Exploring the Skill Retention of Circuit Simulation Learning from the Perspective of Sustainability

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Abstract. The purpose of this study is from the perspective of sustainability, from the three aspects of sustainability: environment, society, and economy, design an experimental course to compare the skill retention about three kinds of electronic circuit teaching methods in vocational school. The experimental samples are selected from the 2nd grade students of Department of Control Engineering, Taipei Municipal Nei-Hu Industrial Vocational School. They are divided into three groups for an 8-week teaching experiment. Traditional group (TRA group) uses traditional lecture and operation methods; the second group (DB group) uses Digital Breadboard simulation software to help construct electric circuit conception and actual operation; and the third group (TINA group) uses TINA Pro simulation software to carry out conception learning for electronic circuit and actual operation. The differences in the learning retentions are analyzed using statistical software SPSS 25. For the skill retentions of circuit theory learning, after three times of non-warning methods, the post-skills retention was evaluated. After the 14th day of the experimental course, TRA group and DB group were significantly better than TINA group; and on the 42nd day after the end of the experimental course, TRA group and DB group were significantly better than TINA group; and on the 28th day after the end of the experimental course, all TRA group, DB group, and TINA group were no differences in the three groups of retention. At the same time, from the perspective of sustainable education, the teaching and evaluation of this experimental course has also achieved the purpose of sustainability.

1. Introduction

People's lives are limited, but the spirit of education is infinite. The United Nations Sustainable Development Goals tie together equity, justice, and a more inclusive society with ecological sustainability [1]. With the rapid development of science and technology, how to explore education from the perspective of sustainability and use technology to achieve learning results, whether to achieve effective knowledge or skills, is a topic worth exploring. Especially with regard to the study of electronic circuit theory, there are many computer simulators on the market. Before the actual paper calculation and hands-on operation, students are provided with more auxiliary learning. From the educational point of view of sustainable management, in addition to eliminating the purchase of parts, materials, tools and equipment, it is also possible to avoid the risk of damage to parts and equipment due to misconnection of parts, which is of great interest to researchers.
Therefore, from the three aspects of sustainability: environment, society, and economy, design an experimental course, whether it can replace or assist traditional teaching to achieve learning effectiveness or retention, and achieve the purpose of environmental protection, social education and economic benefits, is the important topics for current research. Universities and colleges around the world are exploring ways of reorganizing curricula to educate future leaders in sustainability [2].

And exploring the research limitations/implications: The sustainability assessment approach adopted in the study is constrained by the question of what constitutes a sustainability syllabus. Expert-derived sustainability themes used in the study are unavoidably incomplete and may limit the conduct of an exhaustive sustainability content assessment [3].

Owing to the prevalent popularity of simulation system, it is important to understand and adopt simulation system to develop future educational plans [4]. This study is to investigate the skill retentions of hands-on operation in cooperation with computer simulation software in electronic circuit technique teaching, under current teaching situation. The difference between traditional learning method and simulation software assisted learning method is compared. Best electronic circuit technique teaching model is found out to provide research reference for relative technical teaching field.

2. Literature Review

Technique is a compound noun which is the combination of “knowledge” and “skill.” According to the classification by Novak & Gowin [5], Figure 1 shows the complete outline of the explanation.

![Figure 1. Components of Technique (Novak & Gowin, 1984)](image1)

We examined The University of Vermont's new sustainability requirement for undergraduates through the lens of just sustainability [6]. Li [7] advocated teachers can structuralize knowledge and clearly and definitely present knowledge. Learning performance is produced as: the learner gains "motivation" from the learning material which attracts the learner's "attention; "Learner's memory conception" interconnects with "short-term memory" to find the meaning of learning. It is shown in Figure 2.

![Figure 2. The internal and external links between old and new knowledge memories (Li, 2008)](image2)

3. Research Methods, Procedures, and Hypothesis
This chapter consists of three parts: research methods, procedures, and hypothesis, which are listed separately as follows:

3.1. Research Methods
This study adopts “experimental method” to carry out the teaching experiment. The experimental design is a quasi-experimental design. The experimental targets are students (104 students) from three classes of the 2nd grade of Department of Control Engineering, Taipei Municipal Nei-Hu Industrial Vocational School. Among the students, one class is assigned to the TRA group (33 students), one class is assigned to the TINA group (38 students) and one class is assigned to the DB group (33 students). The teaching experiment is carried out to all the students in these three groups. The experimental item is the “Digital Logic Circuit” of “Electronic Circuit Practice” in vocational high school lesson. The learning period of the unit is eight weeks (24 hours in total, six hours a week, fortnightly). TRA group uses traditional teaching method without assisted simulation software. TINA group uses TINA Pro simulation software in cooperation with actual operation. DB group uses Digital Breadboard simulation software in cooperation with actual operation. During the teaching period, the content of the teaching unit is the same and the teaching environment is controlled in order for the experiment to proceed successfully. After the teaching is completed, effectiveness analysis is carried out. Post-learning assessments (include knowledge assessment and skill assessment) are used to carry out quantitative statistics. Knowledge assessment is carried out by written examination and skill assessment is carried out by actual operation (without the assistance of the software used in the experiment). The reliability and validity of the questions and scales are up to standard.

The interface of TINA Pro contains five zones as shown in the Figure 3. And the Digital Breadboard interface contains six zones as shown in the Figure 4. The learning content is shown in the Table 1.

![Figure 3. TINA Pro manipulation interface](image)
3.2. Research Methods

The main steps of this study are: 1. Literature Discussion: Collect, analyze, conclude and sort out literatures related to the research; 2. Teaching Material Edition: 5 digital logic practice teaching units are designed (include combination logic and sequential logic) using “traditional teaching method,” “TINA Pro” and “Digital Breadboard”; 3. Expert Meeting: Confirm the assessment questions and the effectiveness of the questions; 4. Pre-test of Assessment Questions: Carry out question analysis to confirm the credibility of the assessment questions; 5. Experimental Grouping: Three groups—Students are divided into “TRA group,” “TINA group” and “DB group” to carry out the teaching experiment; 6. Teaching Experiment: Experimental deviations are controlled and students’ learning situation is observed; 7. Post-learning Test: Knowledge assessment and skill assessment are carried out to compare the learning effectiveness of “TRA group,” “TINA group” and “DB group”; 8. Information Statistical Analysis; 9. Conclusion and Suggestion.

3.3 Hypothesis

This study mainly discusses the skill retention of circuit simulation learning from the perspective of sustainability. Post-study retention refers to the phenomenon that individuals can still express their learned behavior without repeated practice after a period of learning activities. Retention and learning are similar, they all mean the memory of the experience, but the learning is biased towards the immediate
memory after the practice, and the retention is biased towards the memory after only a period of practice [8], so the researcher is based on the skills used. The skill retention of this study is defined as follows: Skill Retention = Learning Outcomes after a period of Practice ÷ Learning Outcomes immediately after Practice.

Based on the experimental design, the following three assumptions are proposed:

H1. There were no significant differences of skill retention in post-learning among the different groups (TRA group, TINA group, and DB group) after two weeks (14 days) after the post-learning skills assessment.

H2. There were no significant differences of skill retention in post-learning among the different groups (TRA group, TINA group, and DB group) after four weeks (28 days) after the post-learning skills assessment.

H3. There were no significant differences of skill retention in post-learning among the different groups (TRA group, TINA group, and DB group) after six weeks (42 days).

4. Data Analysis

This chapter consists of two parts: homogeneity test of regression coefficients in variable arrays, and the skill retention measured at three different times (14th day, 28th day, and 42nd day), which are listed separately.

4.1. Homogeneity test of regression coefficients in variable arrays

The skill retention measured at three different times (14th day, 28th day, and 42nd day), all of their regression line slopes among different groups (TRA group, TINA group, and DB group) are the same, the basic assumptions that conform to the homogeneity of the regression coefficients in the covariant array.

4.2. The skill retention measured at three different times (14th day, 28th day, and 42nd day)

The skill retention measured at three different times (14th day, 28th day, and 42nd day), skill retention post-comparison summary table as shown Table 2, Table 3, and Table 4.

| Table 2. The skill retention measured after 14th days, skill retention post-comparison summary table |
| --- |
| group | TINA | TRA | DB |
| Adjusted average | .9420 | .9865 | .9965 |
| TINA | — | .0445** | .0545** |
| TRA | — | — | .0100 |
| DB | — | — | — |

**P<.01

| Table 3. The skill retention measured after 28th days, skill retention post-comparison summary table |
| --- |
| group | TINA | TRA | DB |
| Adjusted average | .9565 | .9904 | .9956 |
| TINA | — | .0339 | .0391 |
| TRA | — | — | .0052 |
| DB | — | — | — |
Table 4. The skill retention measured after 42nd days, skill retention post-comparison summary table

| group | Adjusted average | TINA | DB  | TRA  |
|-------|-----------------|------|-----|------|
|       |                 | .9595| 1.0028 | 1.0077 |
| TINA  | .9595           |    - | .0433* | .0482* |
| DB    | 1.0028          |    - |    -  | .0049  |
| TRA   | 1.0077          |    - |    -  |      - |

*P<.05

Three times of the post-skills retention was evaluated after the experimental course. The first evaluation on the 14th day after the end of the experimental course. TRA group and DB group were significantly better than TINA group, and the third evaluation on the 42nd day after the end of the experimental course. TRA group and DB group were significantly better than TINA group, as to the second evaluation on the 28th day after the end of the experimental course, there was no difference in the three groups of post-skill retention.

The researcher analyzed this phenomenon, which is different from the post-school cognitive retention phenomenon. It is believed that because TINA Pro has many functions and requires advanced professional knowledge and software operating procedures, it is far better than digital breadboard and pure traditional learning. On the 14th day, the skill retention evaluation for the initial acceptance of pure breadboard operations was less favorable for students using TINA Pro-assisted learning, so the students who used TINA Pro had a post-study skill retention after the 14th day of the experimental course. Significantly lower than students who use traditional learning and students who use digital breadboards to assist in learning.

As to the second time (on the 28th day after the end of the experimental course), there is no difference in the retention of skills after experimental course. The researcher believes that the influence of time factors on different three groups has tended to be moderated, so no difference occurs; the results of the third time (on the 42nd day after the end of the experimental course) skill retention were same as the result of the first time (on the 14th day after the end of the experimental course), the students who use traditional learning and the students who use digital breadboards are significantly better than those who use TINA Pro’s student. The researchers believe that students who use traditional learning to repeat the same practical problems, as well as students who use digital breadboards to assist in learning, are close to the repeated operation of the same practical students, and their operational proficiency will be higher than the student using TINA Pro-assisted technology learning, so the post-skills retention on the 42nd day after the end of the experimental course, the students using traditional learning and the use of digital breadboard-assisted learning, the average value of post-skill retention is significantly higher than Students who use TINA Pro to assist in learning should also be reasonable.

5. Conclusion and Suggestion
This chapter consists of two parts: conclusion and suggestion, which are listed separately as follows:

5.1. Conclusion
After eight weeks of experimental teaching, for the skill retentions of circuit theory learning, the experimental results are: After the 14th day of the experimental course, TRA group and DB group were significantly better than TINA group; and on the 42nd day after the end of the experimental course, TRA group and DB group were significantly better than TINA group; and on the 28th day after the end of the experimental course. All TRA group, DB group, and TINA group were no differences in the three groups of retention.

At the same time, from the perspective of sustainable education, the teaching and evaluation of this experimental course has also reached the three aspects of sustainability: environmental, social and economic purposes. Save on avoiding the purchase of parts, materials, tools and equipment, and avoid
the risk of damage to parts and equipment due to incorrect parts connections, and achieve the same assessment, even better.

5.2. Suggestion
The researcher finds that the teacher teaches electronic circuit technique, if the teacher carefully designs a sustainable teaching environment and curriculum, and appropriately selects the simulation software in combination with the actual teaching, the teaching effect of the technology will be excellent, and the retention rate will be further improved to achieve the goal of sustainability.

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Acknowledgments
The author would like to thank International College of Krirk University for handling this conference, and Dr. Colin W. K. Chen for his assistance and guidance in the paper.