Session 2532

Instructional Laboratory Integration with Course Contents: A Learning Hierarchy Approach

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Abstract

The positive educational effects of integrating the lab work with the theoretical course contents are incredible. Historically, there was, and still is in some cases, a kind of educational 'separation' between lab work and the course contents. It is very easy, and very common, to have students in the lab doing experiments on subjects they did not study or have a good understanding of the concepts they are to consolidate by the lab work. There exist two main models for using lab work in conjunction with regular class work. The most popular, and easier to implement, is first-lecture then-lab (FLEL) model. This way, the lab work consolidates the class work. If this model is used without detailed and close integration, as usually is the case, students are up for too much frustration and miss-conceptual education. This scenario is well known amongst students and is taking place all the time.

The second model is the first-lab then-lecture (FLAL) model, which builds on the lab work to develop concepts and theories. This approach, if properly designed and implemented, leads to a very good and effective education.

This communication discusses both approaches with more emphasis on the widely adopted, least integrated, FLEL model. A learning hierarchy is employed to design and integrate the lab work with the class work. A step-by-step algorithm is provided to help a wide range of educators with adopting this model with less frustration, less damage to the students' affective and cognitive domains, and a much better educational experience and outcome for the students. It also makes the educational process more manageable for the instructor.

I. Introduction

There is too much effort and funding these days directed towards innovative changes in education. Web-based education, computer-enhanced education, and distributed-networked classrooms, are just a few very powerful new concepts in education. [1-9]

In our quest for novel and new ideas, we tend to forget an important activity; clearinghouse. Several of our current practices that we developed over the last decades need some adjustments that can improve education drastically. One area is the instructional laboratory and its use in education.

Instructional laboratory work is an integral part of electrical engineering education. Over the last century, electrical engineering educators gradually moved toward a balance between theoretical and lab skills, with more emphasis on theoretical (cognitive) skills. Electrical engineering technology educators reached a different balance, with increased emphasis on lab (psychomotor) skills. In either case, the instructional lab plays an important educational role.

Doing the lab work, from the student point of view, is time consuming with less credit given (one credit hour for every three clock hour work.) Accordingly, the student aspires for a very efficient lab experience. What he goes through is some times a very lengthy and very exhaustive, marathon type experience. And if this experience is not very carefully and meticulously designed and integrated with the lectures of the course, the student is up for lots of frustration and misconceptual education. In some cases, some instructors even consider studying the material in the lecture before doing the experiment a 'luxury' that they cannot afford. [10-13]

As an educator, the author of this communication takes the integration of the lab and lecture work very seriously; at least time wise.

A very effective educational tool to design and implement this integration is the learning hierarchy. [14] In this communication, we discuss the learning hierarchy and its use to design an integrated lab experience.

II. Models

There are two educational models to use instructional labs in electrical engineering education, and in other disciplines with experimental components. These two models are the first-lecture then-lab (FLEL) and the first-lab then-lecture (FLAL) models. The FLEL model is the one most widely used. The FLAL model is very scarcely used even though it is very effective educationally.

FLEL Model. In this model the student attends a lecture to understand the subject matter, build proper concepts, and acquires necessary tools to be able to handle the problems he faces in that area. Then, the student goes to the lab to do experiments to consolidate the concepts he developed in class, and to make sure that he properly comprehends the concepts and can apply them in controlled environments.

As an example, a student would study the field-effect transistor before he goes into the lab to build and test circuits using this component.
Now, imagine a student going into the lab to design an inverter using the FET without understanding the theory of operation and characteristics of this FET. How much frustration he is up to, and what misconceptions will he develop?
Be sure that this takes place ALL the time in many educational institutions.

FLAL Model. In this model, the student goes to the lab to do some experiments, analyze the results, and through a guided process reaches conclusions and concepts about the subject. Here, the student develops the concepts and tools himself from experimental results. This model of education is very effective and has a long lasting positive effect on the student skills and capabilities.

For example, a student would go into the lab and do some carefully designed experiments to obtain information on the voltages and currents in a circuit, and through guided analysis develops Ohm's law, KVL, and KCL.

The author did apply this model in developing and teaching several basic and advanced courses in electrical engineering with outstanding results.

III. Learning Hierarchy

The learning hierarchy is an educational concept/tool where one breakdowns an educational concept into its component-concepts and relate these component-concepts together horizontally and vertically. Vertical relation indicates educational dependence; understand lower one to understand upper one. Horizontal relation indicates same educational level; no educational dependence, Fig. 1.

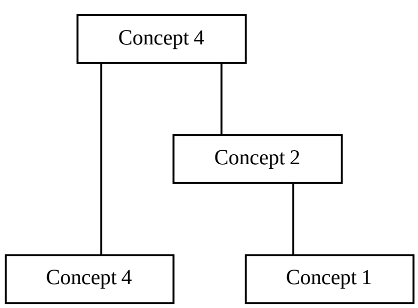

Figure 1 Learning hierarchy applied at the concept level.

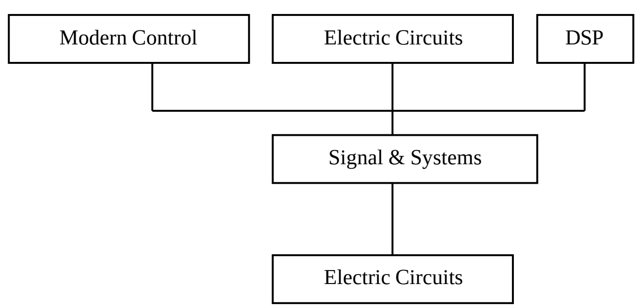

Figure 2 Learning hierarchy applied at the curriculum level.

The learning hierarchy is equally applicable at any educational level; from behavioral objectives up to curriculum components.

Figure 2 shows an example of applying the learning hierarchy tool at the curriculum level.

IV. Design and Integration

In this section, we apply the learning hierarchy approach to design and integrate a lecture and an instructional lab.

Lecture. Design And Test A Two-Stage BJT Amplifier. The electrical engineering concepts/tools that are involved in such a lecture are BJT, amplifier, two-stage, design, construct, and test; Fig. 3. Each of these is a concept that is needed, independently and integrally, to *understand* and *accomplish* the task required.

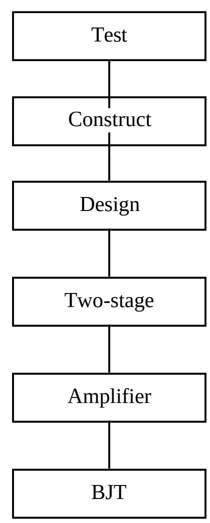

Figure 3 Learning hierarchy of the 'Design and test a two-stage BJT amplifier' example

The concept of a BJT as a discrete circuit element, in addition to the physics of its operation, is the first building block required. A student cannot employ such a circuit element without complete comprehension and mastering of its basic characteristics.

The general concept and tool of an amplifier is the second building block for this educational experimental experience. A student must be able to analyze the operation of an amplifier as a first step to designing one.

The concept of a two-stage device is the third building block. How the second stage interacts with the first one, and the effects of coupling, are essential for such an exercise.

The concept of designing an electronic circuit is the fourth building block. It involves all the previous concepts, in addition to a clear and logical line of steps. It is at the *fifth* level of Bloom's Taxonomy of the cognitive domain; synthesis. [15] At this higher level, one before last, a good grasp of the previous four levels of the taxonomy is essential. This includes, knowledge, recall, application, and analysis. This will require, on both the instructor's and student's sides, some extra work to develop this skill properly.

The concept of constructing an electronic circuit is the fifth building block. This includes proper component handling, circuit layout, and connections; lots of psychomotor skills. This kind of learning psychomotor skills requires a coaching approach from the instructor with lots of managerial skills. A *sitting by marry* method of education always proves to be very effective in such a situation.

The concept of testing a constructed electronic circuit is the sixth, and last, building block. This includes identifying checkpoints on the circuit and quantities to measure, applying proper equipment handling and measurements' techniques, and proper logical development. This includes cognitive domain activities in the first four levels of Bloom's Taxonomy in addition to appropriate psychomotor skills. Again, a *sitting by marry* method of education always proves to be very effective in such a situation.

Before a student can properly benefit from such an educational experience in the lab, with all the mentioned concepts and tools at all the cognitive domain levels, affective and psychomotor domains' skills, a proper division of the learning process between the lecture and lab should be carried out.

In lectures, the student must develop the cognitive domain concepts before he goes into the lab. In such a case, he must have clear concepts of the BJT, amplifier, two-stage, and design process. This should be up to the level where he can confidently, with reasonable effort and no frustration, handle effectively the circuits under consideration. Also, he should comprehend the design processes with all its advantages and disadvantages, and be able to apply it effectively, confidently, and in a reasonable time period. In parallel with these developments, the instructor and student, together, should work on developing the affective domain of the student in a way for the student to emerge with a positive attitude towards the subject. ONLY when these educational objectives are met the student can go to the lab to construct and test his design.

The time line of developing the required concepts is evident from Fig. 3; from bottom to top. This sequence is crucial in the development, or else the student will be up for frustration and miss conceptual education. (Usually, most educators do not do any of the above and throw the student to the sea to learn how to swim by himself!)

Now the student is ready to greatly benefit from a lab experience. This lab experience should include the last two concepts; construct and test. When the student goes to the lab with a well-designed circuit, based on educationally sound grounds, he can achieve mastering the next two levels of the learning hierarchy. A good construction and a good testing can now be achieved.

Step-by-Step Algorithm. What we have done is to go through several steps, logically built on each other, to achieve our goal of designing and integrating the educational experience for the student; a step-by-step algorithm. The following comprises this algorithm.

Perform:

1. <u>Task Analysis</u> to determine the involved educational concepts/tools.

2. <u>Domain Determination</u> (cognitive, affective, or psychomotor) and level within, for each concept/tool.

3. <u>Learning Hierarchy</u> construction to arrange the developed concepts/tools in the proper educational order.

4. <u>Integrate Lecture(s) and Lab</u> by dividing the concepts/tools between the two in the proper order and fashion.

V. Conclusions

The educational analysis, discussion, and algorithm presented in this communication pave the way for educators to properly design and integrate lab activities with lectures to achieve proper educational objectives. The presented material is equally applicable to all disciplines that employ lab work as an educational experience in their educational process. The material is presented in the context of applying it to electrical engineering education.

Bibliography

1. Ko, C. C., et al, A web-based virtual laboratory on a frequency modulation experiment, IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews, Vol. 31, pp 295 –3031 (2001).
2. Kim, Y., et al, Collaborative surgical simulation over the Internet, IEEE Internet Computing, Vol. 5, pp 65 –73 (2001).
3. Armstrong, B. and Perez, R., Controls laboratory program with an accent on discovery learning, IEEE Control Systems Magazine, Vol. 21, pp 14 –20 (2001).
4. Jimenez-Leube, F. J., et al, Networked implementation of an electrical measurement laboratory for first course engineering studies, IEEE Transactions on Education, Vol. 44, pp 377 –383 (2001).

5. Koku, A. B. and Kaynak, O., An Internet-assisted experimental environment suitable for the reinforcement of undergraduate teaching of advanced control techniques, IEEE Transactions on Education, Vol. 44, pp 24 –28 (2001).
6. Ko, C.C., et al, Development of a web-based laboratory for control experiments on a coupled tank apparatus, IEEE Transactions on Education, Vol. 44, pp 76 –86 (2001).
7. Lord, S. M., Optoelectronics experiments for first-year engineering students, IEEE Transactions on Education, Vol. 44, pp 16 –23 (2001).
8. Tan, K.K. and Soh, C.Y., Instrumentation on the Internet, J. Engineering Science and Education, Vol. 10, pp 61 –67 (2001).
9. Avouris, N. M., et al, Development and evaluation of a computer-based laboratory teaching tool, Computer Applications in Engineering Education, Vol. 9, pp .8-19 (2001).
10. Goldner, R. H., Research report: learning has prerequisites, Instructor, Vol. 82 (1973).
11. Bergan, J. R., The structural analysis of behavior: an alternative to the learning-hierarchy model, Review of Educational Research, Vol. 50, pp 625-46 (1980).
12. Coward, L. A., The recommendation architecture: lessons from large-scale electronic systems applied to cognition, Cognitive Systems Research, Vol. 2, pp 111-56 (2001).
13. EC2000, www.abet.org.
14. Esseff, P. J. Instructional development learning system—learning hierarchy construction, Columbia, MD: Educational systems for the future (1974).
15. Bloom, B. S., et al, A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy for education, New York, NY: Longman (2001).

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