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Chapter 8

# Developing Educational Simulation for Rockwell Hardness Test Machine

Ahmed Hadi Shubber, Amirmudin Bin Udin and Asnul Bin Minghat

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**Abstract**

The purpose of this paper is to analyze, develop, design, implement, and evaluate the engineering simulation model in metallurgy subject [Rockwell hardness test simulation (RHTS)], according to analyze, design, develop, implement, and evaluate (ADDIE) model and the Mechanical Engineering students of Babylon Institute in Iraq are chosen for case study. This paper presents the various steps involved in the simulation procedures. The detail simulation development process and its significant characteristics are highlighted. The flowchart of the model is rendered, displaying the different components used to develop the simulation algorithm using Microsoft Studio 2010 computer programming language. The advantages and limitations of the simulation model are identified by interviewing experts. The findings resulted from the simulated model reveal that the learners can learn easily and effectively. The developed software package is expected to provide valuable tool for both students and instructors. Furthermore, the same package in the form of a bi-product can also be used as a "research tool" together with the application for engineering education.

**Keywords:** RHTS, education simulation, Rockwell hardness test, metallurgy, ADDIE

## 1. Introduction

Modeling and simulation go hand in hand. Definitely, model building is a well-recognized way toward the understanding of the real world. Truly, it is a simplification of some complex structure or a system. Conversely, it may be for prediction, a substitute for experiential learning or simply for entertainment. The major difference between simulation and experimentation must be mentioned. In simulation, one experiments with a model and not with a phenomenon. The use of simulations represents the natural way of "learn by doing." Alike

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students' role playing, we use computer simulations to understand intricate systems, real situation, or dynamic processes. Computer simulations allow us to mimic situations or processes that would be difficult, impossible, dangerous, too long, or too expensive to perform in reality [1–3].

Undoubtedly, the purpose of an educational simulation is to motivate the learner to engage in problem solving, hypothesis testing, experiential learning, scheme construction, and development of mental models [4, 5]. Lately, these new information technology tools are changing the learning environment in engineering education from primarily teacher-centric to student-centric. Unfettered access to web-based or computer educational materials are highly useful [6].

In order to meet the growing demand for engineers those well versed with computer tools for problem solving and metacognitive skills, engineering educators are increasingly incorporating in curricula information technology-based learning tools. Consequently, web-based multimedia modules, virtual collaborative environments, virtual laboratories, software for simulation, and visualization of engineering phenomena [7] are developed. The twofold objective of this ongoing transformation is: (i) to improve the quality of instruction with innovative course materials that cater to the learning styles of present generation students and (ii) to provide students exposure to computer problem solving tools so as to facilitate their transition from academia to industry [8].

In this research, we attempt to design a simulation model for Rockwell hardness test machine to enhance the metacognitive skills of metallurgy lesson for mechanical engineering students of Iraq. The model is tested, implemented, and analyzed, and the results are compared and understood.

## 2. Theoretical background

In the past, overall education in Iraq has suffered from severe deterioration due to the decrease in spending, lack of supplies, collapse of infrastructure, and overcrowded schools. These are compounded by the continuing prevalence of classical teaching methods that focus on lectures and memorization. The stress analysis and deductive skills, the spirit of initiative, and creativity are all failed to optimally encourage student engagement. Much educational necessities such as libraries, laboratories, modern teaching techniques, smart boards, roving laboratories, electronic library, and computers and their accessories to a considerable percentage of schools and institutions of higher education are already rendered. Despite many efforts since 2003 to develop courses for all levels of education, there is still a need to develop study courses and provide additional supports to maintain international standards [9–11].

Metallurgy is considered as one of the most important branches of engineering materials. The emergence of various metal industries enforced the students teaching more significant for their work. Particularly, technicians in factories producing various types of engineering materials require knowledge of integrated types of metallic materials. In addition to

their knowledge on physical, thermal, and chemical properties, they must be aware of the conditions for the manufacturing process [12]. Metallurgy is always considered as one of the hardest lessons taught in the Department of Mechanics in Iraq because many students fail to succeed in the first attempt [13]. Consequently, metallurgy is proven as a difficult subject for many students [14].

The present research aims to find ways that may transform the engineering curriculum of Department of Mechanics in Babylon Technical Institute into simulation-enhanced engineering curricula. It emphasizes on the incorporation of simulation-based interactive modules to enhance student learning. The pedagogy of "learning-by-doing in virtual environments" is being employed in the development of modules. In fact, one of the practical and efficient way in which engineers can learn is through hands-on activities in computer laboratories. The Rockwell hardness test module being a part of the metallurgy lesson is expected to complement student learning achieved through computer laboratories and conventional classroom instruction. However, our emphasis is not directed toward distance learning. It is rather focused for on-campus classes in enhancing the quality of student learning by embedding computer simulation in conventional mode of teaching and learning processes.

## 3. Rockwell hardness test

This hardness machine is the most popular one due to its accuracy, swiftness, and precision capacity to differentiate between small or large hardness in hardened steel. This has the ability to subject pressure on apparatus or materials under test without being damaged or destroyed. The advantages of the Rockwell tester [15] are the following:

**a.** Widely applicable in the industry due to the rapid and simplistic performance.

**b.** Highly accurate because the produced impression is small in size.

**c.** Easy conversion of Rockwell hardness number to Brinell number using special table or chart.

**d.** Suitable for testing both hard and soft materials.

## 4. Methodology

### 4.1. Objectives

The identification of goals for the construction of lesson is considered as the important standard to determine their contents, nature, activities and exercises accompanying the methods. Furthermore, the modes of using particular teaching methods and the goals for lessons are categorized into general and specific one. General goals primarily focus to enhance Engineering

Education and improve the metacognitive skills. Conversely, special goals intend to administer students having following perspectives:

**a.** Students identify when, where, and how to use the Rockwell hardness test.

**b.** Students identify the parts and components of the Rockwell hardness test.

**c.** Students identify the sequence of steps involved in the Rockwell hardness test.

**d.** Students identify the advantages and disadvantages of the Rockwell hardness test.

**e.** Students know how to safely use the machines.

**f.** Students know how to measure Rockwell hardness correctly.

**g.** Students know how to recognize the differences between the Vickers test and the Rockwell hardness test.

### 4.2. Simulation design and development

The researcher followed simulation model development process depended on the analyze, design, develop, implement, and evaluate (ADDIE) model (developing instructional model steps) in designing and developing the simulation according to the following procedures: analyzing, designing, developing, implementing, and evaluating.

ADDIE is considered a guide in designing and effectively tracking a project's progress. "ADDIE" stands for Analyse, Design, Develop, Implement, and Evaluate. This sequence, however, does not impose a strict linear progression between each step. Rather, each stage is a clear instruction on its own. This means that even if the individual applies ADDIE at the middle of the project, it will still retain its value and be able to provide a sense of structure to the whole program. Educators find this approach very useful having stages clearly defined which makes implementation of instructions effectively. As an Instructional Design (ID) Addie Model has found wide acceptance and use [16–18].

To conclude, using ADDIE model is the best tool to simulate the machine model. By revising such design model, the researcher found that ADDIE design model best suits the simulated model in the present study as it considered a generic process that is traditionally used by instructional designers and training developers. Moreover, the five phases applied in this model namely analysis, design, development, implementation, and evaluation are dynamic and flexible guidelines for building effective training and performance support tools. In this model, each design step has an outcome that feeds into the subsequent step that makes the final product more flexible and accurate. What differentiates this model from others is the accepted improvement using rapid prototyping. During each step of designing, the model received continual or formative feedback while instructional materials are being created. In a nut shell, such model could save time and money by identifying the problems while they are still easy to fix [19–21].

The simulation process is developed for RHTS models in the metallurgy lesson as described hereunder.

RHTS development involves the underlined steps:

1. Identification of general and special goal of the model.
2. Use of metals group such as stainless steel, mild steel, steel, brass, and aluminium in conducting the real test.
3. Manufacturing specimens from these metals by machines turning and milling, wire cutting, and polishing suitable for the apparatus specified in the research.
4. Conducting the test on real apparatus. In addition to the registration of the real data and results during the test, capturing pictures of each step, movement, and reading of apparatus is also considered.
5. Modification and calibration of pictures for the measurements are performed with the real equipment and specimen using a set of computer programs such as Photoshop and other image processors.
6. Designing a computer program using Microsoft Studio 2010 to simulate the model and conversion of data and images to the software codes. Devising the computer interfaces representing the real test steps.
7. Acquiring data from the program alike a real machine when running the simulation or executing the program.

The user is responsible for checking the statement true or false with the possibility of re-trying it several times, data collection, and storage in specific places to be audited.

*4.2.1. Simulation Design Process*

The development processes of RHTS are illustrated in **Figure 1** [22, 23]. The computer language Microsoft Studio 2010 is used to design and develop the RHTS model. An evaluation of the proposed model is carried out to identify their strengths and weaknesses through pilot test. A group of experts with mechanical engineering and teaching methods background are chosen to get their consensus and confirm the content validity.

The researcher reviewed the previous literature related to the characteristics of designing the simulation. Previous studies [3, 24] identified the main characteristics of simulation, which were fit for engineering education that could be summarized as the following:

1. Simulation program offers a series of clear events to the students allowing them the opportunity to participate actively in the program.
2. It offers the learner many suitable choices.
3. It helps the students to learn using the sound, images, and animation drawing.
4. It directs the students using the proper guidance to the study depending on their control in the learning environment.

5. It provides a large base of information to the learner useful in understanding the subject matter under consideration.
6. The simulation program assists the learner to understand the reality, thought, and emotions.
7. It allows the learner to commit mistakes without affecting the results adversely.
8. It permits the learner to achieve great freedom in the learning process.
9. It proffers a new style to the learner which is very different from traditional approaches.
10. It grants a chance to the learner to apply some of the learned skills.
11. It generally creates appropriate conditions for learning and skills training with the computer which are very similar for the real world.

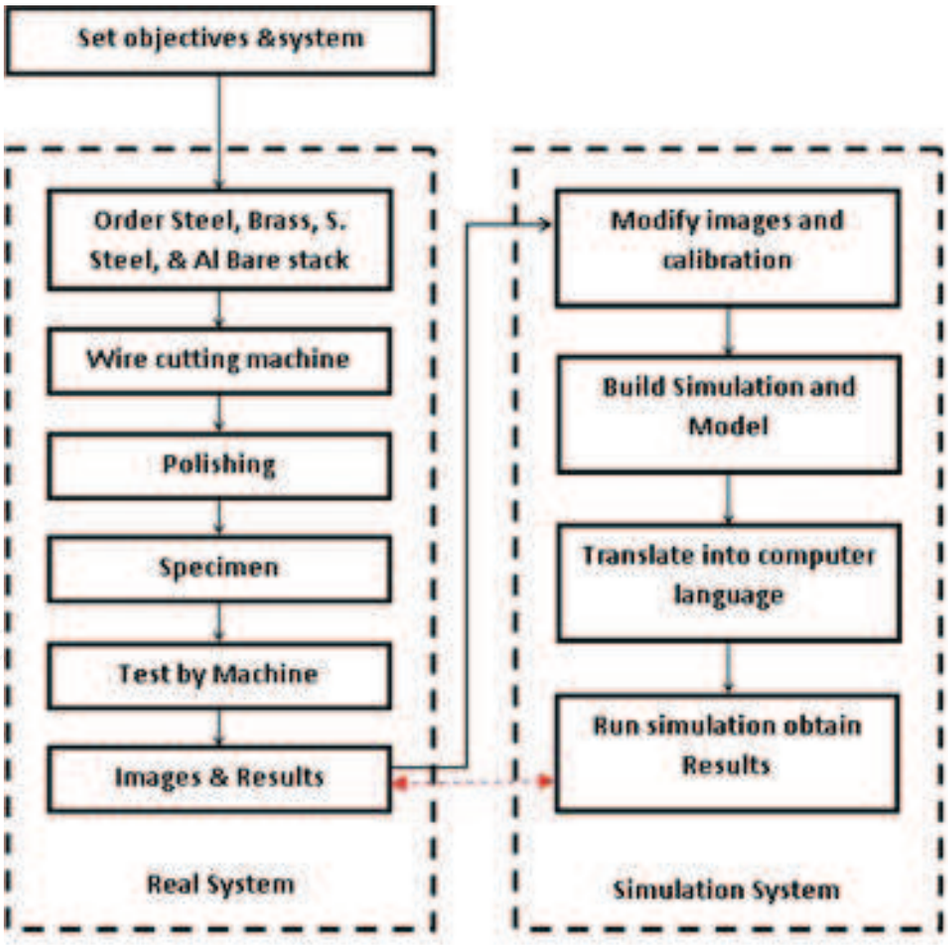



**Figure 1.** Block diagram for the simulation development processes.

*4.2.1.1. RHTS design*

The RHTS designed by [22, 23, 25] is performed using the following stages:

**A.** Design of Screen 1 as depicted in **Figure 2** is comprised of the following options:

1. ABOUT ROCKWELL TEST: Review the information related to the Rockwell Test.
2. ABOUT SIMULATION: Review the information relating to how to use the simulation model.
3. TEST STEPS: Review the information related to the test steps.
4. SIMULATION TEST: Move to the next screen to use the simulation model for the Rockwell Test.
5. EXIT: End of simulation model.

**B.** Design of Screen 2 as shown in **Figure 3** includes the following options:

1. Aluminum Al: Use Aluminum specimen and the next screen.
2. Steel: Use Steel specimen and move to the next screen.
3. Brass: Use Brass specimen and move to the next screen.
4. S-Steel: Use S-Steel specimen and move to the next screen.
5. EXIT: End of simulation model.
6. Back: Back to the previous screen.

**C.** Design of Screen 3 as illustrated in **Figure 4** contains the following choices:

1. Load operating lever: Click on lever to apply the load.
2. Capstan hand wheel: Click on it to increase or decrease elevation.
3. Image of hardness dial gauge: To show that the value of hardness is clear.
4. Dial adjusting hard wheel: Click on it to rotate the large needle dial to the "C"
5. Input text "Rockwell hardness number": To input the hardness value.
6. "Enter" Key: Click on it to show whether the hardness value is true or not.
7. Label: To show whether the result is true or not.
8. Back: Back to the prior screen.
9. EXIT: End of simulation model.

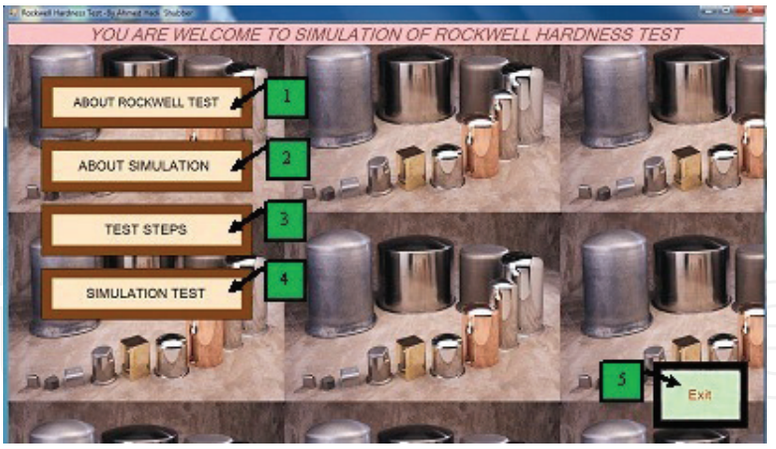



**Figure 2.** Schematic diagram displaying the design of screen 1 for simulating Rockwell hardness test.

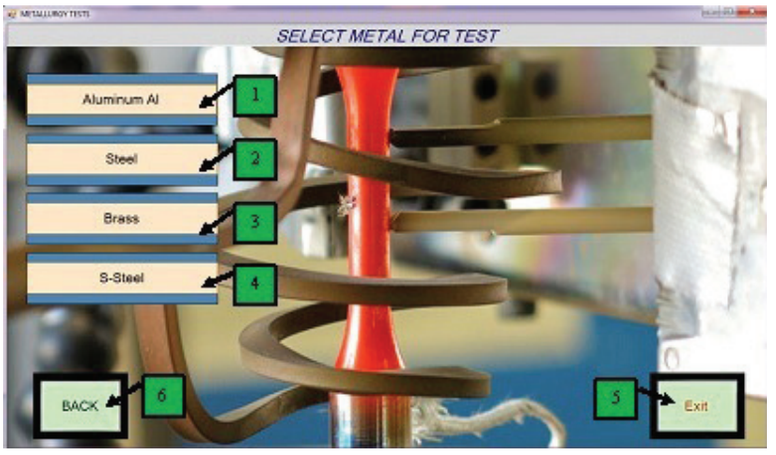



**Figure 3.** Schematic diagram displaying the design of screen 2 for simulating Rockwell hardness test.

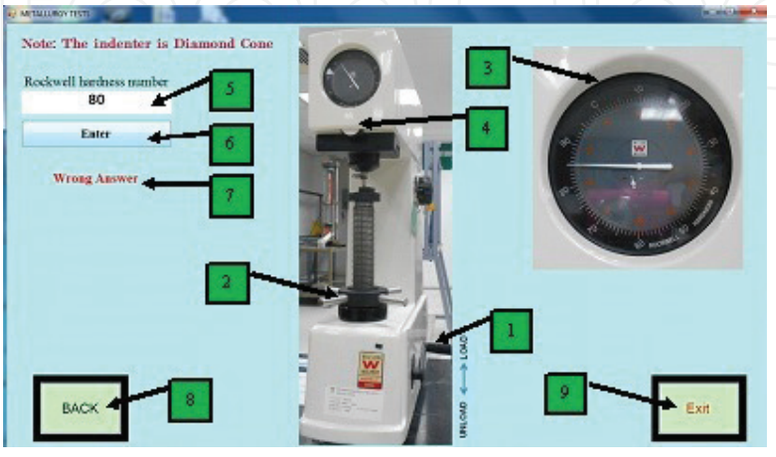



**Figure 4.** Schematic diagram displaying the design of screen 3 for simulating Rockwell hardness test.

*4.2.1.2. RHTS procedures*

1. In the screen 1, click on (Simulation test (4)) to move to the next screen to use simulation for Rockwell Test.
2. In the screen 2, click on one of the options (Aluminum Al (1), Steel (2), Brass (3), and S-Steel (4)) to choose material and move to the next screen.
3. In the screen 3, follow the following options:
   - **a.** Two clicks on Load operating lever (1) to become unload.
   - **b.** Click on Capstan hand wheel (2) to up elevating screw rod then continuous clicks until you watch the touch marker.
   - **c.** Click on Capstan hand wheel (2) clockwise until the hardness scale needle (large needle) rotates three revolutions and the preliminary load needle (small needle) points to the red marker (3).
   - **d.** Click on dial adjusting hard wheel (4) until the needle position deviates to the "C" zero point (3).
   - **e.** Two clicks on load operating lever (1) to the tester applies the total load and the needle begins to move (3).
   - **f.** Waiting until the hardness scale needle stops moving (3).
   - **g.** Two clicks on Load operating lever (1) to remove the main load.
   - **h.** Waiting until the hardness scale needle stops moving (3).
   - **i.** After the main load has been relieved, you can read the Rockwell hardness value at which the needle points to the dial scale (3).
   - **j.** Input the Rockwell hardness value in Input Text (5)
   - **k.** Click on Enter (6) to watch result is true or false.

The flowchart illustrating the entire modeling and simulation process of the proposed algorithm is shown in **Figure 5**.

*4.2.2. Simulation model development*

In order to develop the simulation model, the researcher seeks the opinions of experts, specialists, teachers, and the laboratory supervisors in order to modify and develop the model to be more clear, easy, content accurate, and suitable for the students.

*4.2.3. Simulation model implementation*

The model was applied on a group of experts and specialists in metallurgy laboratory course on the mechanics Department students at the Al-Furat Al-Awsat Technical University.

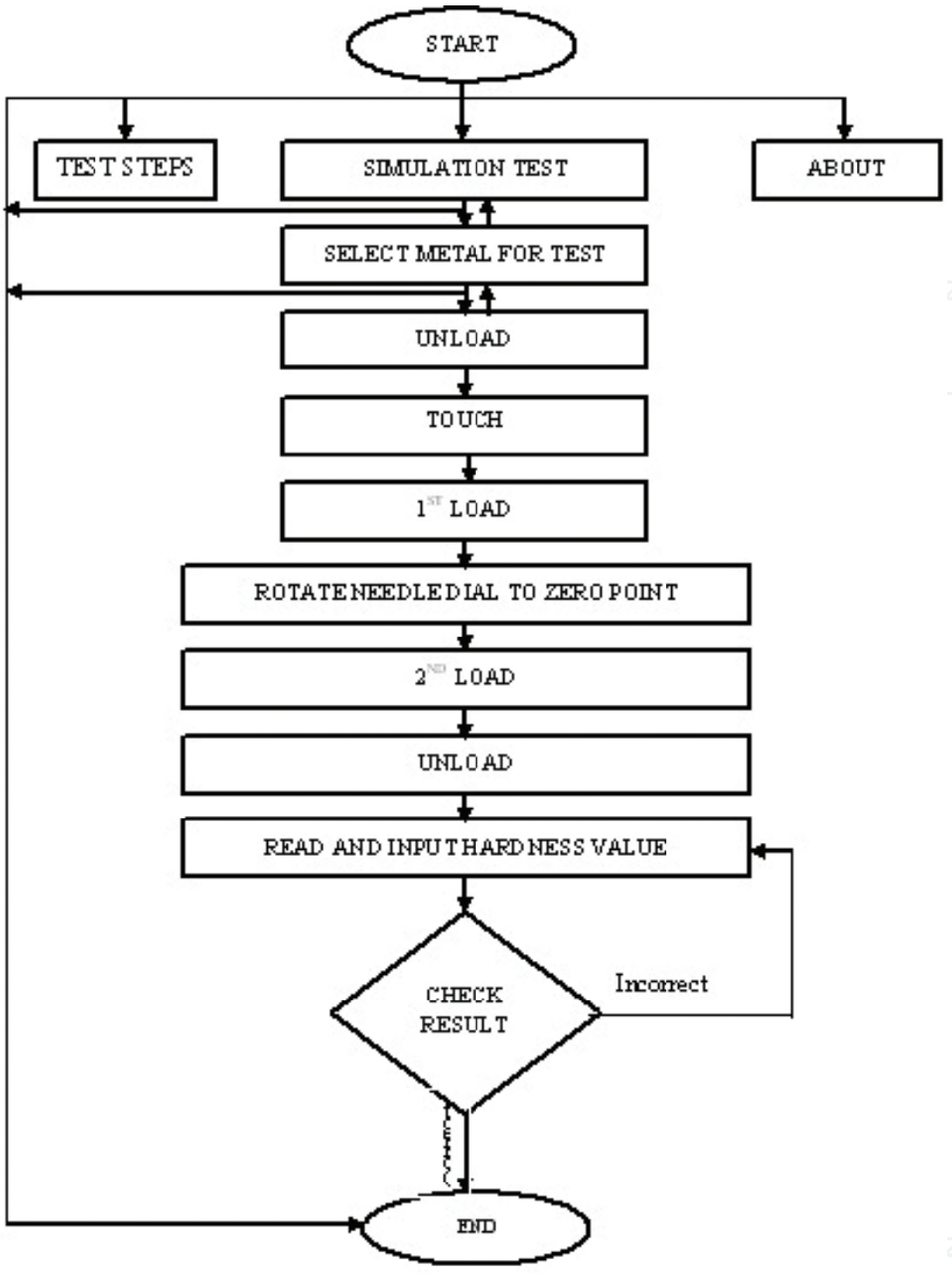



**Figure 5.** Flow chart of all the events in the proposed algorithm for the Rockwell test machine.

*4.2.4. Simulation model evaluation*

For validity purpose, the simulation model exemplified to 12 experts and specialists in the Department of Mechanical Engineering and the Faculty of Education in the Al-Furat Al-Awsat Technical University and the University of Babylon during the interview with them in their Departments. Also, Tokmak et al. [26] work in terms of evaluating the simulation system was found to be consistent with the purpose of designing the model in the present study. Additionally, the experts' discussion resulted in four main points. Firstly, with respect to the curriculum matching and procedures, they all emphasized that the model was matching

the planned curriculum for the students in the Department of mechanics. This included the experiment procedures, which were screened in a manner similar to the machines in the real word. One of the experts indicated the possibility of developing and adding some vocabulary to the model to be applicable to other similar colleges, institutes, and universities.

Secondly, with respect to accuracy and modernity, all the experts indicated that the results of the simulated model was found to be accurate, and based on their knowledge they had not seen such model before. Thirdly, with respect to the clarity of the used language, some linguistic corrections have been identified and some terms have been modified. All of the language corrections and terms modifications were taken into consideration by the researcher. Finally, with respect to the motivation, learners' participation, and the clarity of the design, all the experts emphasized that the model was rich soil for learning motivation. This is because the model contained exciting images and movements for the students, which could raise the possibility of engaging all the students in the tests and which could not be achieved by the traditional method. The experts also emphasized the clarity of the model's designation purpose. In general, the experts stressed that designing such model will support and facilitate education in engineering and educational laboratories. After taking into consideration all of the experts' suggestions and after modifying the model, the researcher reinterviewed the experts and they expressed full agreement on the model. As such, the model was ready to be applied to the students.

## 5. Conclusions

The influences of Rockwell hardness test simulation in achieving enhanced metacognitive skills are inspected. The researcher designed RHTS relying on established approaches is clearly able to identify striking simulation characteristics. Researchers are expected to employ the simulation design to evaluate the increased reliability and validity of the study instrument in identifying the presence of possible deficiencies during actual implementation [27, 28]. The simulation is executed to determine the effectiveness of metacognitive skills on mechanical engineering students of Iraq as test sample. Simulation design suggests that the developed model may serve as a research tool for both students and instructors in metallurgy lesson to improve their metacognitive skills. Laboratory experiments are carried out, data are collected, and computer algorithms are developed using Microsoft Studio 2010. Relevant theoretical background and formulae related to the RHTS are designed via user-friendly approach. The simulation model contains meticulously executed steps including the generation of metacognitive tasks, its goals, and effective tools that promote overall ability and efficiency in education. It is hoped that the capability of students in understanding metallurgy lesson will improve via the acquisition of metacognitive skills. It may also enable learners in controlling their cognition, emotion, and motivation in addition to solve complex problems in mechanical engineering. The present model simulation is highly instructive for successful process of cognition and learning. This simulation will definitely enhance the susceptibility of students to understand and solve multifaceted problems in metallurgy. Finally, it may be applied to the students of technical institutes in Iraq to know the influences on the enhanced metacognitive skills in engineering education.

The findings related to the proposed simulation model indicate that the simulated model was suitable for undergraduate Iraqi students majoring in Mechanical Engineering and they were appropriate for teaching metallurgy lessons to students. After examining the interview findings, the experts indicated that the curriculum and procedures in the simulated model matched the planned curriculum for the students. With respect to accuracy and modernity, all the experts indicate that the results of the simulated model were accurate. With respect to the clarity of the language, most of the experts identified linguistic corrections and modified a few terms. Finally, with respect to the motivation, learner participation and the clarity of the design, all the experts agreed that model is fertile soil for motivating learners.

The students were attracted by the simulated model as the instructions are written in a clear way and associated images and active interfaces were indicated using color. In addition, the students conducting the experiments on their own and at their own pace were easy and considered individual learning differences. This was consistent with Stančić and Yilmaz, who studied the features of effective simulated model such as user suitability, applicability, attraction to users, clear instructions, clear images and motions, and ease of use. The proposed simulated model was relevant, suitable, and applicable to the teaching medium.

The simulated model was designed using the ADDIE model that found to be applicable and efficient. ADDIE model provides clear instructions for each design step and calculated the errors for each stage before circulating to the next stage, which makes the final product more accurate and applicable. It also saves time, effort, and money if the product is fully designed at once, then found there are deficit in the product. In this case, the product was drawn from the market and reworked. Each simulated model for the metal machines was simulated according to the characteristics of each machine. Students using these simulated models found them to be easy and effective as each simulated model offered flexible options.

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