European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available on-line at: www.oapub.org/edu

doi: 10.5281/zenodo.3890894 Volume 7 │ Issue 6 │ 2020

EFFECT OF A DEVELOPED PHYSICS LABORATORY MANUAL ON THE CONCEPTUAL UNDERSTANDING OF INDUSTRIAL TECHNOLOGY STUDENTS

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Abstract:
The study aimed to find out the effect of a developed laboratory manual in Physics on the conceptual understanding of Industrial Technology students. A pretest-posttest matched group design with experimental and control groups, consisted of 21 students each that undergone matching procedures were used in the conduct of this study. Descriptive statistics like mean and standard deviations, and t-tests were used to interpret and analyze the data. Cohen's d effect size measure was also employed in order to measure the practical significance of the instructional material. This effect size can be operationally defined as learning gains due to experimental treatment. Findings suggest that the developed laboratory manual in Physics was found to be effective in enhancing the conceptual understanding of the students during their Physics laboratory class. Thus, this positive result indicates a strong support for a utilization of the learning material for instructional and institutional use.

Keywords: laboratory manual in Physics, quasi-experimental design, Cohen's d, industrial technology students

1. Introduction

The noble objective of Science education poses a great challenge for Science teachers to accomplish significant contributions in the field. It is therefore the task for Science teachers to know the kind of classroom activities that will utilize multidisciplinary, contextualized, and problem/issue – based approaches that will develop the learning domains of Science. Since the national goal for education has been set, educational institutions should align their practices to this goal that would create learning environment employing varied learning activities. In effect, life-long learners today will

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be developed holistically acquiring the 21st century skills (K to12 Science Curriculum Guide, 2013).

Instructional materials as one of primary sources of science learning content for both students and teachers can also serve as a primary influence on how teachers should teach science (Reiser, et al, 2003). From a constructivist perspective, the curriculum for the science and mathematics students should aim for "knowledge in action" rather than the rote learning method of the traditional approach. The constructivist principle holds that learners actively construct new knowledge by fashioning it to meet their needs and capacities and integrating it into their existing cognitive structure (University of Mass. Physics Education Research Group website, 2001, as cited in Hudgins, 2005). Furthermore, according to Duit and Confrey (1996), the applicability of science and mathematics must be student-centered in a way that promotes learning activities which develops acquisition of 21st century skills. These skills include collaboration and communication, creativity and innovation, critical thinking and problem-solving skills.

To fully enhance the shift towards an Outcome-Based Education Curriculum, a mandate from the Commission on Higher Education (CHED) stated under its "program specialization" was to encourage higher education instructors to *utilize effective science teaching and assessment methods by designing and utilizing appropriate instructional materials* (CHED Memorandum Order 46 s. 2012). And to strengthen further the need for developing an instructional material, one of the recommendations of the Accrediting Agency of Chartered Colleges and Universities in the Philippines, Inc. (AACCUP) to one of the state universities and colleges (SUCs) in the province of Negros Occidental was to encourage teachers to make instructional materials. As science educators, we all know that constructing any instructional material aims to provide a better understanding of the subject matter for both students and teachers. However, the processes used to select those materials are critical and must be properly evaluated in order to provide students and teachers a solid foundation for achievement and successful teaching. Hence, with the purpose of providing relevant material for instruction to the Industrial Technology students taking General Physics, the proponent developed a laboratory manual in Physics to address the need of the students, teachers and the institution.

Because of the dearth of research-based instructional materials for use in physics classroom, this study aims to determine the effectiveness of a developed laboratory manual in Physics for Industrial Technology students. Specifically, it sought to answer the following problems:

1) What are the pretest and posttest scores of the students for the experimental and control group?
2) Are there significant posttest gains for the experimental group and control group?
3) Is there a significant difference in the posttest gains between the experimental and control groups?

2. Conceptual Framework

The conceptual framework of the study as shown in Figure 1 was anchored on the ADDIE Model of instruction. The left box showed the need of an institution to develop instructional materials as recommended during its AACCUP visit and similarly supported by CHED's Memorandum Order 46 s. 2012. Moreover, the lack of laboratory manual in a General Physics course paved the way for the development of a learning material that was anchored on Outcomes Based Teaching and Learning (OBTL) utilizing cooperative (constructivist approach) and experiential (cognitivist) learning strategies.

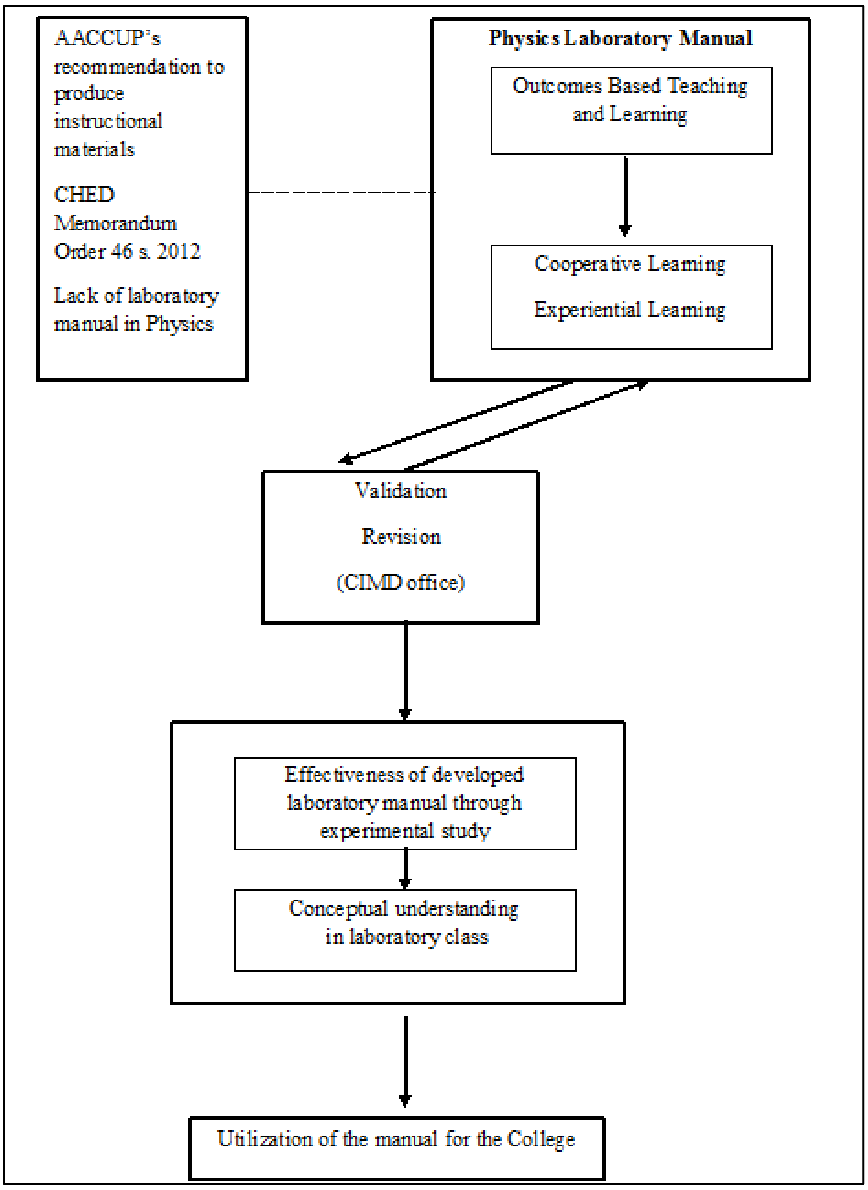

Figure 1: Conceptual Framework of the Study

The effectiveness of the learning package as an intervention in improving the conceptual understanding in the laboratory class has been assessed by the institution's Curriculum of Instructional and Materials Development (CIMD) office through undergoing validation and revision processes as shown by the two opposing arrows. Before this learning material could be utilized in the college, proper procedures of evaluating its effectiveness through research-based study must be accomplished.

3. Material and Methods

A. Research Design

Utilizing a quasi-experimental research design, the main theme of this study focused on the effect of a developed Physics laboratory manual on the students' conceptual understanding in a laboratory class. A comparison was made between an intact class exposed to the use of the laboratory manual and another intact class without the developed material. In particular, the study used pretest-posttest matched group design. According to Dimitrov and Rumrill (2003), this kind of nonrandomized experimental design does not disrupt the existing research setting especially when intact groups were the participants. The reactive effects of the experimental procedure were reduced thus improving the external validity of the design but making the design more sensitive to internal validity problems. However, these were reconciled by carefully matching the participants in terms of their age, gender, past grades in Mathematics for the Modern World (GECMAT) which was a pre-requisite subject and both classes were handled by the same teacher. This Physics instructor had atleast 3 years of experience teaching the subject.

B. Research Environment

This study was conducted in one of the SUCs in the province of Negros Occidental. One of its curricular offerings under the College of Industrial Technology was the Bachelor of Science in Industrial Technology (BSIT) with several majors that include Architectural Drafting, Automotive, Electrical, Electronics, Food Trades, Garments Trade, Furniture Fabrication, Machine Shop, Refrigeration and Air Conditioning (RAC).

In connection with this study, the developed laboratory manual was intended for these students since this was one of the courses that require General Physics as prescribed in the prospectus of their College.

C. Research Respondents or Participants

The participants in the study were two intact classes of first year college students taking up Bachelor of Science in Industrial Technology (BSIT) major in Food Trades Technology during the second semester of the Academic Year 2018-2019. The said intact classes were composed of heterogeneous students in terms of intellectual ability. A purposive sampling was used in terms of their age, gender, and GECMAT grades from the first semester of AY 2018-2019. The result of matching formed two groups as shown in Table 1 below, each consisted of n = 21. Random assignment was used on which group will serve as experimental and control. Both the experimental and control group are composed of 17 females and 4 males, respectively.

Table 1: The Experimental and Control Group

	Experimental	Control
Male	4/7*	4/6*
Female	17/20*	17/23*
Total	21/27*	21/29*

*total number of females and males in the class

Note: Those that were excluded may have not completed the pre- or post-test and/or the age of the students are under or beyond 19 years old.

To confirm whether the groups were really matched, the researcher made some preliminary calculations to test that there were no significant differences between the two groups based on their Mathematics in the Modern World (GECMAT) grades.

Table 2: Computed t-value Between Experimental and Control Group on a Matching Variable

	Mean		SD		n				
Variable	**EG**	**CG**	**EG**	**CG**	**EG**	**CG**	**Computed t**	**p-value**	**Interpretation**
GECMAT	84.38	83.85	1.80	2.41	21	21	0.903	0.377	NS

$\alpha = 0.05$, NS = not significant

As shown in Table 2, the result of the t-test obtained a p-value of 0.377 which suggests that a greater value than the 0.05 alpha level means that there was no significant difference on their GECMAT grades between the groups when compared. Hence, it can be confirmed that the two groups were indeed matched because the differences between the experimental and control group were insignificant.

Also, to reduce the bias and threats to internal validity, the participants were not aware that they were part of the research study. Hence, their performances and scores on their laboratory class can serve as one of the bases of their grades as well as additional data for further insights on the study.

Other than the participants who used the laboratory manual and without the manual, the study also involved physics experts and instructors who validated the materials and approved it for the testing phase handled by the Curriculum Instructional Materials Development (CIMD) office.

D. Research Instruments / Sources of Data

The developed Physics laboratory manual was primarily anchored on an outcome based teaching and learning framework which embodied the concepts of a constructivist and cognitivist learning theoreies. With expected learning outcomes after each experiment, cooperative and experiential learning strategies were also utilized so as to optimize the intended goals. The manual focused on experiments about fundamental quantities, and basic concepts of mechanics, heat, electricity, magnetism, sound and light anchored on the OBE syllabus prepared by the institution.

The Curriculum of Instructional and Materials Development (CIMD) office has managed the evaluation process of the instructional material based on an approved criterion of the institution. These were based on the following criterion: Content Quality, Curricular Value, and Appropriateness to User, Organization and Packaging. The developed laboratory manual obtained a general average of 4.14 with a descriptive rating of **Very Good**.

Moreover, experts from the field across the different campuses were chosen to validate the material as well as the test instrument to be used for the pretest/posttest. Their suggestions, comments and corrections were considered for revisions. Further, test-retest method was used to check the reliability of the teacher-made test. It was pilot tested to the two sections of second year BSIT students major in Food Trades during the first semester of AY 2018-2019. The 30-item multiple choice conceptual tests were based from the concepts of the laboratory manual that obtained a reliability coefficient of 0.88 indicating an acceptable standard for reliability.

4. Results and Discussion

In this section, descriptive statistics like mean and standard deviations, and t-tests were used to process and analyze the data. Through comparing the pre- and post-tests mean scores of the experimental and control group, the intervention of utilizing the developed laboratory manual will be determined if its effective or not. Also, Cohen's d effect size measure was used to measure the practical significance of the instructional material. The effect size can be operationally defined as learning gains due to experimental treatment.

Table 4: Descriptive Statistics and t-test Results in the Pre- and Posttests

Variables	EG		CG			t	df	p-value	Interpretation
	M	SD	M	SD	n				
Pre-test	11.29	2.51	10.38	3.94	21	1.037	20	0.312	NS
Posttest	19.67	3.69	14.43	3.56	21	4.932	20	< 0.001	S

EG=experimental group, CG=control group, NS=not significant, S=significant, $\alpha = 0.05$.

As presented in Table 4, the 21 participants in each group got pretest scores of 11.29 (SD = 2.51) for the experimental group and 10.38 (SD = 3.94) for the control group. Meanwhile, it can also be revealed that the posttest scores of the experimental and control group obtained values of 19.67 (SD = 3.69) and 14.43 (SD = 3.56), respectively. To determine if there is a significant difference in the pre-test scores between the experimental and control group, the researcher utilized the t-test for matched groups and presented the computed t-value for the comparison.

As gleaned above, the pretest scores between the experimental group and control group obtained a p-value of 0.312, which is greater than the 0.05 level of significance. This suggests that there is no significant difference between the experimental and control groups in terms of their scores in the pre-test. This implied that the entry knowledge level of participants on both groups were the same. This result further strengthens Savinainen (2002) statement that the pre-test scores are relatively low for beginning physics students.

Moreover, the posttests mean scores between the experimental and control group was also calculated using the paired t-test for comparison. Based on the result, the computed p-value (< 0.001) showed a lesser value than the alpha level of significance

(0.05). This means that there was a significant difference between the experimental and control group's performance in the post-test.

To further validate this data of information, comparison between pre-test and posttest mean scores of the two groups was calculated by finding if there was indeed posttest gains for the experimental and control group.

Table 5: Computed t-value in Posttest Gains: Experimental vs. Control Group

Group	Pretest		Posttest		Gain			*t*	df	p-value
	M	SD	M	SD	M	SD	n			
Experimental	11.29	2.51	19.67	3.69	8.38	3.44	21	11.16	20	< 0.001
Control	10.38	3.94	14.43	3.56	4.05	1.72	21	10.80	20	

$\alpha = 0.05$

As shown on Table 5, there was a mean gain of 8.38 (*SD* = 3.44) and 4.05 (*SD* = 1.72) for the experimental and control group, respectively. The increase in the test scores was greater for students in the experimental group than for those in the control group. Though this was the case, the difference between the pre-test and posttest mean scores was still statistically significant for each group: experimental t (20) = 11.16, p < 0.001 and control t (20) = 10.80, p < 0.001. Thus, there was a significance difference on the pre-test and posttest scores using the developed laboratory manual in conjunction with the traditional instruction for the experimental group and the traditional method of instruction without the laboratory manual for the control group.

The experimental group which employed the laboratory manual in their laboratory class and the control group which did not use the instructional material both improved in their conceptual understanding of the topics in Physics. The two groups showed an increase performance in the posttest given to them after the instruction. Hence, it can be suggested that the developed laboratory manual can be a potential learning resource for their laboratory class in Physics in conjunction with traditional instructions.

Table 6: Comparison of the Level of Improvement
in Post-test Scores between the Control and Experimental Groups

Group	Mean	SD	Difference	*t*	df	p-value
Experimental	8.38	3.44	4.333	5.163	40	< 0.001
Control	4.05	1.72				

$\alpha = 0.05$

In this result, the post-test gains were analyzed using an independent t-test. The increase in the test scores was greater for students in the experimental group (M = 8.38, SD = 3.44) than for those in the control group (M = 4.05, SD = 1.72), with t (40) = 4.333, p < 0.001.

The computations showed a statistical significance (p < 0.001) in the posttest gains of the scores for the experimental and control group. It seemed that both groups had improvements on their conceptual understandings with or without the material. However, it can be clearly shown that one method was better in increasing the scores.

The mean gain of 4.333 indicated that the experimental group has greater improvement in their scores compared to the control group. Thus, utilizing the developed laboratory manual in the instruction was found to be effective in enhancing the conceptual understanding in its Physics laboratory class of the experimental group.

4.1 Effect Size Measure

To help the researcher determine the practical significance of the instructional material which resulted in gaining more conceptual understanding, if any, measures of effect size was taken consideration. The measure of effect size was often reported in educational research and metrics such as Cohen's d was one of them. Measurement of effect size was important because an instructional intervention might be statistically significant, but depending if the gains were small or large, it will tell if that instructional intervention was of practical importance for classroom use.

The result of the Cohen's d effect size measure for pre-test and post-test scores of the experimental and control group is presented in Table 7 while the description of the effect size is shown in Table 8 as defined by Cohen (1988).

Table 7: Cohen's d Effect size between Experimental and Control Group

Variables	Mean Difference	SD	n	*t*	Cohen's d effect size	Description of effect size
Experimental	8.38	3.44	21	11.158	2.435	Large effect
Control	4.05	1.72	21	10.804	2.358	

Table 8: Description of Effect Size

Effect Size	Description
d > 0.80	Large effect
d = (around) 0.50	Medium Effect
d = (around) 0.20	Small Effect

The results revealed that the administration of the laboratory manual in Physics as part of classroom instruction gained a large effect (d = 2.435) in making students understand the concepts in General Physics. Numerically, the experimental group has a greater effect size of 0.077 as compared to the control group. However, we cannot still deny the large effect brought by the conventional method of the control group (d = 2.358) in enhancing the conceptual understanding. According to Zeilik and Morris (2004), values of effect size larger than 0.8 were considered of large practical importance or significance in education research. The effect size measure obtained in this study manifested the effectiveness of the developed laboratory manual. Although the lecture method of instruction was also as effective with accompanying activities prepared by the instructor, it is important in a laboratory class to utilize a laboratory manual for students to fully grasp the concepts learned in the lecture. Learning is best when one clearly understands what they themselves construct from their own experience (Hudgins, 2005). Constructivism gives teachers another perspective to rethink how students learn and to focus on process and provide ways of documenting change and transformation. It also reminds teachers to look for different ways to engage individual student, develop rich environments for exploration, prepare coherent problem sets and challenges that focus the model building effort, elicit and communicate student perceptions and interpretations (Abdal-Haqq, 1999). More importantly, the investigative laboratory activities can provide cognitive and social affordances that support the construction of shared understanding of scientific phenomena (Kozma, 2003).

5. Conclusion and Recommendations

With the results of this study, it can be suggested that the developed laboratory manual in Physics for Industrial Technology students was found to be effective in enhancing the conceptual understanding in its Physics laboratory class. This laboratory manual, which was anchored on Outcomes Based Teaching and Learning (OBTL) that utilized cooperative (constructivist approach) and experiential (cognitivist) learning strategies, showed positive results as indicated on their test scores. Although the lecture method of instruction was also as effective with accompanying activities prepared by the instructor, it should be noted that the relevance of a laboratory manual in a laboratory class are essential tools for students to fully grasp the concepts learned in the lecture.

Hence, the evaluation of this study strongly supports the utilization of this learning material for instructional and institutional use.

Furthermore, it is recommended that a similar study shall be conducted for other specializations of BSIT course that include Architectural Drafting, Automotive, Electrical, Electronics, Garments Trade, Furniture Fabrication, Machine Shop, Refrigeration and Air Conditioning (RAC).

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