# Renewable Energy Remote Online Laboratories in Jordan Universities: Tools for Training Students in Jordan

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**Abstract**

The use of the concept of technology-enhanced learning is a design already applied in developed countries and incorporated as an active part of their educational models and curricular development. This is even more relevant in the case of eLearning, where these technologies correspond to remote / virtual laboratories. They are very useful in the fields of Science and Engineering. According to this, the current work shows the incorporation of this type of technology to traditional curricular schemes, with the aim of improving the effectiveness of learning. Another objective is to build reusable infrastructures among

Universities, supported with public and private government resources. Specifically, this paper shows the development, implementation, and integration of remote renewable energy laboratories in Jordan, and how they have been used within the director plan of the Jordanian government for the promotion of renewable energies in that country. This plan includes not only the design of remote laboratories but also their integration into a curricular model. This integration is done at the level of online learning courses and pilot experiences in the development of these types of learning technologies. In a distance methodology environment, the instructors must design the course structure keeping in mind that students are online, but not face-to-face in the classroom. Additionally, they have to propose adapted resources (remote laboratories, guidelines, etc.) and content.
The paper focuses on the incorporation of remote/virtual laboratories, showing how these labs were developed/integrated into online courses. To validate the incorporation of this type of resources in an environment usually not online, a set of surveys was designed to support a technology evaluation methodology (TAM, Technology Acceptance Model). This evaluation allows knowing the degree of satisfaction of the technology (remote and virtual laboratories as resources) using a structured experimental method (SEM, Structural Equation Models). As a result of the application of this experimental method, the calculated statistical data indicate that the use of remote and virtual laboratories improves the perception and use of virtual environments at a distance. Also, it can be indicated that these laboratories are presented as an essential resource to improve the quality of online teaching in engineering courses.

**Keywords**

Renewable Photovoltaic Energy Sources; eLearning; Wind and Solar Power Experiments; Remote Laboratories; University Education; Evaluation.

## 1. Introduction

The implementation and development of government policies should be based on the support of the available resources in the country itself. It must be supported by the appropriate external agents, aware of the success factors in the implementation of these government policies. In the case of Jordan, one of the defined objectives in the energy plan [1] [2] [3], developed by the Jordanian authorities was the training of qualified professionals in the field of renewable energies [4] [5]. These professionals should encourage and assist in the implementation of an energy policy based, not only on oil, but also on other sources of energy in which the country is very rich, such as solar energy. This way, the country's dependence on oil could be reduced to achieve its own energy infrastructures, allowing the full integration of these technologies as part of the electricity system in Jordan [6].

One of the barriers within the renewable energy development is the lack of qualified professionals [7]. This issue is more severe in developing countries, in which the gap between education and industry is bigger, and there is a mismatch in the curricula on this topic. Online learning and the employment of remote laboratories can be a solution to minimize this issue. With the aim of training these professionals [8], it was stablished that the University environment was the most appropriate ecosystem to implement a specific curricula in renewable energy as in many other countries [9]. So, the involved Universities, appointed by the Jordanian government, began to contact other institutions with proven experience in the field of education and, specifically, in renewable energies [10]. As a result of these contacts, it was possible to create a group of interest between European and Jordanian institutions. This group was granted with a project supported by the European Union through its Tempus program.

According to this, the MUREE (Modernising Undergraduate Renewable Energy Education) project [11] had the global objective of ensuring that Universities in Jordan could offer quality education, which was compatible with European standards. In addition to this, MUREE took into account the socio-economic needs of the emerging knowledge-based society by strengthening the teaching of renewable energy for professional graduates who can meet market needs of the country. From the perspective of the European Higher Education Area (EHEA), it is very relevant to consider the internal quality management of education based on the students' competences, moving us from teaching to learning [12].

There are also specific objectives of MUREE, which really define the actions needed to get the achievements:

1. Develop, integrate, accredit and evaluate a bachelor's degree program with an appropriate laboratory component in renewable energy, with the Bologna requirements in Jordan.
2. Involve teachers in the development of interaction techniques with remote laboratories and sharing experiences with European Union (EU) Universities partners.

3. Develop and implement courses content by using virtual learning environments (VLEs) and remote labs. VLEs are also known as Learning Management Systems (LMS).
4. Extend services and training in collaboration with the local and regional industry and community.
5. Improve the human capacity of Jordanian Universities by providing training and upgrading opportunities in the EU for aspiring young, men and women academic members and ~~of~~ staff.
6. Leave a longer-term legacy for Jordanian universities in engineering education.

To achieve these objectives, the development of specific components for learning and training becomes essential [13] [14]. Experimentation allows students to observe the operation of real equipment and the application of the theoretical concepts that are associated to the models studied in the classes [15]. This means that experimentation plays an essential role in engineering education. So, any institution dedicated to this type of teaching must incorporate laboratories as an essential part of its learning model. In the specific case of the MUREE project, the laboratories were deployed in different universities, so one of the main objectives was to share these laboratories among them. This way, the development of remote online laboratories became an essential prerogative for the project and the learning scenarios associated to them in the area of renewable energies. Likewise, the remote laboratories became the link between different Jordan Universities and the main tool for teaching the different concepts related to renewable energies.

This paper describes the different developments carried out to implement the different types of laboratories shared by the Jordanian Universities involved in the project, as well as other related works. The technologies used are shown, as well as the hardware and software architectures that support these laboratories. Next, the integration of the renewable energy remote laboratories in the VLE is detailed, emphasizing the management services of the laboratories in terms of access and authorization. In addition, it will be seen how this integration facilitates the development of virtual courses that use remote laboratories as a learning tool, and it can be easily extended to other types of laboratories [13] [16]. Finally, the data associated with the implementation of the courses and the learning results obtained will be shown, paying attention on the users' acceptance of technologies.

## 2. Related Works

This section summarizes a set of similar relevant works. These works were focused on reducing the gaps between formal higher education and renewable energies training. First, the influence of faculty over the learning process from the students' point of view, and their qualitative perspectives about renewable energies, is detailed in [17]. The study also considers the period of the educational programmes, which was offered at the Carl von Ossietzky University in Germany, as well as the later period of students' career and personal growth. Its main problem is that authors do not evaluate their proposal in a quantitative way, nor propose the employment of remote laboratories to improve the learning process.

In addition to this, the status and challenges of wind energies in the field of education and training in China are presented in [18]. Wind energy in China has been recognized as an important alternative kind of resource to complement the production energy of the country. At the end of 2012, wind energy was already the third energy source for electricity. This fact becomes very relevant since China is nowadays a big market place. For this reason, institutions have started to provide high-level education and training related to wind energy, which is accredited by Ministry of Education in China. On the other hand, some professionals and companies prefer short-time specialized courses to gain a fast knowledge to be applied in industry. Some of them have started internal courses for this purpose. This proposal has similar drawbacks than the previous one.

Another work [19] describes the level of students' knowledge regarding renewable energy at a University level; by including technical, economical, and policy issues in Palestine. Results do not show differences in students' knowledge in the field of renewable energies in terms of gender, educational level, and parental education. It concludes that specializations are correlated with the level of knowledge, and vocational institutions (and students) are currently more aware of renewable energies (paying attention on solar energy). Results shows that students' awareness and knowledge about renewable energies are now limited. Therefore, there is a gap between education and renewable energies that it is necessary to be reduced in a nearby future, but they do not state how to reduce this issue in a clear way.

In [20], the society's acceptability about renewable energies is discussed, since these kinds of energies are acquiring more importance, among other, due to the climate change of the world. The South Korean government has starting policies to increase the use of these energies. To measure the society's preferences, a hierarchical Bayesian model is employed in this work. Results show that the acceptability of renewable energies is very high, and it depends on the respondents' level of education. They not employ remote laboratories to improves courses, nor propose any technology acceptance model.

Additionally, a specific laboratory for solar and wind renewable energies, named RELab, which has already been employed in several institutions around the world is detailed in [21]. Its design and implementation are presented in this study, and the importance of using technology to reduce the gap between education and renewable energies is discussed, but acceptance of technological models is not measured.

The associated related works are very interesting to reduce the gap among education and industry on the renewable energies topic, even some of the cases with the support of technology. Their main drawback is that these proposals only make an evaluation in a qualitative and/or quantitative way, by using exploratory parameters, but not confirmatory ones with a set of hypotheses. To achieve this, a Structural Equation Model (SEM) [22] is built to get structural relations and significant results from several hypotheses, as well as validating them.

## 3. Renewable Energy Laboratories Deployment

To solve the problem of providing practical skills to students, technology-enhanced learning is suggested for wide-scale implementation across countries. This is based on the sharing of equipment between institutions. Despite the lack of equipment and funds at educational institutions, a set of achievements have been performed in this direction. This was a breeding ground for new researchers to establish a seamless, interoperable, and shareable integrated architecture that encompasses remote laboratories from several universities, to span their dissemination and inter-institutional operation. Inside this vision, MUREE aims the creation of a distributed network of shareable remote labs among the project participants in Jordan.

The lack of common standards in laboratory definition and connectivity specifications is a major drawback to the adoption and wide-scale networking of remote laboratories for teaching and training purposes. Some efforts have already been performed in the field of renewable energy due to its exponential growing. For instance, an ad-hoc tool, which is built over LabVIEW, for students and engineers to learn about solar and wind renewable energies in presented in [21]. Its main concern is that it is dependent on the commercial NI ELVIS platform. A standardized access interface could help in this direction, as it's done in our proposals.

To overcome this problem, the creation of adaptive Laboratories as a Service (LaaS) [23] is employed in this work. This is a service-based approach that allows the use of remote laboratories to be consumed from third parties in a versatile and customizable way. These LaaS are based on the deconstruction of remote laboratories into smaller "chunks", which can be combined to allow the flexible creation of customizable Remote Experiments (RE). The development of LaaS has among others the following benefits. LaaS allow the versatile creation of on-demand experiments. This can be achieved by means of using the laboratory services that are needed for each specific experiment, avoiding the need to use all the unneeded services, and thus keeping students away from the unnecessary complexity which may jeopardize their learning process. Thanks to this, the same laboratory can be used for a wide set of experiments/scenarios (just varying the services that are visible in each case), which increases their level of use. This also affects the revenue of the institution, since they can be used for more purposes at virtually the same cost.

Another main advantage of this approach is modularity. Each laboratory is composed by a set of HTTP RESTful web-services as interfaces. The internal details of these webservices are hidden for the final service consumer. In our case, remote laboratories must first be deconstructed. That means their functionality must be provided in an independent way for each service, similarly to [23]. Second, a container must be chosen to hold the clients and create customizable learning/teaching scenarios. Clients consuming the laboratories services must also be created and included in the container. A basic client can be a HTML page that access to the services by means of AJAX technology.

More details about the deconstruction of remote laboratories can be found in [24]. Particularly, as initial approach to this work, authors focus on the creation of a solar and aeolian remote laboratories, to work as adaptive LaaS as prototypes. These laboratories help students to understand how sun and wind is directly related to the generation of energy [25]. Also, these prototypes have been built using low-cost components, making their reproduction easily affordable for partners with restricted budget.

Once the effectiveness of the methodology selected for the construction of the remote laboratories and their implementation has been verified, four different remote laboratories have been selected within the project for their distributed deployment among the four participating Jordanian Universities.

These laboratories are:

- Wind and solar photovoltaics power trainer. This trainer (see Figure 1) that is designed to teach students the characteristics of solar photovoltaic panels and wind power generators. Students may be able to monitor data such as the output current, voltage and power from solar photovoltaic panels and windmills. Additionally, they will be able to measure temperature, wind speed, battery voltage and load current. The experiments covered topics such as load box and parameters configuration, measuring the characteristic curve of the solar photovoltaic module, measuring photocurrent by incidence angle and distance, theory of wind generation characteristics, wind and solar combined power generation, Trainer main components included windmill, electric fan, solar photovoltaic panel, anemometer, temperature sensor and load box. This trainer is physically located at Princess Sumaya University for Technology (PSUT).
- Fuel Cell. This trainer setup is designed to teach students the concepts of energy conversion using fuel cells, electrolysis and solar cells. The experiments covered were solar cell photovoltaic characteristics, solar cell as diode, electrolysis and fuel cell characteristics. The main components were solar cell, electrolyser, fuel cell and load box. It's physically located at Mutah University (MU).
- Hybrid Energy. The alternative energy trainer is designed to teach students the major alternative energy generation technologies using solar photovoltaic, windmills and fuel cells. The experiments topics as windmills characteristics, solar photovoltaic panels characteristics, using fuel cells for electrical generation and configuring combined alternative energy systems. The trainer main components were wind turbine, fan, solar panel, fuel cell, lights and rechargeable batteries. The hybrid energy trainer is physically located at Hashemite University (HU).

- Solar Tracking Control. This trainer setup is a two-axis solar tracking control system designed to teach students real-time control of the location of solar panels based on sun radiation and location. The trainer main components were Halogen lamps to replace the sun function, 10W solar photovoltaic panel, sensors for vertical and horizontal control and limit switches to get feedback of the position. It's physically located at Jordan University of Science and Technology (JUST).

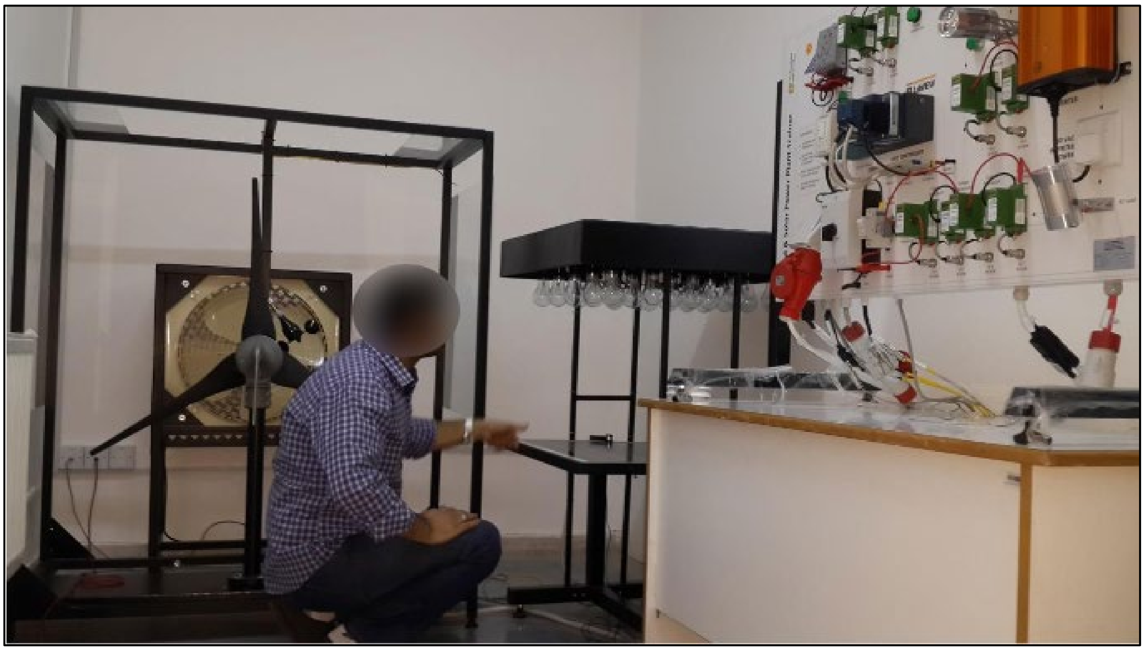

Figure 1. Wind and Solar Power Remote Lab Installed at PSUT. Source: DEV2.6-Labs and Educational station on RE report MUREE Project.

## 4. Assembling e-Learning courses and renewable energy laboratories

One of the main challenges reflected in the objectives of the MUREE project is the enforcement of educational innovation practices used in distance education environments. Due to this reason, six accredited online courses were created during the project (2013/2014 and 2014/2015 courses) to support the development of the project [26]. A snapshot of the experiment user interface, used in the remote experimentation for courses, is shown in Figure 2. These courses focus on:

- Energy Conversion.
- Solar Energy.

- Renewable Energy Systems.
- Electric Machine Drives.
- Sustainable Energy Conversion.

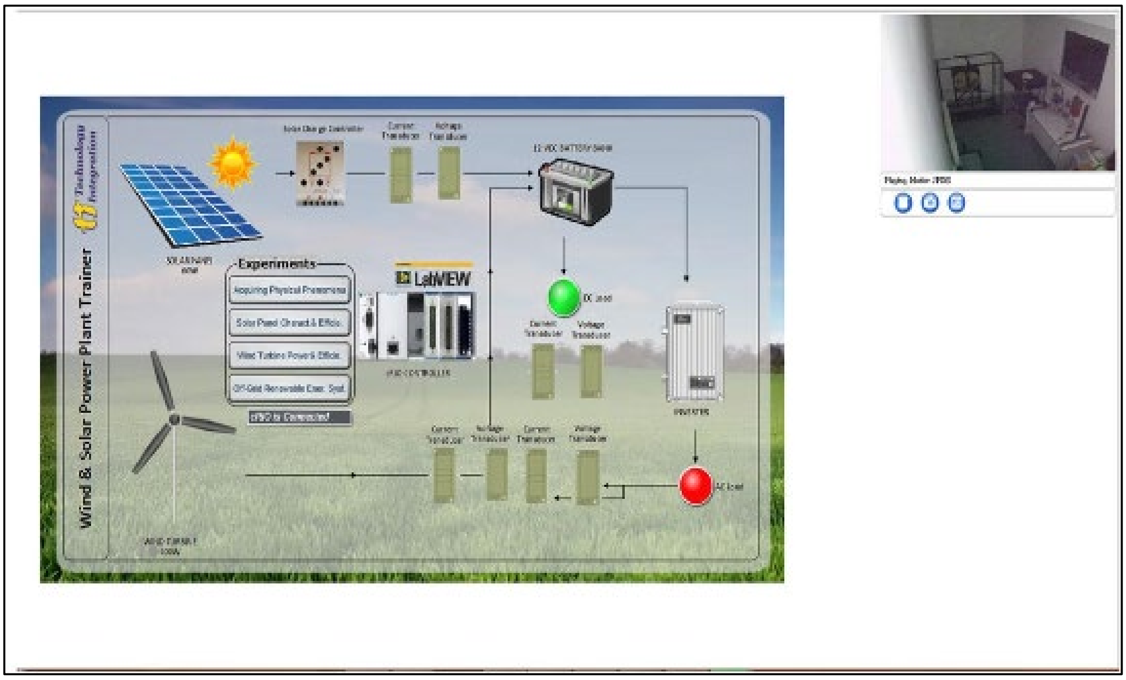


Figure 2. Snapshot of the Experiment User Interface. DEV4.3 Integration of Remote Labs into VLE.

The four university participants in Jordan are distributed geographically in a wider area, so students enrolled in these courses must use the online courses platform (LMS) to share the course's content and remote experimentation. Figure 3 show the Jordanian Universities involved in the project: The University of Jordan (UoJ), Princess Sumaya University for Technology (PSUT), Hashemite University (HU), MUTAH University, and Jordan University of Science and Technology (JUST). This was the first time they were using this combination of applied technologies, so a study of acceptation of these technologies could allow to know if the project was achieving their outcomes. Also, this LMS facilitates the provision of theoretical online classrooms by means of integrated features and tools, such as administrative tools, synchronous and asynchronous communication tools, assessment and tracking tools, multimedia sharing tools, and standard compatibility. The learning is conducted by LMS in online courses.


Figure 3. Geographical Area of the Jordanian Universities: The University of Jordan (UoJ), Princess Sumaya University for Technology (PSUT), Hashemite University (HU), MUTAH University, and Jordan University of Science and Technology (JUST).

However, there are not integrated features in the most known LMS which provides facilities to connect/integrate with remote laboratories. Fortunately, there are several initiatives which have been launched to integrate remote laboratories into LMSs.

The more remarkable approaches are:

- Using existing middleware software, called Remote Laboratory Management System (RLMS), such as MIT iLabs [28], WebLab-Deusto [29], Labshare Sahara [30]), RELATED [31], or the proposed in [32]. These RLMSs provide development toolkits to incorporate remote laboratories, as well as management tools and common services. But they must also be integrated into LMSs.
- Extending well-known learning content standards, such as SCORM and IMS (Lila Project [32] and Ocelot [33]) for the integration of remote laboratories into LMSs.

- Exploiting the different extension mechanism provided by the LMSs platforms.

The project used the last approach in order to keep simplicity of the solution and to reuse the LMS features. Every remote laboratory should manage a subset of the following features: authentication, authorization, scheduling of experimental sessions for users to ensure exclusive accesses, user tracking, and administration tools. These features are common to most remote laboratories, and they are independent of the remote laboratory objectives. On the other hand, the LMS environment provides students with all the theoretical documentation, protocol tasks, and complementary information they may need, as well as communication channels between students and instructors. An example of experiment for a solar remote laboratory integrated into Moodle is shown in Figure 4. The LMSs also provide features, such as authentication or authorization, but they must be extended with features with scheduling capabilities, as it is done in this work.

The Moodle platform [34] has been chosen for achieving our purposes. It includes the possibility of employing plugins, which are a flexible way of extending some of its features. An activity module was implemented to integrate the available services of remote laboratories. As a difference with other LMS platforms, the laboratory is seen as a set of services, a LaaS. It is not mandatory to integrate all the laboratory's services as a full module, by increasing the flexibility of creating lighter adaptive laboratories according the users' needs. The general functionality of the developed plugin for Moodle, the registration of laboratories and experiments, the creation of an experiment after its creation, and the execution of a session are detailed at [16].

In addition to the integration of remote laboratories within the work plan of the courses, students have been able to develop their skills through four face-to-face laboratories, which complement the training activities. These four laboratories focus on:

- Power System Protection.
- Power Systems.
- Electric Machines.
- Power electronics.

These on-site laboratories have been replicated in the participating Universities of the project (see Figure 5). When integrating these types technologies into a learning process by using a distance learning methodology, in our case remote laboratories for renewable energy, a set of characteristics could influence the curricular plan and, also, the students' workflow (and progress) within online courses. For this reason, remote laboratories for renewable energy must be adapted to the new way of teaching on distance. The design structure of an online course must be very detailed and guided. Additional resources (and how to use them) are necessary from this perspective, the way of teaching and providing content are different because students are not physically in class. It becomes essential to study the interaction among these characteristics, and their impact over the quality and outcomes in online courses, by also checking if the maintenance of quality at distance education is possible. The data of the current research will consider these indicators with the definition and validation of acceptance models.

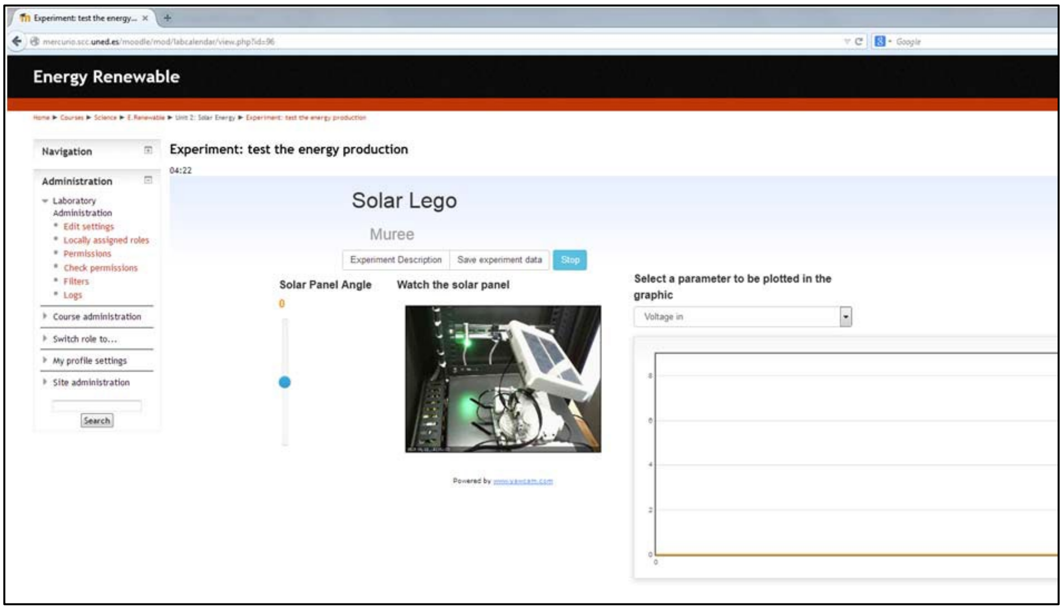


Figure 4. Experiment with a Solar Remote Laboratory into Moodle.

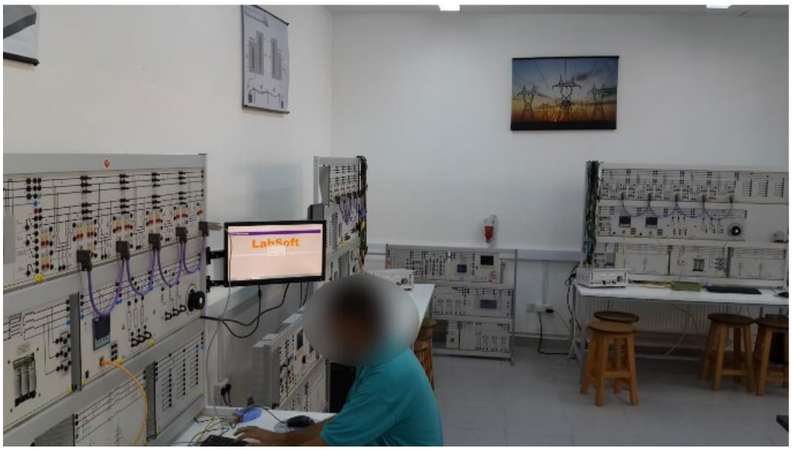


Figure 5. Electric Machines and Power Electronics Lab in Operation at PSUT. DEV2.6 Labs and Educational station on Remote Experiments.

## 5. Quality Evaluation of Online Classroom

In this section, the factors that influence the quality of online courses proposed for the MUREE project in Jordan [26] are studied both in exploratory and confirmatory ways. A set of renewable energy remote laboratories form are employed in these online courses as main resources. The answers obtained from the satisfaction survey are used for analyzing the overall courses' quality. Although the full quality evaluation will be shown, the conclusions will focus on the parts of the evaluation model that correspond to the use of remote laboratories as resources.

The survey was sent to students, which had enrolled in them, 79 answers were collected. When developing this research, statements of the survey were adapted from related works [36] [37], to infer learners' willingness to accept technological systems, in terms of usefulness, perceived ease of use, and intention to use. Each statement is a five-point Liker-type scale ranging from (1) "strongly disagree" to (5) "strongly agree". The questions are presented in Annex I, which refer to the design structure of the online courses, the proposed contents and resources in them, the instructors' behavior, and the general quality of the proposed online courses for renewable energy.

Some more modern efforts have been done in recent years. In [38], an online network focused on learning English enables students access resources, and interact among them, and with faculty. Researchers proposes a Technology Acceptance Model (TAM), which extend the external variables as well as the perceived constructors. By means of a Structural Equation Model (SEM) [22], they propose a set of hypotheses to be validated, which indicates that the extended variables effectively predict the intention to use similar online learning courses.

On the other hand, an extended TAM model to assess the acceptance and intention to use LMSs, which are considered as third generation of platforms, were proposed and validated in [39]. The obtained results pointed out the intention to use this third-generation of LMSs is determined by the gadgets and the design of resource containers, whereas the previous experience does not affect very much to the intention to use LMSs. Another interesting work [14] performed an exploratory analysis of a service-oriented learning/teaching system to automatically assess practical activities and check the students' progress in Computer Science Engineering. Ease of use, usefulness, and confidence are analyzed to find out the acceptance of this system. Students and faculty found the system significantly easier to use and useful for their purposes, as well as they are confident with it.

With the gathered data from surveys, an initial study effectiveness of the eLearning method has been made [26]. This study focusses on basic statistical methods (mean, standard deviation, t-test, etc.), but a more complex model can be built to get more structural relations and significant results. To achieve this objective, a SEM has been proposed. This kind of model is a general multivariate analysis technique that includes specialized versions of several other analysis methods as special cases. An application of SEM is causal modeling, which hypothesizes causal relationships among all types of variables and validates these ones with a linear equation system. Causal models contain either manifest variables, latent variables, or both. A manifest variable is a variable that is directly observable or measurable. In our case the manifest variables are the results of each question of the satisfaction survey. Latent variables are the objective variables of this type of analysis, which behavior can be observed only indirectly through their effects on manifest variables. In Annex I, latent variables are named as constructors, whereas manifest variables are named as statements. One latent variable is composed of a set of manifest variables, at least two.

In addition to this, we can distinguish between two types of variables according with its interaction with the context: exogenous variables (external and outcomes variables in our model) which have causes that are assumed to be external to the model; and endogenous variables (perceived variables in our model) which are predicted by other variables in the model.

SEM models have a graphical representation by means of a graph where nodes are latent variables and the arrows represents the correlation among endogenous and exogenous variables and, also, the prediction of outcomes variables. Remembering that these are exogenous variables.

A relevant case of SEM is the TAM was first introduced by Davis [40]. This model tries to predict and explain the users' acceptance of a given technological element. This model is widely used in different studies related to technology acceptance. It is based on the perception of utility and ease of use as key factors when deciding which information technologies (IT) is being evaluated. Perceived usefulness means that users think the technology of interest improves their performance. This model has been successfully adapted to its use in the education field [38].

The description of a SEM includes external latent variables or constructors (income or independent factors), perceived latent variables or constructors, and outcome latent variables or constructors (objective of the analysis). These three kinds of are not directly observable, since they are composed by a set of manifest variables. Our proposed model is shown in Figure 6. Our external variable is named Design Structure (DS), and it contains questions related to the structure of design for the online courses of the MUREE project.

A well-designed structure of the online course is clearly one of the most important points to keep in mind when developing the learning process of students, since it can help users learn more easily and reduce their cognitive load. Additionally, a user-friendly structure of a course allows students to take advantage of them and to be guided for a correct way of learning. Therefore, there is a clear relation between Design Structure (DS) and Content (C) variables. A relation between Design Structure (DS) and Resources (R) variables are also considered. The available services of renewable energy laboratories can be considered as resources. Variables about Instructors (I) may well be affected by Design Structure (DS) variables.

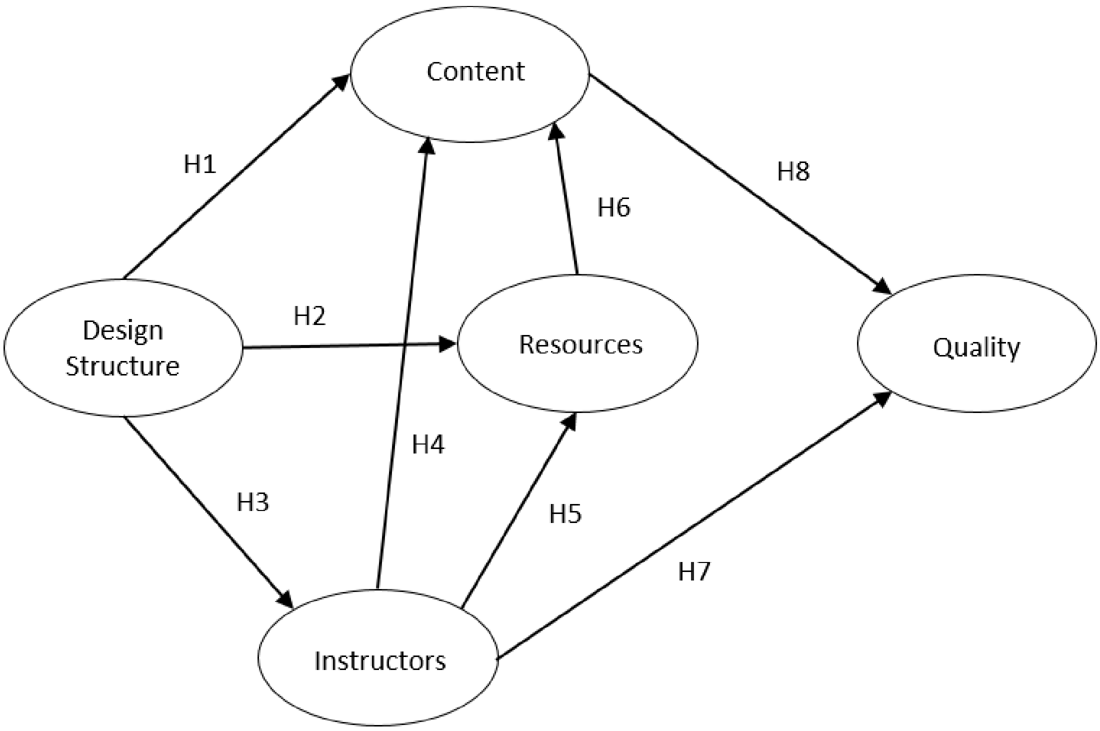


Figure 6. Proposed SEM for the Courses, in which laboratories are used. Hypotheses (H1 … H8).

The previous section linked online courses about renewable energy (in terms of their design, resources, content, teaching...), with the curricula when a distance methodology is employed. These factors have been transformed in a set of indicators, each of them composed of a set of questions, in order to establish a SEM model with the corresponding hypotheses, and to statistically validate it from both exploratory and confirmatory ways. The outcome quality of the proposed online courses will be examined. Considering this discussion, the following hypotheses are proposed:

- H1. Design Structure (DS) affects positively the Content (C) of the courses, where laboratories are employed.
- H2. Design Structure (DS) affects positively the Resources (R) of the courses, where laboratories are employed.
- H3. Design Structure (DS) affects positively the Instructors (I) of the courses, where laboratories are employed.

The perceived variables for our proposed model are Content (C), Resources (R) and Instructors (I). There can be also a set of relations among them. First, instructors select the resources (including the necessary services of remote laboratories) to be used in the course and, consequently, they are employed to generate content. The use of remote laboratories in online courses seen as additional resources can become very relevant during the students' learning process. According to this, instructors also decide about the content of the course, and laboratories' deployment.

On the other hand, there is a relationship between some of the perceived and outcome variables. In this case, both instructors and content will influence about the final Quality (Q) of courses. It has been considered to remove the relation among resources and quality, because their dependence is only indirect.

Hence, the following hypotheses for our proposed model have been identified, by considering our experience with online course and distance interactions with students:

- H4. Instructors (I) will positively affect the Content (C) of the courses, where laboratories are employed.
- H5. Instructors (I) will positively affect the Resources (R) of the courses, where laboratories are employed.
- H6. Resources (R) will positively affect the Content (C) of the courses, where laboratories are employed.

- H7. Instructors (I) will positively affect the Quality (Q) of the courses, where laboratories are employed.
- H8. Content (C) will positively affect the Quality (Q) of the courses, where laboratories are employed.

The outcome variable of our proposed model is the Quality (Q) of the courses, where laboratories are employed. Then, the model tries to predict if the courses' outcomes in terms of quality, due to the use of remote laboratories for renewable energies. Based on the above theoretical variables, our proposed structural model is presented and the relationships between all the factors that influence the use of laboratories are discussed.

### *Descriptive analysis*

Table 1 presents the basic psychometric characteristics of the model dimensions (DS, Content, resources, Instructors, Quality), as an exploratory analysis of the collected data from the survey filled by students (see Annex I to review survey questions). Psychometric properties are values oriented towards detect the quality of the analysis in terms of reliability, validity, standardization and equivalence. The values of the mean of each dimension are very good, and they are the calculated by adding the result of each item on the dimension and dividing by the number of associated statements. The standard deviation, minimum and maximum values are also giving for each dimension.

Table 1. Descriptive Statistics and Basic Psychometric Characteristics.

| **Dimension** | **Design Structure (DS)** | **Content** | **Resources** | **Instructors** | **Quality** |
|---|---|---|---|---|---|
| ***Mean standardized*** | 4.03 | 3.97 | 3.87 | 4.24 | 4.10 |
| ***Standard deviation (mean)*** | 0.094 | 0.099 | 0.109 | 0.096 | 0.098 |
| ***Minimum value*** | 1.00 | 1.25 | 1.00 | 1.00 | 1.10 |
| ***Maximum value*** | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| ***Cronbach´s Alpha*** | 0.987 | 0.986 | 0.988 | 0.990 | 0.986 |
| ***Asymmetry*** | -0.989 | -0.606 | -0.719 | -1.422 | -1.102 |
| ***Kurtosis*** | 1.350 | -0.025 | 0.285 | 2.594 | 1.069 |

Cronbach´s alpha is bounded between 0.98 and 0.99, as shown in Table 1. The best value is for 0.986, whereas the minimum value is for 0.990. According to [38] and [39], the factor´s reliability is adequate. Additionally, the asymmetry indicator measures the symmetry degree of the data distribution of each construct of the model, and kurtosis describes the concentration of data around the mean, respectively. The asymmetry values are negative in all cases, so their distribution tends to the left of coordinate axes, but not only concentrated in only one of the axes. The kurtosis values of constructors are positive with not very high values in most cases, and one of them negative with a very low value, so the data distribution is nearby the mean (they are not dispersed). Therefore, asymmetry values are also in the ranges of normality.

The basic psychometric characteristics of the variables used show that both the reliability of the scales and their average discrimination are adequate. Therefore, these instrument's psychometric properties are satisfactory.

***Confirmatory analysis***

Figure 7 shows how our model fits with the hypothesis proposed in this work, after performing a confirmatory analysis with the proposed SEM. Each arrow has been labelled with the resulting reliable influence value (shown as λ) for each hypothesis. As higher is λ, the influence of the starting node of the arrow over the ending node is stronger. If a λ-value is more than 0.4, it would have a high [41].

The analysis of the results obtained for the proposed model points out that the design structure of virtual courses clearly influences their resources (λ=0.72) and instructors (λ=0.96), who teach in them. That is, the use of remote laboratories affects the online course and instructors' teaching. In addition to this, the design structure slightly affects the content (λ=0.34) of the courses, but with less intensity.

From the proposed model, it can be checked that instructors affect with a low intensity the content (λ=0.23) and resources (λ=0.24) of online courses. Remind that the MUREE's laboratories are resources themselves, and they are part of the online courses' content. Additionally, resources affect the content (λ=0.42) positively. That is, remote laboratories have an impact over the renewable energy content, as well as instructors. Focusing on the analysis of data on the quality of online courses (see Figure 7), the content (λ=0.45) and instructors (λ=0.55) are both very relevant to have courses with a high quality.

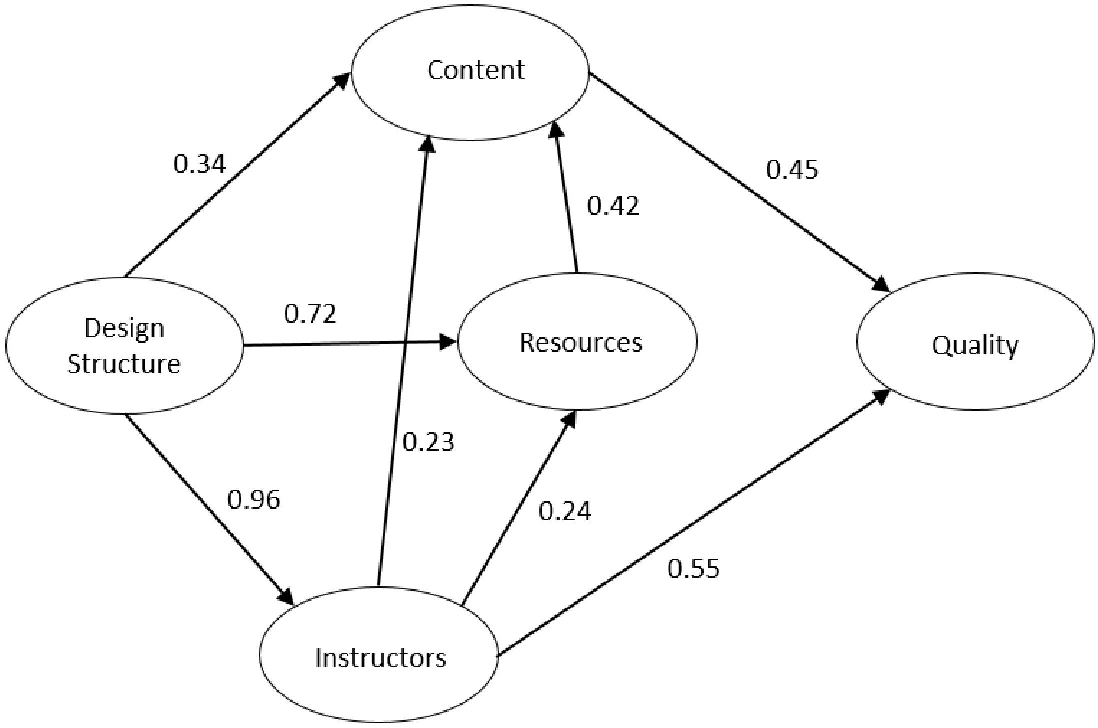


Figure 7. Proposed SEM for the Courses, in which Laboratories are used. Confirmatory Analysis.

Table 2 shows de most relevant statistical results obtained for the proposed model, once their confirmatory analysis has been performed. As for the proposed model, it can be observed that χ2/DF (Chi-square / Degree Freedom) is 0.857, which is lower than 3.0, and the χ2 is 1.713, which is higher than 0.5. So, they are good values for the model, since they are satisfies the optimal values detailed in the literature (according to [37] [38] [41]).. The GFI (Goodness of Fit Index) and CFI (Comparative Fit Index) indicators must be higher than 0.9. In this case they are good enough with a value of 0.991 for both. The RMSEA (Root Mean Square Error of Approximation) indicator of the model is also great, since this value is lower than 0.08.

Table 2. Statistical Results from the Confirmatory Analysis for Laboratories SEM.

| *Model for Laboratories* | *χ2* | *χ2/DF* | *GFI* | *CFI* | *RMSEA* |
|---|---|---|---|---|---|
| *Optimal values (according to [37] [38] [41]* | >0.5 | <3 | >0.9 | >0.9 | <0.08 |
| *Proposed Model* | 1.713 | 0.857 | 0.991 | 0.991 | 0.000 |

From all values shown in Table 2, it can be concluded that our proposed model has a good and reliable fit, since the values of these indices are above the thresholds of the optimal values [37] [41]. This fact means the collected data matches our SEM model, and all hypotheses are validated. In addition to this, comparing Figure 6 and Figure 7, it can be concluded that H2, H3, H6, H7, and H8 hypotheses have the stronger influence over the model.

The validation of the H6 and H8 hypotheses implies that there is a stronger influence on the use of remote laboratories (resources) on the content (H6) and quality (H8) of the online course itself. This influence is significant (0.42 and 0.48 respectively), and it is corroborated by the confirmation analysis. In this case, we can say the perception of the quality of the online course is directly related to the perception of the use of the virtual environment. So, it can be concluded that the use of remote and virtual laboratories improves the perception and use of virtual environments at a distance. Also, it can be indicated that these laboratories are presented as an essential resource to improve the quality of online teaching in engineering courses.

## 6. Conclusions

This work describes the efforts carried out by the Jordanian Universities involved in the MUREE project to adapt their courses to the online education or blended learning in the field of renewable energies. Their curricular programs have also been adapted to the EHEA, already standardized in Europe. In addition to this, the incorporation of remote/virtual to traditional curricular schemes has been described here, with the aim of improving the learning process and supporting distance education with shared infrastructures among institutions. In particular, the development, implementation, and integration of remote renewable energy laboratories in virtual courses are detailed. This is supported by the Jordanian government for the promotion of renewable energies. The remote laboratories are fully-integrated into the Moodle online platform, including access and authorization management services. A remote laboratory is viewed as another integrated resource within the virtual course, so it’s a way of improving the quality of the virtual course. Therefore, the curricular models of online courses are evolved by including these kinds of additional available resources and adapting the rest of them, and content, to a distance education methodology.

Perceptions from the users' points of view have been conducted to analyze students' satisfaction. Therefore, a structural model has been built to measure the quality of courses, which employ laboratories as resources to improve the learning process of students. The model has been presented and validated. Both a descriptive and confirmatory analysis have been performed. From the descriptive analysis of the proposed model, it is concluded the obtained values are suitable and in ranges of normality. The descriptive statistics and basic psychometric indicators have been the standardized mean, standard deviation, minimum and maximum values, Cronbach's Alpha, Asymmetry, and Kurtosis.

From the confirmatory analysis of the model, it fits the hypotheses defined in this work with a reliable influence form each one. The constructors are Design Structure, Content, Resources, Instructors, and Quality. From these variables, a set of hypotheses with direct effect were measured to find out: 1) how the design structure of courses can influence content, resources and instructors; 2) how content, resources and instructors may impact over the quality of online courses; and 3) how instructors could influence over content and resources, and these resources over the content itself. The design structure of courses undoubtedly influences the available resources (in this case, renewable energy remote laboratories) and instructors, as well as the content of courses. In addition to this, instructors' impact over resources and content, since they guide students during their learning process. As for the quality of online courses, both instructors and content impact about them. Finally, the proposed model has been validated by using a set of statistical indicators that they indicate the goodness of the model.

These indicators allow validating the influence of the use of remote laboratories as resources on the quality of the course (hypothesis H6 and H8 of the SEM model). So, it can be concluded that these remote laboratories are an essential resource to improve the quality of online teaching in engineering courses. Additionally, the use of remote and virtual laboratories improves the perception and use of virtual environments at a distance.

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# Annex I

| | Statements | Constructor |
|---|---|---|
| DS1 | The objectives of the course are clear | ***Design Structure (DS)*** |
| DS2 | The course is well-structured | |
| DS3 | The practical part of the content is supported well with relevant examples, by employing remote laboratories | |
| DS4 | Links to relevant disciplines is clear | |
| DS5 | Lecture and non-lecture content are well integrated | |
| C1 | The workload of the course is appropriate for the assigned credit hours | ***Content (C)*** |
| C2 | I am confident that subject content of the course is up-to-date | |
| C3 | Prerequisites to take the course are appropriate | |
| C4 | There is not overlap with other courses in the program | |
| R1 | Handouts are effectively designed to complement each lecture | ***Resources (R)*** |
| R2 | The teaching resources are appropriate for the course, by including remote laboratories | |
| R3 | Reading lists and references are linked to reading resources that are readily available | |
| I1 | The instructor times the presentation of the lectures effectively | ***Instructors (I)*** |
| I2 | The topics covered are explained well | |
| I3 | The instructor displayed a good knowledge of the subjects covered | |
| I4 | The use of teaching aids and media are appropriate | |
| I5 | The instructor motivates my interest in the subject | |
| I6 | The instructor communicates the material effectively | |
| I7 | The instructor is easily approachable following the lecture to answer questions | |
| Q1 | I would recommend this course to other students | ***Quality (Q)*** |
| Q2 | The course has motivated me to continue exploring the subject area | |
| Q3 | There is a positive atmosphere of “learning together” in lectures | |
| Q4 | This course is important for my career | |
| Q5 | The physical teaching and learning environment were of high quality | |
| Q6 | The course has significantly increased my knowledge in the subject area | |
| Q7 | I am confident that I can apply what I have learned in the course | |
| Q8 | Examination standards were made clear in the lectures | |
| Q9 | I was well-motivated to attend all lectures, and activities on this course | |
| Q10 | Working and learning collaboratively in groups was actively encouraged | |