# Comparative Study of Traditional, Simulated and Real Online Remote Laboratory: Student's Perceptions in Technical Training of Electronics

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**Abstract**—The developments in technology and communication networks have enabled the possibility of establishing virtual and remote labs, providing new opportunities for students on campus and at a distance overcoming some of the limitations of hands-on labs. The impact of innovations on students' performance can be analyzed statistically by looking at specific skills or indicators, respectively. This paper addresses the lack of empirical evidence supporting electronics education innovations in three practical teaching methods, namely, hands-on, simulation, and online remote real labs. The paper reports on the application of a methodology that takes into account the interaction between students and teachers at different levels of abstraction to evaluate a DC motor laboratory practice, on 150 students at the Polydisciplinary Faculty of Beni Mellal in Morocco. In this work the students' attitudes towards a specific practical method depend on its usefulness, usability, motivation and quality of understanding; these parameters were measured using a questionnaire that considers the relationship between the student, the teacher and the practical work environment. The data collected in each type of experiment environment were was tabulated and analyzed by statistical methods. The results validate the students' satisfaction towards the environments of practical works and identify some aspects that need to be improved in future works.

**Keywords**—Technical training, Engineering education, remote laboratories, simulation, hands-on laboratories, technology enhanced learning, practical work

## 1 Introduction

Practical exercises and experiments are fundamental in any technical discipline, whether in education or investigation. The simplest way to implement these activities is to go to experimental laboratories, which offer real pieces of equipment [1-4]. However, in recent years, the number of students enrolled in open access faculties has increased remarkably. Many of these experiments require special and expensive instruments or the number of equipment needed is not sufficient for all potential users because of their size and maintenance requirements [5].

The equipment necessary to carry out the practical works is physically installed and the students performing the experiments are invited to be physically present in the laboratory [6]. Simultaneously, communication and instrumentation technologies are evolving rapidly and dramatically, becoming available in most institutions. In such a scenario, virtual (simulation-based) or remote laboratories can play a crucial role in teaching specific areas of technical subjects such as electronics [7-10].

Indeed, simulated laboratories require only a personal computer (PC) and a software application. Thus, students can manipulate process and phenomenon parameters based on simplified models [11]. It is a method that should favor a better integration of the concepts taught, as it encourages the active participation of students in their learning process and should be conducive to the development of specific communication and interpersonal resource skills [12].

In [13], Rutten et al. develop an online PHET site (for Physics Education Technology). The most innovative aspect of PHET lies in the possibility of interacting directly with physical concepts and virtual devices, the main qualities of which are to encourage students to use them with a minimum of framing to explore physical phenomena [14,15].

On the other hand, remote laboratories try to reproduce as faithfully as possible the actions that the user performs in local laboratories. The same physical space can cope with much larger numbers of students, and greater flexibility can be offered to the students as to when they undertake their practical work. Various surveys on the design and implementation of remote laboratories have been reported since early 1990, and a useful review can be found in [16-19].

There are three particular circumstances when the provision of experimental work remotely can enable experimental work to be more readily offered to students [20]:

1. When the students are studying at a distance from the institution.
2. When the equipment required for the desired experimental work is considered prohibitively expensive.
3. When it is difficult to cope with large numbers of students given the available lab space.

Students have access to the experiments via an internet connection to the remote laboratories, based on a client-server architecture. They can come back repeatedly on concepts and practice learned by themselves, and these laboratories help improve the performance of the equipment available thus the access time [21,22].

In recent years, there have been several methods to approach electronic engineering, most of them focusing on motivating students to learn [23]. Various researchers have examined the suitability of remote and virtual laboratories for analog electronics and have recommended that remote laboratories should not be used in this field [24,25]. After a few years of technical evolution in remote sensing, this assertion has been challenged by the researchers who established the suitability of remote analog electronics laboratories from a methodological point of view.

This study aims to determine the impact of the use of the three methods of practical education (hands-on laboratories, simulation tools, and real online remote laboratories) on the perception of students, in a practical work that the authors have developed for this purpose. The perception of students regarding the usefulness, usability, the motivational dynamics of students, and the quality of understanding, these parameters in each type of experiment environment were measured using a questionnaire that takes into account the Students-Teacher-Environment relationship. The paper reports on the application of a methodology that operates at different levels of abstraction to evaluate a DC motor laboratory practice, on 150 students at the Polydisciplinary Faculty of Beni Mellal in Morocco.

The body of this paper is laid out as follows: Section 2 explains the nature of the pilot experience in the three practical work environments. Section 3 reports the assessment and evaluation, which focuses on the methodology followed, and the discussion of the results obtained. At the end of this paper, a general conclusion is presented summarizing the strong and weak points of the three proposed techniques to carry out the practical work and some concluding remarks.

## 2 Description of Practical Work Environments

This section focuses on the three practical work approaches selected for comparative study in order to conclude the perceptions of students in each type of environment. A description of the technology adopted in each type of practical work environment, as well as the organization and the steps to follow for the accomplishment of the work, is described in the following subsections.

A DC motors laboratory practice was selected for our studies because it is an attractive piece of equipment in many industrial applications requiring variable speed and load characteristics due to its ease of control, see Figure 1. It is a mechanism generally used to teach basic control concepts [26,27].

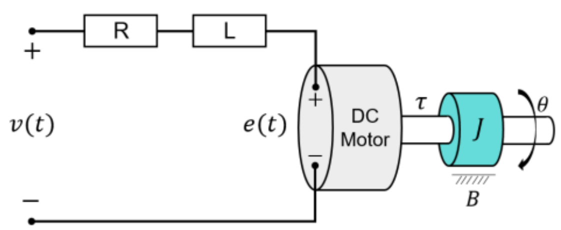


**Fig. 1.** Scheme of a controlled DC motor

### 2.1 Real online remote practical work

The advent of Internet technologies and new methods of sharing information has enabled the emergence of a variety of e-learning scenarios. The best known in the practical pillar of education is the creation of remote-controlled laboratories. In the remote laboratory, the same DC motor laboratory interaction between students and real devices takes place at a distance using an infrastructure based on a client-server architecture.

Information and guidelines for conducting the experiments using the experimental setup are provided to our students through our educational platform for distance learning FpVBm [28]. Usually, the experiment is done employing online applications, designed with a user interface to replace known laboratory experiences. Since data transmission is the central issue in remote experimentation, the architecture, the protocol, and the format play the three main roles in this communication.

The client-server architecture is defined on the central element, which provides all the information, data and services which are offered online. Figure 2 illustrates the architecture that the authors have adopted for the installation of the DC motor remote control in the laboratory.

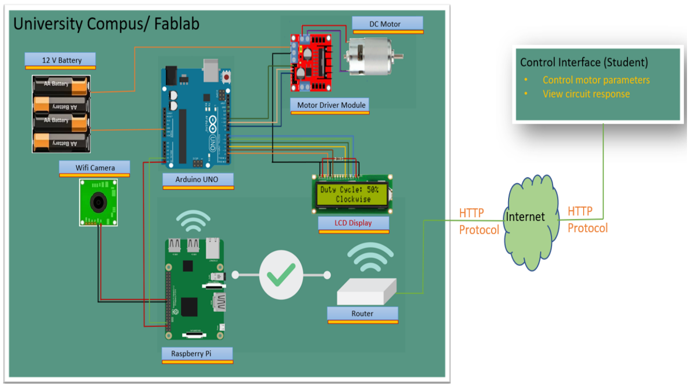


**Fig. 2.** The adapted architecture for the remote control of a DC motor

The purpose of the experience is to control two types of devices remotely:

- An engine has D.C current (Automating of DC engine)
- Command of an alternative power circuit with 220V

For this purpose, a Raspberry Pi running as a web server in the university's campus center and communicates locally with the Arduino microcontroller through the internet, which will allow a student using a computer/smartphone to access the command page deposited on the Raspberry Pi. Students can type the IP address "172.16.223.5" that the authors have predefined in the browser of a Wi-Fi device either in the same network dedicated to the exploitation of practical work or outside the university campus using another network.

**Fig. 3.** The real DC motor remote control system

Figure 3 shows the web page in HTML, which allows students to change and visualize the actual electrical states of the equipment. Through this web page, the student can command the DC motor and change the revolutions per second and the speed at which rotates. This last can command an alternative circuit remotely. Students can also program a PID controller for the acceleration of the engine speed by entering the values of Kp, Ki, and Kd [29,30].

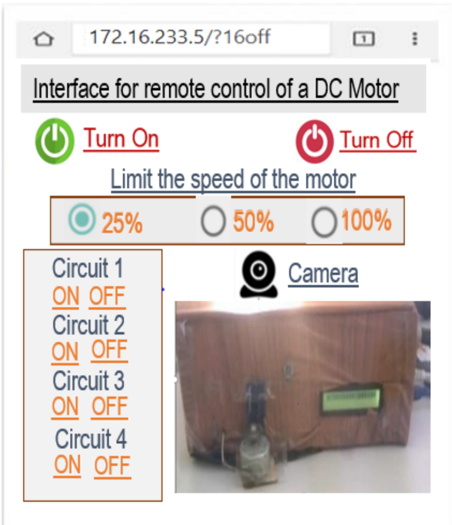


**Fig. 4.** The developed interface for the remote control of the DC motor

Students can supervise practical work via webcam and connect to a mini pc using VNC software (Virtual Network Connect).

### 2.2 Simulated practical work

The students perform the same practical work with a simulation tool. The Proteus ISIS software was chosen because it allows simulating the function of the Arduino and Raspberry. This software is mainly known to publish electric diagrams; besides, this last also makes it possible to simulate these diagrams, which makes it possible to detect certain errors as of the stage of design. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards. Thanks to this software that can be used in the most graphical aspect to control the DC motor experience selected for practical work in this work. In this lab experiment, students are asked to reproduce the same manipulation as explained in the online remote lab, in order to control a DC motor using Arduino. The students follow the teacher's instructions to perform the required measurements.

The assembly diagram is composed of the following elements:

- Arduino
- An engine has D.C current
- An integrated circuit of piloting of the engine
- Short props pushrods
- Measuring instruments and a map of relay

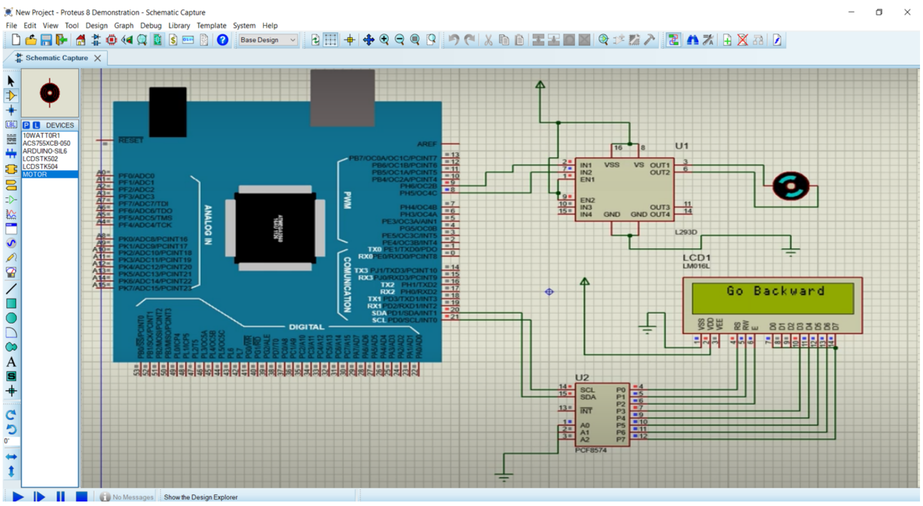


**Fig. 5.** The Dc motor control on the Proteus simulator

### 2.3 Hands-on practical work

In this part, the same students who performed the practical work by the first two methods carried out the same practical manipulations in a laboratory, which contains ten manipulations. A group of 150 students was divided into three sessions, 50 students in each session so that every five students were distributed to manipulate one practical work. A handout with instructions, questions, and procedures for the practical work was distributed to the students beforehand. Each group had to set up the practical work according to the sheet given by the teacher. In the end, the group of students had to make a report by answering the questions related to the requested actions.

## 3 Assessment and Evaluation

Capturing student perceptions of their learning experiences on different dimensions is an important issue in the evaluation process of any kind of practical work. The impact of innovations on students' performance can be analyzed statistically either globally or locally by looking at specific skills or indicators. In this work, the authors adopt a methodology that takes into account the interaction between students, teachers, and the practical work environment at different levels of abstraction to evaluate a DC motor laboratory practice and measure the satisfaction of our students with the three practical work methods.

We have defined that the students' attitude towards a specific practical work method depends on its usefulness, usability, motivation, and quality of comprehension, these parameters have been measured utilizing a questionnaire that considers the relationship between the student, the teacher, and the practical work environment during each laboratory session.

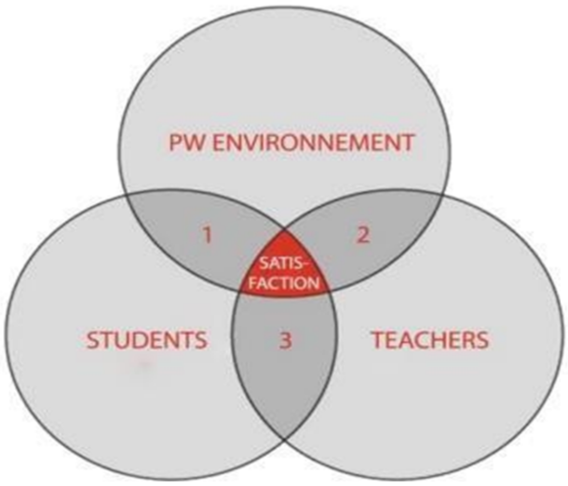


**Fig. 6.** Student-Teacher-PW environment relationship

The evaluation was carried out with 150 students enrolled in the physics degree program at the Polydisciplinary Faculty of Beni Mellal. Students were required to answer a questionnaire in the last of each laboratory session.

### 3.1 Methodology

The authors prepared questions for the survey based on key factors that were identified from the literature reviews in order to gather information on our students' perceptions when using each practice method [31-33].

The adopted questionnaire in this study consists of two parts:

- The first part focuses on the relationship between the three actors involved in the realization of the practical work, namely, students, teachers, and the working environment, in the three experiences as shown in Figure 6.
- The second part consists of measuring student satisfaction toward four indicators namely, usefulness, usability, student motivation, and quality of understanding in each experiment.

#### a) First part of the questionnaire

Students' and teachers' reactions and perceptions of their interaction toward each practical work environment are obtained by completing a questionnaire with closed-ended questions. Students were limited to answering **Yes** or **No** to the following questions presented in Table 1.

**Table 1.** Questionnaire on the interaction of the different actors in the practical works.

| | |
|---|---|
| **Interaction Students-PW environment** | |
| Q1 | The practical work environment is good for your learning? |
| Q2 | Is this practical work environment collaborative? |
| Q3 | Does the practical work environment save you time? |
| Q4 | Does the practical work environment provide you with Good understanding? |
| Q5 | Do you have more time flexibility in this practical work environment? |
| **Interaction Teacher-PW environment** | |
| Q6 | Does the practical work environment improve teaching transmission? |
| Q7 | Does the practical work environment ensure traceability? |
| Q8 | The practical work environment facilities the framing of the students? |
| Q9 | Is the practical work environment secure? |
| Q10 | Effective time utilization in the practical work environment? |
| **Interaction Teacher-Student** | |
| Q11 | Students more independent in this practical work environment? |
| Q12 | Stronger group work in this practical work environment? |
| Q13 | Do students make mistakes in this practical work environment? |
| Q14 | Are Students motivated in this practical work environment? |

#### b) Second part of the questionnaire

This part aims to measure the students' attitude towards each specific practical work method, which in this work depends on its usefulness, usability, motivation and quality of understanding. These indicators are obtained by filling in a questionnaire with closed-ended questions. Responses are rated on a four-point Likert scale

The authors define these indicators as follow:

- **Usefulness** of these methods, which refers to the level at which someone thinks using the new technology, will improve its effectiveness.
- **Usability** refers to the effort that someone considers necessary to use the technology and do the job required.
- **Motivational dynamics** of the students originate in the first place with the value that it grants to practical activities. As well as his perception of his competence with accomplishments and his feeling of control over their progress.
- **Quality of understanding** refers to the retention of concepts physical, the profit of information, and the level of the experiment.

The evaluation of these indicators in the three methods of practical work was carried out in total among 150 students. They were divided into three groups, with 50 students in each group. The first group was in charge of the manipulation in the laboratory, while the second group of students used the simulation method and finally the last 50 students performed the practical work using the real laboratory online remotely. The authors adopt the same factor applied at the same university to validate a new online practical work strategy on power electronics for embedded systems in 2017, to measure each indicator presented in Table 2 [9].

A K factor is calculated using both equations (1) and (2), where S is the average of the student responses for each question and K is the percentage of S by the number of choices in each question. In our case N = 50 represents the number of students in each group, M = 4 is the number of answers for each question and the "$R_j$" is the response of student j for each question.

$$S = \frac{1}{N} + \sum_j R_J \tag{1}$$

$$\mathrm{K} = \frac{S}{M} * 100\% \tag{2}$$

Each indicator was assessed by three questions, therefore, students' responses to these questions gave an overall picture of this indicator in each type of practical work. The average of the three factors for each indicator is calculated according to equation 3 and the results for the four indicators are presented in Table 4.

$$\mathrm{A} = \frac{1}{n} * \sum_{i=1}^{n} K_i \tag{3}$$

**Table 2.** Questionnaire on students satisfaction with four indicators

| Factors | Usefulness Questions | Response level |
|---|---|---|
| K1 | Q1: Was the PW environment useful? | 1. Yes, Totally<br>2. Yes, Partially<br>3. Not so much<br>4. Not at all |
| K2 | Q2: Were you able to understand how to control the system in this PW environment? | |
| K3 | Q3: Were the capabilities of the laboratory adequate? | |
| **Factors** | **Usability Questions** | **Response level** |
| K4 | Q4: Was the system in the PW environment easy to understand and use? | 1. Yes, Totally<br>2. Yes, Partially<br>3. Not so much<br>4. Not at all |
| K5 | Q5: Were you able to use fully the PW environment by following the instructions provided? | |
| K6 | Q6: The ideas and concepts incorporated in the laboratory was easy to follow? | |
| **Factors** | **Motivation Questions** | **Response level** |
| K7 | Q7: The value of the experience is interesting? | 1. Yes, Totally<br>2. Yes, Partially<br>3. Not so much<br>4. Not at all |
| K8 | Q8: The perception of your skill is high? | |
| K9 | Q9: Is your perseverance high? | |
| **Factors** | **The quality of understanding Questions** | **Response level** |
| K10 | Q10: Did the PW environment help you to learn the concept Faster? | 1. Yes, Totally<br>2. Yes, Partially<br>3. Not so much<br>4. Not at all |
| K11 | Q11: Was the level of the experiments adequate? | |
| K12 | Q12: Did you gain as much information as you would? | |

## 4 Result and Discussion

This section deals with the results and analysis of the data collected from the case study presented in the methodology section, where a well-structured questionnaire is used because they generate the response frequencies to compare student opinions.

The results of the questionnaire are presented in two parts:

- The first main part results of this study are summarized in Table 3, which refers to the students and tutors answered about their relationship in each environment of practical. These questions are presented in the first part of the adopted questionnaire in Table1, and the average of the actor's responses to each question are presented in Table 3.
- The second main part results of this study are summarized in Table 4. In this part, students answered 12 questions aimed at measuring indicators, namely, utility, usability, motivation, and quality of comprehension. These questions are presented in Table 2. and the average of student responses to each question are presented in Table 3, according to the statistical method presented in the methodology section using equations 1, 2, and 3.

**Table 3.** Results of the interaction of the different actors in the pratical works methods

| Interaction | Question | Agree (Remote labs) % | Agree (Simulation)% | Agree (Hands-on)% |
|---|---|---|---|---|
| Students - Environment | 1 | 80 | 75 | 95 |
| | 2 | 75 | 80 | 90 |
| | 3 | 95 | 80 | 75 |
| | 4 | 80 | 75 | 95 |
| | 5 | 90 | 70 | 60 |
| Teacher - Environment | 6 | 80 | 80 | 90 |
| | 7 | 85 | 80 | 90 |
| | 8 | 70 | 80 | 95 |
| | 9 | 100 | 100 | 75 |
| | 10 | 100 | 90 | 75 |
| Teacher - Student | 11 | 60 | 70 | 90 |
| | 12 | 50 | 60 | 80 |
| | 13 | 80 | 60 | 80 |
| | 14 | 80 | 60 | 80 |

Based on their responses, students believe that the three types of practical work environment presented in this study are generally valuable. The results presented in the first part of the questionnaire prove the flexibility of students in using information and communication technologies, mentioning that most of the students did not manipulate an experiment remotely before. The results indicate also that the student's interaction with the three practical work environments was high.

This assessment aimed to compare actors' attitudes with traditional, simulated, and real remote labs. The results of the first five questions in Table 3, which measures student perceptions of the three types of labs, showed that the majority of the students preferred the traditional laboratory to do technical experiments which also dominates in terms of collaboration.

Although the simulation and the remote-controlled lab have almost similar values, the authors can conclude that the students found that remote handling saves them time and gives them more flexibility. Results also suggest that remote labs are comparable in effectiveness to hands-on labs, at least in teaching basic applications.

Open-ended questions are a complement to closed questions that invite honest and personal comments from students. They are especially useful when the number of respondents is reduced [33]. The students were asked to provide the most common positive and negative aspects at the end of the questionnaire. The most common positive feedback from students on the hands-on experiment was their handling of equipment. On the other hand, students find that the time for reflection with the equipment is insufficient because of the number of students in the laboratory.

For the simulation, the most common positive comment was that the software environment allows them to establish the reality of the studied phenomenon or to measure electrical parameters. However, the students have a lack of contact with the real material. On remote manipulation, the most common positive comment was the connection to real experiments from any place at any time. However, Students suggested that the live experiment should be available over an extended period to gain full benefit from the experience.

The perception of the five professors who followed the three experiments also guarantees that when carrying out the distance work that they save in terms of time and safety, however, the subject is complex when the authors add to this the warnings of the professor on the use of the equipment, the fear of working with high voltages. But a face-to-face work remains essential when it is the first time that the students are in a laboratory where not only must understand and assemble the circuits, but also understand and see how the equipment works with the change of each component in the practical work.

On the other hand, the results of the satisfaction questionnaire which refers to the second main part results of this study are summarized in Table 4, the authors presented the average satisfaction of the three factors K dedicated to measuring each indicator calculated with equation 3.

**Table 4.** Indicator satisfaction results

| Parameters | Agree (Remote labs)% | Agree (Simulation)% | Agree (Hands-on)% |
|---|---|---|---|
| Usefulness | 95,75 | 95,25 | 97,75 |
| Usability | 95,25 | 97,5 | 98,5 |
| Motivation | 97,5 | 85,25 | 90,15 |
| Understanding | 95,15 | 90,5 | 90,5 |

From the results cited in table 4, the authors can note that the hands-on usefulness is adequate to other methods. Furthermore, usability using a remote lab is best than others with a minor difference. The authors can also remark that hands motivational and quality of understanding are very close to the simulation and remote lab. But in a general way, it proofs that it can be adopted in the current educational system taking into account the critical points.

## 5 Conclusion

The introduction of computer simulations, virtual instruments, and remote laboratories as an addition to hands-on lab sessions are powerful solutions to increase the efficiency of the engineering and technology education process. In this work, we have adopted a method that takes into account the relationship between student teachers and the environments of practical work in order to compare the satisfaction of our students by measuring some indicators. This information is fundamental to progress towards the best methods of teaching electronics in open access universities. The results indicate that student satisfaction with the three practical work environments is high, demonstrating the flexibility of students in the use of information and communication technologies, noting that most students had never manipulated a remote experiment before. The usage of labs in electronic education is a key element, and it gains more importance in the distance education paradigm due to the difficulties involved.

In fact, each type of laboratory has advantages and disadvantages. One can distinguish the fact that students prefer to combine the types of laboratories: simulated, hands-on, and remote lab, but also combine approaches to use classical instrumentation, virtual instrumentation, and modern dedicated instrumentation. Remote laboratories have the advantages of access, programming, and repeatability. As these laboratories are accessible at any time, they allow students to repeat the laboratories leading to a better understanding of the phenomena studied.

The authors are treating as future work the development of more complex experiments in electronics that will allow to compare the results of the practical work obtained in class and at distance with a large number of students, we also seek to take advantage of the automatic assessment paradigm to collect indicators in a fast and effective way, thus reducing the effort required in this process.

## 6 Acknowledgement

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