The augmented reality application for simulating electromotive force concept

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Abstract. The discussion of the concept of electromotive force often leads to misconceptions. Unity program can produce 3-dimensional media from 2-dimensional media. In this article, we will describe the form of electromotive force simulation that is displayed with augmented reality technology. Development of electromotive force simulation using 4D development model (define, design, develop, and disseminate). The application of augmented reality technology can visualize the three-dimensional form of abstract electromotive force processes into reality. The design process is based on pedagogical content knowledge. The electromotive force display can simulate the impact of changes in the number of turns, magnetic fields, and time of playback of the generator against the value of electromotive force. The simulation has succeeded in providing an interesting description of the ratio of variables to the magnitude of the force of electricity produced in the generator. Display simulation electromotive force with augmented reality technology has met the principle of technological pedagogical content knowledge (TPACK).

1. Introduction

Augmented reality (AR) has been widely used in various fields. AR has been used in the fields of medical, military, manufacturing, visualization, entertainment and games, robotics, education, marketing, navigation, and part planning, tourism, geospatial, urban planning and civil engineering [1]. In the field of education, AR has been widely used as a learning media [2-5]. AR is very helpful in implementing constructivism learning. Learners can investigate objects clearly, actively make observations [6]. AR can display interactions between real and virtual objects in realistic simulations [7,8].

The use of AR technology can improve the quality of the learning process [9,10]. The use of effective technology in learning must pay attention to technological pedagogical content knowledge (TPACK) [11]. AR media that has been produced has not been based on pedagogical content knowledge. Users can only observe but cannot learn from the media. AR media in interactive 3D will make learners build knowledge from the observation process.

The development of electromotive force media with pedagogical content knowledge augmented reality technology is expected to help users learn from the media. This article describes the use of AR technology in producing interactive 3D media. The electromotive force theory will be displayed in interactive 3D media. Users can pay attention to the 3D form of the electromotive force process and can change existing variables so that they observe the impact on other variables.
2. Method
The development of AR-based electromotive force media was developed with the 4D model (define, design, develop, and disseminate). The define step; electromotive force will be displayed in interactive simulation media using AR technology. The design step; design marker, blueprint AR-based interactive electromotive force simulation media. The develop step; in this simulation, voltage variables are generated from variations in changes in playback time, number of coils, and different magnetic field strengths. The voltmeter is used as an indicator of the voltage generated by the generator (shown in figure 1). The disseminate step; the process of forming the voltage can be visualized by showing the movement of the coil in the magnetic field and measuring its voltage in a voltmeter. The whole system is a generator system and visualized in figure 2.

![Volt Meter](image1)

**Figure 1.** A voltmeter is used as an electromotive force indicator.

![Volt Meter](image2)

**Figure 2.** Generator system to produce an electromotive force.

3. Results and discussion
In this application simulation, there is one image that is used as the target of marker augmented reality (figure 3) and the initial interface is used as a simulation menu option that can be selected (figure 4). This simulation provides two variations of the magnetic field B, two variations of coil N, and two variations of the time interval \( \Delta t \). The simulation illustration using this arrangement is shown in figure 3 - figure 8.

![Augmented reality target marker](image3)

**Figure 3.** Augmented reality target marker.

![Simulation selection interface](image4)

**Figure 4.** Simulation selection interface.

After the interface is installed, do the programming with the source code in the vuforia file, Default Trackable Event Handler.cs as follows.

```csharp
#region PRIVATE_MEMBER_VARIABLES
    private TrackableBehaviour mTrackableBehaviour;
#endregion

#region PRIVATE_MEMBER_VARIABLES
    private void OnTrackingFound(){
        Renderer[] rendererComponents = GetComponentsInChildren<Renderer>(true);
        ...
    }
```
Collider[] colliderComponents = GetComponentsInChildren<Collider>(true);
foreach (Renderer component in rendererComponents){
    component.enabled = true;
}
foreach (Collider component in colliderComponents){
    component.enabled = true;
}
Debug.Log("Trackable " + mTrackableBehaviour.TrackableName + " found");
}
private void OnTrackingLost(){
    Renderer[] rendererComponents = GetComponentsInChildren<Renderer>(true);
    Collider[] colliderComponents = GetComponentsInChildren<Collider>(true);
    foreach (Renderer component in rendererComponents){
        component.enabled = false;
    }
    foreach (Collider component in colliderComponents){
        component.enabled = false;
    }
    Debug.Log("Trackable " + mTrackableBehaviour.TrackableName + " lost");
}

Simulation 1 - simulation 4 gives a B magnetic field variation of 30 Tesla and 60 Tesla, Variation Turn time for 6 seconds and 10 seconds, as well as one wire coil. Illustration of simulation using one twist is shown in figure 5 - figure 8.

![Figure 5](image1.png)  
**Figure 5.** Simulation 1 with a total electric motion of 9 volts.

![Figure 6](image2.png)  
**Figure 6.** Simulation 2 with a total electric motion of 15 volts.

![Figure 7](image3.png)  
**Figure 7.** Simulation 3 with a total electric motion of 18 volts.

![Figure 8](image4.png)  
**Figure 8.** Simulation 4 with a total electric motion of 30 volts.

From the simulation, we get a complete picture of the data obtained through the application and process of the occurrence of electromotive forces on the generator system. The data obtained are shown in table 1 and figure 9.
Table 1. Comparison of electric motion force values $\varepsilon$ in simulation 1 to 4.

| Simulation | $N$ | $B$    | $A$ | $\Delta \cos \theta$ | $\Delta t$ | $\varepsilon$ |
|------------|-----|--------|-----|----------------------|-----------|-------------|
| 1          | 1   | Coil   | 30 Tesla | 3 m$^2$   | 1         | 10 s       | 9 V        |
| 2          | 1   | Coil   | 30 Tesla | 3 m$^2$   | 1         | 6 s        | 15 V       |
| 3          | 1   | Coil   | 60 Tesla | 3 m$^2$   | 1         | 10 s       | 18 V       |
| 4          | 1   | Coil   | 60 Tesla | 3 m$^2$   | 1         | 6 s        | 30 V       |

Figure 9. Graph the relationship between the magnetic field, time lapse, and electric motion force in the 1-4 simulation.

Simulation 5 – simulation 8 gives a $B$ magnetic field variation of 30 Tesla and 60 Tesla, $\Delta$ Variation Turn time for 6 seconds and 10 seconds, and in the situation of 2 wire windings. The simulation illustration using 2 wire loops is shown in table 2 and figure 10.

Table 2. Comparison of electromotive force values $\varepsilon$ in simulation 5-8.

| Simulation | $N$ | $B$    | $A$ | $\Delta \cos \theta$ | $\Delta t$ | $\varepsilon$ |
|------------|-----|--------|-----|----------------------|-----------|-------------|
| 5          | 2   | Coil   | 30 Tesla | 3 m$^2$   | 1         | 10 s       | 18 V       |
| 6          | 2   | Coil   | 30 Tesla | 3 m$^2$   | 1         | 6 s        | 30 V       |
| 7          | 2   | Coil   | 60 Tesla | 3 m$^2$   | 1         | 10 s       | 36 V       |
| 8          | 2   | Coil   | 60 Tesla | 3 m$^2$   | 1         | 6 s        | 60 V       |

Figure 10. Graph the relationship between the magnetic field, time lapse, and electric motion force in the 5-8 simulation.
AR-based electromotive force media produced have met technological pedagogical content knowledge (TPACK) [11]. Simulations 1 – simulation 4 and simulation 5 - simulation 8 help users understand how work processes and variables affect electromotive force. The electromotive force display can simulate the impact of changes in a number of turns, magnetic fields, and time of playback of the generator against the value of electromotive force.

4. Summary
The resulting interactive 3D simulation visualization can simulate electromotive force, which is an abstract concept to be more real. Simulation can display the effect of changes in the number of turns, magnetic fields, and time of generator playback on the value of electromotive force. Simulation has succeeded in providing interesting information about the electromotive force process on generators using augmented reality technology. The results of this simulation are very useful in the arrangement of learning the use of generators for various power plants in future research.

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References
[1] Mekni M and Lemieux A 2014 Augmented reality: Applications, challenges and future trends Applied Computational Science 205-214
[2] Wu H K, Lee S W Y and Chang H Y 2013 Current Status, Opportunities And Challenges Of Augmented Reality In Education Comput Educ 62 41–49
[3] Cai S, Wang X and Chiang F K 2014 A Case Study Of Augmented Reality Simulation System Application in a Chemistry Course Comput Human Behav 37 31–40
[4] Nincarean D, Alia M B and Halim N D A 2013 Mobile Augmented Reality: The Potential for Education Procedia - Soc Behav Sci 103 657–664
[5] Birt J and Cowling M 2017 Toward future ‘mixed reality’ learning spaces for steam education Int J Innov Sci Math Educ 25 1–16
[6] Dunleavy M and Dede C 2014 Augmented Reality Teaching and Learning Handbook of Research on Educational Communications and Technology 735-745
[7] Azuma R T 1997 A Survey of Augmented Reality Presence Teleoperators Virtual Environ 4 355–385
[8] Beaney D and Mac Namee B 2009 Forked! A demonstration of physics realism in augmented reality Sci Technol Proc - IEEE 2009 Int Symp Mix Augment Reality 171–172
[9] Kiryakova G, Angelova N and Yordanova L 2018 The Potential of Augmented Reality to Transform Education into Smart Education TEM Journal 7(3) 556-565
[10] Saltan F 2017 The Use of Augmented Reality in Formal Education: A Scoping Review EURASIA Journal of Mathematics Science and Technology Education 13(2) 503-520
[11] Qian Y and Lehman J 2018 Using Technology to Support Teaching Computer Science: A Study with Middle School Students EURASIA Journal of Mathematics Science and Technology Education 14(12)