A GUIDE TO MUSICAL INSTRUMENT DESIGN

FOR PRESCHOOL CHILDREN

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VITA

Derek Scott Smith, son of Roy Wayne and Alison (Pearson) Smith, was born August 9, 1971, in Texas City, Texas. He graduated from Grissom High School in June, 1990. He graduated from Middle Tennessee State University, with a Bachelor of Science in Recording Industry Management, in December, 1997. In May, 2003 he began post-baccalaureate studies in the Department of Industrial Design at Auburn University, and received a Bachelor of Science in Environmental Design in May, 2004. Upon completion of this undergraduate work, he entered the Graduate School at Auburn University in Industrial Design. He graduated with a Master of Industrial Design degree from the Auburn University Graduate School in August 2005. He married Deanna (Sasnette) Smith on December 19, 1998. Their daughter, Sophie Caroline Smith, was born August 29, 2003, in Montgomery, Alabama.

THESIS ABSTRACT

A GUIDE TO MUSICAL INSTRUMENT DESIGN

FOR PRESCHOOL CHILDREN

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In order to improve the ergonomic and aesthetic qualities of musical instruments, intended for preschool children, a guideline, which assists the designer in producing more age-appropriate products, has been be created. Using a contemporary musical instrument, the dimensions, materials, form, scale, and weight of the child's instrument have been determined through studies and comparisons of proportion, anthropometry, psychology, physiology, and existing products. A step by step process is illustrated with a working model which seeks to attract and inspire the young user while making learning easier and less cumbersome.

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Style manual used	APA Publication Manual, Fifth Edition
Computer software used	Microsoft Word

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1. THE PROBLEM

1.1 Problem Statement

A guideline which provides designers and luthiers instruction for the design of musical instruments, that are better suited for young children. A step by step process will be established, that takes into account ergonomics, anthropometrics, aesthetics, physiology, and psychological characteristics of the user, will then be illustrated by the design of a working musical instrument. By researching historical and contemporary practices in early childhood music education, to determine how success has been achieved, this thesis will discover the form of a musical instrument that bests inspires, intrigues, and fits the young user.

1.2 Need for Study

Justification for this thesis exists in that there is currently no contemporary guide to designing early childhood instruments and today's mass produced musical instruments intended for children are either toys or are merely scaled down versions of adult instruments, which do not take into consideration the vast physical and mental differences between adults and children. By researching the many aspects of children's abilities and limitations, this thesis will attempt to discover what dimensions and proportions the correctly designed instrument will possess and therefore seek to improve the quality of the child's musical experience.

The benefits of this study will be that children who interact with better designed instruments will be more excited and willing to play them due to improved ergonomics and a design that will make them feel the instrument is made just for them. In addition, parents will be encouraged to purchase a product that might ignite a passion for music and foster musical accomplishment at a time earlier in the child's life, than is typical in our modern society. It has been clinically proven that children that learn to play musical instruments are better at math and verbal skills and therefore it can be assumed that any step taken to improve the human experience in regard to musical instrumentation will assist the user in advancing his or her general scholastic abilities.

1.3 Literature Review

This literature review provides information, in the form of statistical data and quotes, which supports a need for study in the design of musical instruments intended for preschool children. The goal of this review is to identify the many benefits of beginning music education at a younger age, highlight typical preschool musical ability, support the claim that there is a lack of research on preschool musical instrument design, discuss the marketing potential of musical instrument design, and to ultimately validate the creation of a guideline for designers and companies intent on producing instruments for young children.

To begin, one must understand why parents and guardians, charged with the responsibility of developing young minds, would want to provide their children with musical education. These facts, provided below, are one of the driving forces behind the creation of instruments targeted for children. A designer who produces these products serves the parent well by fulfilling the material need of the music student.

The benefits of learning to play music are numerous. They include creating a strong foundation and overall improvement of one's role in society. According to the *Texas Commission on Drug and Alcohol Abuse Report, "*Secondary students who participated in band or orchestra reported the lowest lifetime and current use of all substances (Houston Chronicle, January 1998). A study at Auburn University showed "significant increases in overall self-concept of at-risk children participating in an arts program that included music" (Barry, 1992). Other studies demonstrate the benefits music education has on improving skills, which lead to success in school. Of 237 second grade children, which were provided piano keyboard training coupled with newly designed math software, 27% higher test scores on proportional math and fractions where achieved, over those that where exposed solely to the math software alone (Graziano, Peterson, & Shaw, 1999). *The College Entrance Examination Board* found that students who studied music appreciation scored 63 points higher on verbal and 44 points higher on the math, than did students with no music education. (College Entrance Examination Board, 2001). Physician and biologist Lewis Thomas in researching the undergraduate majors of students applying to medical school discovered that "66% of music majors who applied to medical school were admitted, the highest percentage of any group. 44% of biochemistry majors were admitted." (Miller, 1994). The correlation between success and music education is evident in the Silicon Valley, where our most talented engineers and designers "are, nearly without exception, practicing musicians" (Venerable, 1989).

Intelligence is increased through music education according to researchers who found that "children given piano lessons significantly improved in their spatial- temporal IQ scores compared to children who received computer lessons, casual singing, or no lessons" (Rauscher, Shaw, Levine, Wright, Dennis, & Newcomb, 1997). The *Journal of Research in Music Education* reports that three- and four-year-olds given lessons with song bells "led to significant improvement of spatial-temporal scores" (Gromko, & Poorman, 1998).

If music education is beneficial, one must decide when it is appropriate to introduce it to children. Roberta Markel argues that children lack "enough self-discipline before the age of eight years to make formal study of an instrument a particularly satisfactory experience," yet proceeds later in pointing out how Shinichi Suzuki "taught three-, four-, and five-year-olds by asking them to imitate" (Markel, 1983). This illustrates the fact that teaching children to play instruments at a young age will not usually yield the same results as with older children. Instrument instruction for preschoolers "should stress the development of accurate performing gestures and the playing of simple nursery rhyme tunes by ear" (Zimmerman, 1971). Children have the mental capacity to learn to play instruments, in fact in general "psychologists today generally agree that all children are capable and often desirous of learning much more, much sooner, than has previously been thought possible" (Webber, 1979). Because "about 17% of the growth takes place between the ages of four and six," what children learn during their preschool years can have "far-reaching consequences on the child's learning pattern" (Webber, 1979). A study published in *Musical Characteristics of Children* reports that half of 441 cases reported show that "musical aptitude manifested itself between the ages of two and four" (Zimmerman, 1971).

Wolfgang Amadeus Mozart began composing minuets at the age of five and is the classic example of the child music prodigy (Landon, 2005). G. Revesz writes about prodigy Erwin Nviregvhazi who's father discovered that his three-year-old son "had a sense of absolute pitch" and could "locate on the piano notes that were sung to him" (Revesz, 1925). Although these two men illustrate the extreme ability of young musicians, numerous other contemporary success stories have been recorded. G.E. Smith, former guitarist of the popular television program, *Saturday Night Live*, claims to have started playing at the age of four (G.E. Smith, n.d./2005) and Elektra recording artist John Campbell says that when he was almost three he began playing the Hawaiian lap steel (John Campbell, 1991). In fact, a slew of musicians can be found online making similar claims about beginning their musical experience between the ages of three and six.

Perhaps the most successful and well known institution providing music education to young children is the Suzuki Music Academy who claims that "for more than fifteen years" to have "provided superior formal classical music training for children, from age 2 - offering formal training in Suzuki violin, Suzuki viola, Suzuki cello, and Suzuki piano" (America's Suzuki Music Academy, n.d./2005). In stating why young children should begin the Suzuki program, Elizabeth Mills writes that "before they are eight, children have more time for music," and "the study of music after age seven is apt to become more intellectual and mechanical." She goes on to add that, by age two, a child has tremendous power to observe and imitate and that "although it has limited judgment about what to imitate, it will repeat whatever it hears" (Mills, 1974). In "Teach Your Kids About Music", Ruby Chroninger reflects on experiences teaching music to her three- and five-year-old children by saying, "it was a joy to see how easily the children grasped musical concepts" (Chroninger, 1994).

Parents who believe that musical education may increases their child's potential to succeed should take it upon themselves to pursue the purchase of musical instruments and play a major role in their child's learning process. Although school initiates the musical education process for children 64% of the time (G. Leblanc Corporation, 1961), parents cannot depend upon the education system to always take an interest in their child's musical development. "Sadly, it is fashionable in most Western cultures to pay tribute to the musically elite minority who are tagged early on as 'talented' and then tracked and provided with the training that others cannot have" (Campbell, 1998).

Another reason for providing the commercial market with instruments aimed at children is that they truly enjoy interacting with these products. Designers and companies can rest easy knowing that their products are absolutely desired by the group they are targeting. Patricia Shehan Campbell observes that young children are "eager to get their hands on the instruments they see sitting in corners or lined up on tables and shelves" (Campbell, 1998). The Pillsbury Foundation School reported in a 1940 study that "four-year-olds enjoyed experimenting with notes on a piano" (Haroutounian, 2002). Children are fascinated with the "diverse sounds" that musical instruments create and want to be given the chance to create them themselves (Chroninger, 1994). Elizabeth Jones of the *National Association for the Education of Young Children,* in researching preschool music education, reflects upon this classroom experience:

> A teacher put a Ukulele, a basket of tea balls…a variety of rattly things – acorns, jacks, rocks, toothpaste caps, balls – inside, to look at and listen to, and five big red temple blocks, with their wooden mallets, on the rug in one corner of the big room. Lauri promptly took the Ukulele to the

housekeeping corner, and it was passed around from three-year-old to three-year-old as the morning went on (Jones, 1969).

Young children have physical constraints when compared to adults and therefore questions arise regarding their ability to play musical instruments. Though they have smaller features and different proportions, young children have, for centuries, learned to play music. There are many products on the market today which are reduced versions of full size instruments because “there is an idea that small people need small instruments” (Young, 2003). Perhaps this is true, but without a thorough evaluation of child human factors including physiology, anthropometry, and ergonomics no one can be sure that simply reducing scale is the best option. Products like the Gibson Les Paul Pee Wee guitar use traditional hardware and strings. They suggest tuning the strings full one and one half steps higher to accommodate the shorter neck. Other options should be explored in order to accommodate the young user and allow him or her to play in the same key as the adult musician. As Mills states in her book “In The Suzuki Style,” her book “In The Suzuki Style,” even a talented child guitarist will have problems with tuning standard guitar pegs before age nine or ten (Mills, 1974). Still another weakness in small instruments is that their sound tends to “be limited to higher pitches and low resonance” (Young, 2003). These types of issues make a strong case for the re-evaluation and improvement of instruments intended for young children.

There exist numerous books on how to build musical instruments with dozens focusing on stringed instruments. However, there is no definitive authority or text which explores and defines how musical instruments for children should be designed. For this reason, a guideline created solely to address this issue, can stand alone as a resource for future luthiers and designers to reference.

Finally, financial gain, the reason that most companies have for making instruments, should be addressed. According to a July 2003 press release from the National Association of Music Merchandisers, a recent Gallop poll was cited claiming that "54% of Amercian households contain at least one person who plays a musical instrument, an increase from 50% in the 2000 Gallup poll" (Robertson, July 18, 2003). The release continues this time quoting Music USA by adding that year 2002 sales of musical products increased by 1.5 percent to $6.97 billion. When compared to similar industries musical instruments are doing well and should remain attractive to any potential manufacturer. The Recording Industry Association of America found that music sales generated $11.2 billion in 2003 (Korzeniowski, July 7, 2004) and according to marketing information provide, NPD Group, 2004 United States sales of video games, software, and hardware, produced sales of $9.9 billion.

1.4 Objective of Study

The study to be conducted will seek to identify the necessary physical considerations in creating musical instruments for children between the age of three and five. The guidelines will be designed so that they may be incorporated into traditional music design practices, such as a piano maker would perform in the construction of a child's keyboard by replacing established dimensions such as key size and spacing. In addition, the typical mental ability of the young student will be researched in order to match the instrument to the child. The steps need to achieve this thesis are as follows:

1. Research contemporary musical instrument products aimed at children.
2. Identify the mental abilities and limitations of children age three to five.
3. Identify the physical abilities and limitations of children age three to five.
4. Identify the anthropometric variables of children age three to five.
5. Identify the ratio of full scale instrument to their intended adult users.
6. Use the ratio of full scale instruments and adults to determine what the size and proportion a child's musical instrument should be.
7. Research aesthetics in children's products and determine what inspires them to interact with a favorite product.
8. Design a working musical instrument based on the findings of the thesis.

1.5 Definition of Terms

Design - the arrangement of elements, aesthetics, and function in a product or artifact

Anthropometry – the study of the measurement of man

Ergonomics – fitting a product correctly to the user

Physiology – the study of the functions, activities, and bodily processes of life

Psychology – the science of mind and behavior

Aesthetics – the beauty or pleasing appearance of an object

Preschool – the age of a child between the years of three and six

Instrument – a device used to produce music

Luthier – a person that creates stringed instruments such as guitars or violins

Guitar – a fretted musical instrument usually possessing six strings

Tempered – fixed tone instruments like pianos and guitars

Plectrum – an instrument played by plucking strings with a pick or fingers

Pick - a small thin object used to pluck the strings of a stringed instrument

Neck – the long part of a stringed instrument which houses the fingerboard

Headstock – the part of a stringed instrument which houses the tuning machines

Fingerboard – the flat area of wood laminated to the neck above which the strings run

Bridge – a device resting on the body which holds the lower end of the strings

Strings – thin metal or nylon wire used to produce sound on an instrument

Body – the main part of a stringed instrument which is used to amplify sound and tone

Body Blank – a solid piece of tone wood sold for the purpose of creating a body

Neck Blank – a solid piece of tone wood sold for the purpose of creating a neck

Truss Rod – an adjustable metal rod running through the inside of the neck

Tuning machines –machine heads, tuners; rest on the headstock and adjust the strings

Pickup – device resting on the body that converts string vibration into electronic signals

Pickup Selector – a switch which lets the player choose between two or more pickups

Pick Guard – a thin plastic or laminate material on the body which protects the surface

Nut – material that braces the strings at the joint where the headstock meets the fretboard

Positioning Markers – inlays; various shapes often ornate that mark specific fret positions

Jack Socket –¼ inch phone jack socket used to connect an amplifier chord to the guitar

Control Knob –rotating knobs used to adjust variances in volume and tone

Binding – wood or polymer strips placed on the body and neck where two materials meet

Fretwire – spools of metal strips used to create frets on the fingerboard

Tone Wood –woods such as alder, mahogany, or maple preferred in luthier design

Scale Length – the total string length from nut to bridge

Nut Width – the width of the nut, usually extending 1/8 inch beyond the outside strings

Fret Distance – the spacing between each fret set at a specific mathematical ratio

Fret Constant – mathematical constant (17.817) used in determining fret distance

Action - The height of the strings above the fingerboard

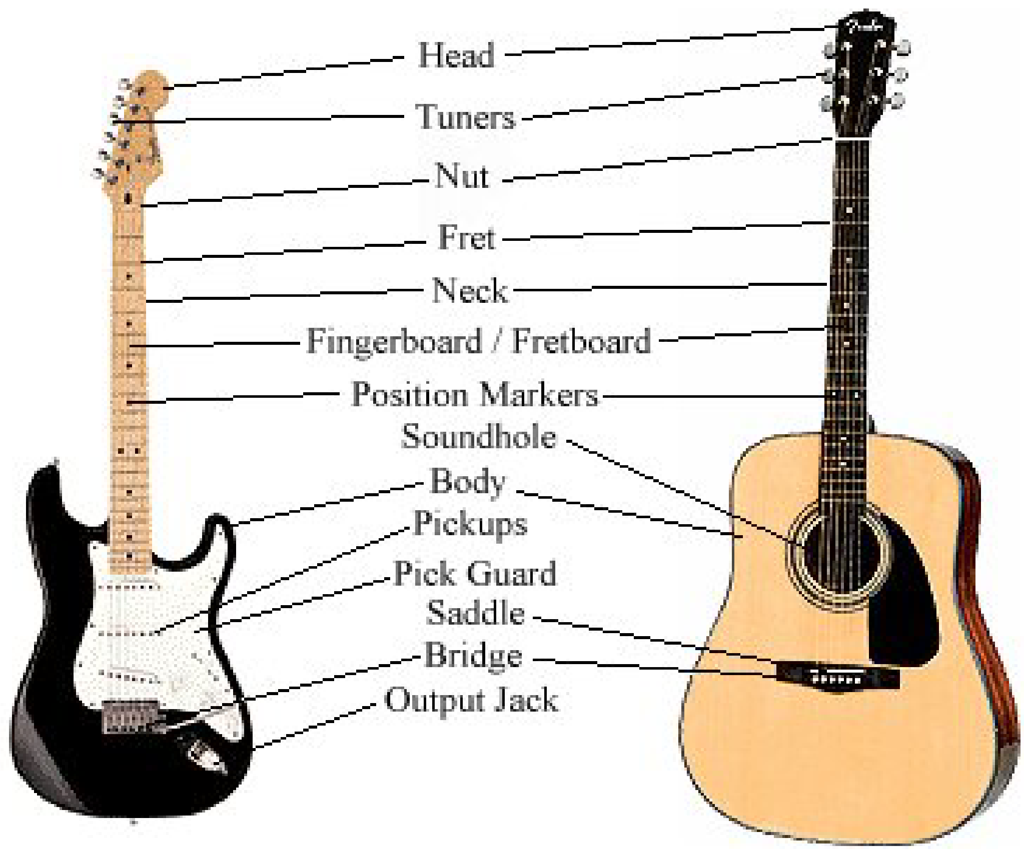


Figure 1.01 Anatomy of the guitar.

1.6 Assumptions

In creating this thesis, it can be assumed that certain constants exist which do not require any level of testing to insure the proof of their existence and that some amount of information will be provided based solely on the author's philosophy, education, and personal social perspective. The intention of this undertaking is to create an original thesis supported by tangible research. However, it is assumed that all intelligent, educated individuals should possess a certain level of understanding regarding their chosen curriculum, and in choosing a particular thesis subject, they probably already possess knowledge regarding that topic as well. With that said, the following assumptions are made regarding the inception and execution of this proposed thesis.

1. Improvements can be made in the practice of designing musical instruments for children
2. Children enjoy interacting with musical instruments
3. Most parents would be pleased to see their young children learning to play an instrument
4. It is the designers duty to improve the ergonomic properties of a product specific to a group of individuals
5. Anytime a niche is created within a product category, market potential is increased
6. Musical accomplishment increases a child's intelligence and ability to learn complex concepts in math and language
7. Musical instrument products are one of the oldest and most successful components of the consumer market

1.7 Scope and Limits

Restrictions, which impede the author's ability to perform certain forms of research, exist and should be defined. These limitations may affect the outcome of the thesis by preventing the author from conducting research beyond the average person's economic, temporal, and social abilities. In light of these circumstances, the thesis may still be written effectively. And, in order to illustrate the author's intentions and make clear why certain information will not be included, the anticipated scope and limitations are defined below.

Scope

The thesis will be conducted over eight months, taking place from January 2005 to July 2005. The research will extend to most accessible forms of text, as well as interviews conducted with key professionals. During this eight-month period, a project will be undertaken which illustrates how a designer would follow the guidelines to create a product.

Limits

Due to time constraints, involved in all academic endeavors, limitations will be set on how long the author will have to conduct research and interviews. During the writing process, any free text-based resources may be accessed. However, it can be assumed that books, which cannot be found locally or online, may not be available to the author. Also, the author will not purchase books that cost in excess of $75, in order to obtain research. Other economic limits may exist in regard to the purchase of equipment and services, which may be required to conduct research. Interviews may be conducted through online surveys, telephone conversations, and U.S. mail. Although these forms of interview are inexpensive, economic restrictions will prevent the author from contacting a certain number of prospective respondents. In regard to interviews it must be considered that not every candidate will be willing or available to participate and that some information may be excluded due to their lack of involvement.

1.8 Procedures and Methodology

In order to draw enough information to either prove or discount this thesis, a considerable amount of information must be obtained and analyzed. The necessary procedures, and their respective methodology, are detailed below. This information can then be used in the re-design of any musical instrument intended to fit preschool children.

Procedures

The subject matter should be approached as one would the design of an instruction manual. The instructions, in this case, lay out a clear guideline for the designer to follow when creating a music instrument's dimensions. The list of steps will include the how, where, when, what, and why of instrument design. The data that must be compiled will be gathered from books, web pages, periodicals, and interviews with parents or educators that have experience in purchasing instruments or teaching music to preschoolers.

1. Interviews
2. Anthropometric data for children ages three to five
3. Selection of interview respondents
4. Research existing products
5. Research marketing strategies for children's toys and instruments

6. Research aesthetics in children's products in relation to their psychological profiles
7. Research early childhood development regarding psychological and physical abilities
8. Research historical and contemporary childhood music education practices
9. Fitting tests to determine correct instrument dimensions
10. Illustrate guideline with working model

Methodology

The following list explains how each procedure will be enacted in order for the data to be compiled.

1. Interviews will be conducted in person if possible or by mail and a website. They will consist of 10-15 questions which ask specific questions regarding their experiences with music education in relation to instruments.
2. Data regarding anthropometry will be gathered through books, software, and websites.
3. Interview respondents will be sought out through friends, colleagues, educational institutions, daycares, and via the internet.
4. By searching online and in periodicals, a list of currently offered products targeted at preschool children will be analyzed, categorized, and compared for their intent and value of music education.
5. Marketing strategies of current products will be examined to determine when where and to what demographic current products are marketed.

6. By reading books and websites pertaining to early childhood development, a clear understanding of what attracts children to their favorite products and what, in their minds, separates a toy from a useful product
7. Books, articles, interviews and websites will provide the necessary information pertaining to early childhood development
8. Research on music education will be found in books, websites and periodicals
9. Fitting tests will be conducted by creating breadboard models and observing them being used by preschool children
10. Thesis will be illustrated through the design and creation of a working musical instrument

1.9 Anticipated Outcome

The anticipated outcome of this thesis is that designers may access the information provided and use it to create tempered musical instruments that are more ergonomic and better fit the anthropometrics and proportions of preschool children. By following the guidelines, designers will know what dimensions a neck or keyboard should be in and be able to proceed with the design knowing that their product will be correctly suited for a child between the ages of three and five. An additional anticipation is that a greater interest and understanding of the importance of introducing young children to real musical instruments will be instilled in the minds of the reader. Perhaps, as a new line of children's instruments begin to emerge, parents and the educational community will begin to embrace the idea of teaching children how to play music at a younger age. The aesthetic qualities of an instrument designed to attract young children will foster increased desire among children to receive the product as a gift. And, children that are currently learning to play and are provided with a better designed instrument will benefit through reduction in discomfort or inconvenience.

2. RESEARCH PHASE

2.1 Early Childhood Development

2.11 Physical Attributes

In order to correctly design a product intended for a specific group of children, a look at what physical attributes they possess is needed to insure that the requirements necessary to operate the product are not beyond the users physical capacity. Both abilities and constraints are important to the study because if the product is intended to fit the user's physical facilities, a product that is too weak may break in the user's grasp, rendering the product useless or causing injury to the child. A product that is difficult or cumbersome to use will not allow the child to perform the functions of the product with ease and will negatively affect the child's attitude toward the product.

The most obvious difference between children and adults is a reduction in strength. Although, it is fact that preschool children already execute the tasks necessary to play musical instruments, a closer look at how much strength and dexterity children possess allows the designer to make the various devices on an instrument easier to manipulate. A child's ability to move strings and keys is vital to playability and a grip dynamometer test is a good indication of one's ability to press objects. According to *Measure in Pediatric Exercise Science*, children between the ages of three and five scored as follows:

3-year-olds……………4.41 lbs

4-year-olds……………11.02 lbs

5-year-olds……………17.6 lbs

(Docherty, 1996)

These findings illustrate a clear increase in strength during the preschool years and should be taken into consideration. Tests on how much force is required to execute the various functions of the adult instrument should be analyzed to determine if devices and mechanisms should be redesigned or if the instrument itself is unfit for the young musician.

In addition to strength, dexterity is vital to musical performance. A 1940 study describes the "developmental trends of a child's drawing and writing behavior during the preschool period." The researcher found that "the child used a palmer grip of the crayon before the age of three or four years, after which the child changes to a more 'adult' grasp of the writing instrument. The pencil is now held with the tip of the thumb, index, and middle finger, the latter being most extended (Kalmerboer, Hopkins, & Geuze, 1993). In other words, the child during these developmental years, changes his grasp of an object from a power grip to a precisions grip demonstrating a greater ability to control whatever he is holding. This data clearly illustrates the developmental changes a child undergoes during the preschool years and how she can perform the functions of many musical instruments.

2.12 Mental Attributes

A survey of the psychological abilities and constraints, of the preschool child, and how they pertain to music education, provides the designer insight into the mind of the intended user. It also provides foresight into ways a product may be redesigned, to assist and communicate with the user, in a language that best fits their mental capacity. A designer should take into consideration the following information when selecting an instrument, to determine if it falls within the abilities of the young musician.

Swiss Psychologist Jean Piaget, the leading authority in child psychology, places the preschool child in the preoperational stage, of his four stage theoretical structure. This is the second stage of a child's mental development and encompasses the ages of two to seven. During this time, informational processing is "more cumbersome than adults" (Abeles, Hoffer, and Klotman, 1984, pp.196-197), and they are unable to resolve logically conflicting perceptual information. However, they do begin to fantasize and store images, which is evidenced in the form of language. Another important evolvement is the ability to classify items by common attribute which is key to recognizing varying rhythmic patterns (Abeles, et al., 1984).

An important characteristic of the preschool child's psychology is that they "respond to music in a natural, uninhibited manner, which makes musical activities extremely important to a child's development during these years" (Abeles, et al., 1984, p.293). Their openness to new experiences is why the "absorption abilities of the children are at a peak in these formative years" (Kendall, 1966, p. 17). Furthermore, an "assessment of rhythmic coordination of preschool children revealed significantly greater rate of improvement between the ages of three and four, than for all other years" (Perry, Peery, and Draper, 1987, p. 111). If parent and child are to exploit these positive attributes, the fact that "preschool children's exploratory behaviors rather than their guided manipulations may be more important in their forming perceptions about pitch and melody," (Perry, et al., 1987, p. 216) should be remembered by the designer in creating an instrument that evokes creativity.

"Children generally begin to react to music as early as 18 months, although other apparent musical behaviors may be exhibited earlier" (Abeles, et al., 1984, p.196), and during this period, as the child's mind rapidly develops, a series of common, yearly evolutionary steps occur among children, in both their ability and their approach to music. For instance, when faced with memorizing songs, "young children progress from imitating words, to singing melodic fragments (ages two to three), to producing whole songs at about the age of three to four" (Abeles, et al., 1984, p.196). And in regards to musical exploration, studies found that "the improvisation of three-year-olds was rhythmical, four-year-olds included repetition and similar phrases, and five-year-olds showed a preference for F' tonality and increased used rhythmic repetition" (Perry, et al., 1987, p. 217). The willingness and desire to explore on ones own, diminishes over the preschool years. "Children during the early stages of development (ages two to three) have a greater tendency for free improvisatory and unstructured note play, which gradually develops with the incorporation of diatonic intervals, and then diminishes into a preference for exact imitation" (Abeles, et al., 1984, p. 196). This demonstrates the child's developing mental capacity and eagerness to memorize and play songs. While the preschool child does change over these three years, it is clear that once she is in her fifth year, mental skill is significantly heightened. "The ability of three- and four-year-olds to assimilate pitched and non-pitched sounds, discriminate between pitches, order the direction of sounds, and associate directions on melodic instruments was less developed that that of five-year-olds" (Perry, et al., 1987, pp. 216-217).

With these newly-acquired mental facilities, the child seeks to express himself, and at this age, children "look for objects to satisfy their inclination to produce sound" (Wright, 2003, p. 200). This is when musical instruments may be introduced to provide the child a means of expression. The child's experience in playing an instrument centers around sight and touch and "musical material developed for children in this stage should rely on visual and tactile cues, since children's learning interactions are dominated by these senses" (Abeles, et al., 1984, p. 197). The designer should keep this in mind when developing a product intended to stimulate the user and leave a positive experience which may further inspire willingness to learning.

2.2 The Product

2.21 Choosing an Instrument

In choosing an instrument appropriate for a preschooler to learn to play, there are many factors that should be considered. Given the differences which exist among the various groups of instruments, a parent should make a decision that not only suits the child's age but his or her personality as well. Not every instrument should be weighed evenly as there are some instruments that have proven to work with preschool children and some that the child simply cannot play.

One important factor in musical success is allowing the child to choose the instrument she will play. Roberta Markel writes that "the choice of instrument should not be haphazard" and should not be based on what is the handiest, cheapest, or most socially acceptable instrument available, nor the one that the parent has enjoyed playing. Furthermore she adds that "too often a child is called unmusical because he doesn't succeed on what was simply the wrong instrument for him" (Markel, 1983, p.52).

Although this is an ideal that parents should strive for, it is not always a possibility. According to Dr. Jim McCutcheon, Woodwind and Brass instruments "are physically difficult to play and require a lot of wind which children under the age of 10 or 11 are incapable of producing" (McCutcheon, April, 2003). Therefore, it is clear that a parent should delay the introduction of this instrument even if the child shows an interest.

In regards to the piano, which Dr. McCutcheon calls "the traditional first instrument for children," the child may find this instrument "very rewarding to play because each note requires a fairly simple movement of only one finger." However, in contrast, Anthony E. Kemp argues that "the piano is often viewed as the instrument with the highest failure rate" because parents assume "that 'it would be good for her to play a musical instrument' with little consideration given to other alternative instruments" (Kemp, 1996, pg. 167). Kemp adds that "it is clear that the piano makes considerable demands upon young children…it requires equal dexterity of all 10 fingers." Pianos also may not be a practical instrument for many households as it "represents a sizable investment of money and floor space in the home" (McCutcheon, April, 2003).

The String family is what the Suzuki method uses in teaching young children and while the piano is a member of this group, violins, cello, and violas are more frequently taught by Suzuki teachers. Plucked or strummed instruments such as the guitars, banjo, mandolin, and lute are also a part of this family. "Over the past few decades, advancements in pedagogy…have resulted in much success with children beginning to play music on string instruments" (McCutcheon, April, 2003). However, some preschool children may have difficulty playing a bowed instrument, such as a viola because "the beginning player needs plenty of good old-fashioned muscular stamina. When played, the instruments are supported entirely by the player" (Markel, 1983, p.60).

For the purpose of this thesis, the guitar will be the instrument of focus and used to illustrate the procedures and methodology used in transforming the adult musical instrument into an age-appropriate instrument intended for children between the ages of three and five.

Why the Guitar?

Besides the benefits mentioned above regarding stringed instruments, there are many reasons why a smaller, well proportioned guitar is a good instrument for a preschool child. "The guitar is the 'people's instrument,' relatively easy to play, quite inexpensive [when] compared to most other instruments" (Markel, 1983). In addition almost all guitars are light weight and may easily be transported to and from the home.

In a 2002 *Electronic Musician Magazine* survey, respondents were asked to check what they considered to be the primary and secondary instruments that they currently play. Guitars accounted for 25.3%, the highest percentage of the primary row, 28.7% of the secondary row, and 54% of all answers (Electronic Musician Magazine, 2002). Similarly, in the 2001 market research report *Australians' Attitudes to Music*, acoustic guitars constitute 25% of the musical instruments Australians play, trailing closely behind pianos in second place (The Australian Music Association, April 9, 2001). With this data, it can be assumed that a child learning to play the guitar will be more likely to know an adult with experience playing the guitar over any other instrument, and hence have more opportunity to receive instruction at home from someone she knows.

In addition to the player's benefits, a prospective manufacturer of such an instrument can potentially carve out a niche in a thriving, lucrative market. A recent sales report published in Music USA calls the guitar "the world's most popular musical instrument" and claims that is seemed to "broaden its appeal during 2002" when "sales of acoustic guitars advanced a brisk 14.8 percent to 973,522 units while electric guitars increased 8.2 percent to 969,103 units" (Porta, March 28, 2003). Sales of guitars in 2002 were nearly $1.1 billion, being spilt between acoustic and electric models (Lieberman, December 16, 2002).

2.22 History of the Product

The guitar is a "plucked, stringed instrument that has a 'waisted' body with incurved sides. There is, according to experts on its history, little evidence of such an instrument existing before the fifteenth century" (Bacon, and Day, 1991, p.12). However, similar instruments dating, back almost 4,000 years, are believed to have contributed to its gradual evolution. As illustrated on chart (Figure 2.01), proof of these early contributors exist in carvings of plucked, stringed instruments found in Babylonia, Egypt and Rome, having been created as early as 1900 BC (Oracle Education Foundation, 2000). Over the centuries, popularity of the guitar waxed and wended until the 20th century, which proved an era of unprecedented popularity, manufacturing, and revenue. "The huge boom in guitar playing occurred in the early 1970's. This boom seemed to have peaked in 1972 when over 2,500,000 guitars were sold in the wake of the folk and rock music revolution that was absorbing the nation's youth" (Bacon, and Day, 1991, p.9). Today, electric and acoustic guitars generate over $1 billion is sales annually and offer the player numerous options in form, style, materials, and special effects.

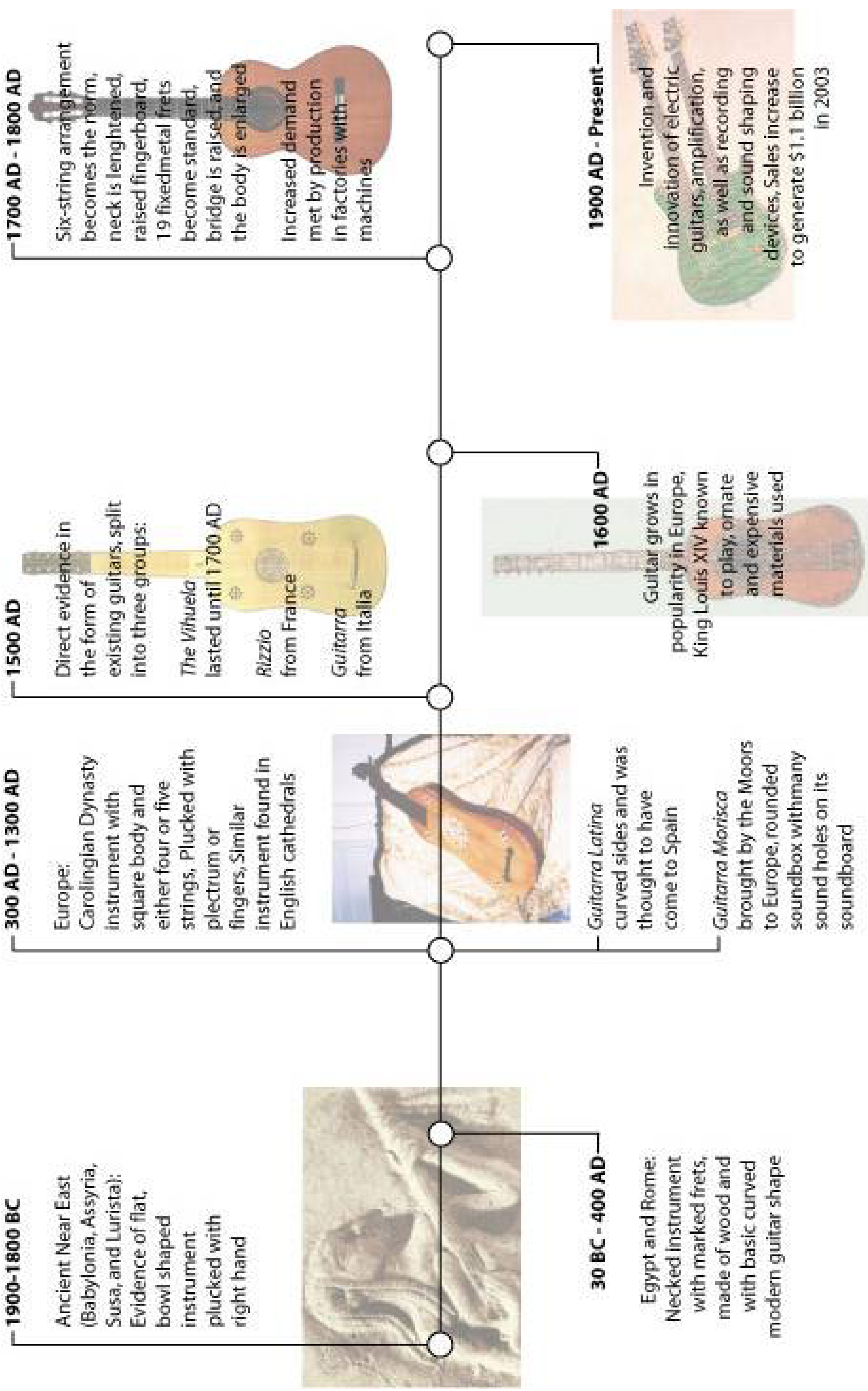


Figure 2.01 History of the guitar**.**

2.23 Existing Products

A look at current products marketed to those wishing to provide musical instruments to children, is key to understanding what needs to be changed, what works well, marketing placement, and trends. Two charts have been created, one sampling an array of musical instrument families (Figure 2.02) and the latter showing examples of guitars (Figure 2.03), both acoustic and electric. Common attributes like scale and pricing can be seen among the competitors of each group. In addition, by observing the style, color and, form of each product, conclusions can be drawn as to how the designer chose specific aesthetic qualities in an attempt to appease child and adult preferences.

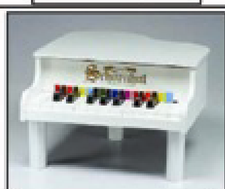
Product Image	Name	Dimensions	Price	Description
	"Musical Tea Table" by Musical Furnishings	25" X 25" X 25"	$600	Red Alder wood; 8 Marimba style keys in the key of C
	"Maxi My Teaching Piano" by Mega Bloks		$35	2-5 yrs; teaching toy with 12 songs and lighted keys
	"Mini Grand Piano" by Kleinway	NA	$169.99	30 keys; ages 3 and up
	"Mini-Grand Piano" by Shoenhut	8-1/2" high x 13-1/4" wide x 15-1/4" deep	$99.99	18 Keys; designed for toddlers
	"My Little Lyre" by Auris	11 1/2" in length	$129.00	maple wood; pentatonic scale; to age 9
	"Winnie the Pooh Speak and Play Computer Organ" by Bontempi	NA	$19.99	3 Years and up; 32 keys; interactive teaching

Figure 2.02 Product comparison chart of various musical instrument groups

Product Image	Name	Dimensions	Price	Description
	Child's Guitar by B.A. Star	30" length	$129.00	ages 4-8
	"Mini Strat" by Squier (Fender)	NA	$165.99	20 frets
	Hondo Electric Guitar	29" length	$179.00	1/2 scale; 21 frets
	"Les Paul Pee Wee" by Epiphone (Gibson)	NA	$129.99	21 frets
	Amigo Classical Guitar	32" length	$79.95	1/2 scale; spruce top
	Music for Little People classical guitar	30" Length	$64.98	Ages 3-6; 1/4 scale;

Figure 2.03 Product comparison chart of guitars for children.

2.3 Human Function

2.31 Anthropometry

Although it is not sufficient to simply reduce the scale of an adult-size musical instrument and assume that it is correctly designed for child, an anthropometric evaluation of proportions is the best place to start the redesign process. Data on specific body measurements of adults and full scale contemporary instruments were compiled. A formula was created which could then be used to determine general dimensions and proportions that a child's guitar might be designed with. By dividing a specific guitar dimension by an adult dimension, a number is produced. These anthropometric numbers were derived by comparing 1%ile men, 99%ile men, 1%ile women, and 99%ile women, or in some case where data is limited, one number for men and one number women. Once all proportions are calculated, an average of each category is produced. Then, by multiplying each variable by its correlating child dimension, for ages three, four, and five, a new guitar dimension and percentage is defined.

Example:

Scale Length of Adult Guitar (25") ÷ Convenient Reach of Adult Male (32.5") = .77"

Scale Length of Adult Guitar (25") ÷ Convenient Reach of Adult Female (23.5") = 1.06"

The average of .77" and 1.06" = .92"

Proportion Variable (.92") X Convenient Reach of Five-year-old child (11.2") = (10.3")

As it occurs, 10.3" is 41.2% of the original scale length of 25". In comparison to other results on the chart, it is easy to see that the resulting proportions vary from as low as 37.2% to as high as 86.6%, and thus proving that a simple reduction in scale is not only a bad idea, but cannot produce a proportionately accurate model. However, by deciding which anthropometric dimension should bear greater consideration for its respective guitar dimension, better decisions can be made on how to size each part of the child's instrument. The highlighted instrument dimensions on each anthropometric category, illustrate what should be grouped and weighed heavier in consideration of proportions. This data will then be used in conjunction with the remaining human factors studies and used to determine scale and proportion.

In addition to proportional evaluations, it is necessary to evaluate aspects of an instrument that do not determine musical function, but effect ergonomics. These include the shape of the body, controls, weight, and balance. By analyzing key preschool anthropometry, conditions such as how the instrument is held and how it rests on the child's lap, can be solved with greater precision. Many of the same bodily dimensions used in the proportions chart will apply to the non-musical chart and should be reused in the evaluation process.

Child Anthropometry

The following chart provides the 3-, 4-, and 5-year-old anthropometric data, which when used to alter a guitar dimensions, will affect the mechanical and musical properties of an instrument. All data is in inches.

hand length		
3yo	4yo	5yo
4.10	4.50	4.70

hand width		
3yo	4yo	5yo
2.00	2.10	2.20

arm length		
3yo	4yo	5yo
10.00	10.50	11.20

index length		
3yo	4yo	5yo
1.60	1.60	1.75

middle finger length		
3yo	4yo	5yo
1.70	1.80	2.00

grip diameter		
3yo	4yo	5yo
1.18	1.22	1.30

convenient reach		
3yo	4yo	5yo
10.00	10.50	11.20

Figure 2.04 Child anthropometric data pertaining to guitar design.

Adult Anthropometry

The anthropometric data in this section correlates to the child anthropometry provided, in order to compare the two age groups. (LM/W = large man/woman, SM/W=small man/woman, MM/W = median man/woman).

hand length			
LM	SM	LW	SW
8.40	6.60	7.80	6.00

hand width			
LM	SM	LW	SW
4.60	3.70	4.10	3.20

arm length			
LM	SM	LW	SW
31.50	25.50	28.50	23.50

index length	
MM	MW
3.00	2.70

middle finger length	
MM	MW
nm	3.40

grip diameter	
MM	MW
1.50	1.50

convenient reach	
MM	MW
32.50	23.50

Figure 2.05 Adult anthropometric data pertaining to guitar design.

Guitar Dimensions

The guitar dimensions shown below were chosen because they will pertain solely to playability and the physical attributes of a string instrument, and as they are changed, so will the sound of the guitar. All dimensions reflect industry standards for contemporary electric guitar design.

Full-Scale Electric Guitar	
fingerboard length	15.50
scale length	25.00
nut width	1.63
nut spread	1.38
bridge spread	2.13

Figure 2.06 Contemporary full-scale guitar dimensions.

Proportions

An explanation of the proportions chart found on the next page is provided in Figure 2.07. As previously stated, a formula was created in order to begin the conversion process. Although proportions vary among adults and young children, this formula was a good starting point in discovery the correct dimensions for a preschool electric guitar. The results of the research can be viewed in Figures 2.08, 2.09, and 2.10, through measurements in inches and percentages of the original value. In each section of the chart, certain guitar categories have been highlighted because they possess greater relevancy to bodily dimension addressed in that specific section.

1. guitar/anthro data = variable

2. average of each row X child anthro = new dimension

3. new dimension/guitar dimension = percent of original

adult guitar		Adults: conveinient reach LM	MM	SM	LW	MW	SW	avg	Children: conveinient reach 3yo	4yo	5yo	Results: percent of fullscale 3yo	4yo	5yo
			32.50			23.50			10.00	10.50	11.20			
fingerboard length	15.50		0.48			0.66		0.57	5.68	5.97	6.36	36.7%	38.5%	41.1%
total length														
scale length	25.00		0.77			1.06		0.92	9.17	9.62	10.27	36.7%	38.5%	41.1%
nut width	1.63		0.05			0.07		0.06	0.60	0.63	0.67	36.7%	38.5%	41.1%
nut spread	1.38		0.04			0.06		0.05	0.50	0.53	0.56	36.7%	38.5%	41.1%
bridge spread	2.13		0.07			0.09		0.08	0.78	0.82	0.87	36.7%	38.5%	41.1%

Figure 2.07 Methodology and formula used in the proportions chart**.**

Figure 2.08 Proportions Chart for hand length, hand width and arm length**.**

Figure 2.09 Proportions Chart for index finger, middle finger, and grip diameter.

Figure 2.10 Proportions Chart for convenient reach.

2.32 Ergonomics

Factors that affect the comfort and ease of operating the guitar are considered ergonomic for the purposes of this study. In many instances the anthropometry data used to analyze playability and musical physics will also pertain to the ergonomic factors of the user, and will thus overlap. The considerations for this section include how the instrument sits on the user's lap, balance of the guitar both while sitting and standing, and areas of the body that may cause discomfort from contact with edges. Figure 2.11 illustrates the key factors in designing an ergonomic guitar for any user within a specific anthropometric group while seated, and Figure 2.12 highlights issues affecting a player while playing the guitar using a strap, to hold it in place.

Bodily measurements that relate to these important ergonomic factors were researched and are presented below for the seated (Figure 2.13) and the standing (Figure 2.14) players. They were used in making decisions on test models as well as the final prototype recommendations. By using the formula illustrated in Figure 2.15, the lower cutout of the guitar can be designed so that it fits comfortably on the leg of the user. The provided example uses the thigh circumference of a three-year-old. The desired curve is yielded by dividing the thigh circumference by pi to get the diameter of the thigh, then dividing the diameter by 2 to get the radius. The radius is multiplied by 1.5 to insure that the curve fits well on the leg but does not fit too tightly. To further explore how each anthropometric measurement weighs in the design of an ergonomic guitar, a chart (figure 2.16) was created. By seeing every bodily dimension as it relates to one or more guitar parts, the designer will reduce oversight and have a clearer view of what needs to be addressed.

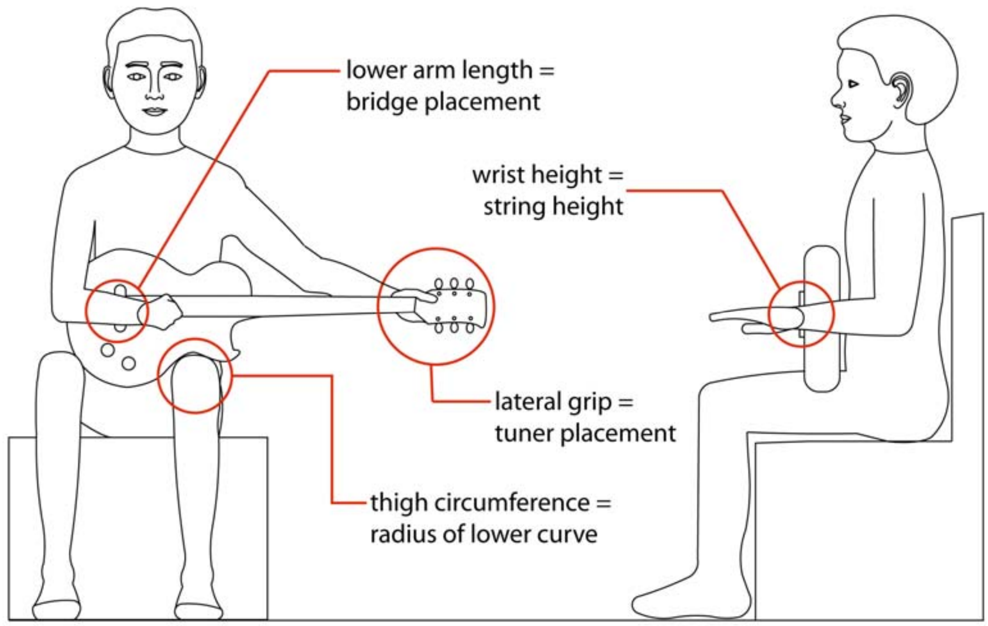


Figure 2.11 Ergonomic issues affecting the seated player**.**

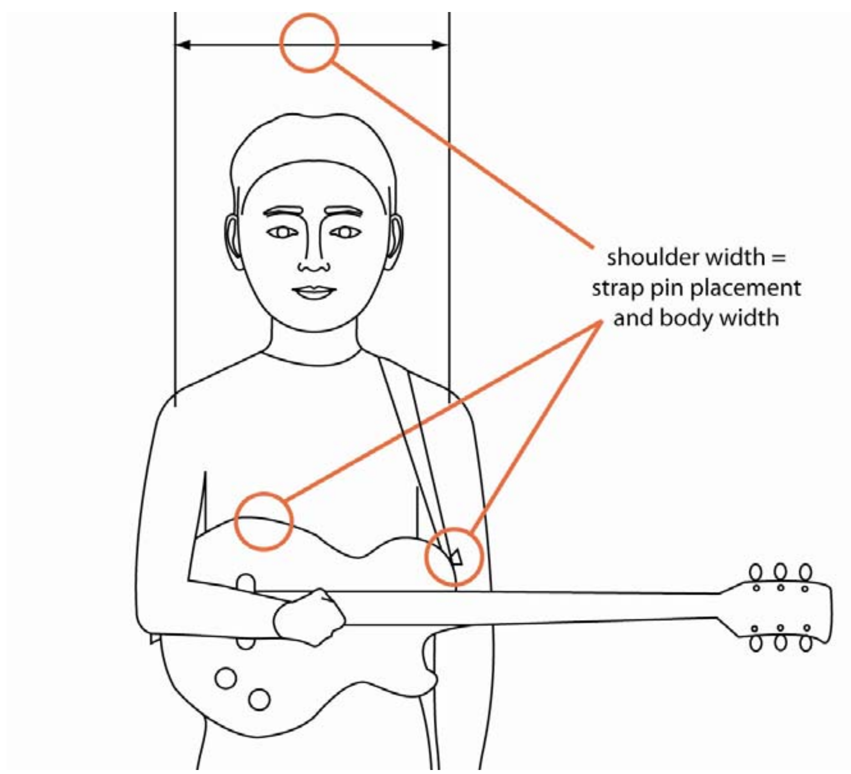


Figure 2.12 Ergonomic issues affecting the standing player**.**

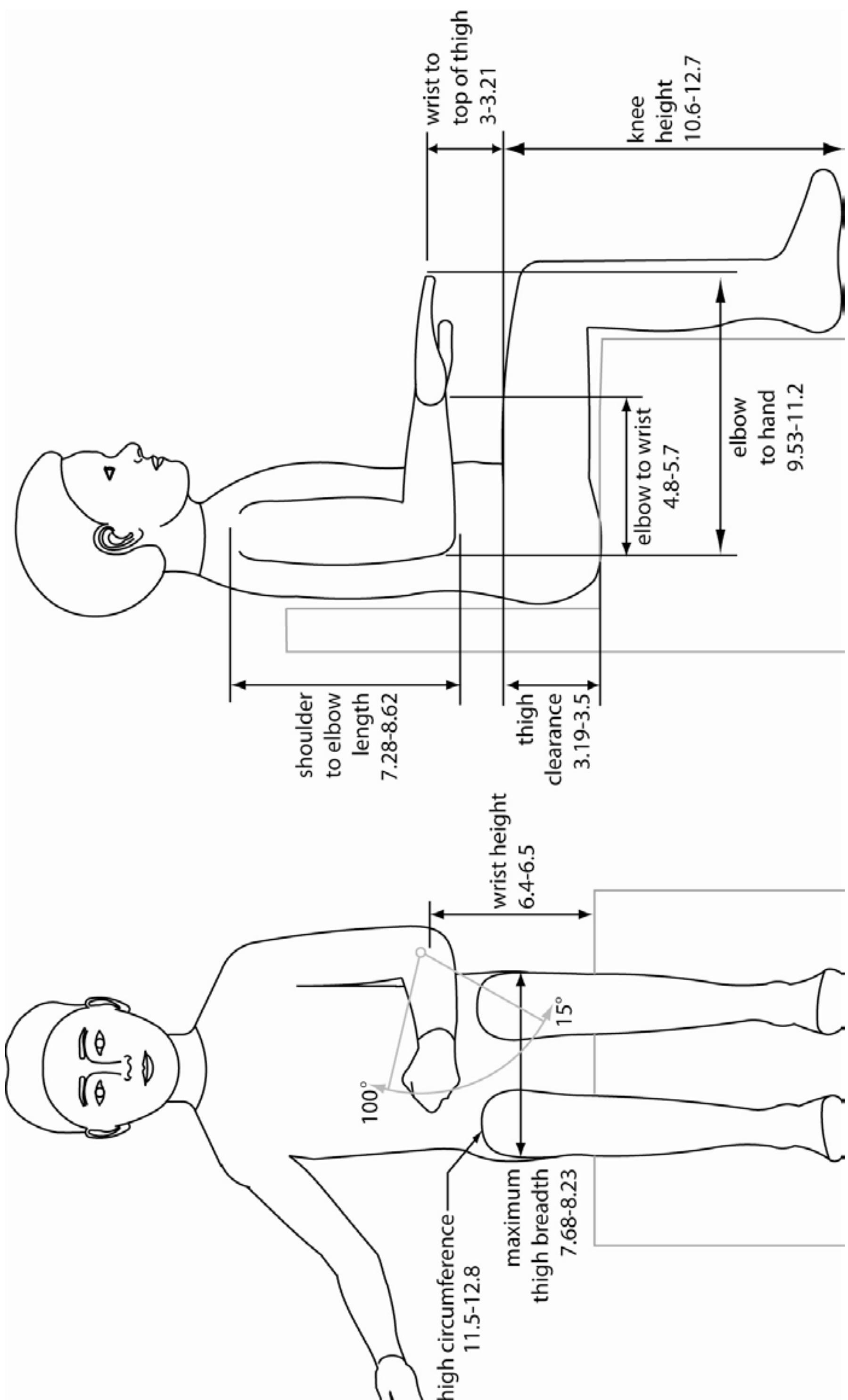


Figure 2.13 Bodily dimensions correlating to ergonomics of the seated player**.**

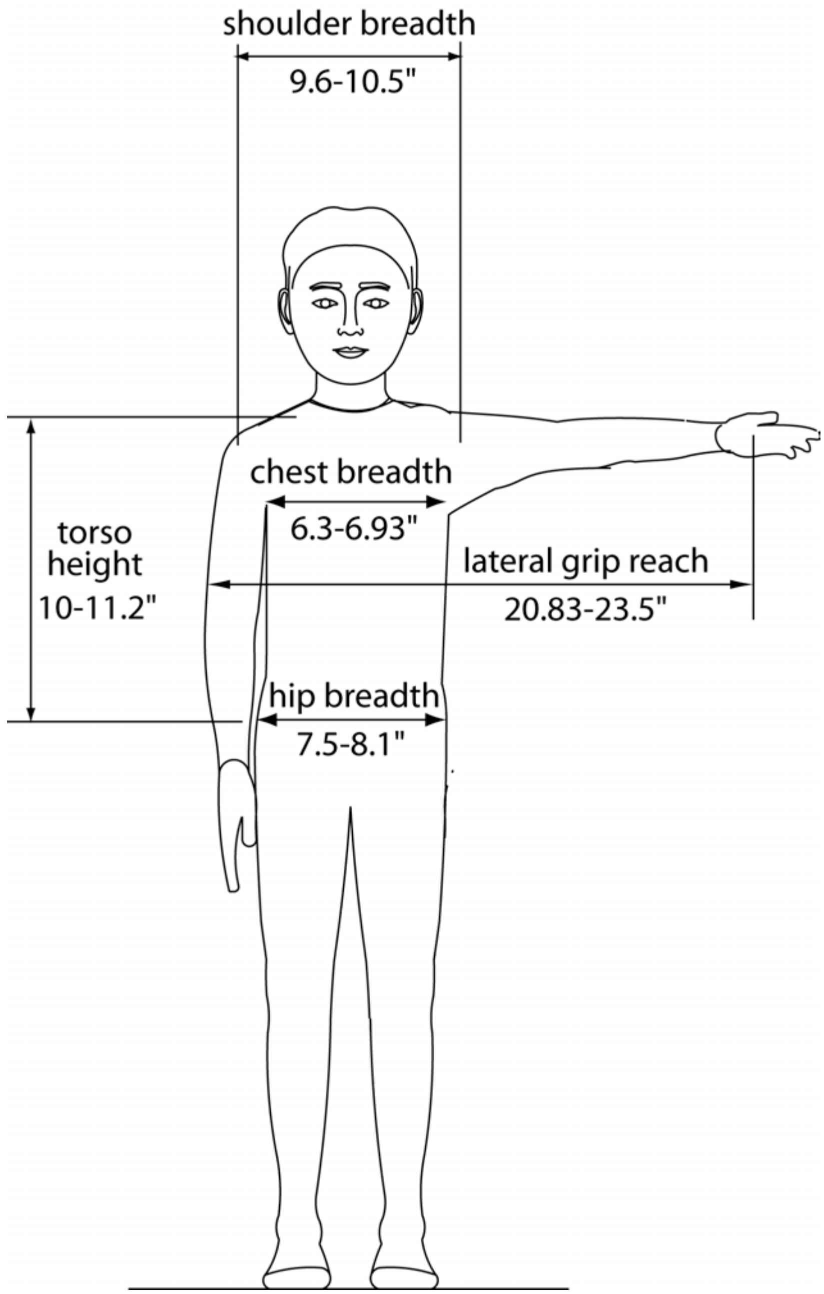


Figure 2.14 Bodily dimensions correlating to ergonomics of the standing player.

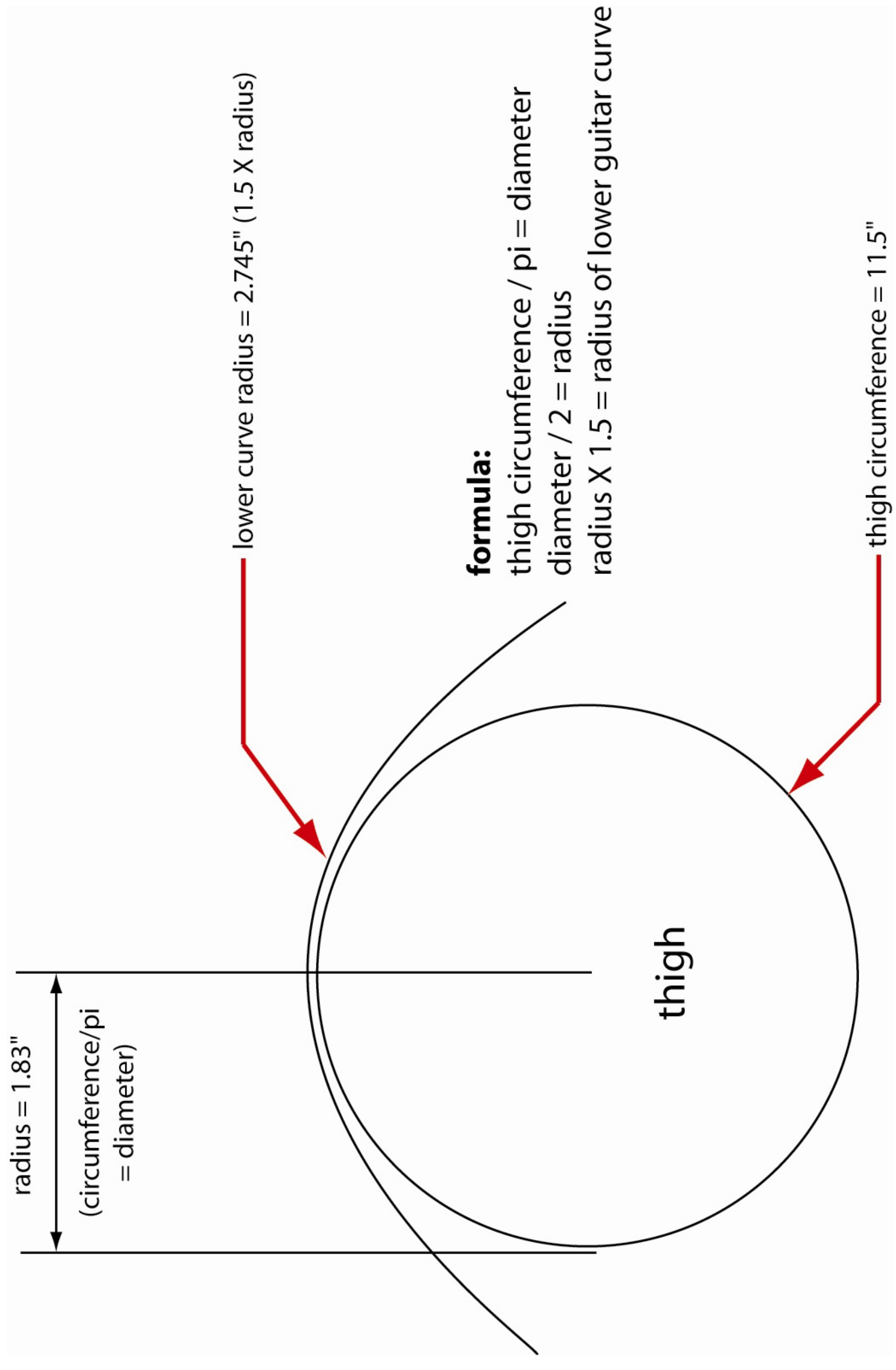


Figure 2.15 Formula for determining an ergonomic lower curve radius**.**

Child Anthropometry	Age			Guitar Components and Dimensions											
	3	4	5	body width	body shape	body height	bridge place	string center	body depth	knob/ switch place	control knob dia.	tuner size	tuner place	strap pin place	neck depth
total height	37.5	39.6	41.8			X									
convenient reach	10.0	10.5	11.2	X				X		X			X		
seated height	20.8	22	22		X	X									
grip diameter	1.18	1.22	1.3								X	X			X
thumb length	1.42	1.5	1.61								X	X			X
index finger length	1.6	1.6	1.75								X	X			X
middle finger length	1.7	1.8	2				X				X	X			X
torso height	10	10.5	11.2		X	X		X		X				X	
chest depth	4.5	4.76	4.84		X				X						
chest breadth	6.3	6.6	6.7	X	X		X				X		X	X	
lateral grip reach	20.8	22.2	23.5					X		X			X		
thigh circumference	11.5	12.7	12.8		X	X									
thigh clearance	3.19	3.31	3.5	X	X										
middle to thumb grip	2.36	2.44	2.56								X	X			X
shoulder-elbow length	7.28	8	8.62			X		X		X				X	
elbow-hand length	9.53	10.5	11.2				X								
max thigh breadth	7.68	7.83	8.23	X	X		X								
knee height	10.6	11.8	12.7		X			X							
shoulder breadth	9.6	10	10.5	X			X							X	
hip breadth	7.5	7.8	8.1		X		X	X							
wrist to top of thigh	3.21	3	3			X		X		X					
elbow to wrist length	4.8	5.2	5.7	X			X			X				X	
wrist height 90 degrees	6.4	6.3	6.5			X		X	X	X			X		

Figure 2.16 Ergonomic considerations chart.

2.33 Aesthetic Preference

"Since the 1950s industries focusing on children, including clothing, food, entertainment, and education, have been mainsprings for many businesses and wellsprings of fortunes" (Heller & Guarnaccia, 1994). A company hoping to join this lucrative market segment should take a serious look at what products preschoolers like and what drives their parents to the products they purchase for their children.

A guitar designed for a child must be what it is, a musical instrument. Semantics however, does play a role in every product's ability to attract its target audience and make them feel that the product was designed with full consideration of the user. As *Designing for Children* states "well-designed is of course a relative term. What an adult might savor a child might shun," yet "today's products and packages must appeal to both kids and parents, and therein is a tension that must be reconciled" (Heller & Guarnaccia, 1994). And while accessing the thoughts of preschool children is not as easy as can be with adults, "young children are concerned with the abstract themes of good and bad, beautiful and ugly, power and control, and love and hate" (Egan, 1988). "If anything characterizes the very young child, it is curiosity about and responsiveness to stimuli in its internal and external contexts. The child is a seeking, active organism that is always impacting and impacted upon" (Sarason, 1990).

The achievements of toy, entertainment, and literature manufacturers reveal formulas marked by success and excessive monetary gain. And while it seems that these formulas have evolved through decades of product development, a question arises regarding styling in children's products originally intended for adults. "Sony electronics for children are cartoon-style interpretations of adult products, but Rappin' Robot, a tape recorder, is a cartoon character, and a delightful one. This child-friendly imagery teaches kids how to use and respect a real machine" (Heller & Guarnaccia, 1994). This is an example of a real working product styled in a way that attracts the young user. After all, "So why inflict the matte black, high-tech aesthetic on them at an early age? Why not target them with a line of products fitted with exciting colors of childhood" (Heller & Guarnaccia, 1994)? However, if a product does not possess the sterile qualities of the average home appliance, for instance a baseball glove, there is often no need to transform the product significantly in visual aesthetics. The questions at hand is whether a child would feel happier with a guitar that looks like their parent's instrument or one that eludes youth and is marked by the qualities of a toy. As seen in the existing product chart, there are instruments that take both approaches. No matter what decision the designer makes the main focus of the instrument, following quality and ergonomics, should be communication with the user.

Beyond the analysis of success in child products, research on child preferences in basic visual elements like color groups, will insure that a guitar will not be off the mark when it hits the shelves. In 1906, a famous German doctor, coined the phrase "Farbendummheit', or color stupidity (Saunders, & Van Brakel, 2002). He was addressing the problem many children have in verbalizing the colors that they see and know. "Though they have, at an age between two and three years, perfect color vision and a good command of the color lexicon and its internal semantical relations, they have problems in assigning color names to pure sensory qualities and in abstracting away from concrete objects, evidenced in the problems they have in linking lexical items to color appearances" (Saunders, & Van Brakel, 2002). Children do eventually resolve this problem, usually at a time occurring in the middle of this test's age group. "Four years seems to constitute some sort of minimum chronological age for correct and consistent color naming" (Saunders, & Van Brakel, 2002).

In addition to developing abilities, children's tastes in color changes over the preschool years. As one study reports, "a decreased preference for red and an increased preference for blue were found at 4 years 6 months and 5 years. The period of greatest transition from warm to cold emphasis tends to be between three and three and a half-a period already described as nodal in the transition from emotional to controlled behavior" (Pickford, 1972). With these changes taking place in the midst of the preschool years and this study's target age group, seeking to find a common denominator among all age groups in regard to color choices is the best solution to insuring a product will attract a wide range of children. A Scottish study of 138 preschool students exposed to combinations of colors on cards, yielded the following results: (Pickford, 1972).

Card 4. Orange-red and blue-violet, maximally saturated-'primitive or impulsive'. This card was favoured by 6-year-olds, and increased in popularity until age 13 years.

Card 6. Orange and green-"offensive". No age trends were found for this card

Card 1. Two shades of gray –'adaptable and flexible'. This was rarely considered attractive, but often unattractive.

Card 9. Orange-red and red-purple-'vibrating reds'. This card was liked by half the 6-year-olds, but then declined in popularity.

Card 7. Polychrome-six sets of complimentaries with triadic interpretations-to appeal to those responding impulsively to color. It was among the most attractive to 94 percent of the 6-year-olds and then declined in popularity

One area of aesthetic preference that seems to be constant is that to a "statistically significant extent," preschool children, "prefer balanced to unbalanced three-dimensional designs" (Pickford, 1972).

2.4 Technical Function

2.41 Interaction Matrix

The Interaction Matrix (Figure 2.17) is used to determine how often a product interacts with another of its own parts. Used in determining the placement of a product's parts, the Interaction Matrix is set up on a scale. The charted parts are provided a number based on the level of interaction they experience, with the other corresponding part:

0 = no interaction **1** = light interaction **2** = heavy interaction

2.42 Interaction Table

Similar to the Matrix, The Interaction Table (Figure 2.18) is used to examine the relationship between the product and its environment. These environments include natural and human elements which may come into contact with parts of the product. The scale used in the Interaction Table translates as follows:

0 = no interaction **1** = moderate/indirect interaction

2 = strong/direct interaction **score** = sum of all scores in parts row

Figure 2.17 Interaction Matrix of the electric guitar.

Figure 2.18 Interaction Table of the electric guitar.

2.43 Compatibility

A look at contemporary equipment, which may interact with the product, is important prior to the development phase, in order to insure that total compatibility will exist between the instrument and the equipment. A Compatibility Table (Figure 2.19) has been created to illustrate the reciprocal actions taking place between the product and products that accommodate the product. These devices include amplification, cables, power sourcing, sound shaping, and accessories.

Figure 2.19 Existing product compatibility chart.

3. DEVELOPMENT PHASE

3.1 Performance Criteria

Based upon the research in section 2 of this thesis, a set of criteria has been established for the design of a preschool child's guitar. The resulting chart (Figure 3.01) provides recommendations for a preliminary set of prototypes. It will be used in the creation of test models and ultimately the final solution of what is believed to be the most ergonomic and anthropometrically correct design of a young child's guitar. Performance Criteria should be seen as a map to solving the problem at hand.

	Function	Parameters	Performance Criteria
Human Function	**practical physiological**	weight	less than 10 lbs.
		strings	nylon
		speaker	3" diameter
		portage	hand held
		output	headphone/cable to amplifier
		knobs	1" diameter
	social/economic	retail	less than $750
	cultural aesthetic	colors	analogous/complementary
		styling	fun and youthful
		form	traditional modern electric guitar
Technical Function	**direct**	power	9 volt battery/amplifier
		speaker	2 watts
		pickup	piezo
		strings	nylon
		power switch	tilt switch
	indirect	storage	width<25", depth<2.5", height<11"
		power source	U.S. 120 volt
		cables	1/4" phono jack
Production Function	**planning**	intended users	3-5 year olds (36-72 months)
	manufacturing	body/neck	CNC/hand made
		pickup	automated
		machine heads	die cast
		knobs	injection molded plastic
		woods	alder/maple/rosewood

Figure 3.01 Performance Criteria.

3.2 Brainstorming

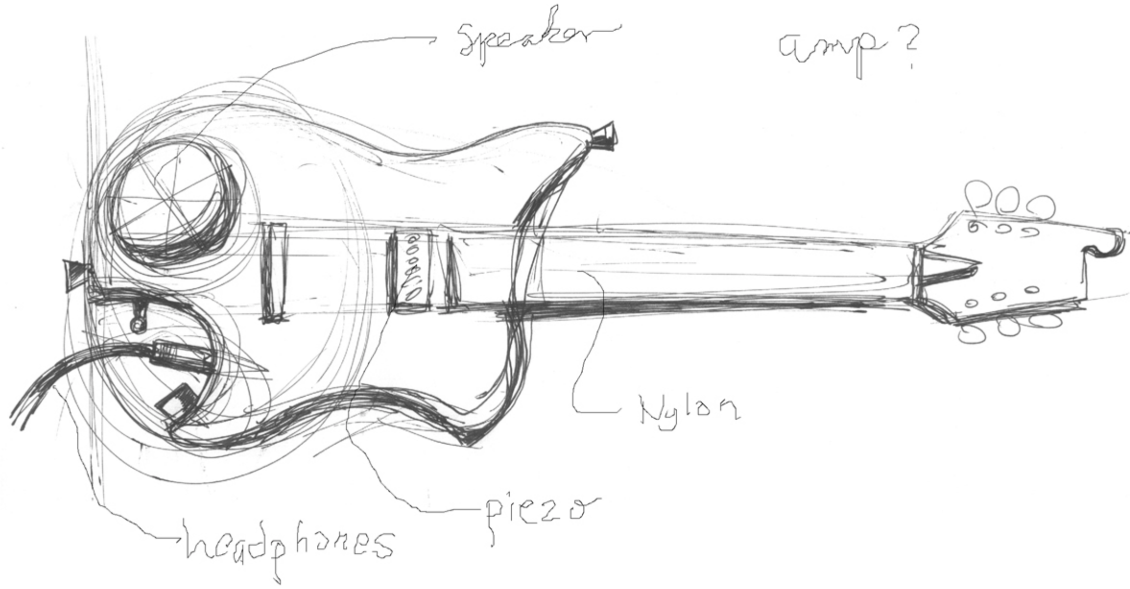


Figure 3.02 Brainstorming sketch for function and design.

3.3 Idea Sketches

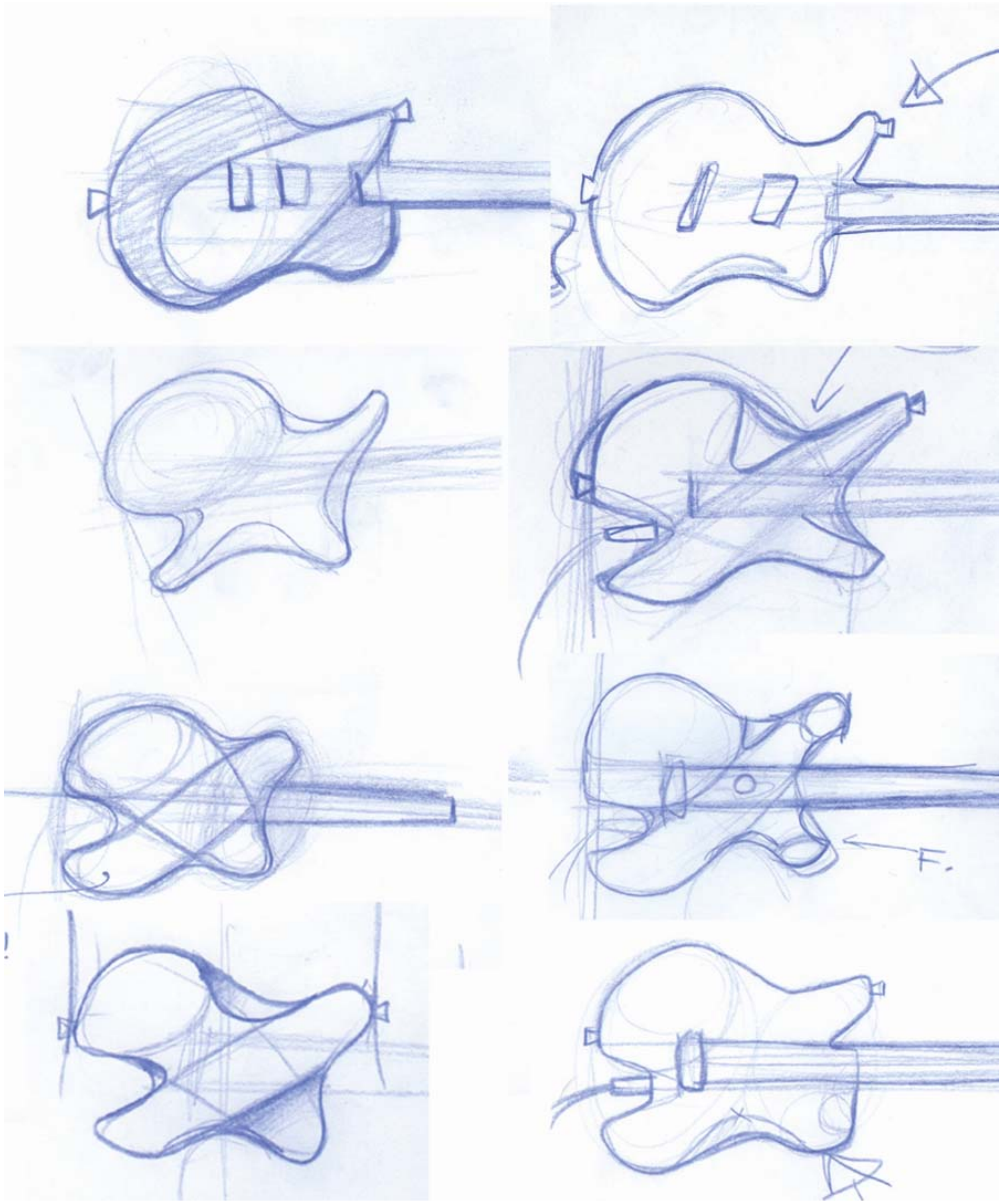


Figure 3.03 Idea sketches for body shapes.

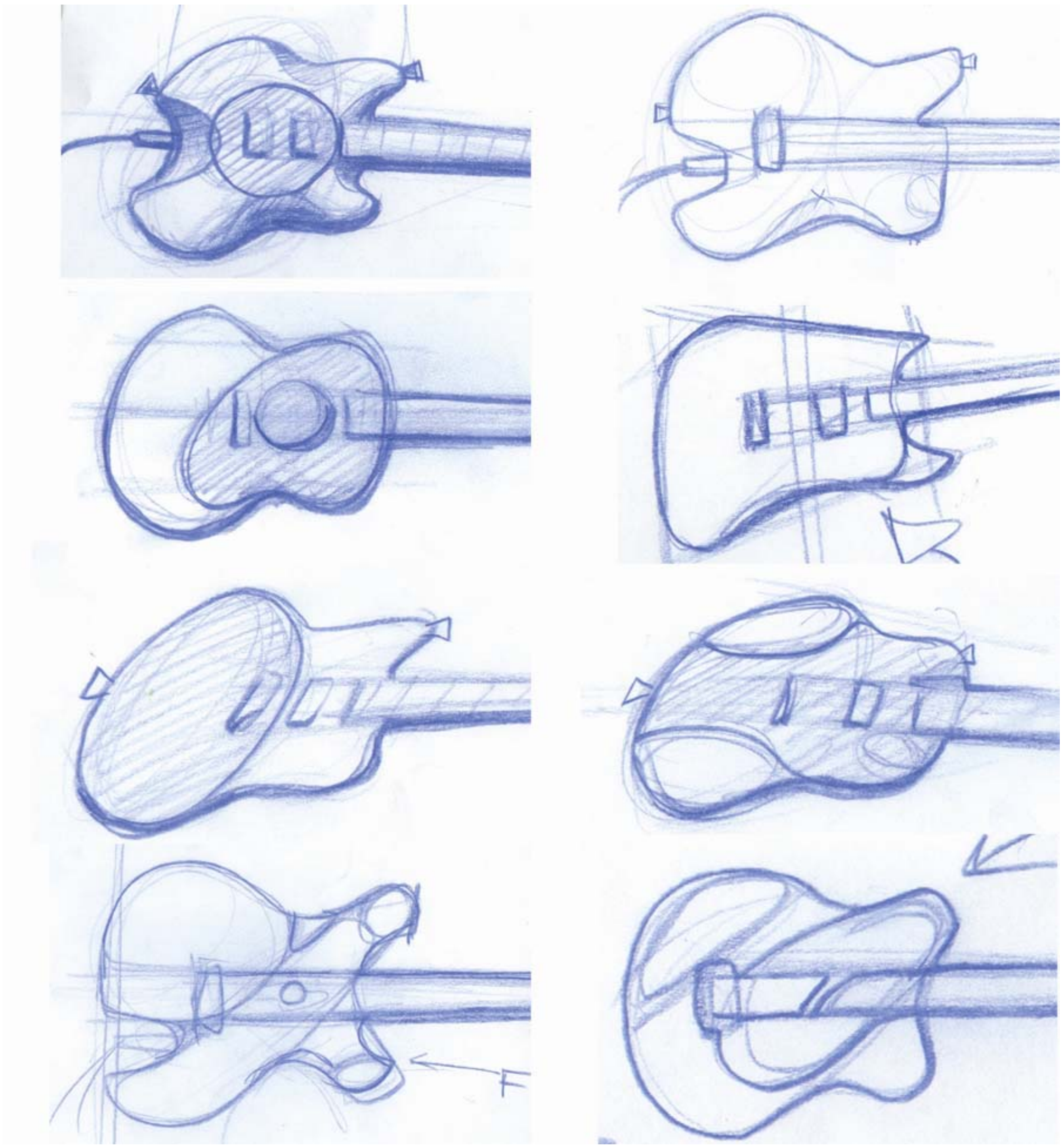


Figure 3.04 Idea sketches for body shapes.

3.4 Concept Sketches

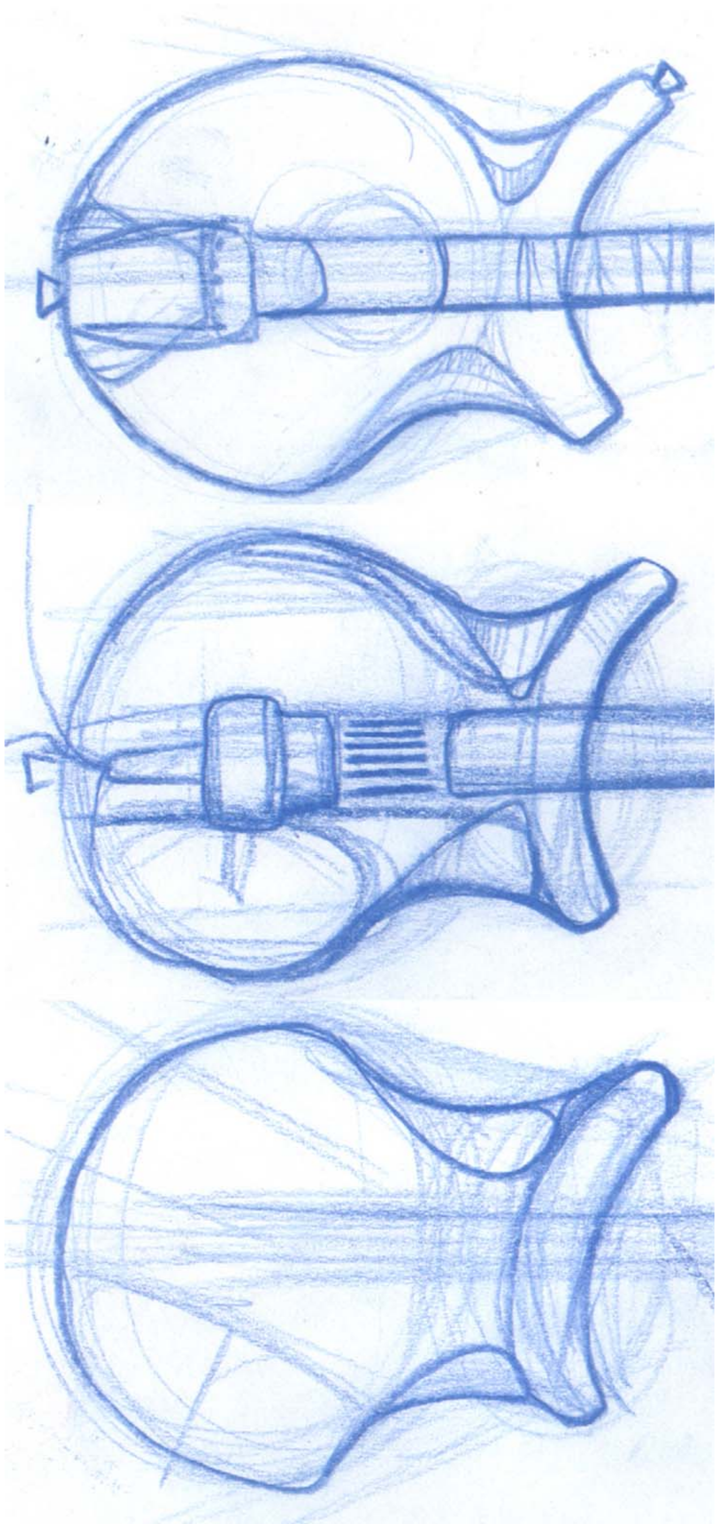


Figure 3.05 Sketches exploring final concept body design

3.5 Trials

A size test, using breadboard models based on the accrued anthropometric data research conducted in phase 2, was conducted in order to determine more accurately the most ergonomic dimensions for a any given group of 3-5 year olds.

Three guitar-shaped models, based on data from section 4.5, were created from sheets of multi density fiberboard. These mock ups were designed to possess specific ergonomic and mechanical characteristics of the guitar including the lower curve for sitting, scale length, neck width, neck thickness, and body size. Once the design of the models were chosen, Rhinoceros 3.0 files (Figure 3.06) of the necks were created, which were used to form the MDF models on a CNC (Computer Numeric Control) router. These proportions were derived, based upon the three scale lengths that were chosen (Figure 3.07) and three body dimensions were determined (Figure 3.08).

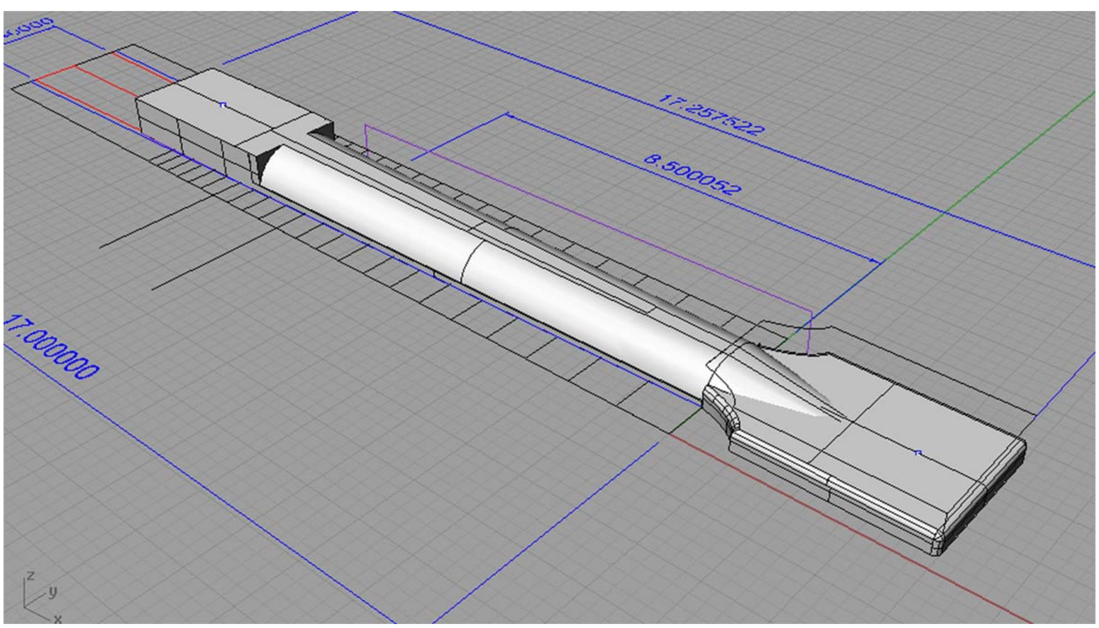


Figure 3.06 Rhinoceros 3.0 model used to create bread board model necks.

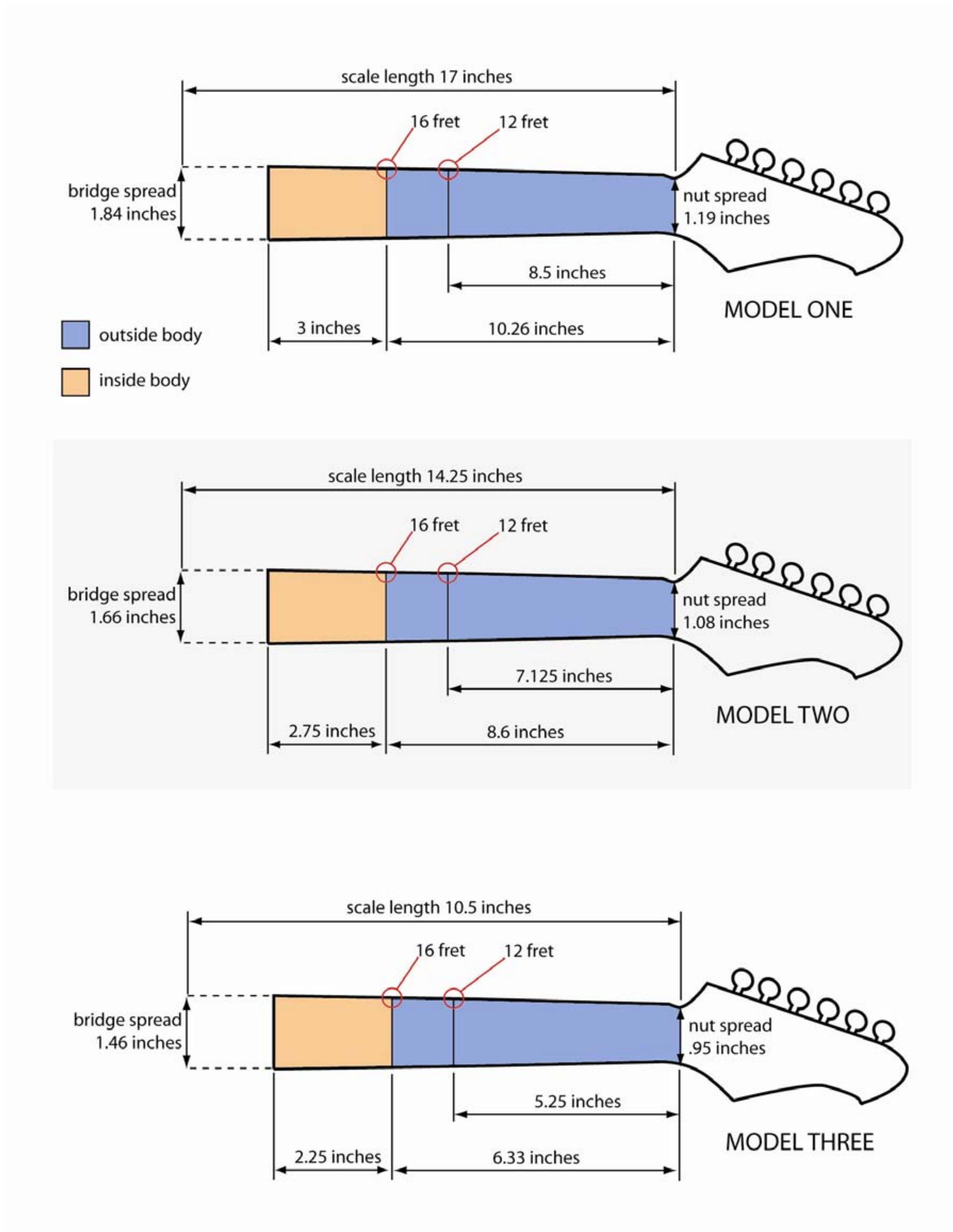


Figure 3.07 Three scale lengths for bread board models.

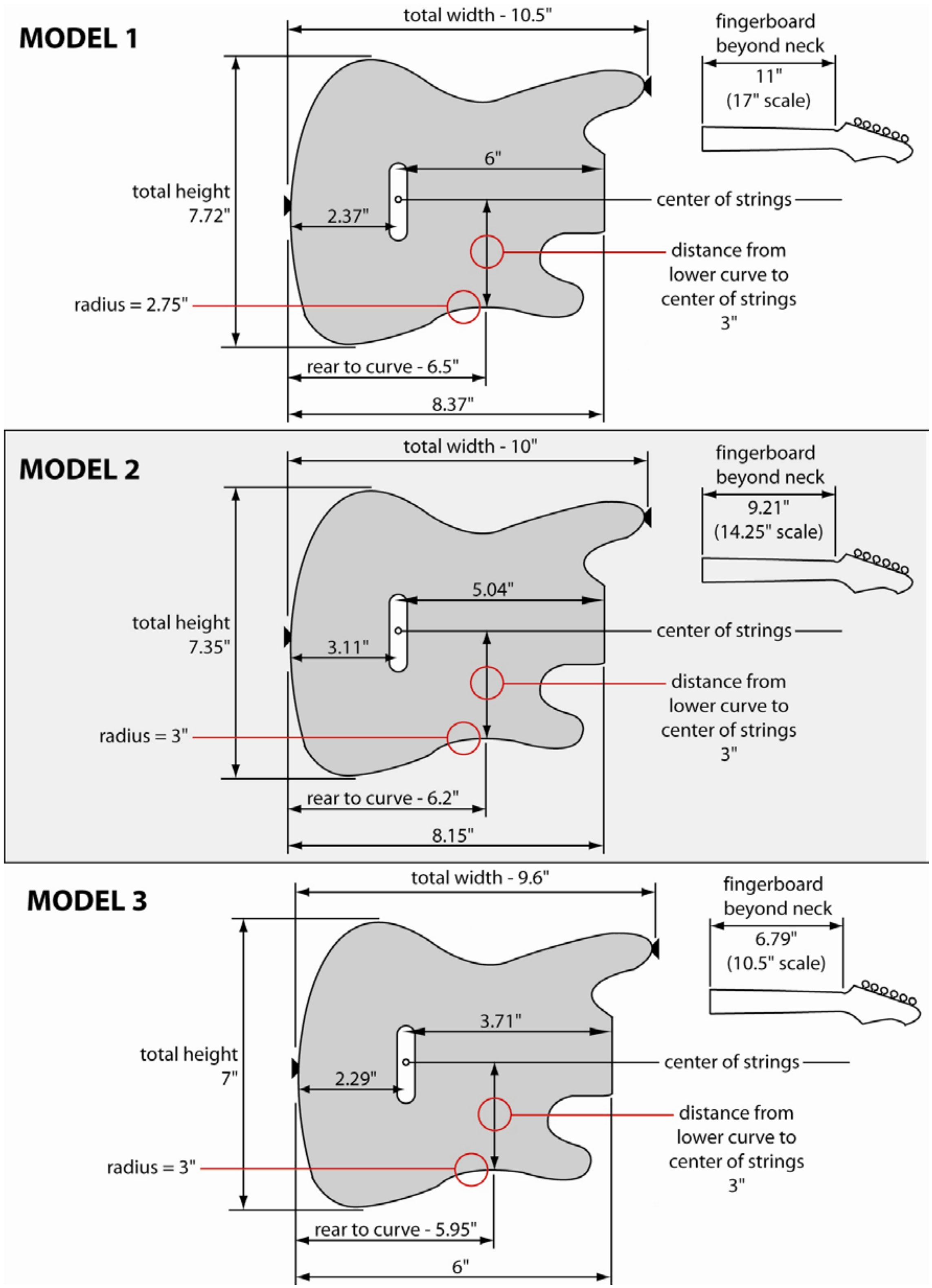


Figure 3.08 Three model body sizes chosen from research.

Other aspects of the guitar, like strings and electronics, were not included in the models as they are not needed for the sole task of fitting the size of the product to the user. The three models as seen in Figures 3.09 range from small to large. It was assumed before the tests that the smallest model might not fit a large 5-year-old boy, and the largest may be too grand for a 3-year-old girl, but without testing, no sound decision can really be made about these statements. Primary colors were used in order to identify easily the three sizes in photographic and video recording (Figure 3.10) after the testing was conducted. In addition, a gray abstract graphic representation of bridge placement was placed on the top of each body to observe arm placement during testing and to see if the guitar was designed correctly.

In order to fulfill the required observation and recording of human subjects handling the models, a testing session was scheduled at the Auburn University Early Learning Center on March 24, 2005, at 2 p.m. This laboratory preschool accommodates students in this study's target age group of three to five years old. Twelve students participated by taking turns holding each of the three models. The session, which lasted 20 minutes, was documented using a digital camera and digital camcorder. Much was learned by conducting these trials and through analyzing the recorded files and footage, decisions regarding scale and proportions were determined. The following images (Figure 3.11) are a few of the photographs taken during the trial.

Figure 3.09 Multi Density Fiberboard test models.

Figure 3.10 Multi Density Fiberboard test models.

Figure 3.11 Photographs taken during sizing test at Early Learning Center.

3.6 Final Concept

3.61 Materials

Materials used for the creation of the final model are as follows:

Neck – quilted maple

Body – alder

Tops – Quilted maple

Truss Rod – carbon fiber

Fingerboard – rosewood

Bridge – rosewood

Inlays – mother of pearl

3.62 Aesthetics

Color preference, though varied, does exist in certain common forms among the age range. It is apparent that children enjoy triadic color schemes (three colors spaced evenly around the color wheel). This is evident in the research, where most of the 6-year-olds chose these patterns. Colors schemes that seem to appeal to children of the preschool years the most include the following and should be considered approved color patterns, in order of preference:

1. Triadic
2. Complimentary
3. Analogous

Tertiary colors according to the research are preferred over primary and secondary colors. The tetrad, especially when possessing green and orange, should be avoided. Wandering very far outside of primary or complimentary color schemes should be abandoned as children seem to consider these patterns unappealing. They prefer vibrant aesthetics that avoid chaotic combinations.

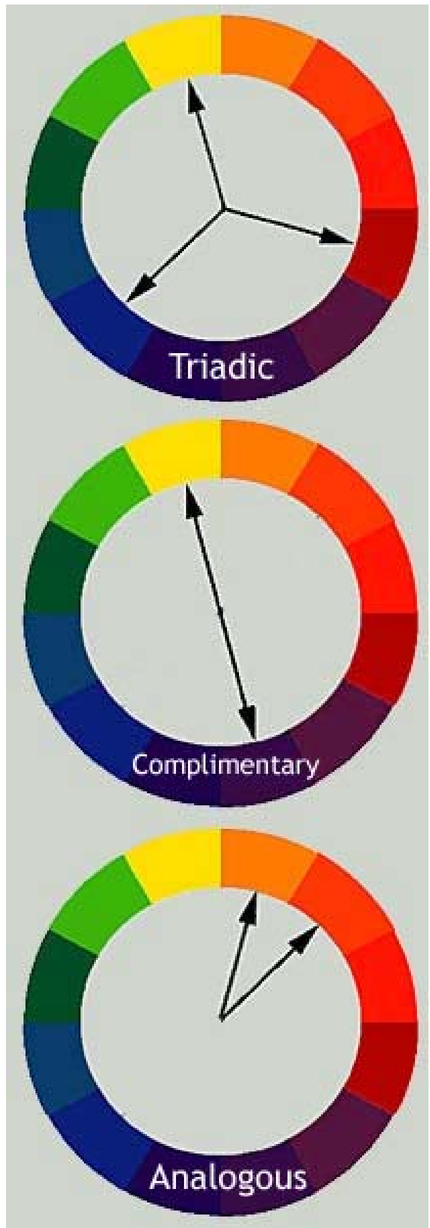


Figure 3.12 Approved color schemes based on child preference research.

Shape should be balanced, either through symmetrical layout or occult balance. And while it is all right to mimic existing popular designs such as the Gibson Les Paul or the Fender Stratocaster, a fresh design may assist in branding and increased recognition in a niche market. The public may begin to associate a shape with preschool guitar design. Although no clear winner was revealed in the survey, regarding shape, it is evident that adults prefer the traditional dreadnought (acoustic guitar) and single cutaway (Les Paul) shapes, while children are open to more exotic and freeform designs.

3.63 Technical Function

The components found within the final model are shows in figure 3.13, in addition to their functions, the following paragraph details all technical activities experienced during the performance and maintenance of the instrument.

The guitar uses nylon strings which must use a piezo, or transducer pickup, which consists of crystalline, ceramic substance applied to a piece of metal, to pick up any vibration within inches of its vicinity. Vibration from the strings is sent through a wire to the one-watt amplifier, which transfers the signal into an electric signal. This signal passes through the volume pot which, when turned counter-clockwise, reduces or completely halts the signal. The signal passes on the input jack. Two input options are available. An electric guitar chord may be used to send the signal to an amplifier or headphones may be used to allow the user to be the sole listener and thus cause no irritation to parents and others. If no chord is present, the signal is passed directly to the two-watt speaker located in the body of the guitar. In addition to these components, an on off switch, with two sounds types (clean and distorted) is present on the top of the body. An LCD light, indicating power, is located near the switch.   The amplifier is powered by a 9-volt battery stored within the body cavity. All components can be accessed by removing the blue maple panel on the back of the guitar kept in place by screws. The strings of the guitar are inserted through the back of the body and wrap around the bridge onto the nut and machine heads. This is known as a "string-through" design. To protect the wood and create a unique aesthetic, two mother of pearl rectangular blanks have been inset on either side of the body.

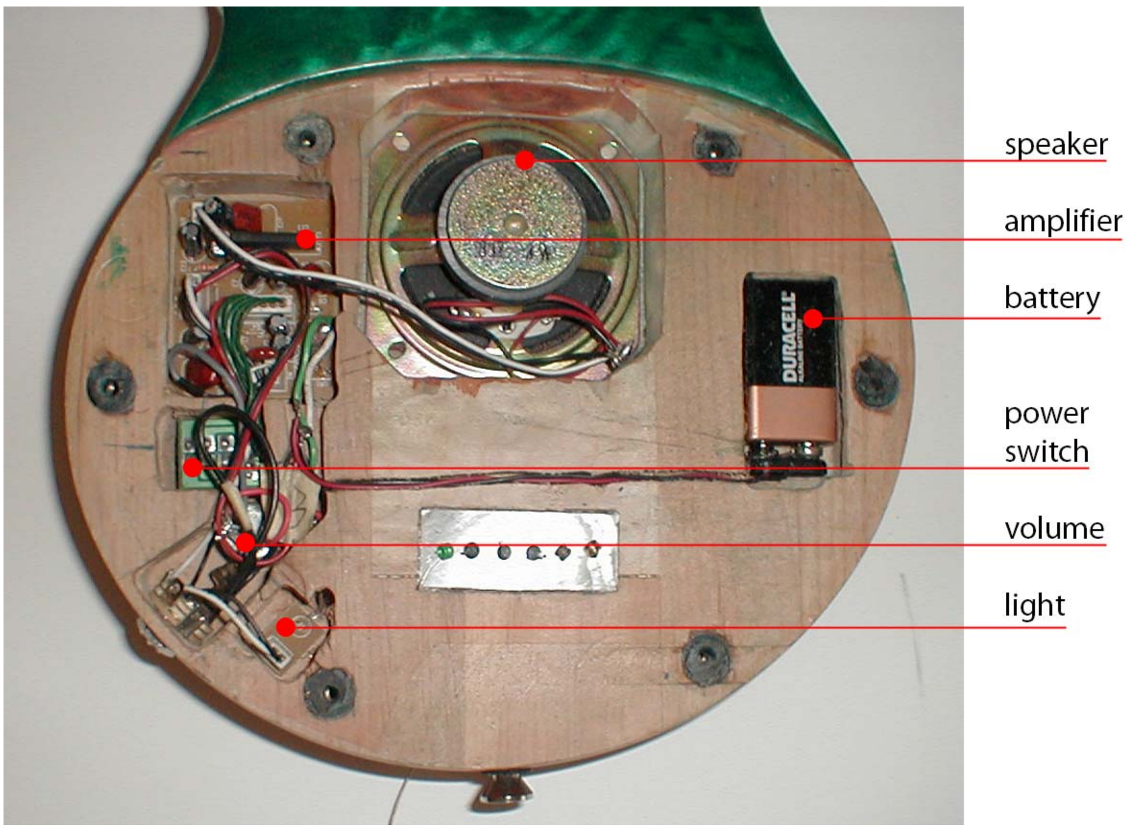


Figure 3.13 Components found within the body of the final model.

3.64 Dimensions

Crucial guitar dimensions, that when used, will accommodate all three years of the preschool age group. Like with any product or dwelling, considerations both two-way and one-way, are important to determining all users from the smallest to the largest. And upon observation, most aspects of guitar proportion design are two-way considerations. A guitar neck should not be too wide for a 1%ile 3-year-old girl to grasp and reach every string, and yet a neck that is too slim will make it difficult for the child to play once she has reached the age of 5. These considerations were weighed and placed in a chart (Figure 3.14) and were subsequently used to determine the final design recommendations (Figure 3.15).

	1 or 2 way	design consideration	based upon
fingerboard length	2	short enough for 1%ile child's reach	grip diameter
		large enough for 99% child's fingers (fret spacing)	hand/finger size
scale length	2	short enough for 1%ile child's reach	arm length/convienient reach
		large enough for 99% child's fingers (fret spacing)	hand/finger size
neck thickness	2	thin enough for 1%ile child's grip	grip diameter
		large enough for 99% child's grip	grip diameter
nut width	2	thin enough for 1%ile child's grip	grip diameter
		large enough for 99% child's grip	string spacing
nut spread	2	thin enough for 1%ile child's grip	grip diameter
		large enough for 99% child's grip	string spacing
bridge spread	0	based upon nut spread	neck integrity
body width	1	large enough for 99% child's shoulder width	strap pin placement/balance
body height	2	short enough for 1%ile child's torso	torso length
		tall enough for 99%ile child's wrist heigt	wrist height/arm length
lower curve radius	1	large enough for 99%ile child's thigh	thigh radius/sitting balance

Figure 3.14 Design Considerations Chart for determining final dimensions.

Dimension	Measurement in Inches	Explanation
fingerboard length	10.25	allows access to higher frets and balance instrument well
scale length	17.00	smaller children may still reach lower frets and use of contemporary strings with no change in key
neck thickness	.75 to .85	fits all %iles hands well
nut width	1.40	provides necessary .10" space on either side of outside strings without affecting grip of smaller children
nut spread	1.20	accomodates all grip diameters
bridge spread	1.75	allows neck to widen at base in order to aid in stability and durability
body width	10.50	wide enough for 99%ile children, but no too wide for 1%ile children
body height	7.75	grants correct wrist and arm height for all users
lower curve radius	3 inches	wide enough for 99%ile children's thigh without affecting smaller children

Figure 3.15 Final Dimension recommendations.

3.7 Computer Models

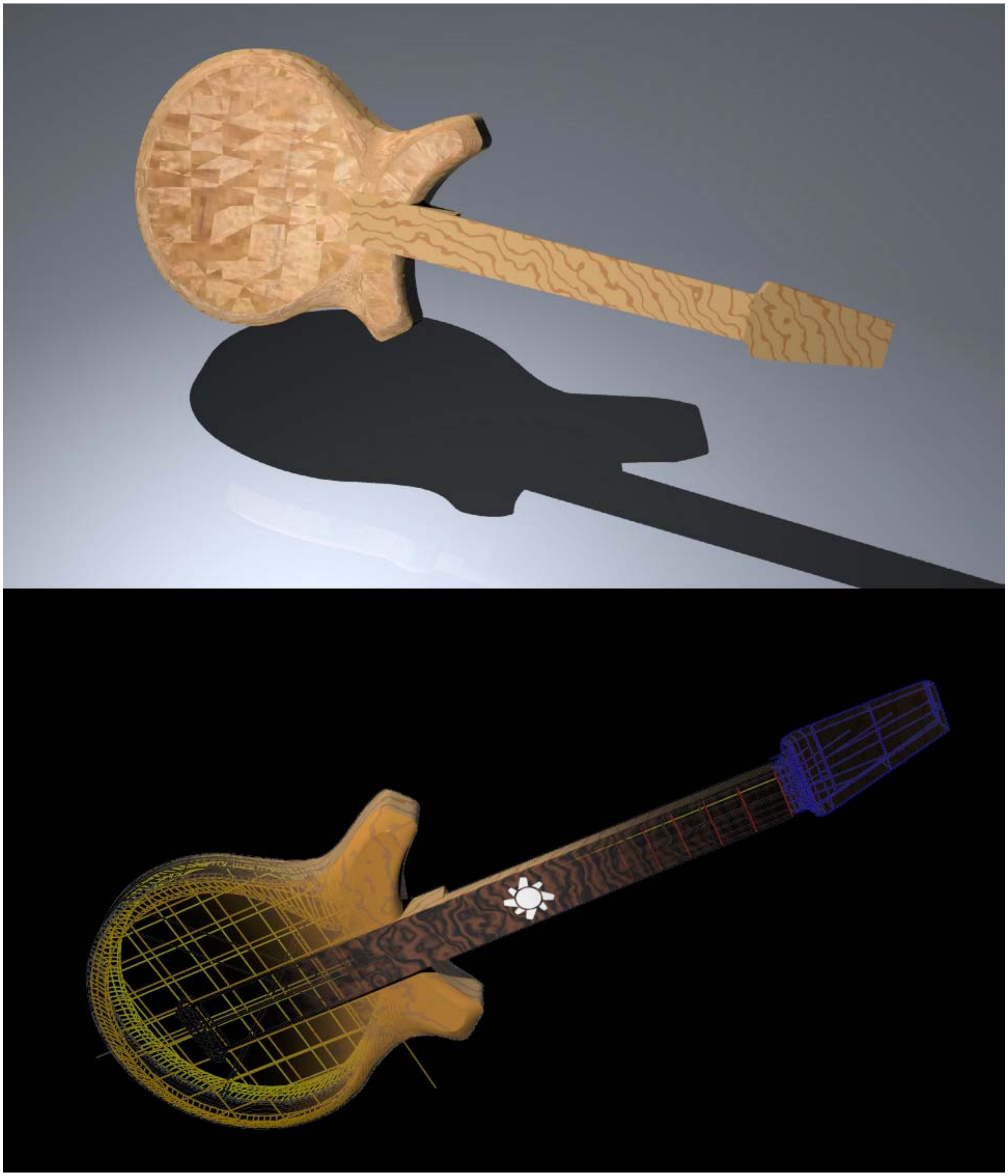


Figure 3.16 Rhinoceros 3.0 models rendered with Flamingo 1.0.

Figure 3.17 Rhinoceros 3.0 models rendered with Flamingo 1.0.

Figure 3.18 Rhinoceros 3.0 models rendered with Flamingo 1.0.

3.8 Control Drawings

In preparation for building the final model, control drawings for inlays (Figure 3.19), dimensions (Figure 3.20), and colors (Figure 3.21) were created. These drawings and instructions were used as reference in every step of the construction of the guitar.

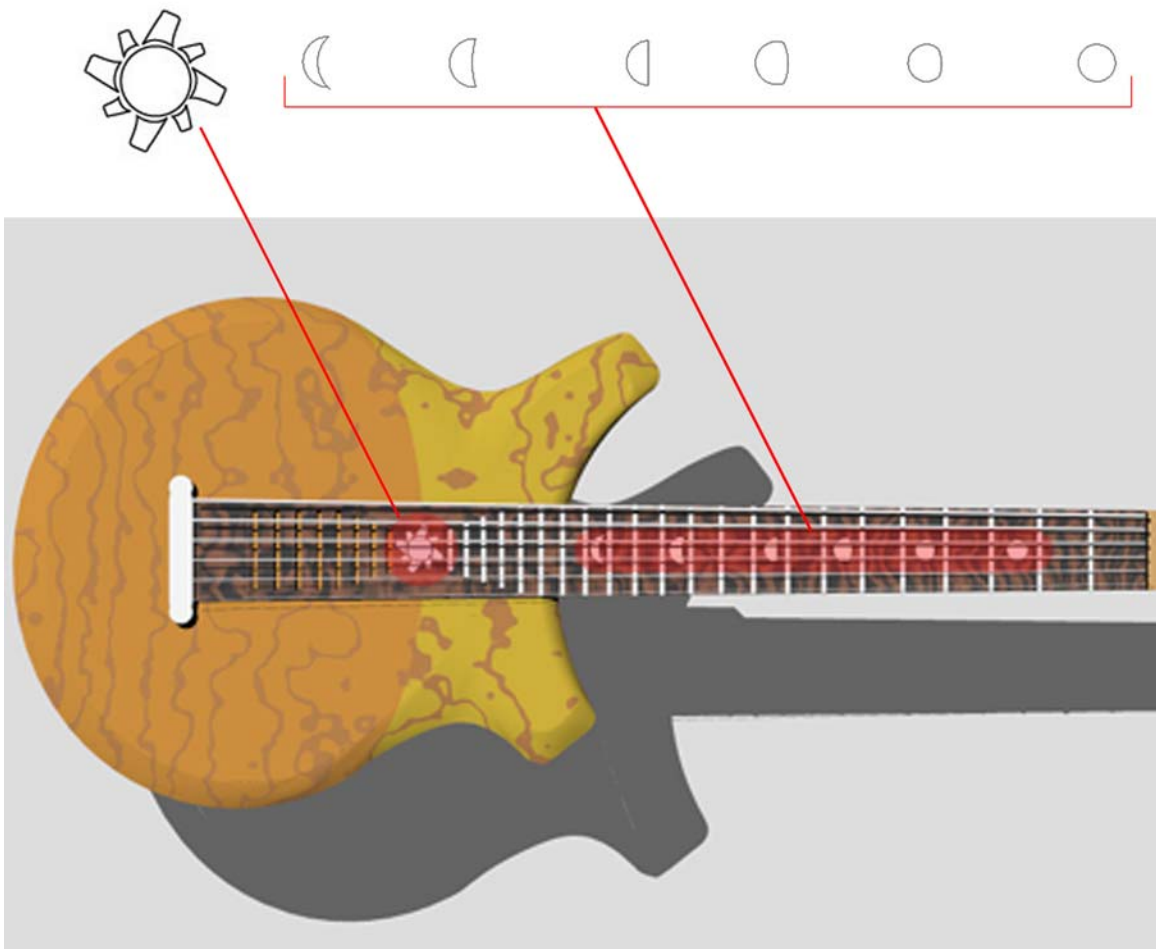


Figure 3.19 Control drawings of mother of pearl inlays.

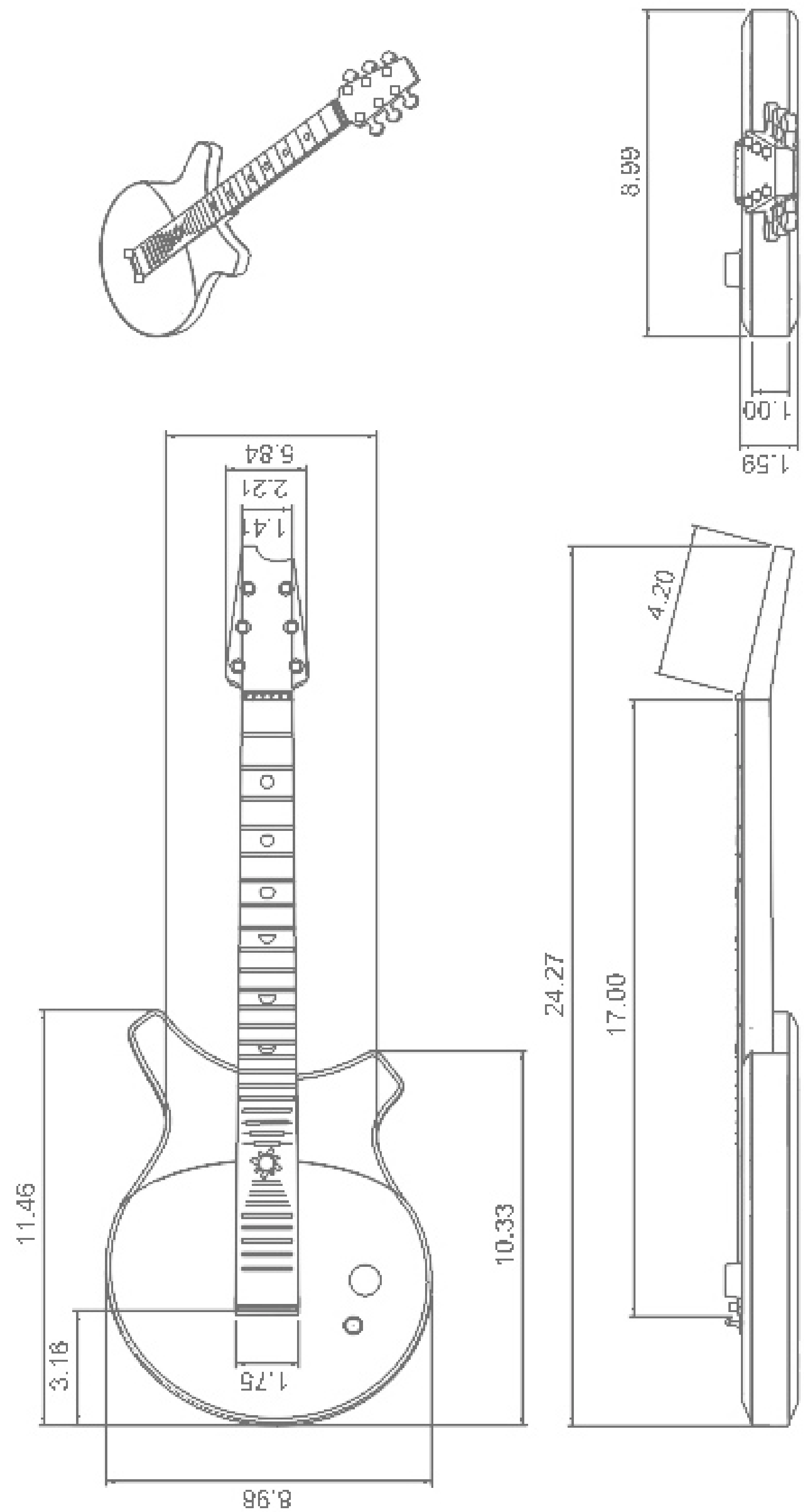


Figure 3.20 Control drawings for guitar dimensions.

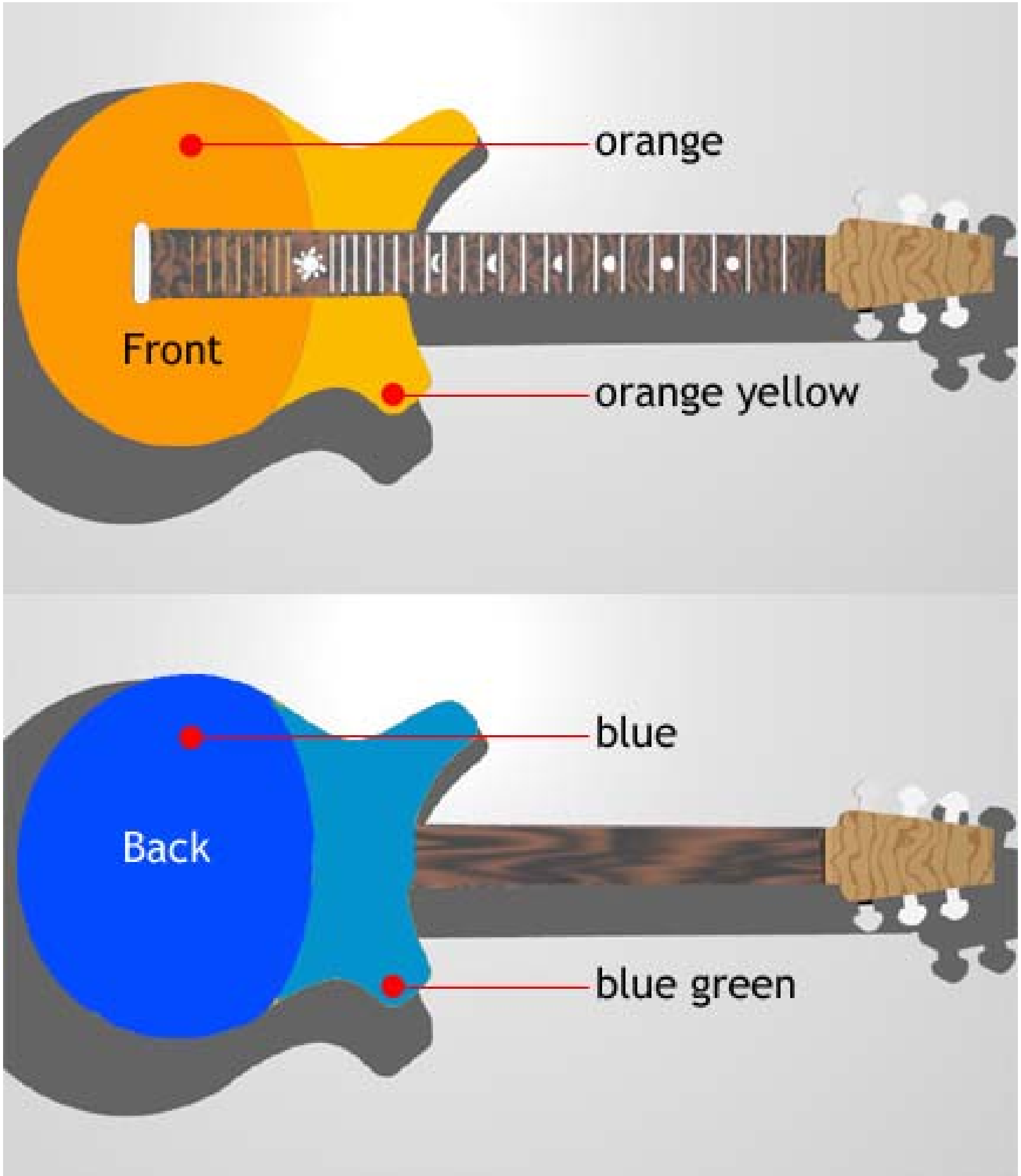


Figure 3.21 Control drawing for dye colors to be applied to maple tops.

3.9 Final Model

3.91 Building

The following photography sequence details the process used to create the body, neck, inlays, bridge, and fingerboard of the final model. From beginning to end, each step involved in transforming the raw materials into one form, that makes a complete guitar, is illustrated and explained textually.

The first step in creating the guitar was to produce 3D and 2D files that were used to cut out the body, maple tops, bridge and neck. A CNC router was used to develop the body and neck, which is one piece of maple and two pieces alder glued together to become what it called a neck through design. Rhinoceros 3.0 was used to create a surface model which was saved as an .iges file and imported into Surfcam, the program that runs the CNC router.

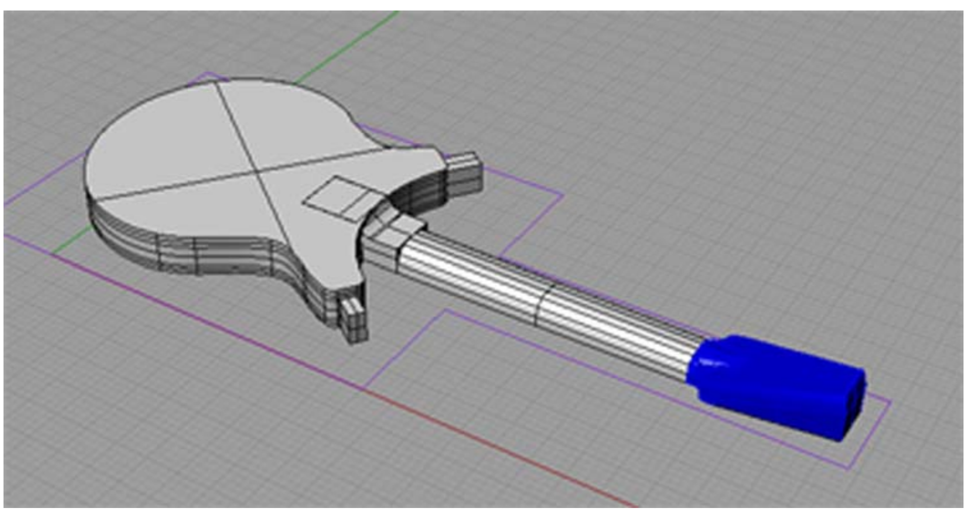


Figure 3.22 Rhinoceros 3.0 file used to route the neck and body of the final model.

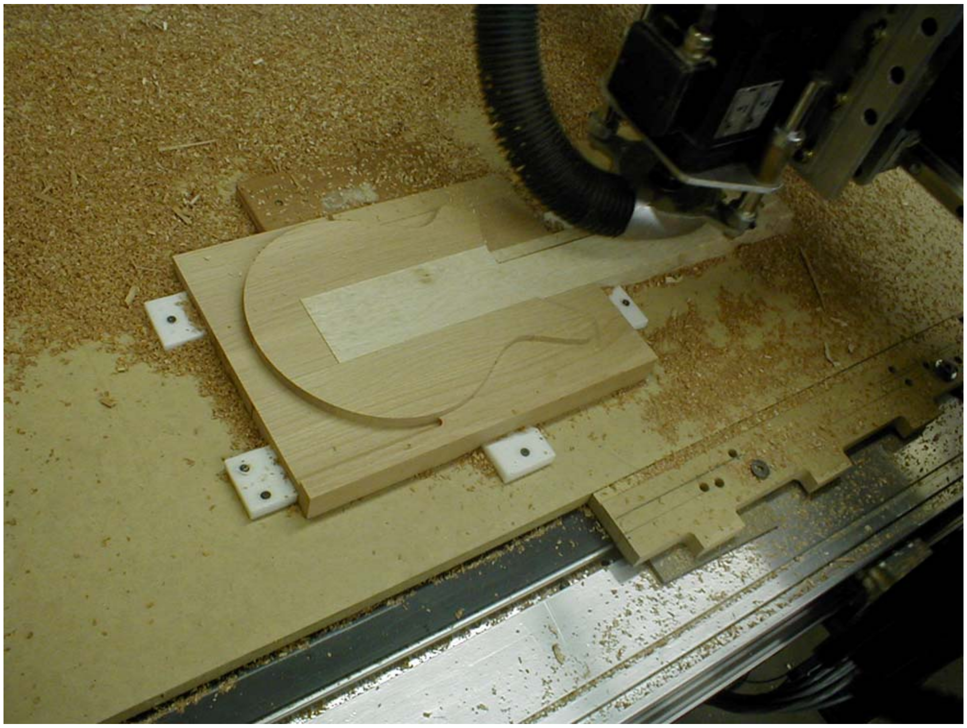


Figure 3.23 Alder and maple block being formed by the CNC Router.

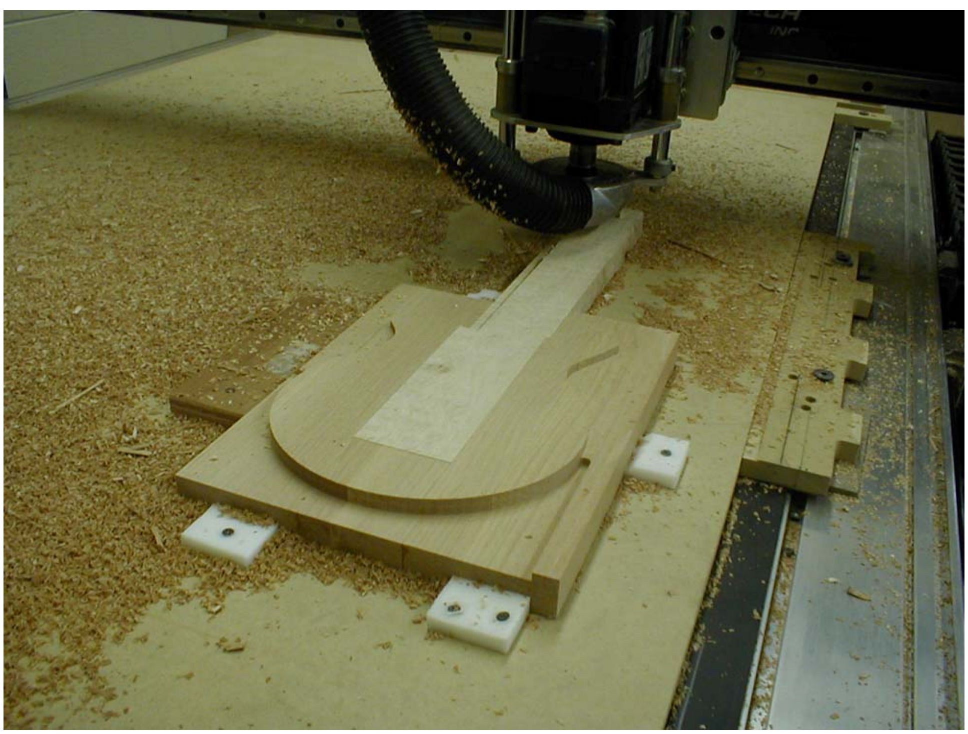


Figure 3.24 Alder and maple block being formed by the CNC Router.

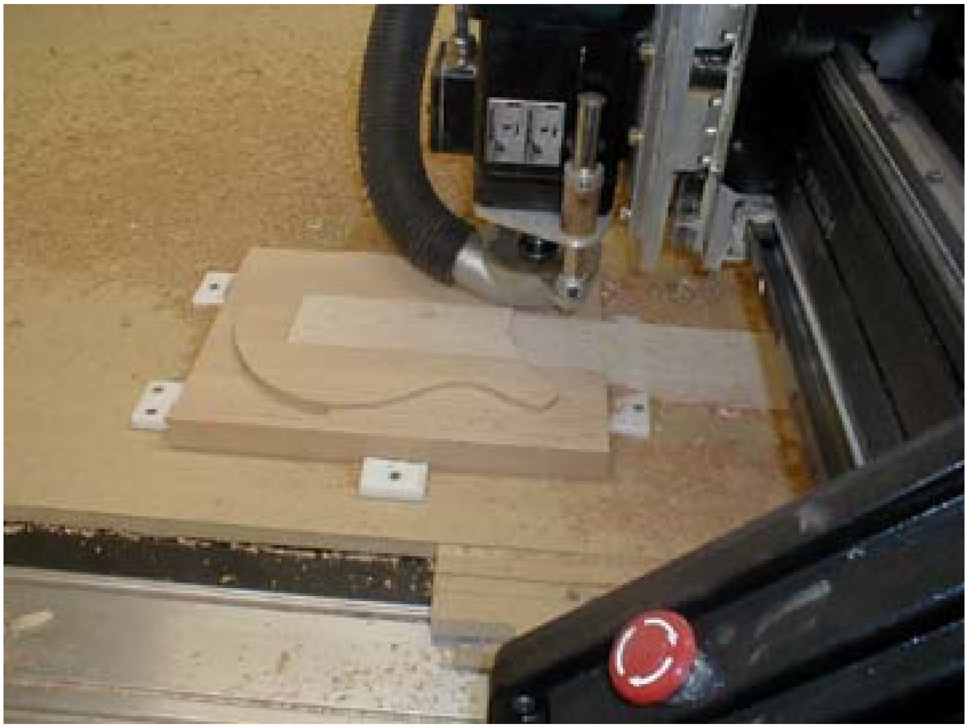


Figure 3.25 Alder and maple block being formed by the CNC Router.

Figure 3.26 Alder and maple block being formed by the CNC Router.

In addition to the router, a laser cutter was used to cut out the four-piece maple tops, the fingerboard, and the bridge. The fingerboard and bridge were cut out of one piece of rosewood and, unlike the CNC router, the laser cutter can only cut outlines.

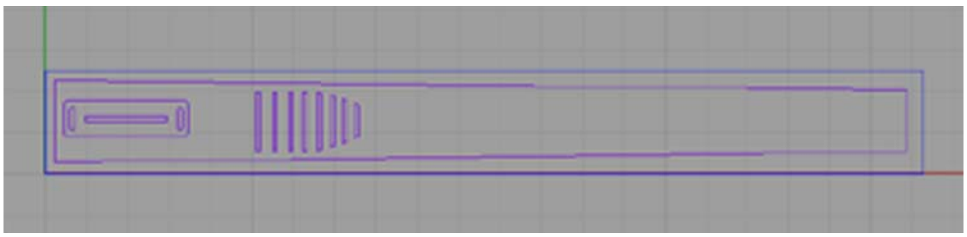


Figure 3.27 Rhinoceros 3.0 file of bridge and fingerboard used on a laser cutter.

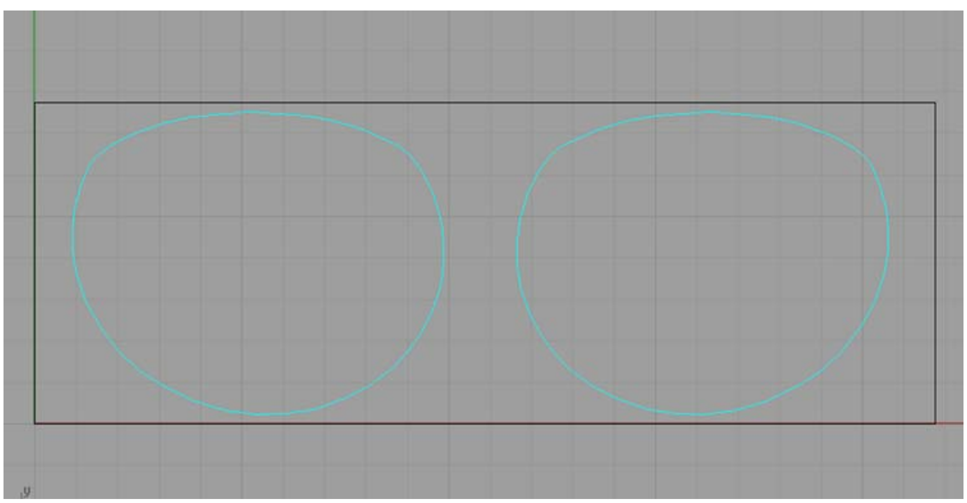


Figure 3.28 Rhinoceros 3.0 file used for the rear sections maple tops.

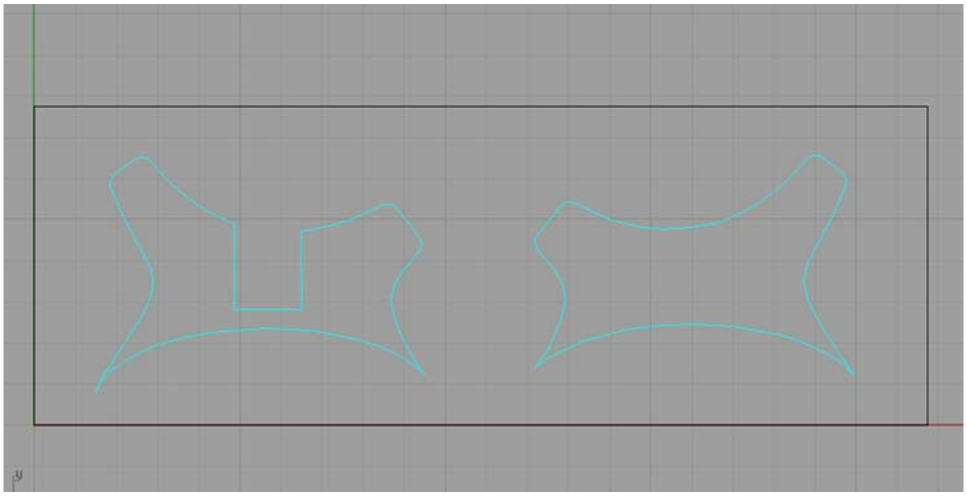


Figure 3.29 Rhinoceros 3.0 file used for the forward sections maple tops.

Once the CNC files had run, the rough cut wooden parts were ready to be formed further by hand using various hand tools and sand paper. The head stock was formed first using files, sand papers and a power sander.

Figure 3.30 The headstock following CNC routing.

Figure 3.31 The headstock after being hand shaped into its final form.

The top of the body, on the front side, was routed down a quarter of an inch to accommodate the maple top and make it flush with the neck height. This was done using a rotary tool. Immediately following this, a hole was created through the body, where the speaker will eventually nest using a hand drill and jig saw.

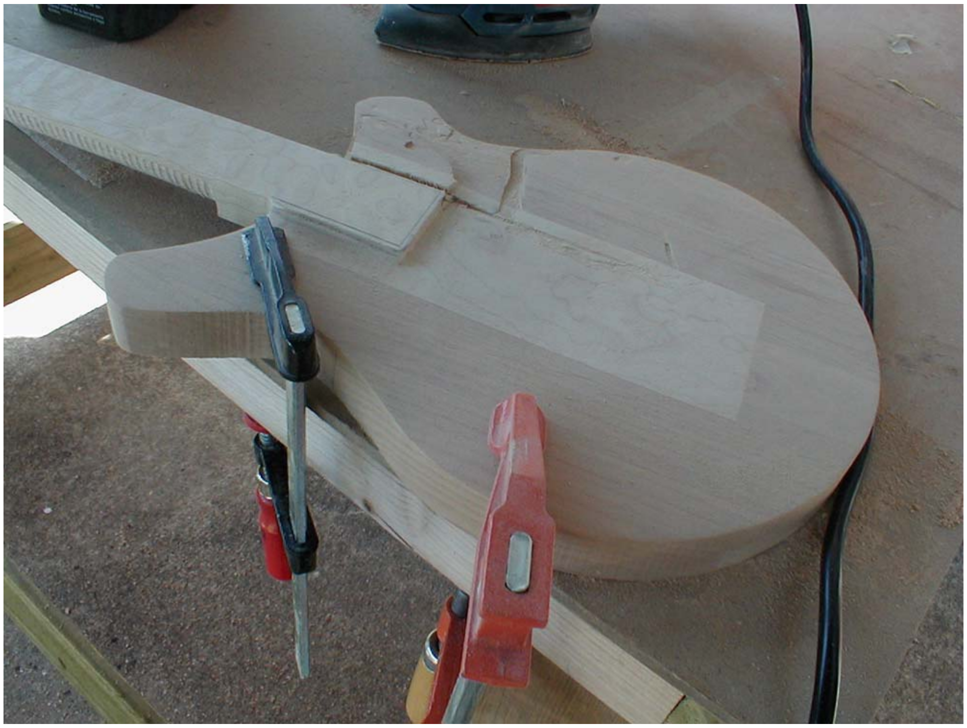


Figure 3.32 Routing down the top of the body to accommodate the maple tops.

Figure 3.33 The body routed down one quarter of an inch.

Figure 3.34 Preparing to cut the speaker hole by creating access holes for the jig saw.

Figure 3.35 The completed speaker hole.

The forward section of the front maple top was glued into place. There exists no routed areas beneath it and therefore would require no further alterations, other than shaping, once all tops were in place. Once the cavities for the electronics are routed, The rear portion of the top maple pieces will be glued into place as well.

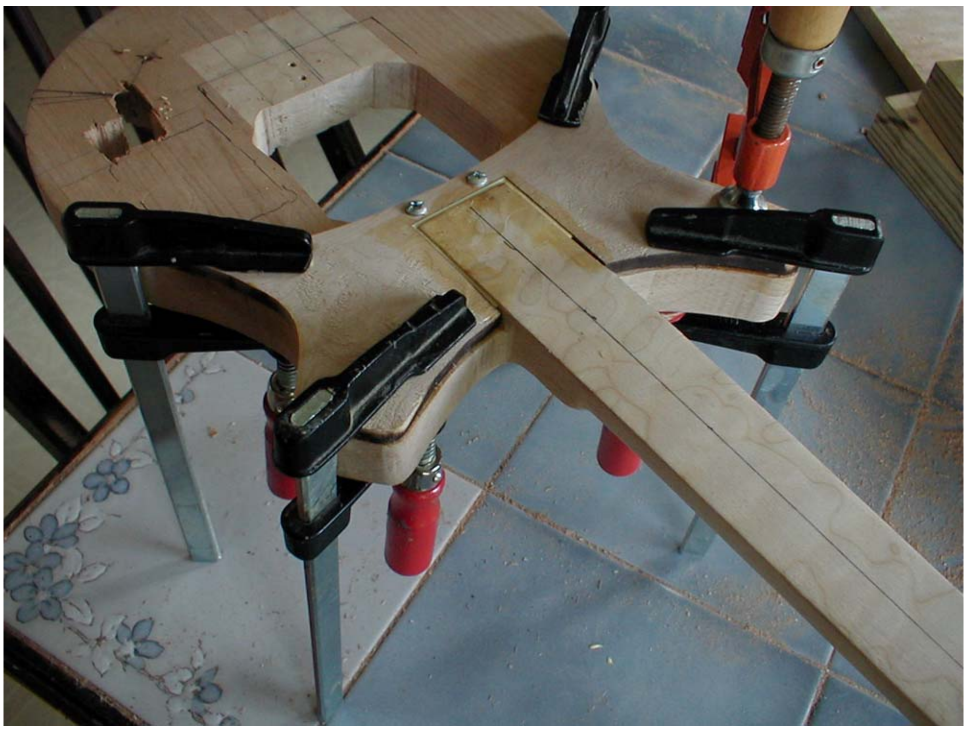


Figure 3.36 The forward section of the front maple top being glued onto the body.

Routing of several areas within the body was conducted next. Cavities which will contain the 9-volt battery, amplifier, volume pot, switch, light, and cables were created. A channel along the top of the neck was also made, using the rotary tool, to allow the carbon fiber truss rod to be inset into the neck. This is an alternative solution, used in many smaller instruments, to a steel, adjustable truss rod found in most full-scale guitars. Carbon fiber is not as easily bent as a steel rod, yet is much lighter. The truss rod was inset and then glued into place.

Figure 3.37 Cavities created to contain electronic components.

Figure 3.38 Routed half inch slot and carbon fiber truss rod.

Figure 3.39 The truss rod after being set into its slot, prior to gluing.

Figure 3.40 Gluing the carbon fiber truss rod into its slot with wood glue.

With the rear portion of the front maple top in place, a hole was created which is the same dimension as the grill located on the fingerboard. This allows sound from the speaker to emit from the body. The body was then shaped using files and sandpaper and holes for the machine heads were drilled into the headstock.

Figure 3.41 Hole to allow sound from the speaker through the grill.


Figure 3.42 Headstock with machine head holes.

The next step in building the guitar was to glue on the rosewood fingerboard and create the mother of pearl inlays. These were formed by printing the design, gluing them onto the pearl pieces and cutting out the design using a coping saw and files. The inlays were then glued to the fingerboard with super glue and traced with an exacto knife. They were then removed and the area where they laid was routed with a rotary tool at a depth slightly more shallow than the thickness of the pearl inlays. The inlays were then inset and glued in place with super glue. Once the glue dried, the inlays were files down flush with the fingerboard.

The frets were the final step in the building process. They are supplied in 2 foot strips which must be cut to fit the width of the fret slots, which were cut using a special saw. The frets are inserted with a rubber mallet and are kept in place using super glue.

3.92 Finishing

The finishing process began once the entire guitar was sanded with 220 grit sand paper using a technique called whiskering. This refers to lightly wetting a piece of wood and letting it dry before sanding. The water makes the grain of the wood stand upright, allowing one to see and sand grains that were not previously visible.

According to the design of this guitar, four panels of the maple tops must be stained using aniline dye. In order to prevent the dye from seeping into areas that will remain natural, these areas were sprayed with lacquer and then masked with painters tape and automotive pin striping tape, prior to the dying process. The dye was then applied to each individual area using a paint brush. They were allowed to dry for 30 minutes, then sanded down and dyed again. This creates greater depth in the final appearance of the wood by allowing the first coat to sink further into the grain.

Once the dying process is complete, the entire guitar was sprayed with four coats of sanding sealer, which was allowed to dry over night. The sanding sealer was then sanded with 400 grit sand paper leaving it with a waxy appearance and smooth touch. Eight wet coats of spray lacquer were then applied to the guitar and left to cure for five days. On the fifth day the lacquer coat was wet sanded with 600 grit paper to level out any inconsistency in the finish. Finally automotive rubbing compound was gently applied to the guitar to bring to buff and produce a greater shine to the finish.

Figure 3.43 Guitar body following sanding the first aniline dye application.

Figure 3.44 Guitar body following the second aniline dye application.

3.93 Completed Product

Figure 3.45 Front view of final model.

Figure 3.46 Back view of final model.

Figure 3.47 Mirror view of final model.

Figure 3.48 Detailed view of final model body.

3.10 Flow Chart

Figure 3.49 illustrates the technical events that take place when the guitar is being played. Vibrations from the strings pass through the pickup to the amplifier, which is controlled by an on/off switch and is provided power by a 9-volt battery. The frequency is transferred into sound by the amplifier and sent to the speaker, unless a chord is inserted into the jack, at which time sound will bypass the speaker and be sent to either headphones or an external guitar amplifier.

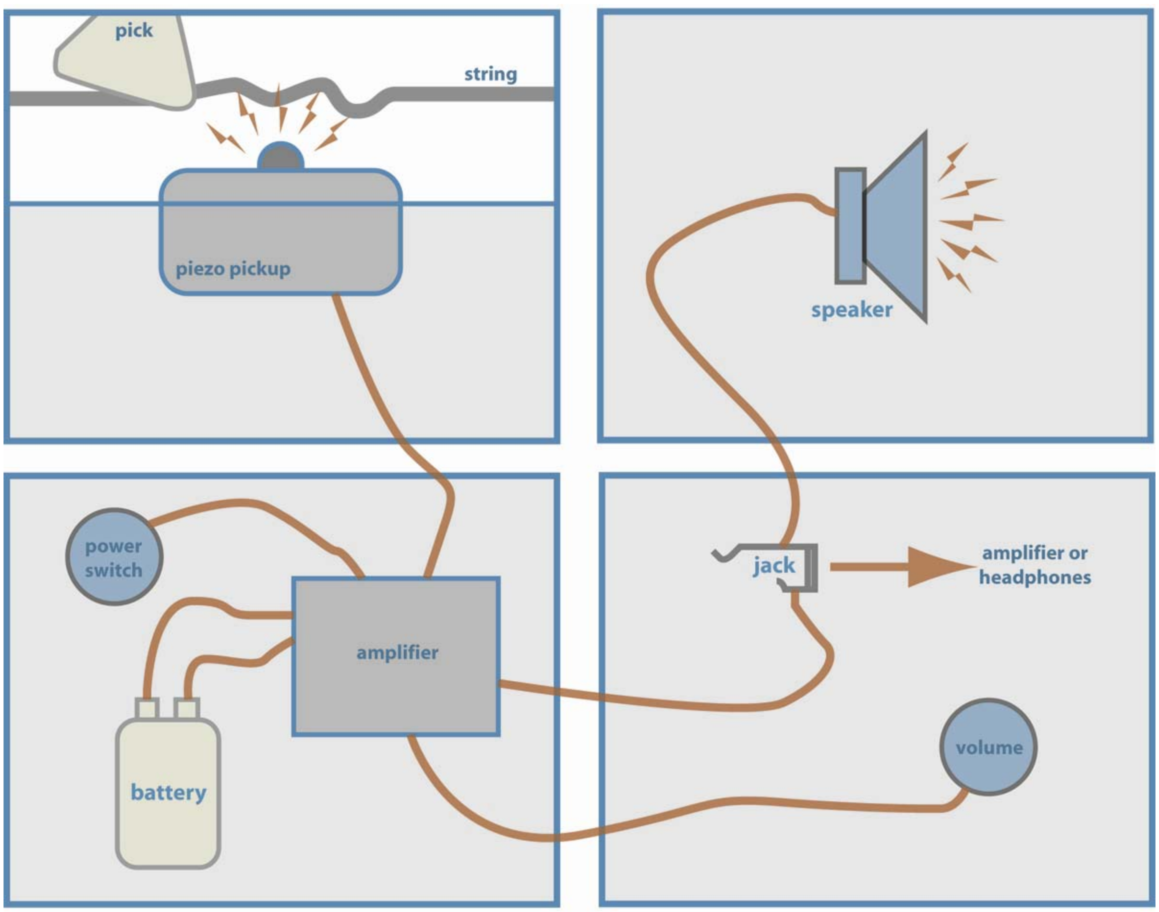


Figure 3.49 Flow chart of technical events during operation.

3.11 Sequence of Use Chart

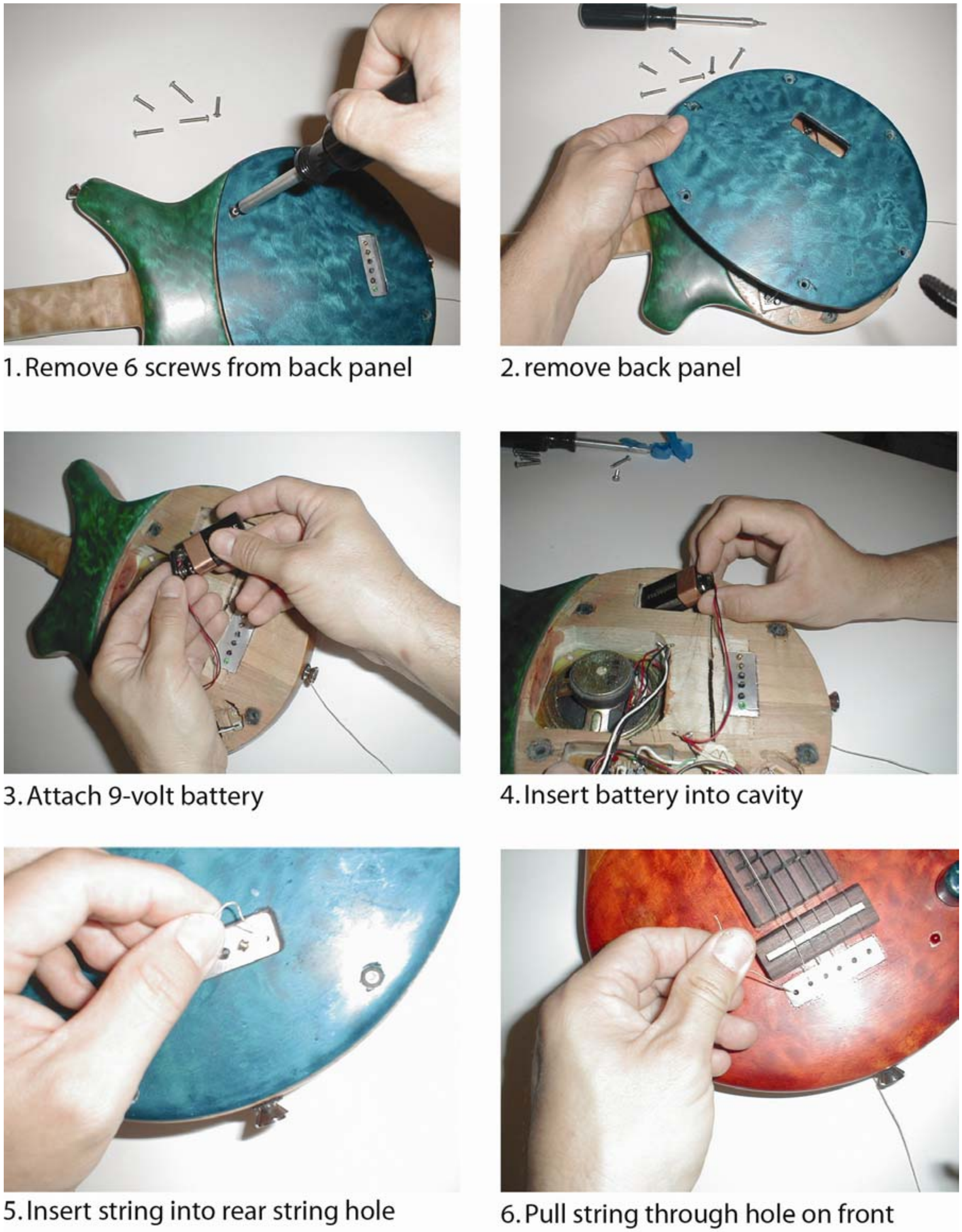


Figure 3.50 Steps one through six of the sequence of use.

Figure 3.51 Steps seven through twelve of the sequence of use.

4. COMMUNICATION PHASE

4.1 Production Function

4.11 Manufacturing

For centuries guitars have been made by hand. Many manufacturers today use CNC routers to aid in the forming of complex body shapes and neck curves. These machines, though costly, help the luthier by saving valuable time and, assuming the computer files they support are accurate, will produce perfect models every time they are used. Beyond CNC routers, guitar manufacturers used conventional power tools and shop equipment to manufacture their wares.

The process documented in this thesis would be the typical way a manufacturer would undergo the mass production of such an instrument. A professional luthier hoping to sell hundreds or thousands of units per year would need a large shop facility, and the support of staff members comprised of production personnel, sales people, clerks, designers, and engineers.

Most companies designing guitars purchase components, like strings, pickups, paints, and wood, from a manufacturer, and use them consistently on their instrument models. Once these components are delivered, even a small shop can then produce a complete guitar, with no additional help.

4.12 Graphics

A mock company has been created, for the purposes of this thesis, to illustrate the type of identity and image a manufacturer should achieve to reflect the product and interests of potential buyers. The name of the company is Progeny, which means both product and offspring. Progeny Guitars will manufacture guitars solely, and therefore a logo has been designed that conveys the wares of the company.

Figure 4.01 Logo design for Progeny Guitars.

4.13 Packaging

Instrument makers often offer a leather-bound, wooden or plastic case at no or some additional charge to the purchaser, depending on the cost of the instrument. Padded "gig bags" are also an alternative, less expensive solution to storing, protecting, and transporting a guitar. However, many manufacturers will simply ship their units in specially made cardboard boxes, covered in their product's graphics, to retailers that hang the instrument with a sales tag. At this point the offer of a case or bag may or may not be available to the buyer, without further inquiry and purchase.

For the purposes of this instrument a unique solution has been decided. A generic black tennis racket bag, which is generally the approximate size of this guitar, would have the company's logo and graphics transferred to its front. This would provide adequate protection and with the provided strap, would permit a child or parent to port the guitar effectively. A hanging sales tag, with the company's logo and model information, would be attached one of the machine heads, prior to shipment.

4.2 Marketing

There are numerous options to marketing products intended for children. Major retail outlets with toy or instrument sections, national and local musical instrument dealers, and online are all possibilities for providing a child's instrument to the consumer. Small companies may consider first selling their products on EBay, or another online auction house, before consigning or shipping a large number of units to a retailer.

The intended user of this guitar is between the ages of three and five. However, as stated previously, all packaging, graphics, and aesthetics should be designed to attract both the parent and the young user.

4.3 Pricing

The model created for this thesis would cost more to produce than those found in the comparative product chart, due to the use of expensive woods and components. This reflects a modern trend among guitar makers who, like automotive manufacturers, typically offer an expensive, better designed, and more aesthetically pleasing model, as well as an affordable, less flashy, yet dependable model. The model used here would cost around $450, allowing for a profit margin of around 67%, assuming each unit could be produced for $150. The instruments listed on the comparison chart ranged, on average, between $125-150. A manufacturer may decide to compete with these companies by creating an affordable model that can be produced for $50 a unit, or may decide to create only an expensive model, like the one used in this thesis, in order to stand out as a leader in quality musical instruments. There are many companies, like Paul Reed Smith Guitars, that do not offer instruments that do not compete with mass produced, economical guitar makers, like Peavey and Yamaha.

5. CONCLUSION

For anyone using this thesis as a guideline for the design of a musical instrument intended for preschool children, taking heed of all guideline steps and understanding their importance will insure the creation of a better-designed instrument. The purpose for these detailed anthropometric studies of children and their comparison of the anthropometry of adults is that it allows the designer to identify variation in proportion and how theses differences should be applied to a specific musical instrument. For the purposes of illustration, a guitar was chosen for this study. However, the designer of another approved instrument, such as a harp or piano, should determine what bodily dimensions will affect important ergonomic issues and then, through use of the provided methodology, discover new variations in proportion, which can be highlighted and used to alter the new instrument. Testing of prototypes and breadboard models should also be conducted by the designers of future instruments, when using this thesis guide. The data and methodology alone cannot be relied upon until a given instrument is examined in use and performance; no positive assertion can be made about either the perfection of the instrument, or any needed adjustments to design.

In addition to scale and dimensions, the style of an alternative instrument may seek to inspire a different attitude of buyers and users. For instance, a violin may not need to stray far from the traditional look of an adult design, unlike the guitar made for this thesis which while evokes many aspects of a contemporary adult electric guitar, possesses aesthetic characteristics that reflect the youth and light-hearted nature of the intended preschool user. And on the other hand, another instrument may be determined to delve further into the whimsical attributes of toys. This is the sole discretion of the designer, who must make a marketing decision at the point of determination of style and color schemes. Quality is the most important factor in the design of any instrument, musical or not, and should be reflected in the aesthetic qualities of the product.

Much was learned, by the author, during the course of this study. While discoveries in methodology may have yielded a valuable new approach to designing instruments for children, research into the vast benefits of musical education, will not soon be forgotten, and will surely cause proclamation and encouragement for friends and family to provide this regressing segment of childhood education, to their children. While many musical products are currently available for preschool children, the author believes that by breathing new life into the products' appearance and quality, and by taking a closer look at what instruments are most frequently being used by parents, whom usually have the duty of instructing children of such a young age, vast improvements in children's lives, scholastic performance, attitudes, civic responsibility, and success, will be witnessed throughout our society.

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