Starting the Study of Electronic Circuits with VISIR

Viewpoints of college students in a Pilot Test in Argentina

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Abstract—**This paper aims at introducing the first intensive use of a remote lab named as VISIR by lecturers and students from Facultad de Ciencias Exactas, Ingeniería y Agrimensura, Universidad Nacional de Rosario. The research was carried under the VISIR + project. It is a pilot test in which 17 students from the third year of an Electronic Engineering degree took part. The pilot test was developed in order to bring forward possible difficulties, assess successes and failures and eventually suggest other possible ways of curricular incorporation of VISIR in the teaching of the Physics of Electronic Devices subject. VISIR was used as a complement to hands-on lab, after the last experimental design activity of basic circuits with bipolar transistor. The students carried out an individual lab work. Then, they were asked to answer an opinion poll made up of 20 items, 1-4 Likert scale. Descriptive statistical analysis and summary of cases were carried out in order to conclude about four dimensions of analysis linked to the students' viewpoint. They are: perceived learnings, VISIR acceptance, perceived teachers' guidance and time and technical restrictions.**

Keywords—remote labs; VISIR; pilot test; curricular integration; fundaments of Electronics; engineering students

I. INTRODUCTION

Laboratories are essential in Electronic Engineering curricula. Well-designed laboratories and activities are supposed to cultivate scientific thinking, inquiry ability, and knowledge construction [1] [2]. Their development is essential for the understanding of theories and concepts, the interpretation of data derived from experiments, the application and putting into context of knowledge and the achievement of important competences for the professional practice [3]. Particularly, in the disciplinary field of Electronic Engineering (EE), the practices carried out in the environment of a laboratory make up priceless activities that allow students to build up and strengthen knowledge through the handling of equipment and data, instruments and electronic circuits. However, along with the shortening of the length of professional studies and, due to several reasons (scarce room for hand-on labs in the institutions, lack of equipment updating, among others), the reduction of time for labs within the Engineering curriculum has been reported [4], [5].

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Besides, the progress in knowledge, methods and techniques associated with the field of information and communication technology (ICT) has made the development of several educational applications easier. Learning Management Systems (LMS), many times boosted with emergent social communication tools and virtual labs are applications based on software development that have achieved widespread. However, they turn out to be insufficient when teaching experimental disciplines [7]. But also, over the last decades, and particularly in northern hemisphere countries, the need to support the development of lab practices (meaning interaction with equipment, materials and phenomena in real situations), has found a way in the development of remote labs. Among them, the Virtual Instruments System in Reality (VISIR) platform is one of these remote labs, suitable to practice in the area of electrical and electronic circuits. It was designed at the Department of Electrical Engineering (AET), the Blekinge Institute of Technology (BTH), Sweden. Quoting from [8] "*in VISIR laboratories, students perform physical experiments and laboratory work remotely*".

Outside Sweden, this remote lab has been set up in different European institutions, among which stand out Deusto University and National Open University in Spain, Polytechnic of Porto in Portugal and Carinthia University of Applied Sciences and University of Applied Sciences Campus Vienna in Austria. After the expansion of the remote lab platform, the VISIR Consortium created around it aimed at sharing experiences and experiments using VISIR as a learning tool which helps students and teachers to achieve the learning outcomes of subjects related to analogue electronics [9]. In this regard, in some research carried out by [10] it is concluded, among others, that both teachers and engineering students consider VISIR more useful in introductory courses. The same study [10] also shows that VISIR is a good choice when combined with a hands-on lab since it diversifies students' ways of learning and enables students to practice freely, increasing their confidence in the lab and enhancing their experimental skills. Furthermore, the continuous attention to the VISIR component by course teachers is highlighted as one of the elements to take into account in curricular integration [10].

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With the goal of spreading the knowledge about VISIR, the VISIR+ project was presented to an ERASMUS+ European Union call, being accepted in July 2015. To fulfil that goal, European universities that have the experience of using VISIR are transferring it to Latin American (LA) institutions, namely Higher Education Institutions with engineering degrees. One of the expected results of the project is a set of educational modules for engineering courses comprising the use of hands-on, simulated and remote labs, following an enquiry-based methodology.

This paper aims at introducing the first intensive use of VISIR by lecturers and students from Facultad de Ciencias Exactas, Ingeniería y Agrimensura (FCEIA), Universidad Nacional de Rosario (UNR), Argentina, one of the LA institutions in partnership with the pool. It is a pilot test developed in 2016, in which 17 students from the third year of an EE degree took part. With a view to effective implementation, the pilot test was developed in order to bring forward possible difficulties, assess successes and failures and eventually suggest other possible ways of curricular integration of VISIR in the teaching of the Physics of Electronic Devices (PED) subject. The aim, in any case, is that VISIR becomes a valuable resource of the curriculum, a facilitator of learning processes and insertable into the variety of teaching resources and strategies used in the subject.

Due to the importance of the context as a condition operating over the results of any curricular intervention, the following section describes the learning environment in which the experience took place. Firstly, general features of the subject and its regular teaching are shown. Then the focus is on the experimental activity carried out by students in the subject and the role of the labs (hand-on and remote) used in its regular teaching. In the section devoted to methodology the pilot test and its assessment are described. The results and conclusions arising from this experience are shown in sections IV and V.

II. The Learning Enviroment

A. The Subject

The PED subject is in the third year of EE at UNR. It accounts for the first approach students have to devices in the electronic world. One of the course aims is that students combine the scientific and technological foundations of basic electronic devices; that they not only understand their technical use, but that the student also "builds" and models physical structures and devices, discovers how they work, how they are polarized and capitalized on, being able to figure out parameters and to try some single application circuits. The teaching team offers students different teaching materials with theoretical backgrounds and activities: written modules, study and experimental activities guides, simulations based on java software, and others developed by the teachers. There is also an hypermedia system and the "Electronic Physics Remote Laboratory" (http://labremf4a.fceia.unr.edu.ar/). Both of them were developed by the teacher team. This remote lab is integrated with an e-ducativa technology platform [11], and also with Facebook and Twitter [12]. Furthermore, it has been federated with Web-Lab Deusto (Deusto University Remote Labs System), allowing students to have access to Deusto remote laboratories; among which the access to VISIR Platform is available [13].

For teaching purposes, the subject is organized into theory and laboratory lectures. Teaching time involves a whole 6 hours a week, with an allocation of 3 hours for theory and 3 hours for laboratory work, during a 16-week quarter. The teaching team as a whole has been trained in the use of VISIR and is motivated for its curricular integration. In order to achieve understanding and knowledge acquisition, it is sought to keep coordination between theory and laboratory. Each lecture type, irrespective of which of them, has a head teacher. In every case there is an appropriate relationship number of teachers/number of students and Internet access in the classrooms. The aim of this is to allow for the development of a multimedia teaching process focusing on the student's activity, offering guidance and customized monitoring of learning.

B. Experimental Activities. Resources and Strategies

In this subject the experimental training is highly important and, according to the curriculum, 16 experimental works take place among hands-on and remote labs. These experimental works comprise from an introductory one for the student to make contact with the instruments in the hand-on lab up to the design and test of diode and transistor basic circuits.

The activities in the hands-on lab cover the analysis of curves and of devices behavior, the calculation of parameters, the modelling and study of properties of different devices, such as: LDR, thermocouple, thermistor, different junction diodes, photodiodes, LEDs, bipolar transistors, JFET and MOSFET. Meanwhile, the remote laboratory developed at UNR is offered to students as a means to incorporate the experimental observation of curves for the theory construction and to guide deeper analysis about the behaviour of basic electronic components and hand-on experiments [14].

Both experimental activities involving circuits, with diodes and with transistors, are conceived as integrative ones. They are brought up to students as open problems after the dictation of the issues envolved. The students are supplied with the protoboard and the necessary components for them, as a group, to make and try the designed circuit application. Although students have some previous knowledge of the theory and about circuits' calculation, at the moment of developing these activities, their curricular path in the area of electronic circuitry starts with this subject, by experimenting circuits. It is a challenging and motivating but at the same time, a complex task for students.

In this regard, it has been reported that in the particular issue of Fundamentals of Electronics, engineering students have difficulties understanding each operation of the electronic circuits, mainly due to their different performance depending on configuration and the load specified [15]. These findings are in agreement with the teacher team´s in PED, who also have observed the difficulties that students have when going from the comprehension of the physical functioning of a device to the comprehension of the behaviour of its typical curves, and furthermore, to the integration of the device into a specific purpose circuit.

C. Curricular Incorporation of VISIR: the Pilot Test

Taking into account the nature of the subject involved, the features of its teaching, the teaching resources available, the potential of VISIR and the difficulties linked to apprenticeships, the way VISIR lab is incorporated into the curriculum was suggested as a complement to hands-on lab, after the last experimental design activity of basic circuits with bipolar transistor. The activity was proposed as an integrative one. It was brought up to the students as a compulsory and individual lab work. It was developed in December 2016, after the carrying out of the last lab work in the syllabus, outside the academic calendar. The 2 lab teachers and the 17 students who regularly attended the subject in the second semester took part. The time of year, the intenseness of the subject teaching and the fact that it was not possible to fit the official activity calendar of the semestre in time implied that the conditions for the incorporation of VISIR were not the ideal ones. In this regard, one of the results of the previous educational research is that students need a hands-on practice session before they start using VISIR [10]. But in the case described, the teachers introduced VISIR in a demonstrative session. They explained to students what the activity to be carried out was about, the features of the VISIR lab and how to access its manual. They also gave students the user names to access the RL VISIR WebLab Deusto. Teachers also suggested December 31, 2016 as the deadline for students to send them the activity done. Doubts were settled via e-mail and in a tutorial face-to-face lesson over the duration of this process. The activity was called: "Basic amplifier circuit with transistors with VISIR Remote Lab test". The instructions were handed in in writing. They combined preliminary circuit analysis questions, which asked for a mathematical solution together with practical activities with VISIR. During the first part of the activity the circuit to be tested was set forth (Fig. 1), requiring for a first circuital analysis with continuous source for students to: a) Identify the way it is connected; b) Specify the working point; c) Determine the load line and d) Indicate how they would experimentally measure the values obtained.

After solving the above, the activity asked for the use of VISIR. Students were already familiar with the use of protoboards, with real instruments and with the wiring of basic circuits with bipolar transistors. After the mounting of the circuit in the VISIR protoboard, students had to: a) Verify if results obtained in the previous calculations were right and b) Infer about possible differences in the results.

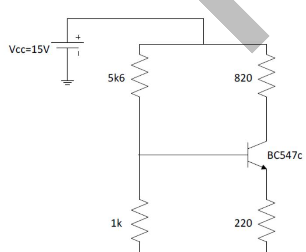

Fig. 1. Circuit set forward for the first part of the activity with VISIR

In the second part of the activity using VISIR, the small signal amplifier basic circuit was suggested (Fig. 2).

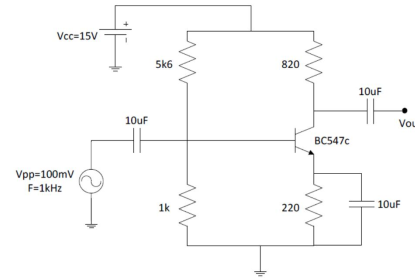

Fig. 2. Circuit set forward for the second part of the activity with VISIR

Students had to try the second circuit, and:

- Watch its performance while varying signal frequency and amplitude, with and without the use of the decoupling capacitor.
- Answer about the function carried out by all the capacitors in the circuit.
- Explain why input and output signal connections are placed in the suggested way.

III. METHODOLOGY

As students' individual reports were received, they were asked to answer an opinion poll elaborated by the members of the VISIR+ project, the ones in charge of Work Package 3, who belonged to Polytechnic Institute of Porto, Portugal, and National Council of Scientific and Technical Research (IRICE), Argentina. The survey is made up of 20 items, 1-4 Likert scale, where 1 means "Disagreement" and 4 "In total agreement", apart from 2 open questions, namely:

- What have you found most interesting when using VISIR? (Q21)
- What drawbacks have you found when using the remote lab? (Q22)

The survey results were processed with the SPSS-18 Software. Firstly, an analysis of frequencies was carried out over the quantitative variables (Q 1 to Q 20) in the Likert scale. In order to get to a conclusion about 4 dimensions considered of interest, the Q variables were grouped building up new quantitative variables Dq. These 4 grouping variables were transformed as categorical variables D. After defining 3 categories associated to each variable D, a case analysis was performed. This analysis over the Likert scale was supplemented with the analysis of the information regarding users' accesses and connection time given by the server at Deusto University. Finally, the answers to questions Q21 and Q22 were taken into account in order to illustrate the results of the previous analysis.Results

The 17 students who completed the course fulfilled the activity with the VISIR remote lab. The survey was completed by 15 students. Table I shows some results.

TABLE I. AVERAGES AND MODES FOR LIKERT SCALE

Likert Scale. Questions and some basic evidence-based results		
Question	*Average*	*Mode*
Q1. I was able to use VISIR 24/7 with which I carried out experiments frequently.	3,26	3
Q2. VISIR helped me understand better some issues in the subject.	2,93	3
Q3. I would rather make traditional experiments than use a remote laboratory.	2,00	2
Q4. I found support in the institutional LMS (hyperlinks, manuals, forums, etc)	2,20	2
Q5. I tried the experiments several times when I found that results were strange.	3,00	4
Q6. I found that devices were easy to use.	3,40	4
Q7. I shared the VISIR experiments with acquaintances who do not belong to the college.	1,80	1
Q8. I could easily find a place in the system to use VISIR.	3,60	4
Q9. I consulted the VISIR manual to learn more about the systems.	1,80	1
Q10. The instructions for the experiments were always clear.	2,93	3
Q11. I have always shared the results with my fellows.	2,80	3
Q12. I was less afraid of damaging the remote lab system than when I work with circuits in the traditional lab.	3,80	4
Q13. I carried out experiments which were different from the ones I was allocated.	2,13	3
Q14. I think I can handle the remote lab very well.	2,93	3
Q15. I have had many difficulties with the server.	1,06	1
Q16. I think I can solve many real electricity problems.	2,73	3
Q17. I wish I had remote lab for other subjects.	3,46	4
Q18. I can see similarities experimenting with remote labs as with traditional labs.	3,40	3
Q19. I found it difficult to find time to carry out the experiments allocated.	1,46	1
Q20. I could use the scientific concepts to explain the results of the experiments.	3,53	4

The 4 dimensions with their categories and the variables that make them up are summarized in Table II. The Likert scale includes two questions whose statements assign values by opposition. Q3 makes up D2, and refers to preferences of hand-on lab over remote lab assigning 4 "In total agreement "and 1 "Disagreement" to students' preference of remote lab over the hand-on one. But the other questions that contributes to the building of D2, link value 4 "In total agreement" with reference to the remote lab. Similar situation happens in Q9 as regards D3. So, Q3 and Q9 were not included in the transformation process; although they were taken into account a posteriori.

TABLE II. DIMENSIONS AND CATEGORIES

Likert scale. Questions and some basic statistical results		
Dimension / new variable	*Variables that make it up*	*Categories*
D1. Perceived learnings	Q2, Q5, Q14, Q16, Q20	Scarce Moderate High
D2. VISIR acceptance	Q1,Q6,Q7,Q8,Q11,Q12,Q13, Q17,Q18, (+Q3)	Low, Medium, High
D3. Perceived teachers' guidance.	Q4, Q10, (+Q9)	Not Enough, Some, Enough
D4. Time and technical restrictions	Q15, Q19	Scarce, Some, Many

The numerical values defining the conceptual categories associated to each dimension were stated by the researchers, according to a criterion taking into account:

- (N) number of Q variables making up each D grouping variable;
- The maximum and the minimum values that D might have in each case;
- Gradation 1-4 in the Likert scale being 1 and 2 linked to "disagreement" and 3 and 4 to "agreement" and
- The definition for each D, of the lower and upper limits in a range of values that might be classified as intermediate.

With the quantity variables Q of the Likert scale and their corresponding D grouping variables, the case summary was carried out. The complete results for D1 are shown in Table III; while the results corresponding to D2, D3 and D4 are summarized in Table IV, Table V and Table VI, respectively. They include the number of cases (F) and the average for each category, calculated for the Q variables that make up the corresponding dimension D. Table VII summarizes the results of comparing the two groups (Student t-test) for D1, D2 and D3

TABLE III. D1.LEARNINGS PERCEIVED BY STUDENTS

D1. Learnings perceived by students. Cases by category, frequency and statistical average by variable. Totals by category of the grouping variable D1 according to component Q								
Category	*N*		*Case*	*Q2*	*Q5*	*Q14*	*Q16*	*Q20*
High	1		1	3	4	3	3	3
	2		3	3	3	3	3	4
	3		6	3	4	3	3	3
	4		10	3	4	4	2	4
	5		11	3	2	3	4	4
	6		12	3	4	4	3	4
	7		14	2	4	3	3	4
	8		15	4	2	3	4	4
	Total	F		8	8	8	8	8
		Average		3,00	3,37	3,75	3,12	3,25
Scarce	1		7	2	2	2	3	3
	2		8	4	3	2	2	3
	Total	F		2	2	2	2	2
		Average		3,00	2,50	2,00	2,50	3,00
Moderate	1		2	3	2	3	2	4
	2		4	3	3	3	2	4
	3		5	2	4	3	2	3
	4		9	2	3	3	3	3
	5		13	4	3	2	2	3
	Total	F		5	5	5	5	5
		Average		2,80	3,00	2,80	3,20	3,40

TABLE IV. D2.VISIR ACCEPTANCE AND SIMPLICITY OF USE

D2. VISIR Acceptance and Simplicity of Use. Number of cases (F) and averages for each Q component, by category									
Category	*F*	*Q1*	*Q6*	*Q7*	*Q8*	*Q11*	*Q12*	*Q13*	*Q17*	*Q18*
High	8	3,50	3,62	2,00	3,62	3,50	3,75	2,25	3,62	3,50
Medium	7	3,00	3,14	1,57	3,57	3,00	3,85	2,00	3,28	3,28

TABLE V. D3. TEACHERS' GUIDANCE PERCEIVED BY STUDENTS

D3. Teachers' guidance perceived by students Number of cases (F) and averages for each Q component, by category			
Category	*F*	*Q4*	*Q10*
Scarce	2	1,00	1,50
Moderate	11	2,18	3,09
Enough	2	3,50	3,50

TABLE VI. D4. TIME AND TECHNICAL RESTRICTIONS

D4. Time and technical restrictions Number of cases (F) and averages for each Q component, by category			
Category	*F*	*Q15*	*Q19*
Some	1	1,00	3,00
Low	14	1,07	1,35

TABLE VII. STUDY OF DIFFERENCES ATTRIBUTABLE TO TEACHER

Study of differences attributable to teacher							
		Test of equality of variances Significance			*Student t test Bilateral significance*		
Teacher	*F*	*Dq1*	*Dq2*	*Dq3*	*Dq1*	*Dq2*	*Dq3*
A	8	0,659	0,099	0,190	0,590	0,335	0,699
B	7						

As it was stated before, both Q3, associated to D2, and Q9 associated to D3, ask for a different analysis. Fig. 3 and Fig.4 show the results of the frequency analysis.

The results on the number of accesses and connection time's users are shown in Fig.5

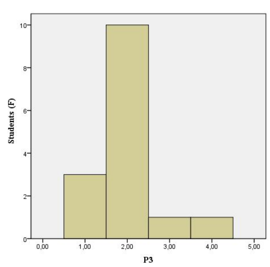

Fig. 3. Students' answers frequency in Likert scale for Q3. "I prefer traditional experiments to remote lab"

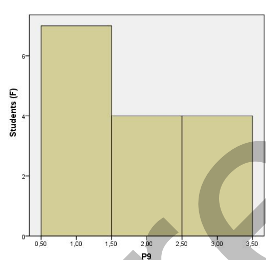

Fig. 4. Students' answers frequency in Likert scale for Q9. "I consulted the VISIR manual to learn more about the systems"

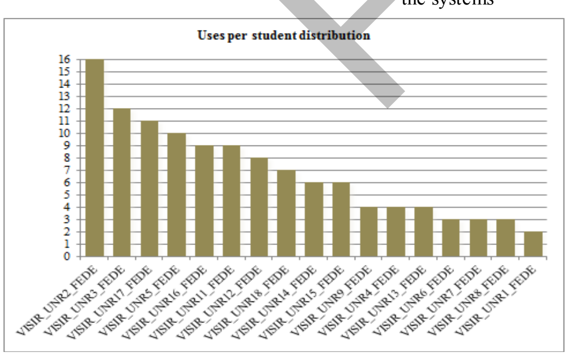

Fig.5. Amount of accesses per user to WebLab-Deusto VISIR

A total of 117 accesses were recorded, being user codified as VISIR_UNR2_FEDE the one with the highest amount of accesses to the remote lab (16 accesses), recording a total 1843.62 s. use times. However, user VISIR_UNR9_FEDE was the one who recorded the highest total connection time to VISIR lab, 7880 s, with four accesses. The total usage time by users was 254221.22 s, with an average of 10168.85 s per user.

IV. CONCLUSIONS

The pilot test in this work made part of the first experience at using VISIR by students from FCEIA – UNR. The study carried out tried to contribute to the achievement of goals of the VISIR+ project. But besides, and beyond the small size of the population, the study was aimed at obtaining first-hand information which allows the team of teachers of the subject PED, to foresee the difficulties, assess successes and failures with a view to the curricular integration of VISIR in 2017.

The study context conditions were not the best ones. And we should bear this in mind when considering the results obtained. They make reference, among others, to the learnings achieved in the field of circuital electronics, to the use of VISIR as a teaching resource and to the conditions which, from the institution and from the teachers' work, become relevant if we want students to develop competences and to build valuable knowledge in the fields of Engineering Education.

Although the experience was coordinated by two different teachers, each of them with their own group of students, the results are not differentiated. This is due to the fact that from the application of Student t test (Table VII) it turned out that the factor "teacher in charge" had no influence, at least in this experience, over the behavior of other variables.

Regarding the learning achievements, the analysis of Table III allows us to state that only 2 out of the 15 students taking part in the test have perceived that their learnings with VISIR were low. However, the teacher team has collected the students' productions and we can state that all of their works were satisfactory. All of them could fulfil the activities given, accompanying the explanations with snapshots taken from the VISIR client interface. Some students even tried variations in the circuit and in its input stimulus thus answering more to their curiosity than to the instructions. Going back to Table III, it is seen that students who do not perceive important achievements in their learnings are the same who answer Q5 unfavorably: "I tried the experiments several times when I considered the results were weird". Whereas, on the other hand, irrespective of the category, most students state they have been able to use scientific concepts to explain the experiment results, revealing the achievement of valuable integration processes for the learning of the electronic devices.

The analysis of both, Table IV and Fig 3, apart from students' answers to Q21, show high acceptance of the VISIR lab. On the one hand, the cases summary shows that all students were divided into the categories high and medium. Besides, to question "What have you found most interesting when using VISIR remote lab?" (Q21), the students remark:

- *The practicality and simplicity; the quick system answer*

- *The possibility to try several circuits totally for free and without it being a simulator, that is to say, that the circuit was real and it was being tested in real time, knowing I could try out things without any damage.*
- *The fact of setting the connections in an interactive way giving me the chance to make mistakes and so realize about my faults.*

With the aim of assessing the results obtained for Q7 and Q13 (Table IV), it is important to consider the time of year the pilot test was carried out; very near final exams dates. There is room to think that the short time and the fact that the activity was given as compulsory to be done individually, was the reason why many students opted for the strict and early fulfilment of the task.

The observation of Table V makes it possible to see that 11 students have considered as moderate the guidance received to carry out the activity with VISIR; 2 students regarded it as low and 2 students as enough. In turn, Fig. 4 shows that 7 students answered "in disagreement" to Q9 "I consulted the VISIR manual to learn more about the systems". These results must also be analyzed taking into account the context previously described, and within, the fact that teachers could not provide students with what the results of previous research show as necessary, i.e. an initial practical session on VISIR.

Finally, the observation of Table VI shows that there were practically no problems regarding server connection (Q15). Whereas, as regards Q19, one of the students showed agreement to it, revealing having had time difficulties to fulfil the task. Finally, Q22 provides more information about the difficulties. To the question: "What drawbacks have you found when using the remote lab?" the students remark:

- *There were some circuits I wanted to try but I could not because they were not available.*
- *The amperemeter does not work, I had problems with the current supply mass but then it could be corrected by asking my partners.*
- *Problems with the mass connection. I could not measure the current, it had to be done in an indirect way and that was fairly uncomfortable*
- *I wanted to assemble circuits different from the one suggested in the lesson but I could not because all of them shown error.*

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