

EduGreen CompostAR: Augmented Reality (AR) Application as a Medium to Learn Composter Machine's Operation

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In the era of high food consumerism amid high population worldwide, there is growing necessity of recycling food waste, where otherwise land, water, and air pollutions would accumulate and harm living beings. This waste would naturally compost in several months. However, this timeframe is not efficient enough to prevent quick piling up of continuous waste. Generally, In Malaysia's education curriculum, there's a lack of knowledge among students and lack of teaching aids among educators about composting and its importances, which could lead to piling up of national food waste and further piling up of waste at the national landfill. Therefore, an interactive educational solution is needed. One of relevant solutions is composter machine, which has been a popular method to solve such global issue with it being able to compost food waste in one (1) or few days instead of months. Such electronically driven machine requires meticulous controlling and monitoring, hence new users would need to be trained. Conventional training method requires the presence of physical composter machine, which is impractical and expensive considering it must be manufactured first and also students feel disgust about composting learning activity that involves handling food waste. It also comes with additional hazardous risk in case improper use or malfunction occurs. As such, this paper proposes a mobile Augmented Reality (AR) based simulation-driven solution to solve the said issues. The novel developed AR application delivers immersive and concise tutorial to use composter machine while also being friendly for hearing impaired people. It has also been assessed and is concluded to be compliant with all of Merrill's principles of instruction model. Thus, this debut

of mobile AR solution for composter machine tutorial would become the stepping stone for future more advanced composter machines, which require similar digital learning solution.

Keywords: AR-based tutorial, composter machine, food security, teaching methodology, sustainability.

1. Introduction

Learning new and unfamiliar machinery equipment for laymen has been known to be lengthy and tedious process. Several problems come with it, such as physical availability of the machine, physical location of the machine, risk of physically damaging the machine, user safety risk, and others related to having to physically attending the machine in order to master it.

A practical and safer way to practice operating a new machine is via its digital representation. Video tutorial is one plausible method, however it lacks immersive environment, uninteractive, and does not involve user's physical engagement. An immersive, interactive, and engaging method is by applying Augmented Reality (AR).

This paper would present an AR-based learning methodology to help users to be able to operate a composter machine.

A composter machine is a machinery equipment that accelerates the composting process of food and/or plant waste to become reusable organic material, which then be used as fertilizer (Sutar et al., 2022). Although each composter machine may differ in terms of technology used, but the all-general procedure to use this machine involves human-driven steps that include safety pre-cautions.

The importance of composter machine is now more crucial than ever, especially with the accelerating world population growth that directly contributes to the increasing amount of food waste (Sadigov, 2022). Unmanaged food waste may pollute the air with its generated methane gas and also pollute water. Furthermore, it may also break the drainage system if irresponsible food waste management is committed. On the other hand, composting food waste may directly sustain food security as the resulting fertilizer can nourish soil, which then boost edible plant's growth.

Current literature review shows that AR-based composter machine's user training module has not been built, therefore this paper has filled a research gap in the niche of composter machine's user training methodology. As such, more users could be attracted to learn about composter machine and use it in everyday life to save the environment.

The subsequent sections would review the proven effectiveness of AR as an immersive and engaging training methodology and the common steps associated with operating a composter machine.

2. AR in Machinery Tutorials Review

The industry has long been supporting and accommodating the use of AR in businesses – arguing that it may bring additional benefits e.g. knowledge transfer via hands-on gestures, standardization, quality assurance (QA), design testing, immersive documentation, and practicality since it utilizes widely owned devices, for example, a smartphone (NeuroSYS, 2024). And especially in machinery-related activities, like maintenance and repair, the use of AR has been normalized (Coon, 2024; UpKeep, 2024). While this paper's previously mentioned assumption that AR would be suitable for procedural tutorial is agreed by UpKeep (2024).

A plausible use case of AR in machinery tutorial delivery was done by a cherry picker manufacturer, which built an AR application to train workers specifically how to assemble hydraulic hose (Ferrati et al., 2019). It managed to reduce errors and duration of assembly.

In courier business, AR application has been used by DHL to assist parcel picking activity (DHL, 2024). Such method has accelerated parcel picking efficiency by 15% and improved the efficiency of new staff on-boarding training by 50%.

Vehicle manufacturing industry has also been assisted by AR, for instance, Ford has used AR application generated by Microsoft HoloLens in order to improve their cars' designs and thus has saved cost, which would otherwise be spent on physical prototypes (Ford, 2024). Similar method has been implemented by Caterpillar, which also uses AR for repair and maintenance purpose other than design (Caterpillar, 2024).

Another car producer Bentley has used AR to let potential customers modify the exterior and interior of a car (Bentley, 2024). This would help them correctly personalize the car according to their taste.

BMW went few steps ahead with AR that not only is used to modify the exterior, but also to project information onto the windshield (Woerns, 2023). This makes the car an intelligent one, while preserving driver's safety since the driver would still look at the road while the information is being projected on the windshield.

Mercedes has also been extensive in their AR implementation, where it is used to deliver staff training, car prototyping, repair, assembly, and immersive customer engagement, such as information projection on windscreen and virtual guidance on car components (Marr, 2023).

AR-based projection of information on windscreen is also deployed by another car manufacturer Volvo, where it is used to display traffic condition in order to help navigate driver through challenging roads (Volvo, 2021). In the case Volkswagen, besides guiding through challenging road conditions, the AR-based windscreen is also used to train driver to drive on racing circuits (Bach, 2021).

Detailed AR-based car maintenance is provided by Siemens for a sports car producer Porsche, which can assist their technicians to inspect electric car's charging components, battery, and cabling. This immersive digital solution has made the car maintenance process less stressful and faster (Siemens, 2024).

When it comes to stretching the capability of AR-driven car windscreen, Tesla has invented

even more interactive immersive windscreen by integrating gaming feature aside from projecting road condition and assistance (Melnick, 2023). Besides immersive windscreen, Tesla also implements AR for faster and less erroneous car manufacturing, which includes car setup, components configuration and calibration, and quality assurance (QA) (Alvarez, 2018).

In a stronger case of AR usability, Boeing applied it to train fighter pilots. Such virtual testbed developed by a company called Red 6 has significantly reduced risks of safety and property loss (Boeing, 2024).

Another example in airline industry is related to AR-based airplane's maintenance training developed by Asia Digital Engineering Sdn (Asia Digital Engineering, 2024). It uses AR to generate digital airplane components and aircrafts to train maintenance staff for commercial airlines. The method would make it more accessible for staff to conduct maintenance training without having to wait for a physical aircraft to be available on the ground. Hence, more staff can be trained within a specific timeframe.

The above-mentioned AR implementations infer the suitability and effectiveness of it as a tutorial medium for machinery-related technologies. Thus, the motivation behind this paper's methodology to utilize AR for composter machine operation tutorial. Per authors' knowledge, such development has not been done before.

3. Composter Machine Technology Review

Composter machine's purpose is to naturally fester solid organic material into nutritious soil fertilizer, which could replenish soil where plants would grow on. This process involves microorganisms, such as worm, fungi, and bacteria. The organic materials that can be festered include food waste or plant waste.

The process of composting can be natural i.e. fallen leaves that are composed naturally by the soil they rest on - or controlled with measured addition of water, nitrogen, air, and carbon.

A controlled composting process can be done by composter machine. It usually consists of a container tube that will hold food waste or plant waste, control panel that would regulate the composting process, and supporting mechanical parts. Some machines may work automatically with embedded-intelligence or semi-automatically (Sutar et al, 2022).

The basic mechanism of the machine would be to mince the food or plant waste into pieces, then optionally add up the necessary supplements and microorganisms before heating the mixture until the compost (fertilizer) is finally produced. Subject to load size, the whole process may take 1-4 days for loads between 25kg-100kg.

An automatic composter machine can detect the humidity level and automatically adjust it via heating and evaporation steps. It may determine the optimal level of moist and complete the process once it is achieved. A semi-automatic one would be operated via control panel, however it lacks the ecosystem sensors and automation. While a fully automatic composter machine with similar technology was also built by (Pare & Aman, 2019). However, this version excludes mincing process of organic waste in order to eliminate noise.

The above-mentioned composter machines all have similar mechanism, including the model which is the basis of this paper’s AR application. Although this model is equipped with cellular connection to transfer composting-related data to a cloud data storage and mobile application, this additional feature is out of scope of the proposed AR application.

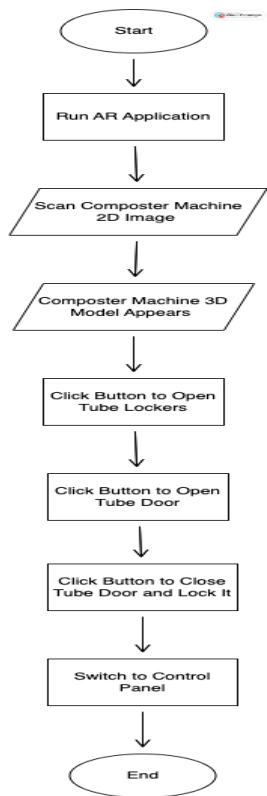
4. Methodology

The proposed AR application was developed using prototyping model software development methodology for it allows quick initiation and repetitive improvements of the application (Bjarnason et al, 2021). Coding-wise, it was developed using Unity software, which is an Integrated Development Environment (IDE) special for AR and Virtual Reality (VR) applications.

The 3D model of the composter machine was imported into Unity, and then it was integrated with the AR code that would make it able to respond to tutorial-related functions.

The fully built AR application works by projecting the 3D model of composter machine via a smartphone’s camera after scanning a composter machine 2D image. The machine operation tutorial can then be initiated by responding to buttons’ actions. Below is the flow chart of the respective AR application.

Figure 1. Composter Machine AR Application Flow Chart



The procedure for the previous Figure 1 flow chart is explained as follows along with every corresponding screenshot of the application:

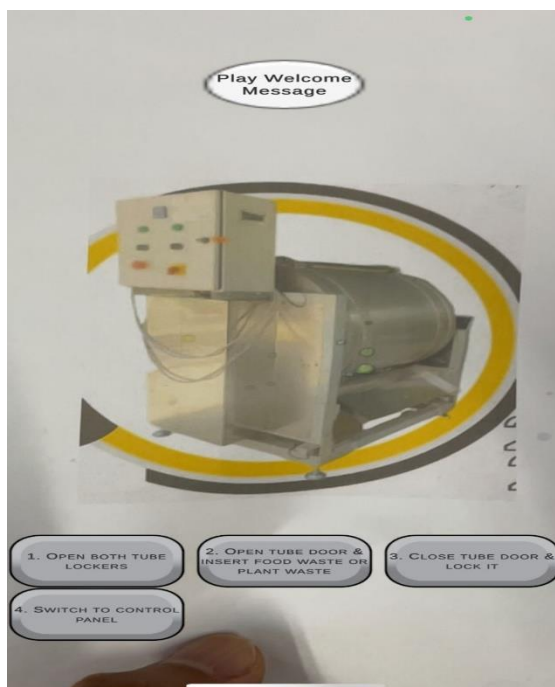
1. The user would run the AR application on their phone or tablet, which shows an instruction signboard to scan a 2D Image.

Figure 2. The AR Application Showing Signboard



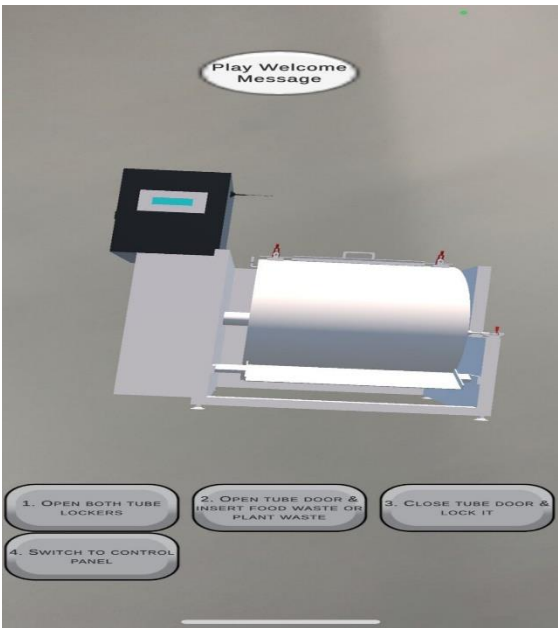
2. The user would scan a 2D image of composter machine.

Figure 3. The Scan of a 2D Image



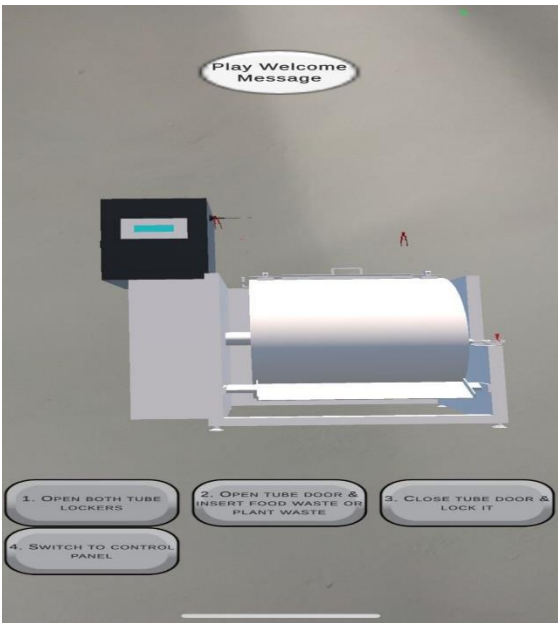
3. The 3D model of composter machine would pop out.

Figure 4 The Appearance of Composter Machine 3D Model



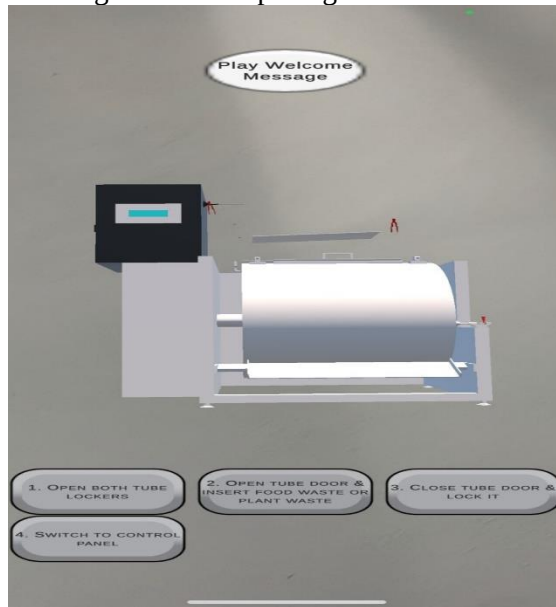
4. The tutorial to operate composter machine would initiate by clicking the button that opens the two tube lockers.

Figure 5 The Opening of Tube Lockers



5. The tutorial continues by clicking the button that opens the tube door - so that food waste and/or plant waste can be inserted into the tube to be composted.

Figure 6. The Opening of Tube Door



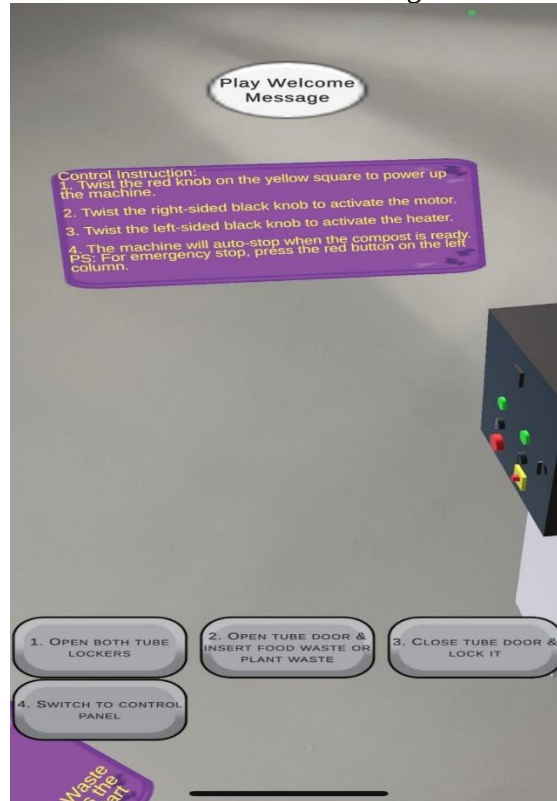
6. The tutorial proceeds by clicking the button that closes the tube door and then locks it.

Figure 7. The Closure and Locking of Tube Door



7. The tutorial subsequently asks the user to click the button that switches the view to control panel. Adjunctive to the control panel is the instruction signboard that mentions the order of buttons to press or twist in order to complete the operation of the machine.

Figure 8 The View of Control Panel along with Its Instruction



The above step-by-step tutorial is driven by buttons instead of touch screen. This preferred approach is to reduce user's confusion when using the application in touch screen mode, which is known to provide freedom of movement that may distract the proper steps of the tutorial. The AR based application would also assist users to memorize the correct steps to operate composter machine. Such expectation is boosted by research findings concluded by paper (Lai et al., 2021) that argues that AR environment is easier for users to remember procedural tutorial.

In our developed AR application, the labeled buttons are also designed to be an assistance for hearing-impaired users. This inclusivity is essential to cover wider diversity of community. The compelling importance of community-driven application is also concurred by authors in (Mamat & Suhaimi, 2021), who encourage the inclusion of hearing-impaired users and also by researchers in (Alshafeey et al, 2019), who promote developing AR applications based on the requirements of disabled people.

5. Results and Discussion

As observed in the previous section, the developed AR application only takes seven (7) major steps or clicks to complete the composter machine operation tutorial. This is significant improvement from conventional book-based tutorial, which would have the user to spend more time navigating the content and pondering about the positions of the composter machine's components. The AR application seamlessly pinpoints the components that the user needs to interact with by projecting and moving a 3D model as if the user is immersed with the machine.

Furthermore, the complexity of operating the machine's control panel is also solved by the AR application using intuitive user interface elements.

In overall, the developed AR application complies to the Merrill's principles of instruction model (Kurt, 2024) that is meant to deliver engaging and effective learning experience. The principles and their corresponding fulfilment in the AR application are as follows:

1. Task-centered: The AR application is specifically built to teach users to operate composter machine.
2. Activation: The activation of users' relevant prior knowledge is quickly executed by the self-descriptive name of the composter machine displayed on the AR application's virtual signboard, which is Smart Economical Food Waste Composter (SEFWC). AR may also further trigger the interest of users to learn deeper about the subject as discovered by (Mokmin et al, 2022).
3. Demonstration: Immersive AR digital environment is provided by the application as the simulation methodology that demonstrates the operating procedure of composter machine.
4. Application: The AR application requires users to apply the taught knowledge by pressing buttons throughout the tutorial.
5. Integration: The tutorial provided by the AR application is transferable to real-life scenario, where users would handle physical composter machine.

6. Conclusion

An effective and quick tutorial delivery method for operating composter machine has been developed in the form of a mobile AR application. Per authors' knowledge, it is the first of its kind specifically suited to composter machine, and thus it is a kick-off of future more advanced similar applications that cater for such machine's tutorial. The characteristics of the said application have also been observed to have fulfilled all standard of principles of instruction designed by David Merrill.

Moreover, future similar applications may use this maiden application as a baseline to add more sophisticated features according to what the future technology may hold. Additionally, future applications may also improve it in terms of usability and portability - in case new types of gadgets will be invented.

Finally, the proposed AR-based tutorial application has achieved the objective of providing alternative training methodology when there is lack of physical composter machine. Rewardingly, it brings monetary and time efficiency, where otherwise fully working physical machine would have to be manufactured first.

Funding Details

Our gratitude towards Sultan Idris Education University (Universiti Pendidikan Sultan Idris) for sponsoring this project called “Development of an Interactive Edugreen Module Based on Merrill’s Principles of Instruction Model to Nurture Students on Environmental Sustainability in STEM Education” under the grant named ‘Skim Geran Penyelidikan Universiti Berteraskan Pendidikan (GPUBP-IPGM)’, Research Code: 2023-0186-107-01. This research is an initiative of the Centre of Embedded Education Green Technology.

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