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Original

# Design, Production, and Evaluation of the Earth Well Model as a Valuable Tool in Electrical Safety Education Technology Using Kirkpatrick Model

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## ABSTRACT

**Background:** In today's academic society, the need for new educational methods and their application in teaching and learning seems highly necessary. The present study aims to design, produce, and evaluate the model of earth well with the Kirkpatrick model. **Methods:** The studied population included 22 occupational health engineering students who had completed an electrical safety course the previous year. The present study was carried out in four phases of design, production, implementation, and evaluation of the educational program. The assessment was based on Kirkpatrick's model in four basic stages: reaction, learning, transfer (behavior), and results. Learning evaluation was done before and after the test using Kolmogorov-Smirnov and paired t-tests in SPSS. **Results:** The results demonstrated that people's satisfaction in achieving educational goals, attracting attention, and creating motivation for better learning and internalizing knowledge had values of 63.6%, 59%, and 54.5%, respectively, and provided a high (high) satisfaction. The mean and standard deviation of the scores obtained before and after were 3.77±0.57 and 4.47±0.62. Findings indicated a significant difference before and after practical training with the earth well model (P<0.001). **Conclusion:** The design and production of the model have had a beneficial effect on the satisfaction, attitude, and behavior of the students. Therefore, it is recommended to pay more attention to the topics of new educational technologies in occupational health and safety, because these things facilitate students' learning and skills and make students' knowledge deeper.

**Keywords:** Educational Technology; Model; Safety; Occupational Health

## Introduction

In the last century, medical education has played an important role in human health, which needs to be changed according to the conditions of the systems over time. This is because medical education has to adapt itself to the changes of new technologies. [1] Significant changes, revisions, and reforms have occurred in the field of education in medical sciences universities of the country due to

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changes in systems in recent years. These changes can be mentioned using student-centered teaching methods, curriculum revision, and holding various educational workshops. [2] Virtual education, the production of educational materials and software with different applications is an example of the growth of educational technologies in the country. According to the educational process in universities of medical sciences, in future, various educational materials will be produced in the country. [2] It seems necessary to implement new educational methods and use them in the process of teaching and learning in universities. [3] One of the important aspects of educational technology is emphasizing new media and its use in teaching and learning. Educational technology (also called the hardware dimension) refers to all devices, tools and media which facilitate teaching and learning. [3,4] It is a principled and logical method to solve educational problems, which facilitates learning by applying the latest scientific findings regarding hardware and software. Moreover, Educational technology uses educational methods and strategies to skillfully implement them in the teaching process. [5] Educational design can be defined as prescribing or predicting educational methods to achieve desired changes in knowledge, skills, and emotions of learners. [4]

Therefore, according to the comprehensive scientific map of the country's health and the increasing growth of the use of equipment and facilities in the provision of various services, it is necessary to teach and learn the rational use of these facilities in the field of occupational health and safety engineering. One of the important topics in this field is electrical safety and grounding. [6]

These systems are important in creating a safe environment for human operators and equipment. [7-9] The use of the earth system is a vital matter for electrical protection and the correct operation of electrical systems. Based on the type of grounding, the performance of the two types of electrical and protective earth are different from each other. Grounding is done to protect against the risk of electrocution. Therefore, to reduce the damage caused by electric shock, it is necessary to use the grounding system in the sets where electricity is used as the main and driving current. [10] Designing different models and types of simulators using different approaches of educational technology in this field is one of the ways to increase the skills of occupational health engineering students in the laboratory environment, and consequently, its easier implementation in the field.

Through educational technology in various fields of the Ministry of Health, including occupational health, new systems of teaching, learning, designing, implementing, and evaluating have been developed. This encourages professors to participate in the design and production of media to facilitate the process of teaching and learning, provide different educational resources, and solve them using an educational design and its diverse patterns according to their underlying approach, providing appropriate solutions. [4]

Therefore, the estimates and investigations, and field experiences showed the weakness of students in the field of electrical safety and the important topic of earthing. Therefore, according to the practical aspect of the electrical safety course and the issue of earthing, it was decided to use the new methods and approaches of educational technology for the design and production of industrial earth models to improve the knowledge, attitude, skills and learning of students.

## Methods

Based on the upstream documents, the opinions of students and experts, the need to produce replicas in line with educational technology was felt, and the goal-oriented model was used. The studied population included 22 professional health engineering students who had completed this course the previous year.

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The conceptual phase and the initial design of the earth well replica started on the beginning of September 23, 2021 to better train students and equip the safety laboratory.

Regarding the experiences and classroom observations of the process manager, the feedback received from students and occupational health and safety experts in academic and industrial environments, and the challenges in classrooms, it was decided to design, produce, implement and evaluate the mock-up of the earth well in the safety laboratory. Figure 1 shows the general framework of the steps, which will be discussed in detail below. As seen in Figure 1, the study was conducted in four phases: design, production, implementation, and evaluation of the educational program.

**First step: Design**

**a.Training needs assessment:** First, the educational needs assessment was conducted according to the feedback from the industry experts and university professors, and the challenges of higher-level students in this field. Field experiences and surveys demonstrated the weakness of students and the ineffectiveness of current educational methods in the field of grounding in electrical safety.

**b. Review of standards:** In this stage, the existing standards with regard to earthing, including the guidelines for implementation of the earth system in buildings and for measuring the resistance of the earth electrode and the specific resistance of the soil approved by the Building Engineering System Organization, were used to make the model.

**c.Preliminary map design:** In this stage, according to the sources, documentation, and standards, the two-dimensional model map was drawn using AutoCAD software (Figure 2).

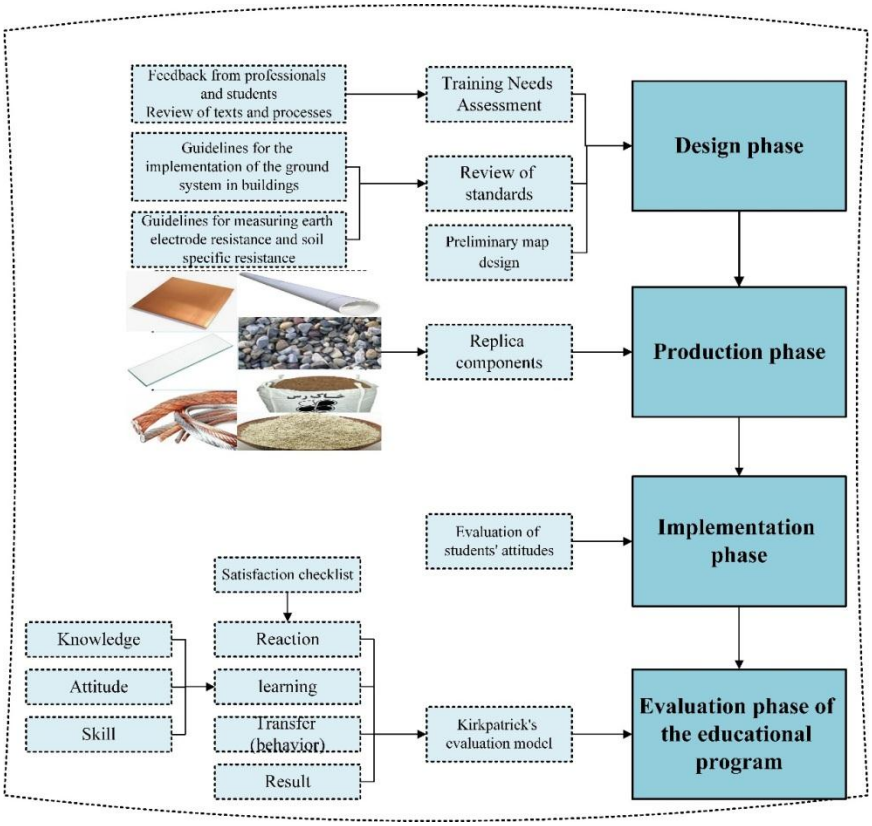


**Figure 1.** Flowchart of study

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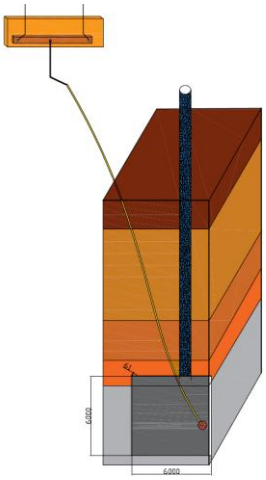

**Figure 2.** The initial map of the earth well model

**Second step: production**

After the initial design of the model, at this stage, with the cooperation of three students, the model of the earth well was developed on a laboratory scale. According to the related standards, the earth well is composed of various parts, which include a copper plate electrode, grounding conductor, electrolyte or bentonite, sanded soil, water injection valve, and exothermic welding to connect the conductor to the electrode in a well with an 80 cm diameter.

Therefore, it was necessary to implement this model in the laboratory in order to create a suitable visual capability for the students. Glass plates with the right thickness created a good visual capability for the replica. To maintain proper mechanical resistance in smaller dimensions, they were placed in the form of a cylinder with a rectangular cross-section and on a fiber with a suitable strength. According to the standard and designed shape, different parts of the model were designed and produced with suitable dimensions.

**The third step: implementation**

At this stage, the evaluation of the attitude of learners and students toward the model was measured using the checklist made by the researcher.

**Fourth step: evaluation of the educational program**

At this stage, the program was evaluated using Kirkpatrick's evaluation model. Kirkpatrick's evaluation model is one of the best and most successful evaluation models due to its logical structure and valuable educational effectiveness measurement. This model was presented by Donald Kirkpatrick in 1952 and has been widely used. [11] The evaluation levels of Kirkpatrick's model include four basic stages of reaction, learning, transfer (behavior) and, results. [11]

**a.Reaction:** This level is comprehensive and measures the feelings of the participants toward training and evaluates the level of interest, usefulness and relevance of the training to their role.

**b. Learning:** Learning is the determination of the amount of knowledge, attitude, skill, self-confidence and commitment taught to the students and clarified for them during the grounding practical training course. In other words, has the education reached the learning goals or not? [12]

**c.Transfer (behavior):** At this stage, behavioral changes after learning and the amount of the learned material used in practice were measured.

**d. Result:** The last level of Kirkpatrick's evaluation model is the result, in which the final results of training should be analyzed. This level focuses on whether the goal of the training program has been achieved or not. [13]

Moreover, evaluation was done before and after considering the students' mid-semester exam scores (regarding the subject of the study), and the researcher's checklist was made based on 5 points using the Kolmogorov Smirnov and paired t-test in SPSS version 21.

## Results

The results of this process were the design, production, and evaluation of the earth well replica to discover knowledge, metacognitive skills, and learning of students in electrical safety and earthing topics. This program was implemented during two

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semesters and was evaluated. The results of students' satisfaction, attitude, and behavior toward the earth well replica can be seen in tables 1, 2, and Fig 3.

According to the results, people's satisfaction in achieving educational goals, attracting attention, and creating motivation for better learning and internalizing knowledge had values of 63.6%, 59%, and 54.5% percent, respectively, showing a high level of satisfaction.

Tables 2 and Figure 3 also reveal the attitude and behavior of students toward the earth well model.

In the end, the learning rate of the students was measured using descriptive questions of 5 points after more than 6 months. The students' mid-semester exam on the topic of the earth was also considered the basis of evaluation before the practical training of the model. The Kolmogorov-Smirnov test was used to check the normality of data distribution in SPSS. According to the results of this test, the data of the study was normal; therefore, the paired T-test was used to compare the two groups. The mean and standard deviation of the scores obtained before and after were 3.77±0.57 and 4.47±0.62, respectively. There was a significant difference before and after practical training with the earth well model (P<0.001).

**Table 1.** Students' satisfaction with the earth well model

| Row | Students' satisfaction with the earth well replica | Frequency (F) and percentage (%) of students' opinions on the topic | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very high | | High | | Medium | | Low | | Very low | |
| | | F | % | F | % | F | % | F | % | F | % |
| 1 | The degree of achieving educational goals regarding electrical safety earthing | 2 | 9.0 | 14 | 63.6 | 6 | 27.2 | 0 | 0 | 0 | 0 |
| 2 | Attracting attention and creating motivation for better learning | 4 | 18.1 | 13 | 59.0 | 5 | 22.7 | 0 | 0 | 0 | 0 |
| 3 | The appearance of the replica attracting attention and interest in internalizing (getting deeper) knowledge | 3 | 13.6 | 12 | 54.5 | 7 | 31.8 | 0 | 0 | 0 | 0 |

**Table 2.** Attitudes of students toward the earth well model

| Row | Students' satisfaction with the earth well replica | Frequency (F) and percentage (%) of students' opinions on the topic | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very high | | High | | Medium | | Low | | Very low | |
| | | F | % | F | % | F | % | F | % | F | % |
| 1 | The desirability of the quality of the educational earth well model from the students' point of view | 3 | 13.6 | 9 | 40.9 | 10 | 45.4 | 0 | 0 | 0 | 0 |
| 2 | Understanding the concepts of education and scientific subjects leading to clarity and learning using the earth well | 5 | 22.7 | 13 | 59.0 | 3 | 13.6 | 1 | 4.5 | 0 | 0 |
| 3 | The amount of using this model causing taking similar actions in the future | 4 | 18.1 | 12 | 54.5 | 3 | 13.6 | 3 | 13.6 | 0 | 0 |

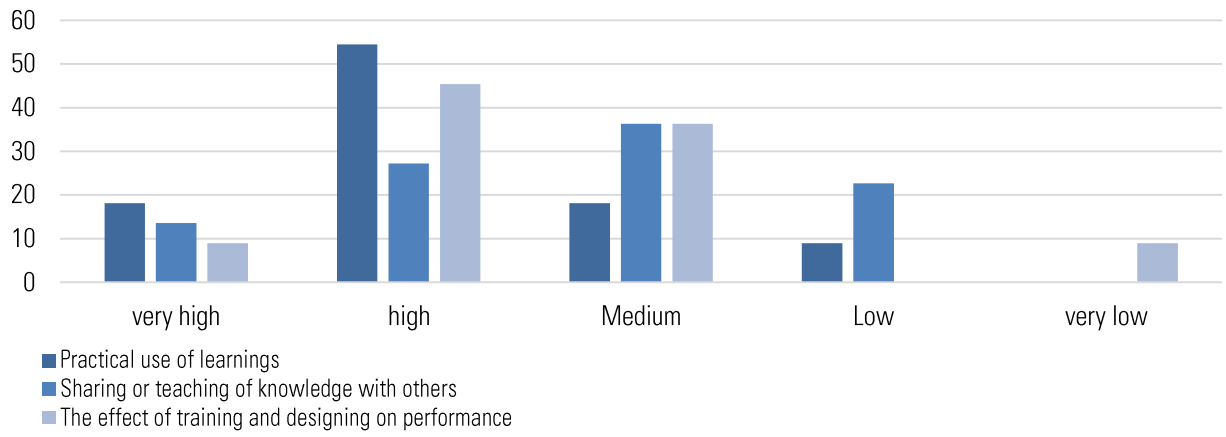


**Figure 3.** The transfer (behavior) of the students (%) toward the earth well model

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## Discussion

This study was conducted to design, produce, and evaluate the earth well model as a valuable tool in electrical safety education technology using the Kirkpatrick model. According to various sources of information, the studies were conducted only with real earth well samples. None of them, however, were conducted to improve the level of attitude, knowledge, and practical skills of students or learners, which was the main objective of the present study.

A study was conducted by Almanda and Ramadhan [14] to optimize the design of the distance grid and ground rod in earthing system in 2019. The design of the electrical panel earthing system was also selected as a case study. The definition of optimal conditions in this case was a combination of quality and cost. Calculations were performed to obtain technical parameters and costs one by one in the range of grid spacing and length of ground rods to determine the optimal point using MATLAB-GUI. The results showed that the grid distance of 23 meters and the ground rod length of 6 meters was the best choice for optimizing this earthing system. [14]

In a study, Mohammadi et al. [15] evaluated various factors in reducing the resistance of an earth well by simulating a real earth well sample in the ground. 192 types of earth wells were implemented in this sample and the value of earth resistance was measured by an earth tester and a three-point method. The results indicated that humidity and density were the most important factors in determining the value of the earth's resistance in such a way that with each change the value of the resistance changed dramatically, which should be given more attention. According to the results, sand was evaluated as the worst type of soil due to its high resistance. [15]

The use of educational technology had a good effect on the satisfaction, attitude, and behavior of students. Moreover, students' learning before and after designing the model had a significant impact. One of the limitations of the current research was the low accuracy and sophistication of the model, which is suggested to be resolved with appropriate investment in this field. A laboratory earth well sample used for real resistance measurement is one of the other suggested items of this study.

## Conclusion

The mean and standard deviation of the learning scores before and after showed a significant differences. In addition, the design and production of the replica have a beneficial effect on the satisfaction, attitude, and behavior of the students. Therefore, it is recommended to pay more attention to the topics of new educational technologies in occupational safety and health, because these things facilitate students' learning and skills and make students' knowledge deeper.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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This article was extracted from the educational process conducted at Birjand University of Medical Sciences.

## Authors Contribution

The authors have cooperated in all stages of the research including Study design, data collection data collection, writing original draft, revising the article

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