VARIATION THEORY IN TEACHING AND PHENOMENOGRAPHY IN LEARNING: WHAT'S THEIR IMPACT WHEN APPLIED IN ENGINEERING CLASSROOMS?

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ABSTRACT

Although phenomenographic research approach has been widely used by education researchers to investigate students' learning, little attention has been paid to the relationship between a pedagogical approach adopted by teachers and students' learning outcomes, particularly in engineering education. This experimental study proposes integrating variation theory as a pedagogical approach to a face-to-face classroom environment for teaching complex engineering contents and adapting a phenomenographic approach to evaluate students' learning outcomes. The teachers who participated in the experimental group incorporated the variation theory in their teaching process. In contrast, the teachers in the control group, being ignorant of the variation theory, taught the same content to achieve the same specific learning outcome. Drawing on data from students' written responses both from experimental and control groups, this article illustrates how teachers implemented variation theory in the classroom and its impacts on student learning. The implementation of variation theory was confirmed by classroom observation, and the variation in understanding the topic was emerged from students' written responses and interview data through phenomenographic analysis. The findings indicate that teachers informed by variation theory use variation and invariance that creates necessary conditions for learning. This study demonstrates how, by incorporating variation theory, a faculty member designed different pedagogical approaches, which helps students conceptualize complex engineering topics more systematically than those who do not discern variation. The study concludes with theoretical, empirical, and pedagogic implications for teacher education in engineering.

1 INTRODUCTION

1.1 Rationale for implementing variation theory

Engineering education deals with complex engineering concepts that require diverse levels of teaching and learning methods [1]. For students to demonstrate such concepts, a few teaching methods are considered effective, such as face-to-face classroom teaching and project-based or problem-based learning [2]. However, the ability of these teaching and learning methods to set up the right conditions for learning is not clear yet. In this connection, the variation framework of teaching [3] claims that students learn to the extent to which the necessary conditions of learning are met. However, the theory has not been applied in engineering education. This research aims to explore the effectiveness of incorporating the variation framework into teaching engineering content.

1.2 Rationale for adopting phenomenography

Investigating 'how students learn' is often raised as an area of interest by academics. Over the last few decades, a substantial amount of research has explored students' conceptions of learning in different fields of education, adopting a phenomenographic approach. In engineering education, teachers and students need to deal with realworld practical problems that demand an appropriate ‘object of learning’ to be discerned by the students, and a phenomenographic approach is required to comprehend this discernment [4]. However, why and how students’ conceptions of such problems vary is often surprisingly ignored by researchers, particularly in engineering education. This study fills this void by seeking answers to the following research question that guides the adaptation of variance and invariance in teaching engineering content.

Does the application of the variation framework in teaching engineering content enhance students’ learning?

2 METHODOLOGY

2.1 Research Settings

The following flow chart (see Fig. 1) represents the steps involved in setting the research environment.

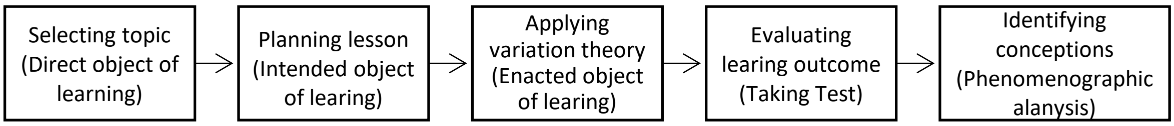

Fig. 1. Steps involved in this research settings

Two university teachers with more than five years of teaching experience participated voluntarily in this study. One of them is the third author of this study. Each of them developed their lesson plan independently to deliver the same *direct object of learning (content)*. The teacher in the experimental group, being aware of the variation theory, developed the lesson plan considering the relationship between students' learning and teaching patterns of variation and invariance. Whereas the teacher in the experimental group, having no knowledge about the variation theory, developed the lesson plan in traditional method.

2.2 Participants

63 third-year students (37 from the experimental group and 26 from the control group) enrolled in the *Industrial Quality Control* Course and two teachers from the mechanical engineering department of a teaching-oriented private university in Bangladesh participated in this study, where one of them applied the variation theory, and the other teacher taught the same topic adopting a traditional teaching method.

2.3 Lesson Planning

Three critical aspects of the phenomenon were identified, and four conditions were constructed to allow students to experience variation in those aspects as part of the lesson plan (see Table 1). The term 'critical aspect' was taken from Pang's research [5].

Table 1: Variation of different knowledge levels required to learn the lesson

	Critical Aspect 1	Critical Aspect 2	Critical Aspect 3	Intended object of learning
Conditions	Mean and Control Limits	Issue of Central Tendency/ Accuracy	Issue of Variance/ Precision	Level of Understanding the complexity
A	V	I	I	Evaluate Components related to Control Charts
B	I	V	I	Judge the Sample Acceptance/ Rejection
C	I	V	V	Complex Scenario Analysis
D	I	V	I	

Note. V = variation; I = invariance

2.4 Data collection

The two groups of students mentioned above were given the same written question (shown below) in two phases. In the first phase, teacher X taught the topic to the control group without using variation theory, and students had 30 minutes to respond. In the second phase, teacher Y used variation theory to teach the same topic to the experimental group. The students were asked to answer the identical question to assess how the variation theory had influenced their knowledge of the topic (learning objective).

Question on Industrial Quality Control

A quality control inspector at the Fun Fizz soft drink company has taken three samples with four observations each of the volume of bottles filled. The inspector collects the data on a regular basis. If the standard deviation of the bottling operation is 3 ml and 3 standard deviation limits for the 250 ml bottling operation are prescribed by the quality inspector, the control chart variables can be constructed with the sampled data. Assume you are the quality assurance manager of the company and are supposed to report to the operation manager to take any action you think is required. Comprehend the production line quality conformance for the data of 2 days as shown in Table 2 (please comment on each day's production operation separately). Justify your comments.

Table 2: Volumes of the sample bottles collected during Day 1 and Day 2 on different shifts of Morning, Noon, and Evening are as follows.

Sample / Observation	Day 1			Day 2		
	Morning	Noon	Evening	Morning	Noon	Evening
1	249	251	250	239	253.5	256
2	250	252	252	243	251	256.5
3	246	249	253	239	252	256.5
4	249	249	251	246	252.5	256
Sample Mean	248.5	250.25	251.5	241.75	252.25	256.25
Sample Range	4	3	3	7	2.5	0.5

Data Analysis

A phenomenographic data analysis technique was adopted to explore the extent to which the *intended object of learning* varied [6]. All the responses were combined into a "pool of meaning," and distinctions were made between qualitatively different explanations to form the category of the responses. Four categories of the object of study were emerged from the data. To arrive at the final categories, the following question was utilized as a guide:

How does 'quality of a production line' be understood by the students?

3 RESULTS

3.1 Comparison of learning outcomes

When exploring students' understanding of factors affecting industrial quality control, four qualitatively distinct ways of understanding the direct object of learning were identified.

A. Quality of production line can be expressed with control charts
B. Quality of production line can be rationalized for sample acceptance/rejection
C. Quality of production line can be explored by the offset from the mean
D. Quality of production line can be explored by the outlying variety of samples

Table 3. Distribution of the Conceptions for the Written Task

	Experimental Group (37 students) (Variation theory applied)		Control Group (26 students) (Variation theory NOT applied)	
Conception	Occurrences	%	Occurrences	%
A	34	91.9	22	84.6
B	30	81.1	16	61.5
C	34	91.9	1	3.9
D	36	97.3	1	3.9

3.2 Effect of variation theory on student learning

Table 3 shows how students in the experimental and control group understood *production line quality control* through the use of the presence and absence of variation theory in the classroom. The majority of students in the experimental group were able to recognize all four aspects of the phenomenon taught using variation theory. The students in the control group were able to understand the lower-order concepts A and B (85.6% and 61.5%), but they were unable to comprehend the higher-order concepts C and D (around 4% for each). In conclusion, this research confirms that variation theory has a better ability to create necessary learning conditions and thus has brought a positive impact on student learning in engineering education.

4 SUMMARY AND ACKNOWLEDGMENTS

This research investigates a novel phenomenon: using variation theory in engineering education and analysing its impact on student learning using phenomenographic principle. This short paper reports evidence of how, by incorporating variation theory, a faculty member designed different pedagogical approaches that ranges from less sophisticated (A to B) to higher (C to D), which facilitates students conceptualizing complex engineering topics more systematically than those who do not discern variation. An extended version of this article is expected to appear in future publications.

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