A11 - Ethical and Environmental Analysis

Year: 2025 **Semester: Spring** **Team: 1** **Project: Electronic Skee Ball**
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Assignment Evaluation: See the Rubric in the Brightspace Assignment

1.0 Environmental Impact Analysis

The Electronic Skee Ball Machine integrates many electronic and mechanical components including an STM32 microcontroller, ultrasonic sensors, a servo motor, a DC motor, an LCD display, a joystick, and a speaker system. These are controlled using a custom PCB that is secured within a wooden machine body. Each stage of the product's lifecycle presents specific environmental concerns.

During the manufacturing stage, several components contribute to potential environmental harm. The PCB fabrication process involves hazardous chemicals such as ammonium persulfate and ferric chloride, both of which pose risks to aquatic ecosystems and require regulated disposal practices [1]. We mitigate this impact by minimizing the size of the PCB we designed, therefore reducing material and chemical usage.

In our design, we utilized 3D printing to create some components which include a lip at the end of the ramp to aid in launching a ball into a scoring hole and the housing for the servo motor to prop it at the correct height and keep it secure. These components were printed with PLA filament. While PLA is bio-based and safer to print with than ABS, it's not biodegradable outside of industrial composting conditions. In some cases, PLA filaments are blended with additives that make them less environmentally friendly than they appear, and printing with PLA still consumes significant energy and releases microparticles and volatile organic compounds (VOCs) into the air [2]. Over time, the structural integrity of PLA can also degrade under heat or UV exposure, potentially shortening the part's life and requiring replacements that contribute further to waste.

The rest of the machine body is made from plywood and off-the-shelf plastic parts. The main structure of the skee ball machine is constructed entirely from plywood, which is relatively sustainable compared to synthetic enclosures. Plywood is typically made from fast-growing wood species and manufactured using layered veneer, making it more resource-efficient than solid wood. According to APA – The Engineered Wood Association, plywood production uses nearly all parts of the log, resulting in minimal waste [3]. However, plywood still carries some environmental costs, such as emissions from adhesives (often containing formaldehyde) and the energy required in its pressing and curing processes. On the positive side, it does happen to be widely recyclable, durable, and easily repairable.

To hold the ultrasonic sensors near the opening of score holes, scoring tubes were constructed from newly purchased plastic water bottles. These bottles are made from polyethylene terephthalate (PET), a common thermoplastic derived from crude oil. PET is not biodegradable and can take several hundred years to break down in landfills. If not properly recycled, PET contributes significantly to plastic pollution and microplastic contamination in aquatic ecosystems [4].

Some of our electronic components, such as the motors, ultrasonic sensors, and the LCD display, may contain trace amounts of rare or heavy metals, including tantalum, neodymium, gallium, or indium. These materials are commonly found in electronics for their conductivity, magnetic, or display properties [5]. However, unless explicitly stated in a part's datasheet or verified through teardown analysis, it's difficult to know for certain which materials are present. To be on the side of caution, we assume that small-scale motors may include neodymium magnets, LCDs often require indium tin oxide, and sensors may include rare earths depending on their construction. While we made an effort to choose components labeled as RoHS-compliant (meaning they restrict the use of certain hazardous substances like lead, mercury, cadmium, and chromium VI [6]) RoHS compliance doesn't necessarily mean the part is free from environmental concerns, but it simply limits certain toxic substances and ensures safer handling and disposal.

During typical game usage, our system is fairly energy efficient. It runs off a 24V wall adapter and uses under 10W of power during gameplay. Unlike many battery-powered designs, our design sticks with wall power to avoid lithium-ion or alkaline battery disposal, which helps eliminate risks of landfill contamination from metals like cobalt or cadmium [7].

When the system reaches the end of its lifecycle, it will be simple to disassemble and preserve components. Screws can allow users to take apart the machine along with forcing apart some of the wood glued panels. All of the interior wiring and connections are secured using electrical tape which can easily be removed. Electrical tape was also used to secure the ultrasonic sensors in the scoring tubes, as well as the joystick in a wood panel. We'll include recycling instructions with the user manual to encourage responsible disposal. The PCB and ultrasonic sensors should go to e-waste centers, and plywood from the machine body and 3D printed PLA filament parts can be repurposed or recycled. According to the EPA, properly recycling electronics can recover valuable materials and significantly reduce energy consumption compared to mining new raw materials [8].

2.0 Ethical Challenges

Bringing the Electronic Skee Ball Machine to market introduces ethical challenges primarily centered around safety, accessibility, and responsible use. Although intended for entertainment, the machine includes a large power supply and high-speed mechanical components that could cause harm if misused or poorly maintained.

One major consideration is physical safety. Our design includes a DC motor that launches balls across a ramp. To prevent injury, the motor is mostly concealed by the machine packaging, and we have included a plastic "slide" for the balls to be delivered to the launching motor such that users don't need to have their fingers near a spinning motor. One important aspect of our design is that the ramp is removable so that we are able to program the PCB that sits inside the machine. Adjacent to the PCB sits our 24 V power supply. Since we do not want balls or users inadvertently interfering with the power supply, we blocked it off using protective netting.

Another ethical consideration involves accessibility. This machine was designed to be inclusive of users with physical disabilities, particularly those unable to perform traditional throwing motions. Our user interface, consisting of a joystick and button, allows for intuitive control of ball direction and power. The addition of an LCD display and sound effects provides multisensory feedback, ensuring that users with visual or hearing impairments can engage with the game. Inclusive design practices align with the IEEE Code of Ethics, which emphasizes the welfare and dignity of all individuals [9].

To address reliability and user trust, our team performed extensive system testing under a range of environmental and usage conditions. We simulated scenarios such as power interruptions, joystick miscalibration, and missed ball detections. These simulations were also necessary to ensure that unexpected button presses or joystick movements would not have an effect during the launching state of the game. Specifically for the joystick usage, we wanted to be sure that the launching mechanism could not be rotated while simultaneously launching or launching outside of the game, both of which would be dangerous. To reduce user frustration and account for unexpected errors, we implemented timeouts and fallback states to recover gracefully when something unexpected occurs.

Ultimately, our work on the Electronic Skee Ball Machine demonstrated that engineering responsibility doesn't end with technical functionality. The safety features we incorporated, the accessible user interface we designed, and the thorough testing we carried out were all guided by our commitment to ethical design. By emphasizing thoughtful use and inclusive interaction, we created a design that reflects not just engineering skill, but also a strong ethical foundation.

3.0 Sources Cited

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