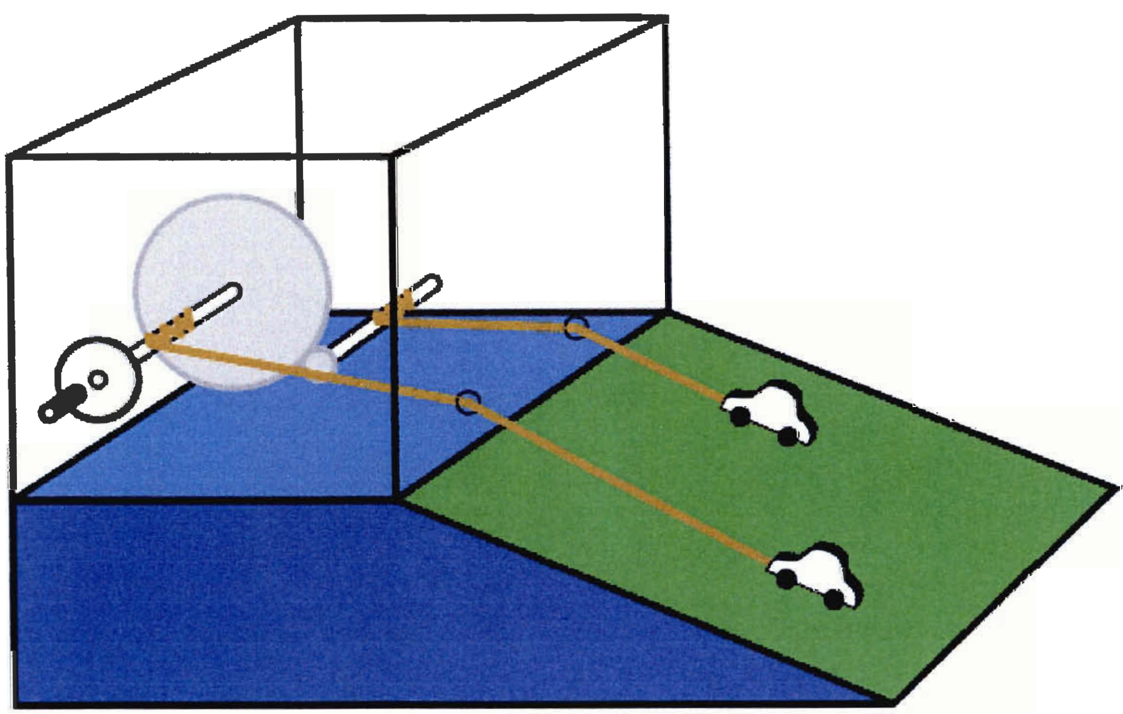
Build Your Own Mobile



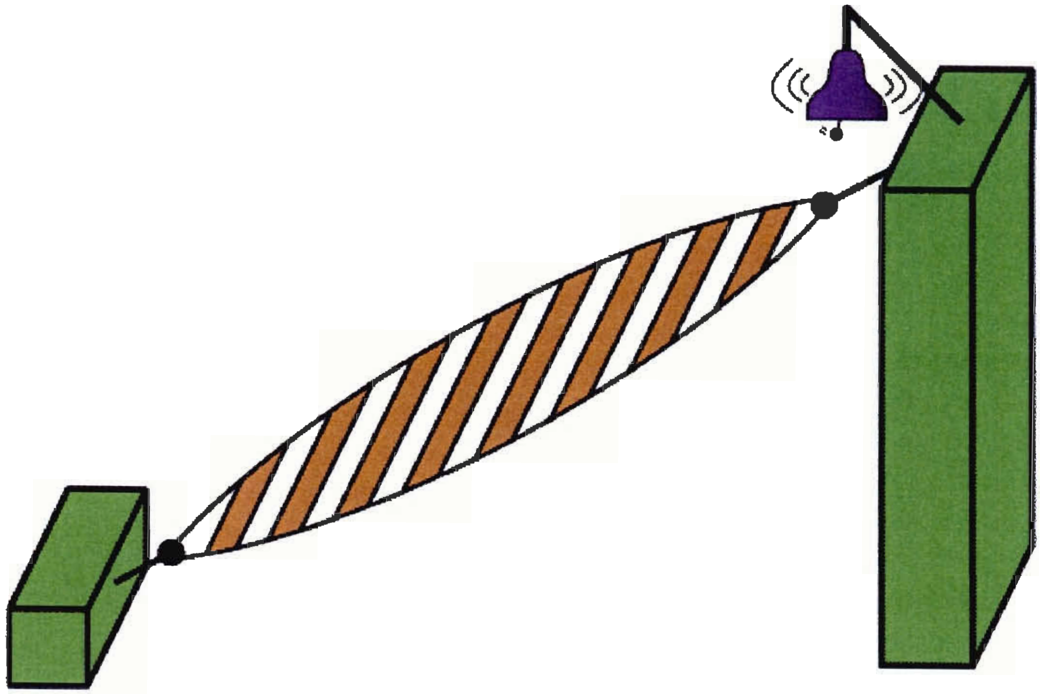
Car Collisions



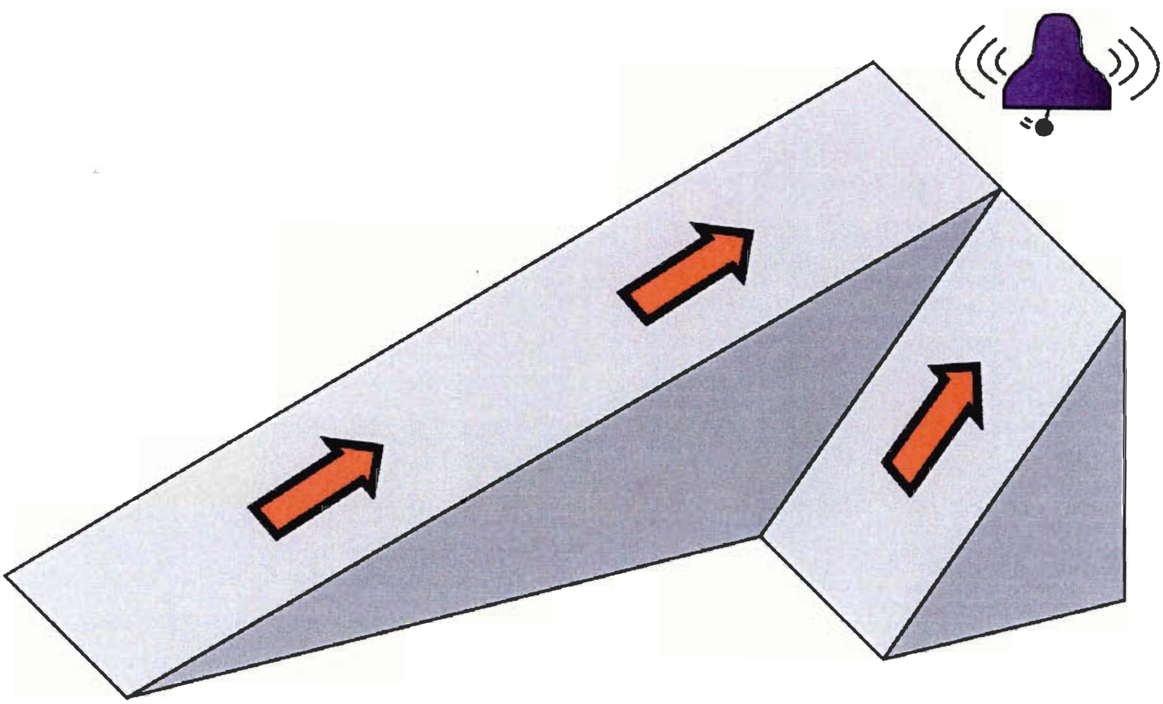
Car Race with Gears



Carnival Ladder

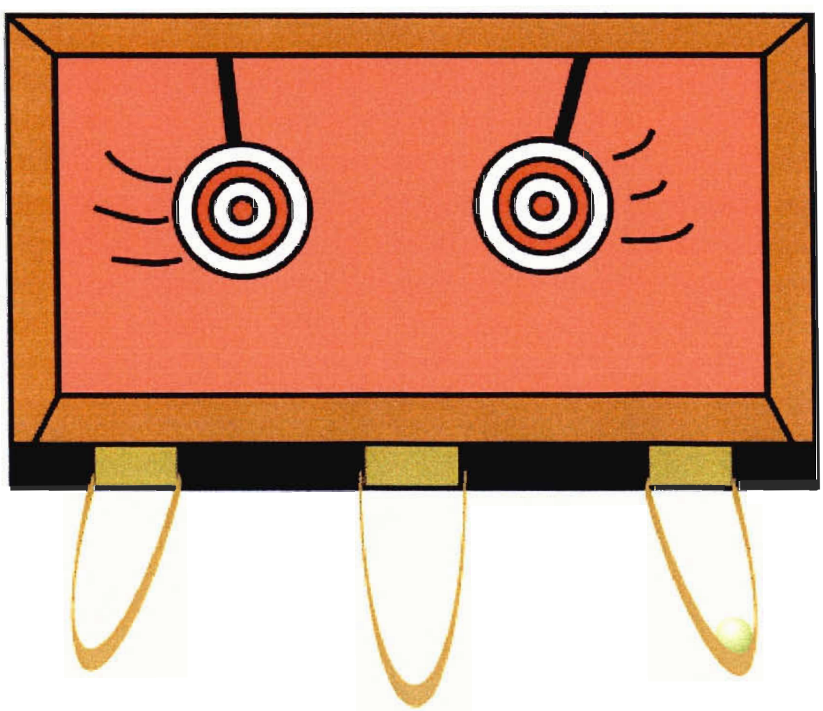


Climbing Slopes

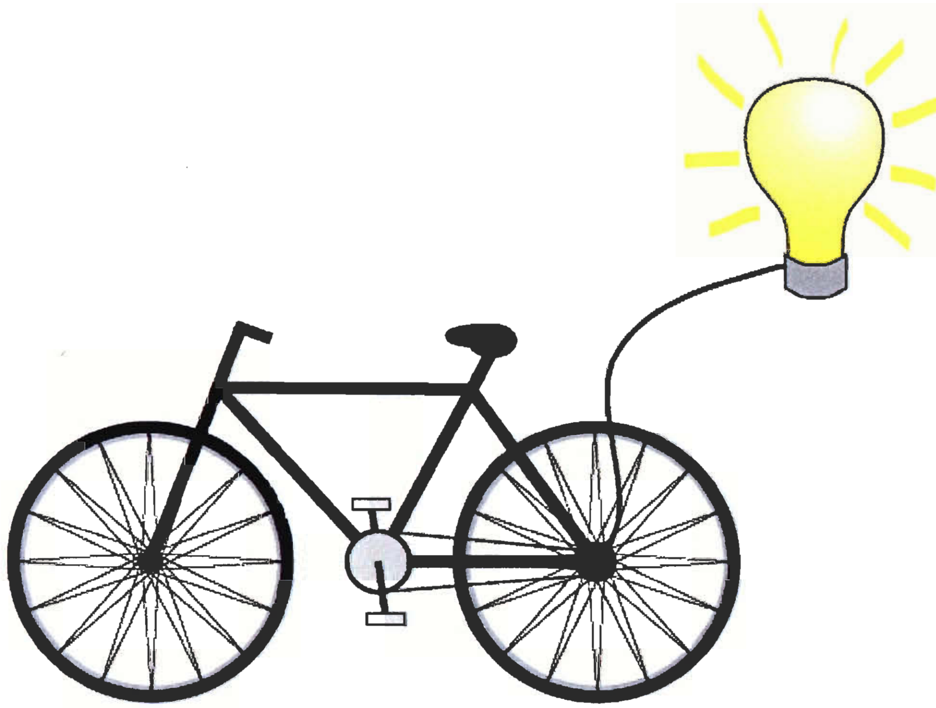


Decaying Motion

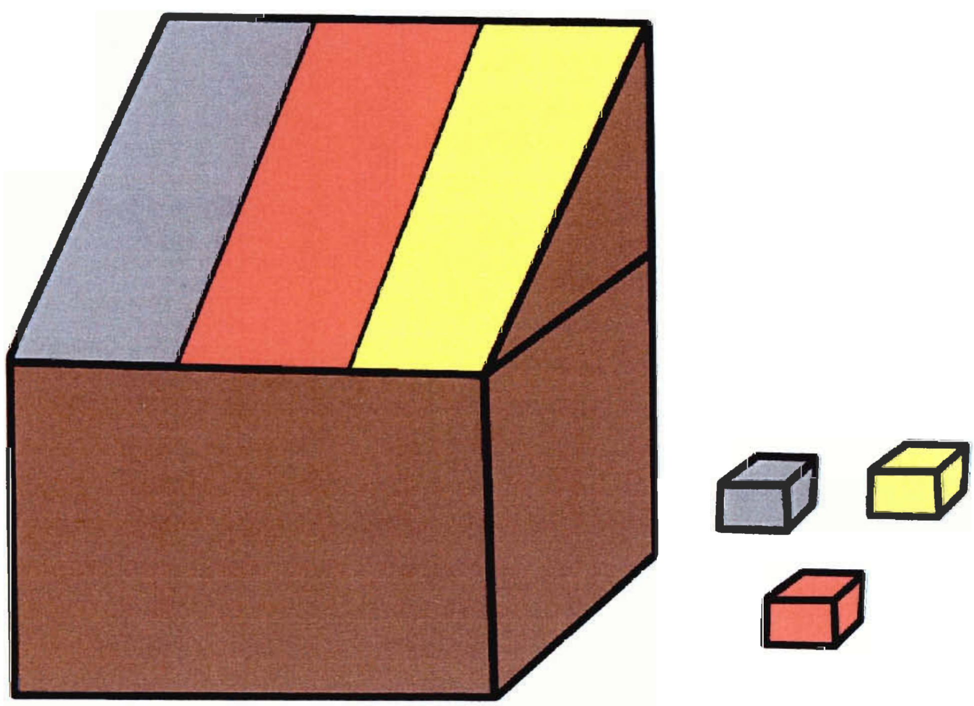
Elastic Shooting Gallery



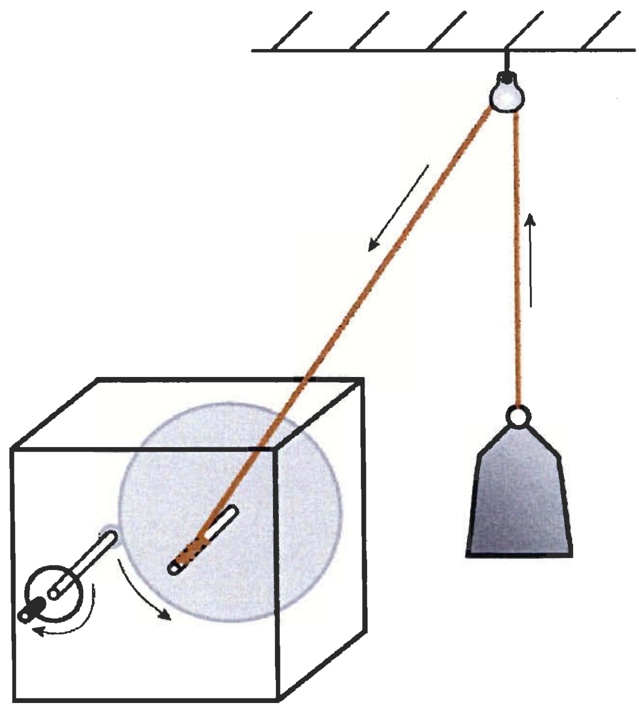
Exercise Bicycle Generator



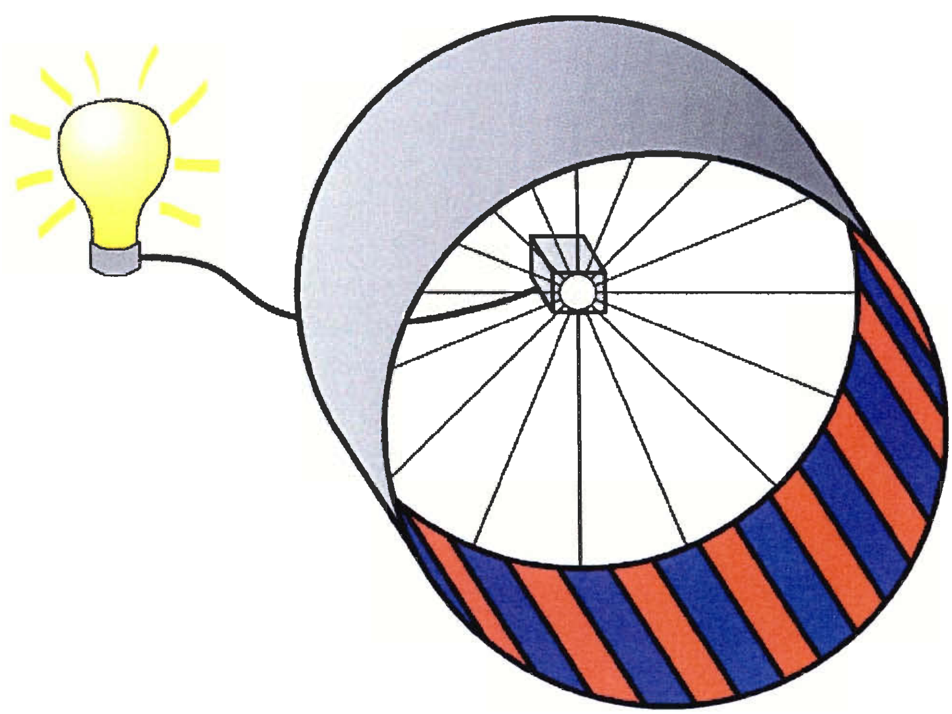
Friction



Gear Lift

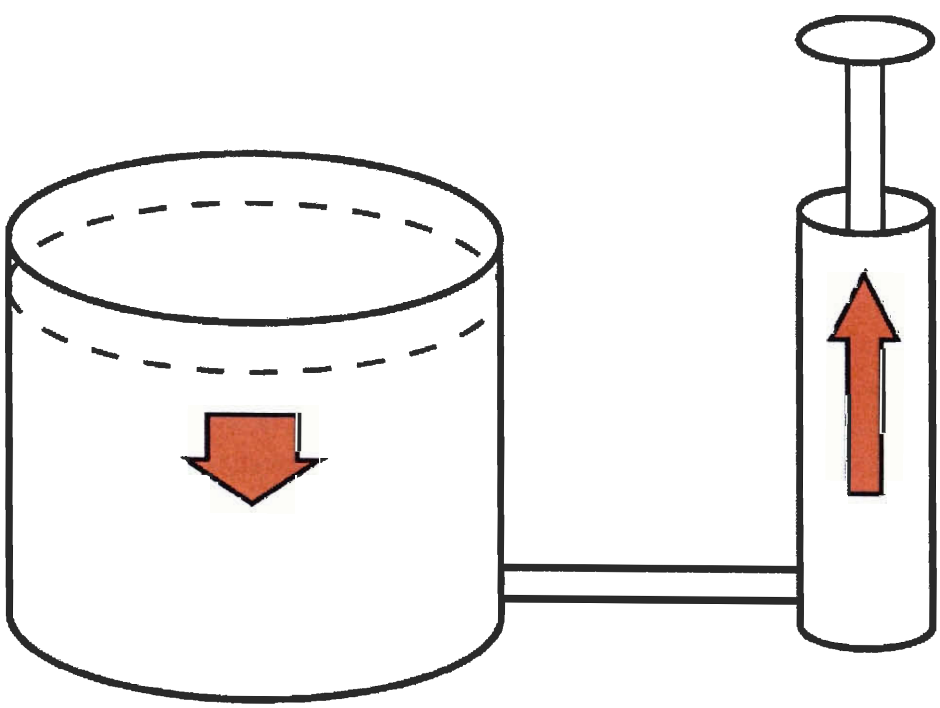


Hamster Wheel Generator

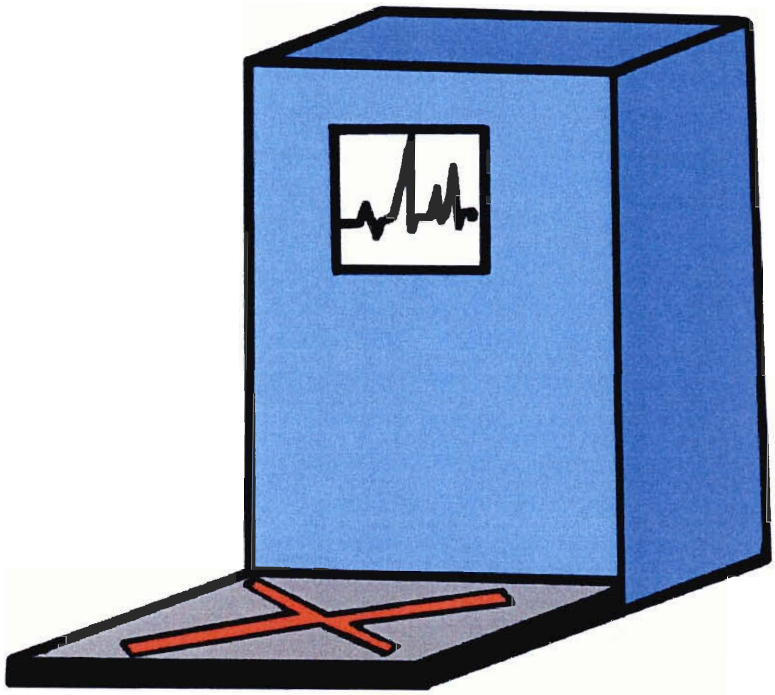


Hanging Bicycle Gyro

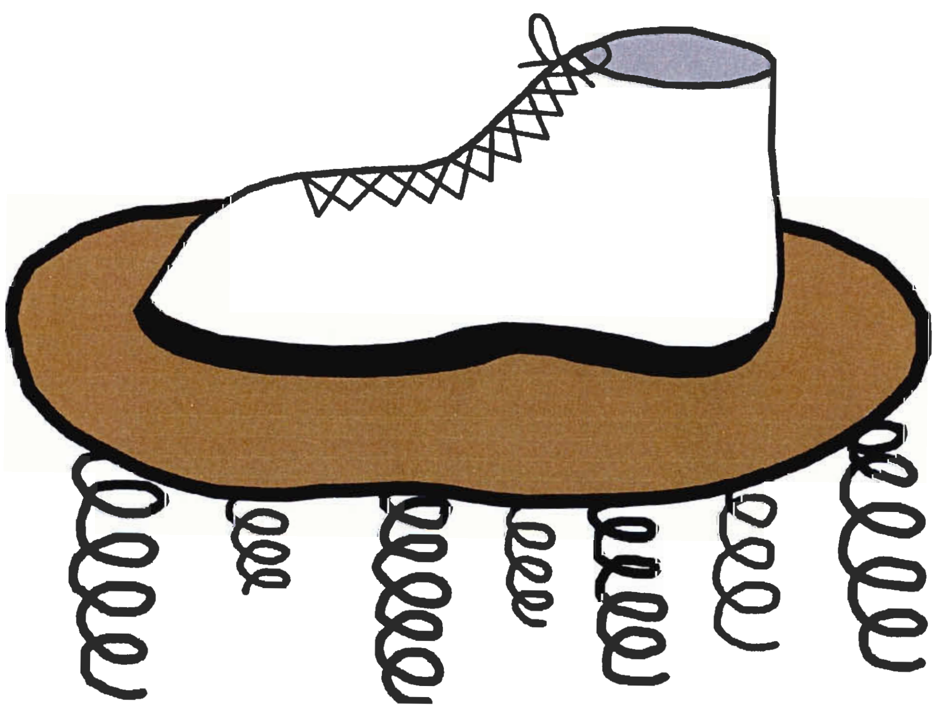
Hydraulic Lift



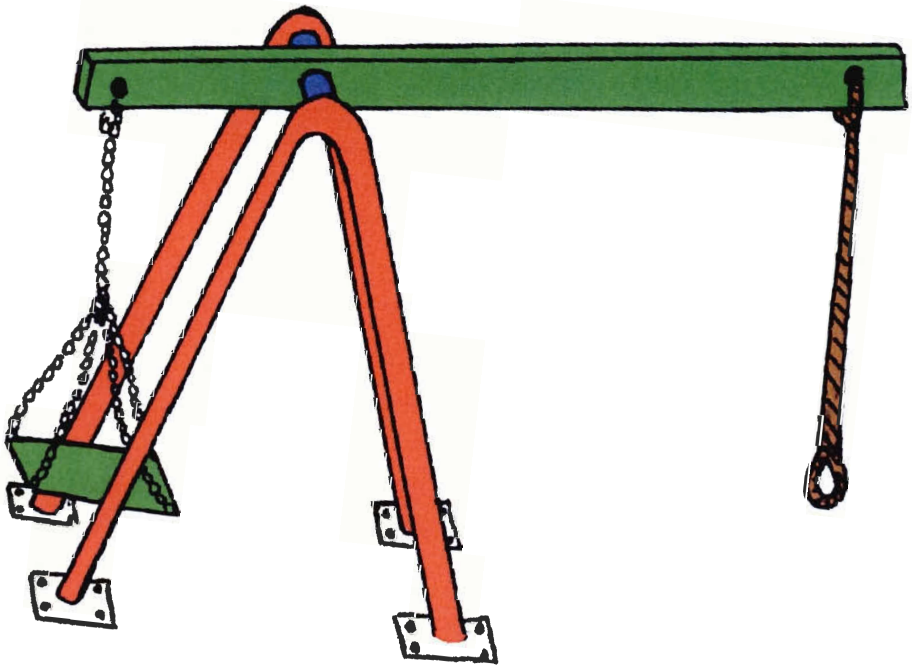
Jump Pad



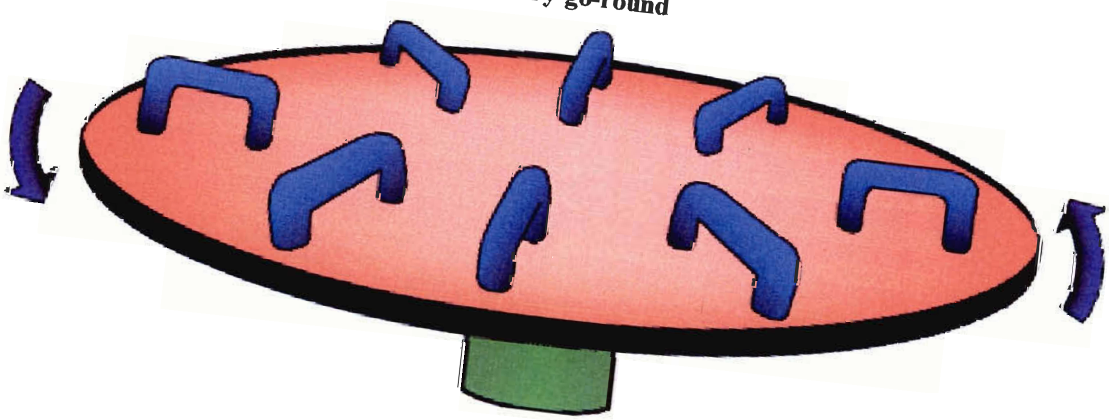
Kangaroo Shoes



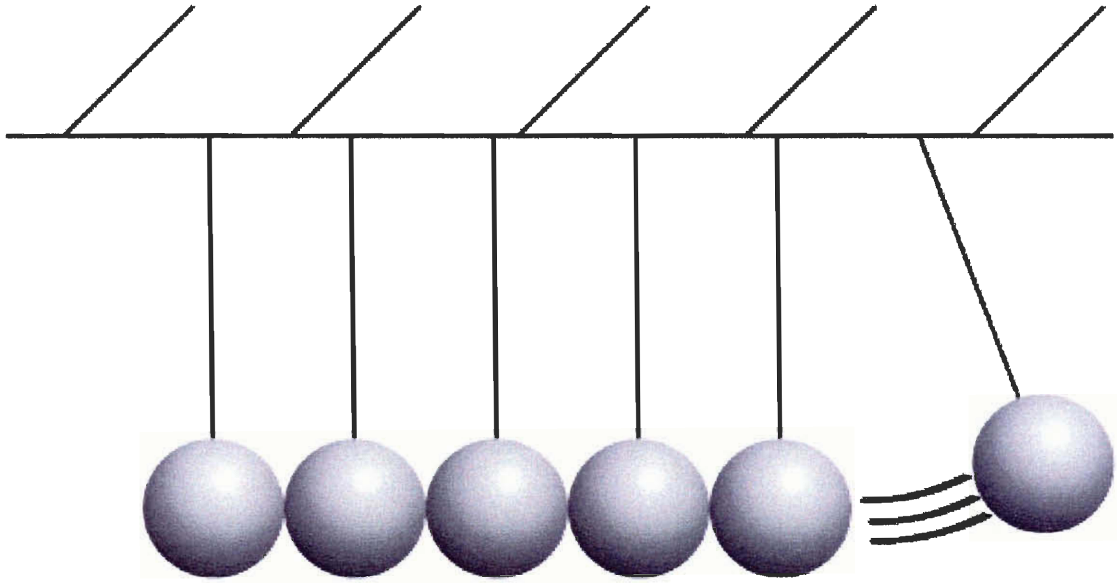
Lever Lift



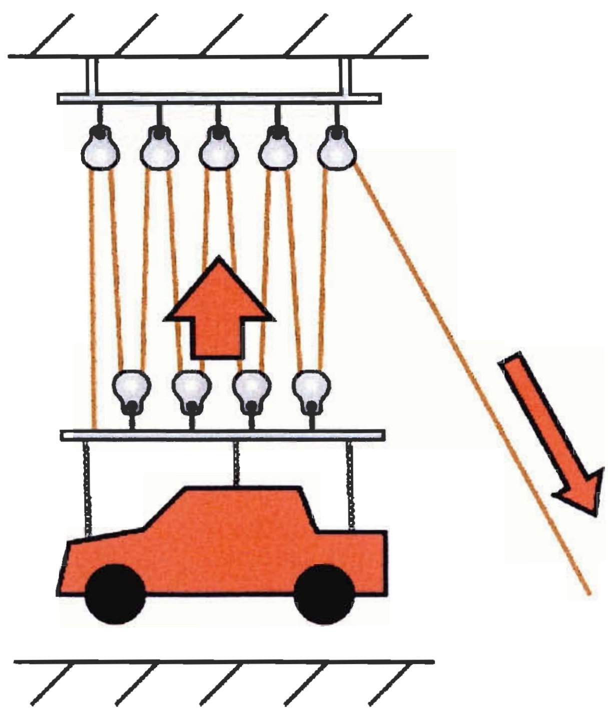
Merry-go-round



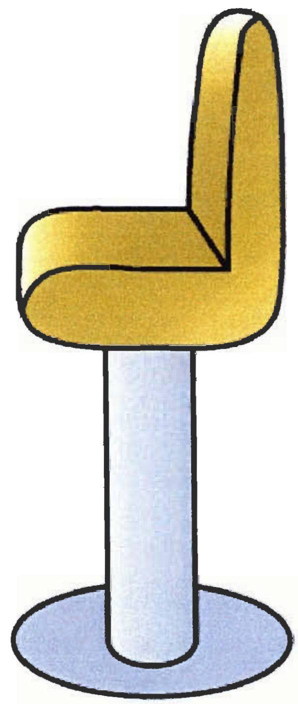
Newton's Cradle



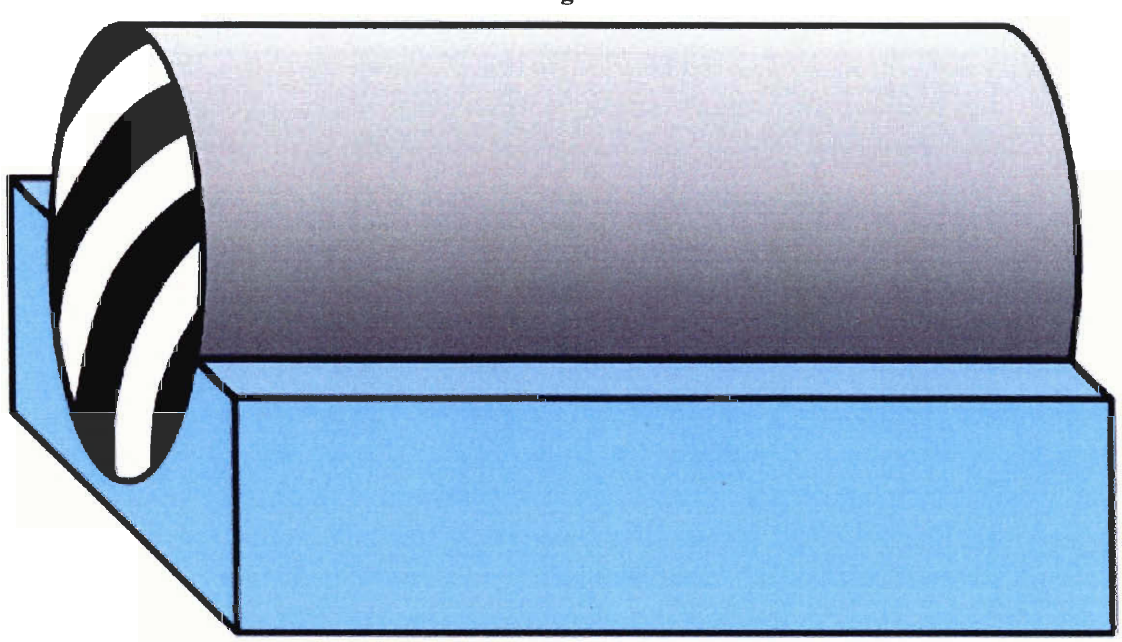
Pulley Lift



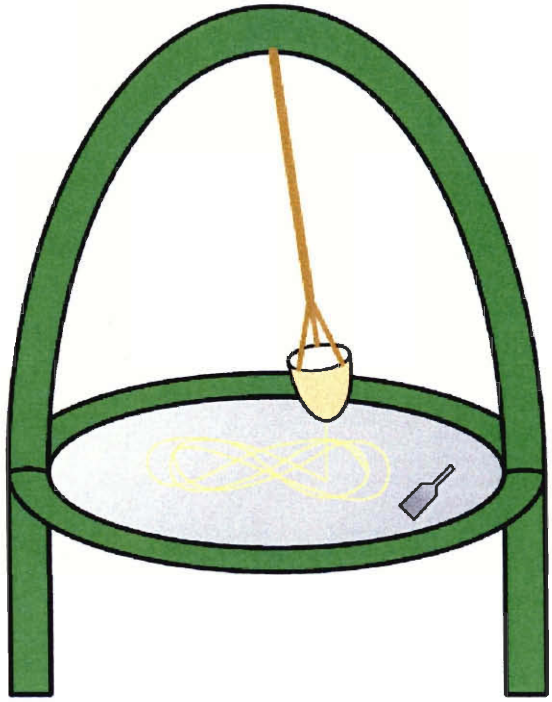
Rotating Chair



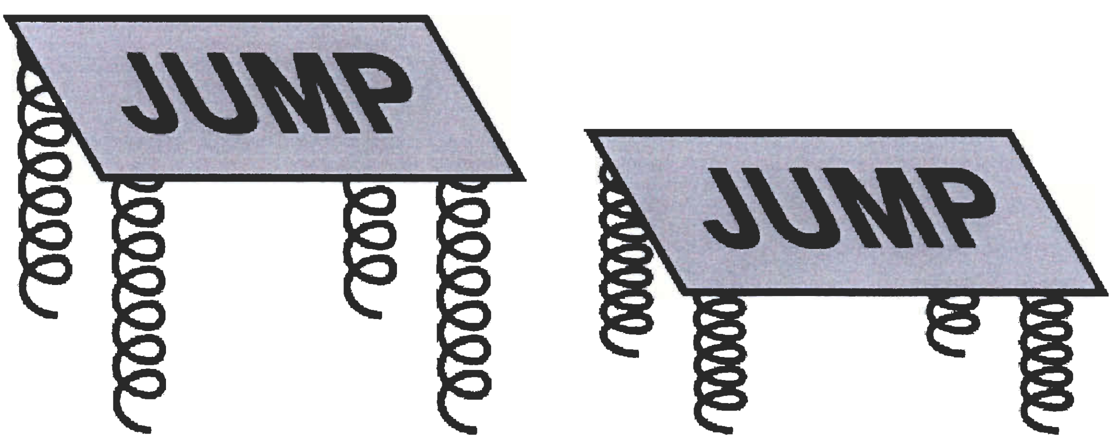
Rotating Tube



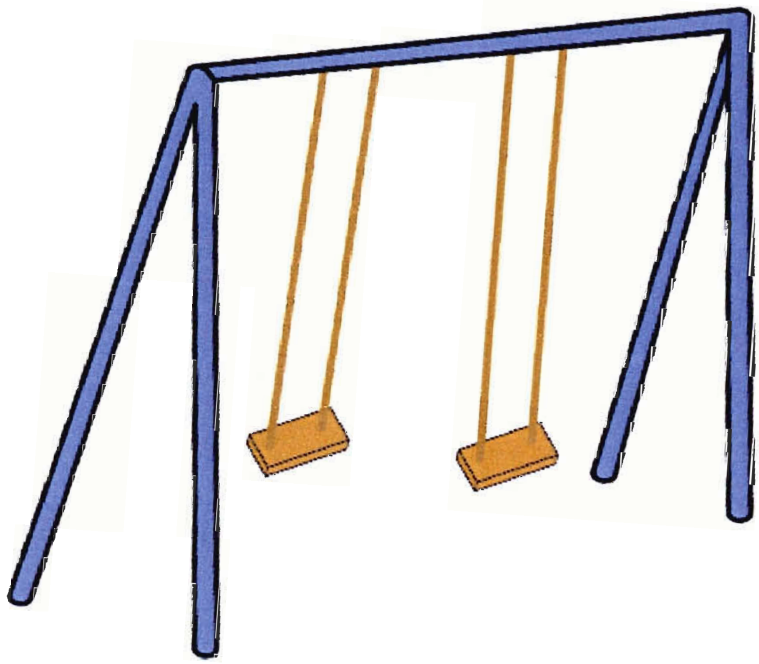
Sand Pendulum



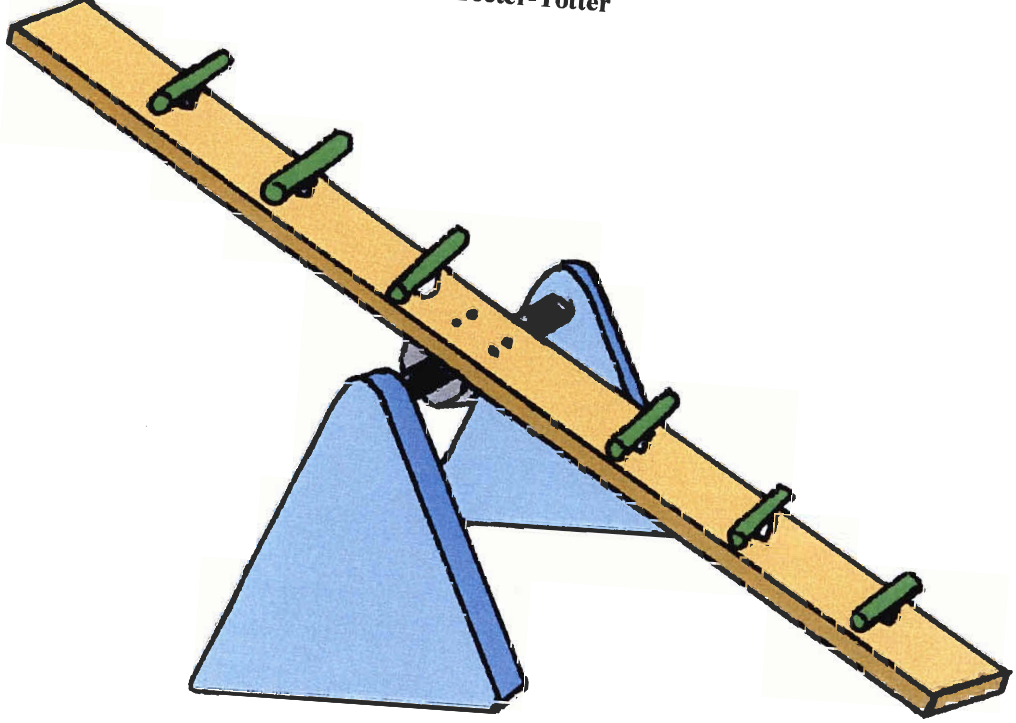
Spring Platform



Swings

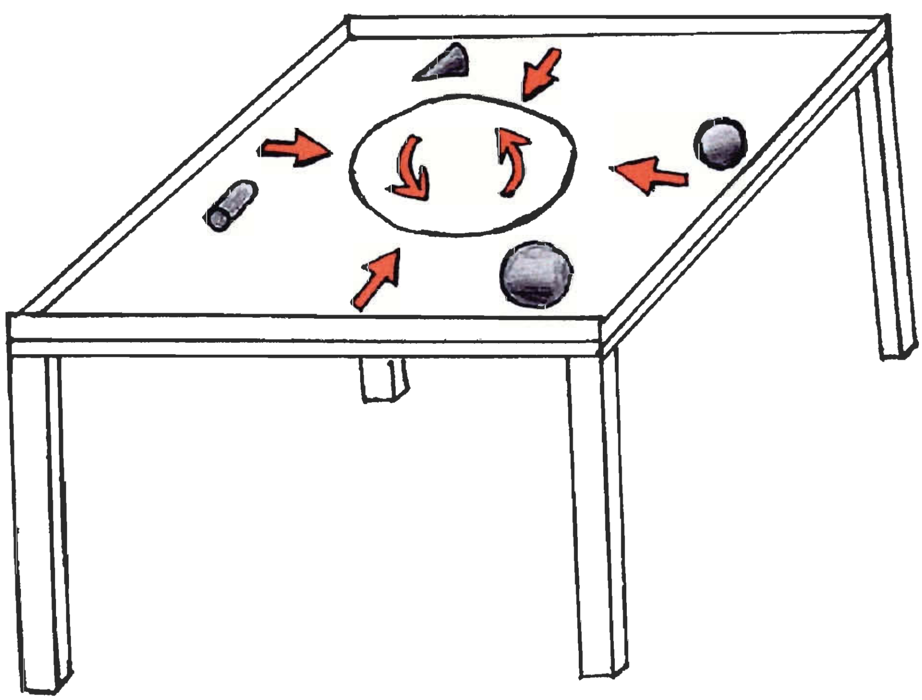


Teeter-Totter

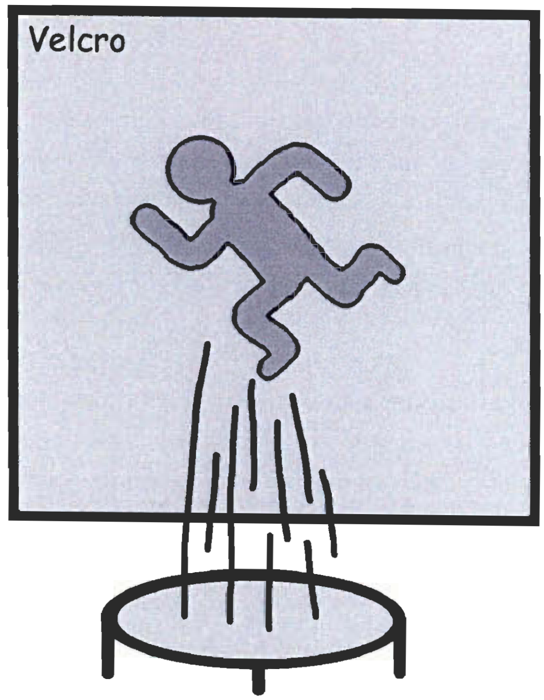


Tin-can Telephone

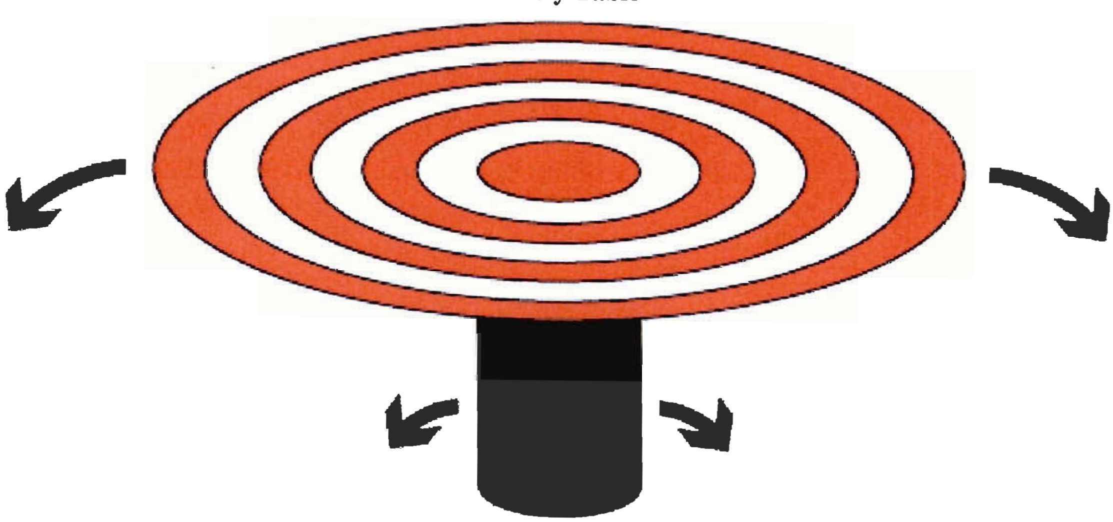
Turntable



Velcro Wall



Wobbly Table



Appendix J – Materials and Costs

This appendix contains a detailed list of the materials needed to construct each exhibit along with their associated costs. If the labor cost is zero, the exhibit can be entirely constructed at the museum. Those exhibits with no labor cost listed have that expense in the price of the materials. Non-zero labor prices indicate what a contractor would charge for the construction of the exhibit. Mr. Sanchez, who helped determine the costs, estimated an error range of about 15% in the figures, so any of these numbers might actually be 15% higher or lower than listed.

	Materials	Cost in Colones
Archimedes Screw		
	Plexiglass (Acrillico)	60,000
	Acrylic Glue	5,000
	Clear Tubing	2,000
	Plastic Tubing 1'	5,000
	Crank Mechanism	20,000
	Water Coloring	1,000
	Labor	30,000
	Total	**123,000**
Ball Drop		
	Pulleys (2)	8,000
	Rope	2,000
	Plexiglass (Acrillico)	30,000
	Timing System	50,000
	Drop Mechanism	15,000
	Wood	8,000
	Labor	80,000
	Total	**193,000**
Bicycle Wheel Gyro Chair		
	Bicycle Wheel with Handles	10,000
	Chair with Rotating Base	80,000
	Total	**90,000**
Build Your Own Mobile		
	Metal Tube 2"	8,000
	Pieces To Hang	3,000
	Paint	3,000
	Labor	12,000
	Total	**26,000**

Car Collisions		
	Wood Crashing Table	30,000
	Trucks	30,000
	Weights for Trucks	1,000
	Paint	10,000
	String and Eyehooks	1,000
	Labor	25,000
	Total	**31,000**
Car Race with Gears		
	Plexiglass (Acrillico)	30,000
	Acrylic Glue	5,000
	Wood Base	8,000
	Paint	3,000
	Cars	30,000
	Rope	2,000
	Crank Mechanism	50,000
	Labor	30,000
	Total	**158,000**
Carnival Ladder		
	Rope 10 meters	6,000
	Metal Tube 1"	6,000
	Bell	5,000
	Paint	5,000
	High and Low Platforms	10,000
	Labor	15,000
	Total	**47,000**
Climbing Slopes		
	Wood	20,000
	Bell	2,000
	Paint	3,000
	Labor	0
	Total	**25,000**
Decaying Motion		
	Metal Tube 2"	10,000
	Sand Pouring Pendulum	2,000
	Rope	500
	Plastic Sand Catch Tray	11,000
	Conveyor Belt and Motor	80,000
	Fine Sand	3,000
	Plastic Shovel	600
	Small Broom	10,000
	Labor	40,000
	Total	**157,100**

Elastic Shooting Gallery		
	Metal Tube 2"	15,000
	Netting	25,000
	Metal Pendulums	20,000
	Rubber Balls	4,000
	Rubber Shooting Sling	5,000
	Sloped Wooden Base	5,000
	Paint	3,000
	Labor	40,000
	Total	**117,000**
Exercise Bike Generator		
	Exercise Bicycle	40,000
	110v Motor Convertor	6,000
	Lightbulb and Base	2,000
	Power Cord	3,000
	Labor	40,000
	Total	**91,000**
Friction		
	Wood	15,000
	Paint	3,000
	Other Materials	3,000
	Labor	0
	Total	**21,000**
Gear Lift - Car		
	Plexiglass (Acrillico)	60,000
	Special Acrylic Glue	5,000
	Wood Base	5,000
	Paint	2,000
	Cable with Plastic Hose	6,000
	Crank Mechanism (Gears, Pinions, & Handle)	80,000
	Pulley (Heavy Duty)	3,000
	Chains to Attach Car	4,000
	Labor	20,000
	Total	**185,000** plus car

Gear Lift - Classmates

	Plexiglass (Acrillico)	60,000
	Special Acrylic Glue	5,000
	Wood Base	5,000
	Paint	2,000
	Cable with Plastic Hose	6,000
	Crank Mechanism (Gears, Pinions, & Handle)	80,000
	Pulley (Heavy Duty)	3,000
	Platform to Stand On	14,000
	Chains to Attach Platform	4,000
	Labor	20,000
	Total	**199,000**
Hamster Wheel Generator		
	Human Size Hamster Wheel	40,000
	110v Motor Convertor	6,000
	Lightbulb and Base	2,000
	Power Cord	3,000
	Total	**51,000**
Hanging Bicycle Gyro		
	Bicycle Wheel with Handles	10,000
	Rope	2,000
	Labor	0
	Total	**12,000**
Hydraulic Lift		
	Hydraulic Lift Platforms	100,000
	Paint	7,000
	Total	**107,000**
Jump-pad		
	Plywood	15,000
	Paint	7,000
	Computer System & Screen	500,000
	Labor	0
	Total	**522,000**
Kangaroo Shoes (per shoe)		
	Heavy Duty Springs	5,000
	Plywood	1,000
	Labor	0
	Total	**6,000** plus shoes

Lever Lift - Car		
	Metal Tubing 2"	8,000
	Metal Beam 2"	8,000
	Rope	2,000
	Steel Plate	16,000
	Chain	8,000
	Labor	60,000
	Total	**102,000**
Lever Lift - Classmates		
	Metal Tubing 2"	8,000
	Metal Beam 2"	8,000
	Rope	2,000
	Steel Plate	16,000
	Chain	8,000
	Labor	60,000
	Total	**102,000**
Lever Lift - Weight		
	Metal Tubing 2"	8,000
	Metal Beam 2"	8,000
	Rope	2,000
	Steel Plate	16,000
	Chain	8,000
	Labor	60,000
	Total	**102,000**
Merry Go Round		
	Metallic Disk 8'	30,000
	Metal Tubing 2" for Handles	16,000
	Metal Tubing 6" for Base	25,000
	Metal Braces	7,000
	Ball Bearing Rotating Device (Heavy Duty)	30,000
	Padding	80,000
	Paint (Non Rust and Finish)	8,000
	Labor	50,000
	Total	**246,000**
Newton's Cradle		
	Metal Balls 3" Solid	50,000
	String and Eyehooks to Hang Balls	3,000
	Metal Tubing 2" Structure to Hang Balls	8,000
	Labor	15,000
	Total	**76,000**

Pulley Lift - Car		
	Cable with Plastic Coating 150'	22,500
	Pulleys (9)	48,000
	Steel Support System	70,000
	Cable to Attach Car	3,000
	Labor	230,000
	Total	**373,500**
Pulley Lift - Classmates		
	Cable with Plastic Coating 150'	22,500
	Pulleys (9)	48,000
	Steel Support System	70,000
	Cable to Attach Platform	3,000
	Platform to Stand On	14,000
	Labor	230,000
	Total	**387,500**
Pulley Lift - Self		
	Plastic Chair to Lift	20,000
	Rope	5,000
	Pulleys	20,000
	Metal Tubing 2" Support Structure	7,000
	Labor	20,000
	Total	**72,000**
Rotating Chair/Disc		
	Chair with Rotating Base	80,000
	Total	**80,000**
Rotating Tube		
	Walk Through Tube (Metal/Plastic)	120,000
	Motor w Rollers to Turn Tube 10x per Minute	350,000
	Wooden Base for Tube	30,000
	Paint	4,000
	Labor	0
	Total	**504,000**
Sand Pendulum		
	Metal Tube 2"	10,000
	Sand Pouring Pendulum	2,000
	Rope	500
	Plastic Sand Catch Tray	11,000
	Fine Sand	3,000
	Plastic Shovel	600
	Small Broom	1,000
	Labor	30,000
	Total	**58,100**

Spring Platform		
	Wood Platforms	14,000
	Paint	4,000
	Heavy Duty Springs	10,000
	Labor	0
	Total	**28,000**
Swings		
	Entire Swing Set	80,000
	Additional Chains	15,000
	Total	**80,000**
Teeter-Totter		
	Metal Beam	5,000
	Metal Sheet (For Base)	16,000
	Metal Tube 1"	3,000
	Metal Tube 2"	5,000
	Paint	4,000
	Pivot Brace	10,000
	Labor	65,000
	Total	**108,000**
Tin-can Telephones		
	Metal Cans	1,000
	String 10'	1,000
	Metal Supports	5,000
	Labor	0
	Total	**7,000**
Turntable		
	Wooden Table with Legs	15,000
	1/4 Motor to Turn Center of Table	50,000
	Assorted Balls	2,000
	Paint	5,000
	Labor	0
	Total	**72,000**
Velcro Wall		
	Thick Padding for Floor	80,000
	Trampoline	60,000
	Labor	0
	Total	**140,000** plus Velcro wall and suit
Wobbly Table		
	Metal Tube 4" for Base	11,000
	Ball and Socket Joint for Top of Tube	5,000
	Wooden Platform 2'-3'	7,000
	Labor	0
	Total	**23,000**

Appendix K – Value Analysis Tables

The following pages contain the value analysis tables we used to rate and rank each individual exhibit idea we collected. Tables containing scores given by the three individual team members are first, followed by the table with the average of those three that we used for our final scores.

Adebayo

	Educational	Interactive/Fun	Self-explanatory	Construction	Maintenance	Safe	Guide Required	Score
Archimedes Screw	5	6	8	6	10	10	0	6.30
Ball Drop	7	4	8	5	10	10	0	6.50
Bicycle Wheel Gyro Chair	5	8	7	8	10	8	0	6.75
Build Your Own Mobile	8	5	8	10	6	10	0	7.45
Car Collisions	8	10	10	10	4	10	0	8.90
Car Race with Gears	8	8	10	7	6	10	0	8.20
Carnival Ladder	5	8	10	10	10	7	1	6.35
Climbing Slopes	6	8	10	10	10	6	0	7.70
Decaying Motion	6	6	10	10	8	10	0	7.30
Elastic Shooting Gallery	5	10	10	9	6	10	0	7.70
Exercise Bike Generator	6	7	10	8	8	6	0	7.15
Friction	8	4	7	10	6	10	0	7.05
Gear Lift - Car	9	10	10	7	6	10	0	9.10
Gear Lift - Classmates	9	10	10	8	6	10	1	8.20
Hamster Wheel Generator	6	7	9	8	8	6	0	7.00
Hanging Bicycle Gyro	8	8	7	10	8	7	0	8.00
Hydraulic Lift	5	6	10	8	10	10	0	6.80
Jump-pad	7	7	7	5	7	10	0	6.95
Kangaroo Shoes	6	10	10	10	6	6	1	7.00
Lever Lift - Car	9	10	10	7	10	10	0	9.30
Lever Lift - Classmates	9	10	10	9	10	10	1	8.50
Lever Lift - Weight	9	6	10	9	10	10	0	8.50
Merry Go Round	5	9	10	8	10	6	0	7.35
Newton's Cradle	5	6	8	10	10	10	0	6.70
Pulley Lift - Car	9	10	10	7	10	10	0	9.30
Pulley Lift - Classmates	9	10	10	9	10	10	1	8.50
Pulley Lift - Self	9	10	10	9	10	10	0	9.50
Rotating Chair/Disc	5	8	7	8	10	7	0	6.70
Rotating Tube	6	10	10	10	10	8	0	8.30
Sand Pendulum	5	4	10	10	6	10	0	6.30
Spring Platform	6	8	10	10	6	7	0	7.55
Swings	5	8	10	10	10	8	0	7.40
Teeter-Totter	8	8	10	10	8	7	0	8.45
Tin-can Telephones	6	7	7	10	8	10	0	7.10
Turntable	6	8	8	8	10	10	0	7.40
Velcro Wall	7	10	9	7	6	6	1	6.95
Wobbly Table	5	6	7	10	10	7	0	6.40
Average	**6.76**	**7.84**	**9.11**	**8.65**	**8.35**	**8.70**		**7.58**

Lee

	Educational	Interactive/Fun	Self-explanatory	Construction	Maintenance	Safe	Guide Required	Score
Archimedes Screw	5	4	7	8	9	10	0	5.80
Ball Drop	9	6	7	7	8	9	0	7.70
Bicycle Wheel Gyro Chair	6	8	5	8	9	9	0	6.85
Build Your Own Mobile	9	6	5	9	8	10	0	7.65
Car Collisions	10	10	9	9	6	9	0	9.50
Car Race with Gears	8	7	8	8	10	10	0	7.95
Carnival Ladder	6	9	5	9	9	7	1	6.10
Climbing Slopes	8	8	10	10	10	9	0	8.65
Decaying Motion	9	8	8	8	9	10	0	8.55
Elastic Shooting Gallery	7	9	9	8	8	9	0	8.05
Exercise Bike Generator	8	8	9	8	9	9	0	8.25
Friction	9	6	10	10	9	10	0	8.55
Gear Lift - Car	10	10	10	6	9	10	0	9.55
Gear Lift - Classmates	10	10	10	8	9	9	1	8.70
Hamster Wheel Generator	8	10	8	6	8	6	0	8.20
Hanging Bicycle Gyro	7	8	8	10	10	9	0	7.95
Hydraulic Lift	4	5	5	5	9	9	0	5.00
Jump-pad	8	9	9	5	9	10	0	8.25
Kangaroo Shoes	8	9	8	9	7	7	1	7.25
Lever Lift - Car	10	10	10	6	9	10	0	9.55
Lever Lift - Classmates	10	10	10	8	9	9	1	8.70
Lever Lift - Weight	10	7	10	8	9	10	0	9.00
Merry Go Round	7	9	9	7	9	7	0	7.90
Newton's Cradle	5	6	7	9	10	9	0	6.40
Pulley Lift - Car	10	10	10	6	9	10	0	9.55
Pulley Lift - Classmates	10	10	10	8	9	9	1	8.70
Pulley Lift - Self	10	9	10	9	9	9	0	9.55
Rotating Chair/Disc	6	8	6	8	9	9	0	7.00
Rotating Tube	6	9	10	6	8	5	0	7.40
Sand Pendulum	7	8	8	9	9	10	0	7.85
Spring Platform	7	6	9	9	8	9	0	7.40
Swings	7	7	9	9	9	9	0	7.70
Teeter-Totter	10	8	10	8	9	9	0	9.20
Tin-can Telephones	6	7	7	10	10	10	0	7.20
Turntable	8	7	8	9	9	10	0	8.00
Velcro Wall	7	10	8	7	7	5	1	6.80
Wobbly Table	5	7	6	10	9	9	0	6.55
Average	**7.84**	**8.05**	**8.30**	**8.03**	**8.78**	**8.89**		**7.92**

Mark

	Educational	Interactive/Fun	Self-explanatory	Construction	Maintenance	Safe	Guide Required	Score
Archimedes Screw	5	5	8	7	9	10	0	6.10
Ball Drop	9	6	8	7	7	10	0	7.85
Bicycle Wheel Gyro Chair	6	6	5	7	8	9	0	6.20
Build Your Own Mobile	8	7	8	9	8	10	0	7.95
Car Collisions	9	9	8	8	9	10	0	8.80
Car Race with Gears	8	6	6	7	8	10	0	7.20
Carnival Ladder	7	7	8	7	8	5	1	6.10
Climbing Slopes	6	6	8	9	10	9	0	6.95
Decaying Motion	8	6	6	6	8	10	0	7.10
Elastic Shooting Gallery	5	7	7	7	7	10	0	6.35
Exercise Bike Generator	7	7	9	6	5	9	0	7.20
Friction	8	6	8	9	8	10	0	7.70
Gear Lift - Car	9	8	9	6	7	10	0	8.40
Gear Lift - Classmates	9	9	9	7	7	7	1	7.60
Hamster Wheel Generator	7	8	8	5	5	8	0	7.15
Hanging Bicycle Gyro	6	7	5	9	9	9	0	6.70
Hydraulic Lift	7	4	6	7	7	10	0	6.25
Jump-pad	7	8	8	5	7	9	0	7.30
Kangaroo Shoes	6	8	8	8	7	6	1	6.05
Lever Lift - Car	9	8	9	5	9	10	0	8.40
Lever Lift - Classmates	9	9	9	6	8	6	1	7.50
Lever Lift - Weight	9	7	9	7	9	10	0	8.35
Merry Go Round	8	8	8	8	9	6	0	7.95
Newton's Cradle	8	6	8	9	9	10	0	7.75
Pulley Lift - Car	9	8	9	5	9	10	0	8.40
Pulley Lift - Classmates	9	9	9	6	8	6	1	7.50
Pulley Lift - Self	9	9	9	6	8	7	0	8.55
Rotating Chair/Disc	8	7	6	9	9	9	0	7.65
Rotating Tube	6	9	8	5	6	6	0	6.95
Sand Pendulum	7	7	7	7	7	10	0	7.15
Spring Platform	6	7	8	9	8	8	0	7.05
Swings	7	7	8	7	8	8	0	7.25
Teeter-Totter	7	7	8	8	8	9	0	7.40
Tin-can Telephones	7	7	6	8	9	10	0	7.20
Turntable	7	6	7	8	8	10	0	7.05
Velcro Wall	5	9	7	7	5	6	1	5.55
Wobbly Table	6	7	7	8	8	8	0	6.80
Average	**7.38**	**7.22**	**7.68**	**7.14**	**7.81**	**8.65**		**7.28**

Average

	Educational	Interactive/Fun	Self-explanatory	Construction	Maintenance	Safe	Guide Required	Score
Archimedes Screw	5.00	5.00	7.67	7.00	9.33	10.00	0	**6.07**
Ball Drop	8.33	5.33	7.67	6.33	8.33	9.67	0	**7.35**
Bicycle Wheel Gyro Chair	5.67	7.33	5.67	7.67	9.00	8.67	0	**6.60**
Build Your Own Mobile	8.33	6.00	7.00	9.33	7.33	10.00	0	**7.68**
Car Collisions	9.00	9.67	9.00	9.00	6.33	9.67	0	**9.07**
Car Race with Gears	8.00	7.00	8.00	7.33	8.00	10.00	0	**7.78**
Carnival Ladder	6.00	8.00	7.67	8.67	9.00	6.33	1	**6.18**
Climbing Slopes	6.67	7.33	9.33	9.67	10.00	8.00	0	**7.77**
Decaying Motion	7.67	6.67	8.00	8.00	8.33	10.00	0	**7.65**
Elastic Shooting Gallery	5.67	8.67	8.67	8.00	7.00	9.67	0	**7.37**
Exercise Bike Generator	7.00	7.33	9.33	7.33	7.33	8.00	0	**7.53**
Friction	8.33	5.33	8.33	9.67	7.67	10.00	0	**7.77**
Gear Lift - Car	9.33	9.33	9.67	6.33	7.33	10.00	0	**9.02**
Gear Lift - Classmates	9.33	9.67	9.67	7.67	7.33	8.67	1	**8.17**
Hamster Wheel Generator	7.00	8.33	8.33	6.33	7.00	6.67	0	**7.45**
Hanging Bicycle Gyro	7.00	7.67	6.67	9.67	9.00	8.33	0	**7.55**
Hydraulic Lift	5.33	5.00	7.00	6.67	8.67	9.67	0	**6.02**
Jump-pad	7.33	8.00	8.00	5.00	7.67	9.67	0	**7.50**
Kangaroo Shoes	6.67	9.00	8.67	9.00	6.67	6.33	1	**6.77**
Lever Lift - Car	9.33	9.33	9.67	6.00	9.33	10.00	0	**9.08**
Lever Lift - Classmates	9.33	9.67	9.67	7.67	9.00	8.33	1	**8.23**
Lever Lift - Weight	9.33	6.67	9.67	8.00	9.33	10.00	0	**8.62**
Merry Go Round	6.67	8.67	9.00	7.67	9.33	6.33	0	**7.73**
Newton's Cradle	6.00	6.00	7.67	9.33	9.67	9.67	0	**6.95**
Pulley Lift - Car	9.33	9.33	9.67	6.00	9.33	10.00	0	**9.08**
Pulley Lift - Classmates	9.33	9.67	9.67	7.67	9.00	8.33	1	**8.23**
Pulley Lift - Self	9.33	9.33	9.67	8.00	9.00	8.67	0	**9.20**
Rotating Chair/Disc	6.33	7.67	6.33	8.33	9.33	8.33	0	**7.12**
Rotating Tube	6.00	9.33	9.33	7.00	8.00	6.33	0	**7.55**
Sand Pendulum	6.33	6.33	8.33	8.67	7.33	10.00	0	**7.10**
Spring Platform	6.33	7.00	9.00	9.33	7.33	8.00	0	**7.33**
Swings	6.33	7.33	9.00	8.67	9.00	8.33	0	**7.45**
Teeter-Totter	8.33	7.67	9.33	8.67	8.33	8.33	0	**8.35**
Tin-can Telephones	6.33	7.00	6.67	9.33	9.00	10.00	0	**7.17**
Turntable	7.00	7.00	7.67	8.33	9.00	10.00	0	**7.48**
Velcro Wall	6.33	9.67	8.00	7.00	6.00	5.67	1	**6.43**
Wobbly Table	5.33	6.67	6.67	9.33	9.00	8.00	0	**6.58**
Average	**7.32**	**7.70**	**8.36**	**7.94**	**8.32**	**8.75**		**7.59**
Median								**7.53**

Appendix L – Weekly Progress Charts and Work Plans

During our time working on the project in Costa Rica, we created these progress charts and work plans to record and organize our work. We have included them in this appendix as a reference for anyone working on a similar project.

Summary Progress Chart and Proposed Work Plan **Week 1**

Project Name: Museo
Date: Monday, May 21, 2001
Students: Bayo, Lee, Mark

Tasks Accomplished This Week:

1) Gave presentation to Fabiola, Gloria, and advisors
2) Survey questions for museum workers
3) Interview protocol for teachers
4) Simple interview protocol for children
5) Discussed prototypes and exhibit ideas
6) Researched how to conduct surveys
7) Spoke to Fabiola's assistant about budget and organization of museum
8) Revised Appendix A
9) Final proposal outline
10) Scheduled Final Presentation
11) Scheduled weekly meetings
12) Attempted to observe children. Foiled by lack of children.

Tasks to be Accomplished in Next Seven Days:

1) Visit one local museum
2) Implement survey of museum workers
3) Begin interviewing teachers
4) Begin interviewing children
5) Start observing children (provided adequate number of children)
6) Continue work on creating prototypes

Summary Progress Chart and Proposed Work Plan **Week 2**

Project Name: Museo
Date: Monday, May 28, 2001
Students: Bayo, Lee, Mark

Tasks Accomplished This Week:

1) Revised Introduction
2) Revised Literature Review
3) Met Keilyn
    a. obtained curriculum information
    b. obtained useful books from library
    c. started arranging interview with person from ministry of education
4) Met with Fabiola
    a. Building prototypes – materials, tools, workspace available to us, free
    b. Testing prototypes – spaces are available in museum
    c. Worker Survey – useful information, changes
5) Visited the warehouse – useful for materials, tools, etc, for prototyping
6) Met Leonardo, asked for floorplans
7) Finalized, translated, and printed survey of museum workers
8) Implemented survey of museum workers
9) Quickly skimmed survey responses

Tasks to be Accomplished in Next Seven Days:

1) Review previous IQP for money/funding issues
2) Review survey responses
    a. Translate
    b. Tabulate
3) Review curriculum
4) Interview teachers
5) Interview maintenance worker
6) Observe children – after tabulating survey data, to observe best and worst exhibits
7) Prototypes – designed and built by end of week, provided materials are available
    a. Discuss possibilities, etc.
    b. List of materials
    c. Design
    d. Construction
8) Revise and expand Methodology and Lit Review

Summary Progress Chart and Proposed Work Plan Week 3

Project Name: Museo
Date: Monday, June 5, 2001
Students: Bayo, Lee, Mark

Tasks Accomplished This Week:

1) Reviewed Survey Responses
    a. Tabulated
    b. Created graphs
2) Reviewed Academic Curriculum
3) Obtained list of previous sponsors of rooms
4) Began investigating financial aspects
5) Revised and expanded Methodology and Lit Review
6) Prototypes
    a. Got materials for prototypes
    b. Built Car collision prototype
    c. Started redesigning the Lever prototype – no circular saw to use
7) Interviewed Leonardo, head of maintenance
8) Visited Gold Museum, Museo Nacional and Criminology Museum

Tasks to be Accomplished in Next Seven Days:

1) Interview with teachers
2) Finish making prototypes
3) Test prototypes
4) Observe Children in selected rooms
5) Work on paper
6) Find out about interview at Ministry
7) Continue work on financial aspects
8) Gather more ideas for display recommendations

Summary Progress Chart and Proposed Work Plan **Week 4**

Project Name: Museo
Date: Monday, June 12, 2001
Students: Bayo, Lee, Mark

Tasks Accomplished This Week:

1) Interviews with teachers
2) Completed construction of prototypes
3) Tested Prototypes: 8 Groups / 186 people
4) Observed children at old mechanics exhibits
5) Worked on paper
6) Scheduled interview with Ministry
7) Researched more sponsor companies
8) Did more research on displays online – Children's Museums

Tasks to be Accomplished in Next Seven Days:

1) Measure Mechanics room for dimensions
2) Create pictures for each display
3) Do interview at Ministry of Education
4) Determine method to rank displays
5) Come up with more possible displays
6) Revise and expand on advisors suggestions

Summary Progress Chart and Proposed Work Plan **Week 5**

Project Name: Museo
Date: Monday, June 19, 2001
Students: Bayo, Lee, Mark

Tasks Accomplished This Week:

1) Measured room for actual dimensions
2) Started drawing pictures for displays
3) Met with the Ministry of Education
4) Created Value Analysis of displays
5) Had brainstorming session to generate more ideas
6) Continued looking for more display ideas
7) Revised and expanded paper where needed
8) Started generating a description of each display for appendix

Tasks to be Accomplished in Next Seven Days:

1) Continue paper revisions
2) Meet Jorge Chica for materials list
3) Revise Value Analysis
4) Determine what displays to recommend
5) Work on rest of display pictures
6) Generate possible sponsors for displays
7) Work on recommendations
8) Generate floor plan
9) Continue working on display appendix

Summary Progress Chart and Proposed Work Plan **Week 6**

Project Name: Museo
Date: Monday, June 26, 2001
Students: Bayo, Lee, Mark

Tasks Accomplished This Week:

1) Revised Paper
2) Met with Jorge Chica to obtain materials list
3) Revised Value Analysis
4) Determined displays to present
5) Finished drawing display pictures
6) Generated possible sponsors for displays
7) Worked on recommendations
8) Generated floor plan
9) Finished working on display appendix

Tasks to be Accomplished in Next Seven Days:

1) Continue revising paper
2) Finish digitizing display illustrations
3) Get costs for displays from Leonardo
4) Prepare slides for presentation
5) Practice Final Presentation
6) Give Final Presentation
7) Hand in Final Paper

Summary Progress Chart and Proposed Work Plan **Week 7**

Project Name: Museo
Date: Monday, July 2, 2001
Students: Bayo, Lee, Mark

Tasks Accomplished This Week:

1) Finished all parts of Final Paper
2) Gave Final Presentation at Museo
3) Handed in Final Paper

Tasks to be Accomplished in Next Seven Days:

1) Relax and enjoy the rest of the trip!