

Installing Piezoelectric tiles in Children Outdoor Playing areas to Create Clean & Healthy Environment; Case Study of El-Shams Sporting Club, Cairo_Egypt

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Abstract: - The pollution rate has increased during the last decades, the increasing percentage of CO₂ and methane causes environmental problems such as changing in climate and rising of new diseases that jeopardize the public health. Creating a clean and healthy environment is an essential goal to protect the planet and human race. The environmental changes became a great issue all over the world especially in the developing countries such as Egypt, lately the electricity generation process and the heavy usage of fossil fuel increased the numbers of children infected by asthma and lung problems due to the air pollution. In order to have clean and healthy environment, these countries must reduce the use of non-renewable sources and replace them with clean renewable sources. Relying on non-renewable sources for electricity generation is not a suitable option anymore for the developing countries that suffers from economic problem, has no medical insurance policy and has high pollution rates such as Egypt. Children usually consumes a lot of energy during their playing period which helps them to learn and to develop their skills, it is considered one of the healthiest and most important routine for the children. This research intends to use the children movements during their playing period to generate clean energy that can be used to electrify children outdoor areas in order to create a clean and healthy environment for children in the developing countries while providing a new environmental friendly source for energy generation. The main scope Integrating piezoelectric cells in the children outdoor play sets and to use quantitative research method to calculate the average energy generated from installing the piezoelectric tiles in the children outdoor area of El-Shams sports club located in Egypt. The study will compare the energy generated from using piezoelectric cells to the club's energy consumption. The results revealed that installing piezoelectric tiles in children outdoor area generated more than 50 % of energy consumed in the sports club.

Key-Words: - Children playing areas; Electricity generation; Piezoelectric tiles; Sports club.

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1 Introduction

During the eighties, researches highlighted the effects of using non-renewable energy sources on human race. Due to ignorance and the minimal actions taken toward the situation, nowadays the world is paying the price of consuming the planet resources and the heavy usage of fossil fuel. In the past few years, researchers were focusing on reducing the use of non-renewable resources and using sustainable sources in all the fields of research to protect the planet and human race. The transformation to sustainability has reached the cities design and planning, today the urban planners and designers are focusing on designing and establishing sustainable cities through implementing sustainable renewable sources of energy and recycling waste materials [1].

The environmental problems that the world is facing today can be solved through applying long term action plan for sustainable development in order to achieve sustainable cities and countries, one of the most efficient and effective way is to generate energy using renewable resources. There is a strong

connection between the renewable energy and sustainable development [2].

Renewable energy plays an important role in improving the public health and environmental quality. Producing electricity using renewable energy sources instead of fossil fuels have many economic and environmental advantages. Recently, researchers were focusing on improving the efficiency of different types of renewable energy harvesting devices in order to improve the capability of renewable sources, to generate energy as much as the typical fuels regular energizes, and to reduce the carbon emissions and radioactive waste. However, the initial cost of renewable energy harvesting devices is still very high compared to fossil fuel which prevent renewable energy sources from competing with fossil fuel sources [3 & 4].

Different technologies can be used to convert energy from mechanical force or mechanical vibration to electrical energy, one of these technologies is piezoelectric cells. This research will focus on studying the effect of generating energy from piezoelectric cells in sports clubs using children movements.

2 Children Outdoor Play areas

Creating healthy environment especially for the children is an important goal for researchers all over the world. Children outdoor play areas are available all over the cities around the world, with various designs and sizes. Children prosperity, security, learning and social advancement, just as their basic delight in youth, are influenced by the degree and the nature of their chances to play.

Chamber officers & individuals, kids' administrations experts, organizers, designers, engineers, lodging chiefs, scene draftsmen & originators, plays hardware providers, parks & entertainment supervisors, local gatherings, wellbeing experts as well as play specialists are only a portion of the general population who have an enthusiasm for developing and providing a cheerful and charming play spaces with good vibes for kids and youngsters [5].

The children improvement of the basic social learning and aptitudes are defined and shaped through the different playing activities [5]. Through playing, youngsters figure out how to socially deal with others, to share, to arrange, and to resolve clashes, while learning self-backing abilities. Playing likewise displays the children initiative and gathering abilities. Moreover, playing is considered an instrument that kids can use to assemble their flexibility and adapting abilities, as they figure out how to explore connections and manage social challenges while overcoming their apprehensions, for instance through re-establishing dream legends [6].

2.1 Design of children outdoor play sets

Outdoor playing is a critical type of playing for young children. Instructors incorporate it in their daily plans, parents admonish their children to get some natural air and expressing their emotions through traditional outdoor playing [7].

Outdoor playing also provides a unique opportunity to teach children about citizenship and the important role they play in keeping the earth clean [8]. Children can understand from jumping in a pile of fallen leaves they have raked why raking is necessary. They can understand from experiencing the weather what role the rain and snow play in renewing the earth. They can watch the bird's nests and then the babies hatch in the spring. Certainly, books can presents all of these on a representational level, however, the sensory experiences and the opportunity to manipulate the components is what makes learning fun, regardless of your learning style [7, 9, 10, 11, 12 & 13].

Although Outdoor playing areas have similar development patterns as interior playing areas, they are known to be more versatile and physical [14].

Comprehensive researches investigated the effects of the playgrounds design on the playing activities. Kids open air playing areas are known as vital part of youngster's development where they use their imagination and innovation while learning significant aptitudes. The children outdoor experience must include access to natural materials. Talbot and Frost defined the word 'Playscape' as an approach to consider how a specific landscape design can affect playing. Fjærtøft examined in her study how the shrubbery manages both hide-and-seek as well as imaginative play such as the playing house, while progressively solid trees would offer climbing and open spaces running 'Tag' games [14].

Designing natural landscape environments are proven to expand and boost the extent of the playing activities. Various types of loose material are significant for kids' improvement, while the transient part of exterior playing is additionally significant, with different conditions like wind, day off, sunset, warmth and cold [14].

Playing areas must be created with regards to other arrangement such as being accessible to kids and youngsters in the area. The design of children outdoor playing areas can offer kids the security that they and their families may need to participate in open air playing areas. These playing areas must be deliberately developed to offer comparative chances to the characteristics of the play-scape. There are certain basic arrangements that meets the neighborhood network such as recognizing the arrangements of holes needed, what kinds of play spaces are required, The availability of different types and sizes of play sets in order to meet all the children ages, since each specific age of children should have a special play set with special design and size as shown in table 1 [15].

Table 1. Examples of age outdoor playing sets [adapted from 15]

AGE	DEVELOPMENTAL MILESTONES	RECOMMENDED EQUIPMENT
INFANTS (0-15 MONTHS)	<ul style="list-style-type: none"> • Develop on individual timetables • Push and pull up • Sit without support • Crawl • Cruise or walk using objects or adults for support • Begin to stand and walk alone 	<ul style="list-style-type: none"> • Soft surfaces • Shade • Tactile materials • Water and sand • Objects to crawl through • Places to sit with adults • Wind chimes and other sensory materials • Safe plants to smell and touch • Toys to push and pull • Sturdy equipment to pull up on

TODDLER S (15-33 MONTHS)	<ul style="list-style-type: none"> • Become increasingly mobile • Push and pull toys while walking • Learn to climb stairs • Begin to use riding toys (with feet on ground) • Run short distances • Squat and balance on feet while playing • Kick and throw balls • Jump in place 	<ul style="list-style-type: none"> • Climbing structures • Slides • Water and sand play equipment • Places to crawl through, over, under • Riding toys • Sensory materials to engage sight, sound, touch, taste • Structures (like playhouses) for make-believe • Shady places to sit • Loose parts for creative and imaginative play • Places to run, throw balls, play
YOUNG PRESCHOOL (2.9-4 YEARS)	<ul style="list-style-type: none"> • Highest activity level of any age in the human life span • Increasingly more adventuresome • Run back and forth • Throw and catch balls • Pedal a tricycle • Somersault • Climb stairs • Push and pull larger toys like a wagon • Enjoy showing off climbing prowess • Hop and jump increasingly well 	<ul style="list-style-type: none"> • Structures for climbing and sliding • Riding toys and paths to ride on • Balance beams • Playhouses • Water and sand play equipment • Loose parts for pretending, creating, building • Talk tubes • Telescopes • Places to run, jump, play ball • Materials to enhance all senses (wind chimes for sound, flowers for smell) • Shade to sit, eat, read, relax • Places to paint, draw and create
OLDER PRESCHOOL (4-5 YEARS)	<ul style="list-style-type: none"> • Physically competent • Climb well, enjoy trying to go higher and higher • Enjoy challenges • Roll balls • Skip on alternating feet • Able to begin riding two-wheel bike 	<ul style="list-style-type: none"> • Climbing and sliding structures that provide challenge for increasing skills • Bikes and paths to ride on and explore • Water and sand play equipment • Art studios • Structures for imaginative play • Loose parts to enhance play • Natural features to experience seasons • Places to run, play ball, play games

The Design of Natural playscapes incorporate different activities that inspire the unstructured and imaginative encounters of outdoor play. According to Pardee, Gillman, and Larson “These playing areas designs are based on the land topography which might offer for example, little mountains, slopes, and hills. They may incorporate grass, sand, mud, water, trees, bushes, and gardens”. Using different surfaces and textures within the spaces, designing raised bed plantings, planting container gardens, and

including sand, water, and other material in the exterior zones are considered as approaches to include the natural components within different urban environments. Sometimes the natural elements might be used for securing the playgrounds. Rather than utilizing extremely high fences to ensure playground’s safety, designers might think of including lower yet more profound fencing, or planting kids- friendly materials within the playgrounds while using thick plants on the outside to give a natural hindrance. Natural playscapes offer youngsters chances to discover and build up their own play world employing natural environmental features and the free parts that are arranged and demonstrated around the play region. These areas are intended to change and develop with the different seasons and according to the youngster’s interests. Usually the playing areas incorporate constructed play equipment that are consolidated within a bigger structure and are not the main focal point of the playing areas [16].

3 Piezoelectric Cells

Generating energy and improving the efficiency of renewable energy sources was lately the scope of various researches that were conducted to investigate the possibility of using renewable energy for energy generation through integrating renewable energy devices with urban context in order to reduce the pollution levels. [4, 17, 18, 19, 20, 21, 22 & 23].

In the past few years, there has been expanding interest for low-power and portable-energy sources as a result of the improvement and mass utilization of convenient electronic devices. In this literature section, the components, types, materials, dimensions, energy produced, lifetime, prices and lifetime will be discussed [22].

3.1 History of piezoelectric cells

In 1880, Pierre and Jacques Curie found direct electric energy impact in a single gem quartz. It was noticed that, under strain, quartz generated electrical charge, this charge was known as piezoelectric. The word “piezo” means "weight" in Greek; consequently, the main meaning of the word piezoelectricity suggested "weight power" it refers to materials that have different geometric strain which generate electric field [25].

Up until the beginning of the century, piezoelectricity did not leave the labs and research centers. It was not available to the market, until a French physicist called Paul Langevin established a submarine detector that was dependent on the impact of piezoelectric in 1917. This innovation was the beginning of using the piezoelectric technology. The accomplishment of Langevin's innovation opened chances for piezoelectric materials to be used and merged in large group of different applications [26]. The first introduction of piezoelectricity to the global market was in 1945, the discovery was based on mixed

oxide compound (Barium titanate). It was a ferroelectric which could be effectively created and formed at a low cost and could make piezoelectric with higher constant than normal materials by an electrical poling process.

This material was a stable material and considered to be one of the essential crystal lattice structures; also lead zirconate titanate was discovered in the beginning of 1950, which played an important role in manufacturing piezoelectric material [27].

3.2 Types of piezoelectric cells

There are several shapes and sizes for piezoelectric cells such as discs, rings, plates and cylinders. Each one of these shapes have different dimensions. The thickness of the piezoelectric disc ranges from 0.20mm to 10.16mm as shown in figure 1. The dimensions of piezoelectric ring cell can be summarized as the following; outer dimensions of the rings are range from 6.35mm to 50.8mm and the inner dimensions can range from 1.778mm to 19mm depending on the OD and thickness, while the rings thickness range from 0.2mm to 10.16mm depending on the material and the manufacturing company as shown in figure 1.

Another shape of the piezoelectric cells are the plates, the length and the width of the piezoelectric plates range from 2mm to 48.2mm, while its thickness range from 0.20mm to 10.6mm depending on length, width and thickness of the material as shown in figure 1.

Finally the outer dimensions of piezoelectric cylinder shape cell range from 8.9mm to 22.9 mm and the length ranges from 3.81mm to 11.5 mm while the minimum thickness of the wall of the cylinder is 1mm as shown in figure 1 [28].



Fig.1. Piezoelectric cell shapes [28]

3.3 Manufacturing companies of piezoelectric cells

There are several companies manufacturing piezoelectric cells all over the world, each has different properties and price as presented in table 1.

The piezoelectric cells have different characteristics such as: the shape, the size and the output voltage for instance, the initial cost of piezoelectric ceramic rings set that consists of two pieces range from 9.00\$ to 38.5\$, while the initial cost of the piezoelectric ceramic disc is approximately 17.78\$ per set which consists of two pieces, each with dimension 20 mm x 3 mm [28].

The properties of piezoelectric plate cells are similar to piezoelectric ceramic generator, the

average output power of this cell is 0.5mW at 100 KHz and its insulation resistance is about 100 MΩ, with dimensions of 40 x10.9 x 1.7 mm, while its initial cost is 19.00\$ [22].

Piezoelectric ceramic bimorph generator is another type that used for higher output voltage, this type can be used in applications where bending force is present. Piezoelectric ceramic can produce 40V under 1mm deflection. The cost of one piece set of this type is 25.48\$, while the cost of piezoelectric ceramic cylinders ranges from 14.00\$ to 53.50\$ depend on the size, material and output voltage as shown in table 2 [22 & 28]

Table 2. The technical specifications, price and lifespan of Piezoelectric types [22]

Company Name-	Product Dimension	Energy Generated	Life span by years
Waynergy Floor	40 x 40 cm	10W per step	20
Sustainable Energy floor (SEF)	75 x 75 cm OR 50 x 50 cm	Up to 30 watt	15
Pavegen tiles	V3 Tile 50 cm each edge	5Watts / footsteps	20
Sound Power	50 x 50 cm tile	0.1 watt per 2 steps	20
PZT ceramic (Lead zirconate titanate)	Manufacturing in a small size	8.4mW	20
Parquet PVDF layers	Layers	2.1mWs per pulse with loads of about 70 kg	20
Drum Harvester s - Piezo buzzer Piezoelectric Ceramics	Vary	Around 2.463 mW	20
hybrid energy floor – which integrate the human power with the solar energy	1 x 2-meter tile 75 x 75 cm tile	Can generate up to 250 kWh per year, per tile up to 250 kWh per year, per tile	20

4 Study Methods

This research is conducted based on the quantitative analysis method, it intends to help in solving the energy problem in Egypt using renewable energy source to create a healthy and a clean environment. The research focuses on generating energy from piezoelectric cells installed in children outdoor play areas in order to benefit from the children movements during the playing time.

The methodology used in this research is carried out

through calculating the amount of CO₂ emissions reduction that is reduced from generating electricity using renewable energy sources and compare it with the amount of carbon emissions produced from generating the same amount of electricity using non-renewable energy sources.

4.1 Study Area

El-Shams sports club was chosen to be the study area for this research, this club located in Heliopolis district, Cairo. Egypt as shown in figure 2. It was constructed in 1963, this sports club is considered one of the largest sports clubs in Egypt with total area of 480 acres. El-Shams sports club has five outdoor children playing areas, one of these areas have been selected to be the research's study area. The selected children playing areas will be used to measure the efficiency of generating energy using children movements through installing piezoelectric cells in the outdoor children playing areas.

Table 3. The visitor's density at El-Shams sport club

Days	Average No. of visitors during Morning period		Average No. of visitors during Night Period	
	Adults	Children	Adults	Children
	Saturday	150	90	250
Sunday	130	80	230	120
Monday	100	65	240	110
Tuesday	120	70	130	110
Wednesday	160	90	200	140
Thursday	200	150	350	250
Friday	270	220	370	200

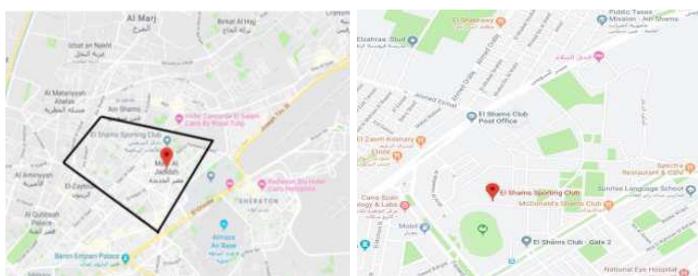


Fig.2. Location of El-Shams sport club

The selected children outdoor playing areas is located almost at the middle of the club, in front of the main swimming pool, and it includes high percentage of children and pedestrians. The total area of the selected children outdoor playing areas is 594 m². A pedestrian path divided the selected children outdoor playing areas into two parts as shown in figure 3.

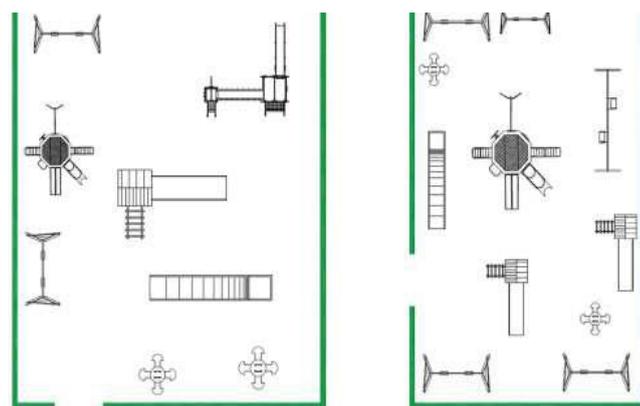


Fig.3. Children outdoor playing area at El-Shams sport club

4.2 Data Collection

According to the information collected from the El-Shams sports club administration office, the annual electricity consumption of the sport club is around 39000000 kWh, and the average monthly electricity consumption is around 650000 kWh/month. The electricity consumption of the club usually decrease during the winter period and increase during the summer period.

4.3 Visitors Density:

It was noticed that the number of visitors increased during the night period starting from 6pm till 12 am and also during the weekends and vacations as shown in table 3. The average number of visitors during the week are divided into two periods, the morning period from 6 am till 6pm and the night period from 6pm till 12 am. The number of children inside the study area vary depending on the time and days. The number of children increased in the morning periods during the weekends. However, the night period increases during the working days and school days as shown in table 3.

4.4 Types of Piezoelectric cells

There are many types of piezoelectric cells which can be used in children outdoor playing areas. This research concentrated on measuring the efficiency of the most suitable three types of piezoelectric tiles that can be used in the study area. Each tile was manufactured by different companies around the world and each one of these tiles has different dimensions, life span, different amount of energy generation and price as shown in table 4. Table 4 presents the properties of three different piezoelectric tiles that can be used in children outdoor playing area of El-Shams sport club.

Table 4. The properties of piezoelectric cells

Company	Sustainable Energy Floor	Sound Power	Pavegen
Dimensions	50*50cm Tiles	50x50cm Tiles	50 cm V3 Tile each edge
Estimated Life Span	15 years	20 years	20 years

Power gent/watt	7W (Continued power from footstep)	0.1W per 2 steps	5W (Continued power from footstep)
Price /EGP	3200	2350	3500

The presented research compared the properties of the presented three piezoelectric tiles. “Sustainable energy floor” tiles has been selected to be used at the children outdoor play area for generating energy. After studying the selected study area, the research calculated the number of tiles needed to cover the children outdoor playing area located inside El-Shams sport club, the specific number of tiles of “Sustainable energy floor” were set according to the playing area design as shown in table 5. Table 5 presents the total costs and energy generated from installing “Sustainable energy floor” tiles in the study area of this research. According to the data presented in table 5, installing 260 “Sustainable energy floor” tiles in children outdoor playing of El-Shams sport club, will generate 1820 kWh and it will increase the project initial cost by 832,000 L.E.

Table 5. The number of tiles needed to generate energy using “Sustainable Energy Floor” tiles

Number of tiles	Initial Cost L.E	Daily Generation Capacity – kWh
1	3200	7
2	6400	14
3	9600	21
4	12800	28
5	16000	35
6	19200	42
7	22400	49
8	25600	56
9	28800	63
10	32000	70
30	96000	210
50	160000	350
100	320000	700
200	640000	1400
260	832000	1820

5 Results

The main source of electricity generation in El-Shams sport club is from non-renewable sources, in which it increases of the percentage of CO₂ emissions and air pollution. Installing piezoelectric tiles in children outdoor playing areas can provide a clean, safe and healthy environment for Egyptian children.

Table 6: Analysis of Piezoelectric tiles at El-Shams sport club

kWh Needed Daily power	2160	
kW Price by Government	1.25	
Average Steps per day per tile	77500	
Total average amount of kW consumed per year in EGP	972000 L.E	
Total average amount of kW produced per year in EGP	751320 L.E	
Feasibility Price	Total Saved amount	220680 L.E
	Saving percentage	77.3%

The research analyzed and summarized the electricity consumption data collected from El-Shams sports club as well as it calculated the visitor’s density in children outdoor playing area.

The aim of this research is using renewable energy sources for producing energy instead of relying on non-renewable energy sources for electricity generation in order to reduce the CO₂ emissions and create a clean and healthy environment for the children. This was done by selecting one of children outdoor play areas at El-Shams sport club and installing piezoelectric tiles to study the efficiency of this renewable energy source. The results revealed that using 260 “Sustainable energy floor” tiles can produce 1820 kW per day, since the average amount of energy consumed by el shams sport club was 2160 kW/ day that means that the use of piezoelectric tiles will help in producing 83% of the total electricity needed every day. The distribution of piezoelectric tiles in El-Shams sport club are presented in figure 4.

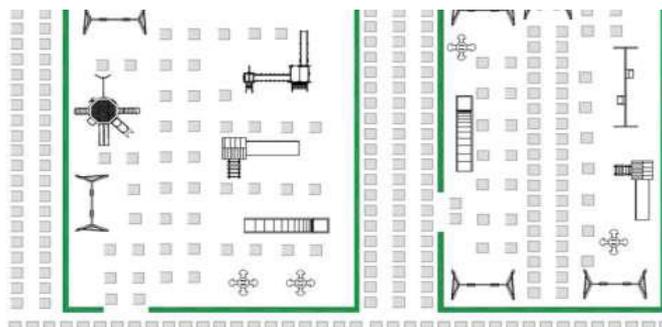


Fig. 4. Children outdoor play area at El-Shams club

The research proved that installing “Sustainable energy floor” tiles in El-Shams children outdoor playing area can produce enough energy to electrify the outdoor playing area and its surroundings through the children movements during their playing period inside the playing area. The total price of electricity generated annually from installing 260 piezoelectric tiles in children outdoor playing area is 751320 LE. Therefore, using piezoelectric tiles at children outdoor play areas have a huge economical advantage to the club, the piezoelectric tiles will save almost 77.3% of El-Shams sport club electricity bills as it is shown in table 6. The club can use the money saved from the electricity bills for other important activities which will improve the quality of life of the people using the club and it can provide more activities and fun for the children inside the club. Using piezoelectric tiles also has social and environmental advantage since this club will participate in creating clean and healthy environment for Egyptian children through reducing the amount of CO₂ emissions produced from electricity generation.

6 Conclusion

Energy represents an essential part of economic development. Today, the activity of energy sector mostly depends on fossil fuel such as coal, oil and natural gas. Recently, many researches proved that fossil fuel will disappear in the next few centuries. Renewable energy is strongly recommended because of its expected need in the upcoming future taking into consideration the growth of the population and the increasing energy demands. Furthermore, the human activities are overloading the environment with carbon dioxide and global warming emissions which results in temperature increasing and their harmful effects on the health and the human body. Generating electricity by coal-fired power plants and natural gas-fired power plants has significant effects on the health. Increasing the supply of renewable energy will allow the world to reduce the growth of environmental problems such as global warming and climatic change.

Energy problems are increasing every day all over the world due to relying on non-renewable energy sources for energy production which lead to the increase of the pollution level and the percentage of CO₂ emissions. Depending on renewable energy sources for energy production became essentially, in order to have clean and healthy environment for the Egyptian children. This could be achieved by using piezoelectric tiles in children outdoor playing areas. Children consume high amount of power during their playing period and their movements can be used to generate high amount of energy using piezoelectric tiles. When correct number of piezoelectric tiles are used in suitable places, this will provide clean energy that can be used for different purposes. Using piezoelectric tiles at children outdoor playing area will always be beneficial in creating clean and efficient energy which in return will provide a healthy environment for the children.

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