Effects of Cooperative Learning as a Teaching Method for an Introductory Course in Engineering Statistics

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Abstract - **Background**: The introductory course in Engineering Statistics appears to be rather difficult to a large number of students. A number of studies have been devoted to methods of teaching general statistics, but very few studies have been conducted for Engineering Statistics at an introductory level. **Purpose/Hypothesis**: This study examined the relative effects of cooperative learning vs. conventional lecture methods of instruction. **Design/Method**: A class was taught during the first half of the semester with lectures. During the second half, the intervention of cooperative learning for small groups of students was used. **Results**: Scores achieved in homework, quizzes, and examination scores were the dependent variables. It was observed that a substantial number of students performed better using the cooperative method and mean scores for homework, quizzes and examinations significantly improved. **Conclusions**: It appears that the cooperative learning method of teaching may be a way to augment student's learning in introductory statistics.

Key Words: cooperative learning, engineering statistics, active learning

INTRODUCTION

Garfield [Garfield, 7] advocates cooperative learning methods for statistics. Over 1200 studies testify that the traditional mode of teaching is less effective than cooperative learning; however, very few studies address the use of cooperative learning in engineering statistics in engineering colleges. The objective of this study was to determine the impact of cooperative learning vs. traditional lecture methods in an engineering statistics class.

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Several researchers [Gal, 6; Rumsey, 16; Utts, 17] have studied the effect of implementation of the recommendations in mathematics, statistics, psychology, sociology, business and economics departments. This study attempted to study the effect of cooperative learning (team work) on an introductory course in engineering statistics at the college level.

BACKGROUND

The dramatic growth in enrollment, great variation of quantitative sophistication levels, and motivation of students to learn have resulted in challenges to teaching an introductory course in statistics. During the last few decades there been several studies to determining how students learn statistics and how to be more effective in helping them to learn [Garfield, 7; Cobb, 2]. The original three recommendations of the Cobb report [Cobb, 2], i.e. emphasize statistical thinking, focus on concepts and foster active learning, have been expanded and the emphasis is placed on statistics literacy and statistical thinking by three authors [Gal, 6; Rumsey, 16; Utts, 17]. In general, the recommendations suggest to: use technologies available, simulations to illustrate concepts, assessment to get feedback of learning, implement changes in small steps, demonstrate software, and actively engage students to work in teams. Since the publication of the Cobb report [Cobb, 2], many changes were implemented to reform teaching of introductory statistics. Garfield [Garfield, 8] surveyed a large number of statistics instructors from mathematics, statistics, psychology, sociology, business and economics departments and concluded that advances in technology and software make tools and procedures easier to use, thus decreasing the need to teach the mechanics of procedures, but increasing the need for sounder grasp of fundamental concepts needed to use the tools.

The American Statistical Association (ASA) funded the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Project in 2003, which consisted of two groups, one focused on K-12 education and one focused on introductory college course [ASA, 1]. The first printing of the college report detailing "Guidelines for Assessment and Instruction in Statistics Education" (GAISE) was published in 2005. Six recommendations for teaching of introductory statistics build on the previous recommendations from Cobb's report are:

- Emphasize statistical literacy and develop statistical thinking;
- Use real data;
- Stress conceptual understanding, rather than mere knowledge of procedures;
- Foster active learning in the classroom;
- Use technology for developing conceptual understanding and analyzing data;
- Use assessments to improve and evaluate student learning.

Definition of Traditional Learning:

Traditional learning involves a lecture format with students working independently.

Definition of Cooperative Learning:

Cooper, et al [Cooper, McKinney, and Robinson, 3] defined Cooperative Learning as "a structured systematic instruction strategy in which small groups work together for a common goal". Migel [Migel, 13] defined "Cooperative learning is a form of active learning in which small groups work together on exercises designed to improve learning". Another definition focused on objectives has been given by Johnson et al [Johnson et al., 10] as the instructional use of small groups to maximize their own and each other's learning. Cooperative learning involving small-group interaction, centered on learning material, should enhance learning as the method is logically connected to effective learning strategies as described in the literature on cognition and learning. These strategies include self-monitoring and testing, repeated and variable contact with the material to be learned, external contact with the material to be learned, external connections between the material and outside ideas, and practice with feedback [Pressley, 15]. Cooperative learning groups offer opportunities to use all of these strategies.

Dale [Dale, 4] created the cone of learning that presented a comparison of different teaching methods in regard to the degree of learning retained after a period of time. He found the lecture as the poorest method whereas cooperative group method produced the greatest retention. Lord [Lord, 12] conducted an experiment involving several classes of students using different teaching methods and found the outcome almost identical to that of Dale [Dale, 4] Figure 1. Similar observations have been found by Herried, et al. [Herried, 9].

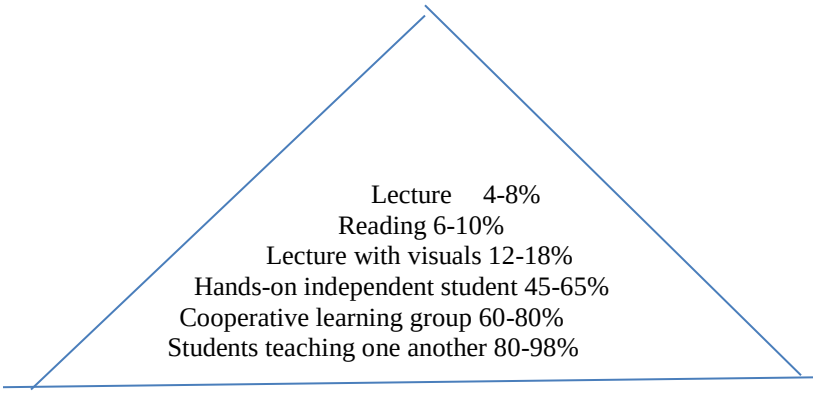

Figure 1 Cone of Learning
Percentage of retention after six weeks
Adapted from Lord [Lord, 12]

The recently adopted GAISE [Franklin, 5] make similar recommendations explicitly stating that, "As a rule, teachers of statistics should rely much less on lecturing, and much more on the alternatives such as projects, lab exercises and group problem solving and discussion activities" .

METHODS

Course Format

The College of Engineering at the University of Alabama offers a course on introductory statistics, "Engineering Statistics I". The course is offered in each semester, i.e. Fall, Spring, and Summer. Students enrolled in this class are from various engineering programs; mostly they are from Civil, Construction, and Environmental Engineering programs with a few from Computer Science, Electrical, Chemical, and Mechanical Engineering programs. The class size varies from semester to semester, but ranges from 65 to 85. The class is a three credit hour course and covers the following topics:

- Introduction and Descriptive Statistics
- Introduction to Probability and Bayes ' Theorem
- Discrete Random Variables and Probability Distributions
- Continuous Random Variables and Probability Distributions
- Joint Probability Distributions and Central Limit Theorem
- Single Sample Confidence Intervals
- Tests of Hypotheses Based on Single Sample
- Simple Linear Regression and Correlation.

Examinations and quizzes

There were six quizzes to test their understanding of fundamental concepts and three class examinations. The quizzes consisted of true/false and multi-choice type questions, while the examinations consisted of two parts. Part one was closed book and questions were of true/false and multi-choice types. Part two consisted of six problems to solve and was open-book. The first half of Engineering Statistics was taught using traditional methods. After the mid-term examination, the teaching method was changed to cooperative learning.

Cooperative Learning Groups

Students were instructed to form four or five person groups. Group choice was left to the students, believing that it would result in better efficiency, since the students got into groups with other students that they might feel comfortable working with. The number of students in a group was dependent on the number and difficulty level of

the problems assigned. It was important to find a balance between a group that was too small compared to one not big enough to solve the problems assigned and too many students in a group resulting in inefficiency and idle time for some students.

Questions

Questions were prepared considering the material covered in the chapter as well as the homework problems. Each group was assigned two questions, one easy and one tougher, involving more difficult concepts. The questions were prepared keeping in mind the time it would take students to solve the problems in the class and making sure it would allow enough time for the students to interact with each other and ask any specific problem to the professor or the teaching assistant present in the class.

Monitoring and intervening during the cooperative learning sessions

A teaching assistant monitored the coop sessions and also provided some tips when required to solve the hurdle faced by the students. Monitoring also discouraged any inappropriate approach.

Analyses

Mean student performance on homework, quizzes and examinations between the traditional portion of the course and the cooperative learning portion were compared with paired t-tests. The distributions of difference scores were examined descriptively to gain insight into individual student performance differences. These differences were also examined with two-independent sample t-tests. Descriptive statistics were also used to examine student opinions from a seven item survey given at the end of the course, which asked students about cooperative learning sessions. They were asked if it helped them understand class material, made the course more interesting, improved their performance and was overall effective. They were also asked about the appropriateness of the level of quality/difficulty of the problems, how groups should be formed and whether cooperative learning should be used during the next semester.

RESULTS

Homework

For homework, the mean (standard deviation) for the traditional method was 65.0 (27.6) compared to 75.7 (26.9) for the cooperative learning method ($t = 3.94$, $df = 58$, $p < .001$). Although the means significantly increased for homework, not all students presented improvement in scores. Thirty-eight (38) students increased their average, three stayed the same and 18 decreased. The amount of increase ranged from one point to 68 points. The amount of decrease ranged from two points to 36 points. This is illustrated in Figure 2 where students were ranked from largest increase to greatest decrease. For clarity purposes, the lines were smoothed by eliminating some students from the graph.

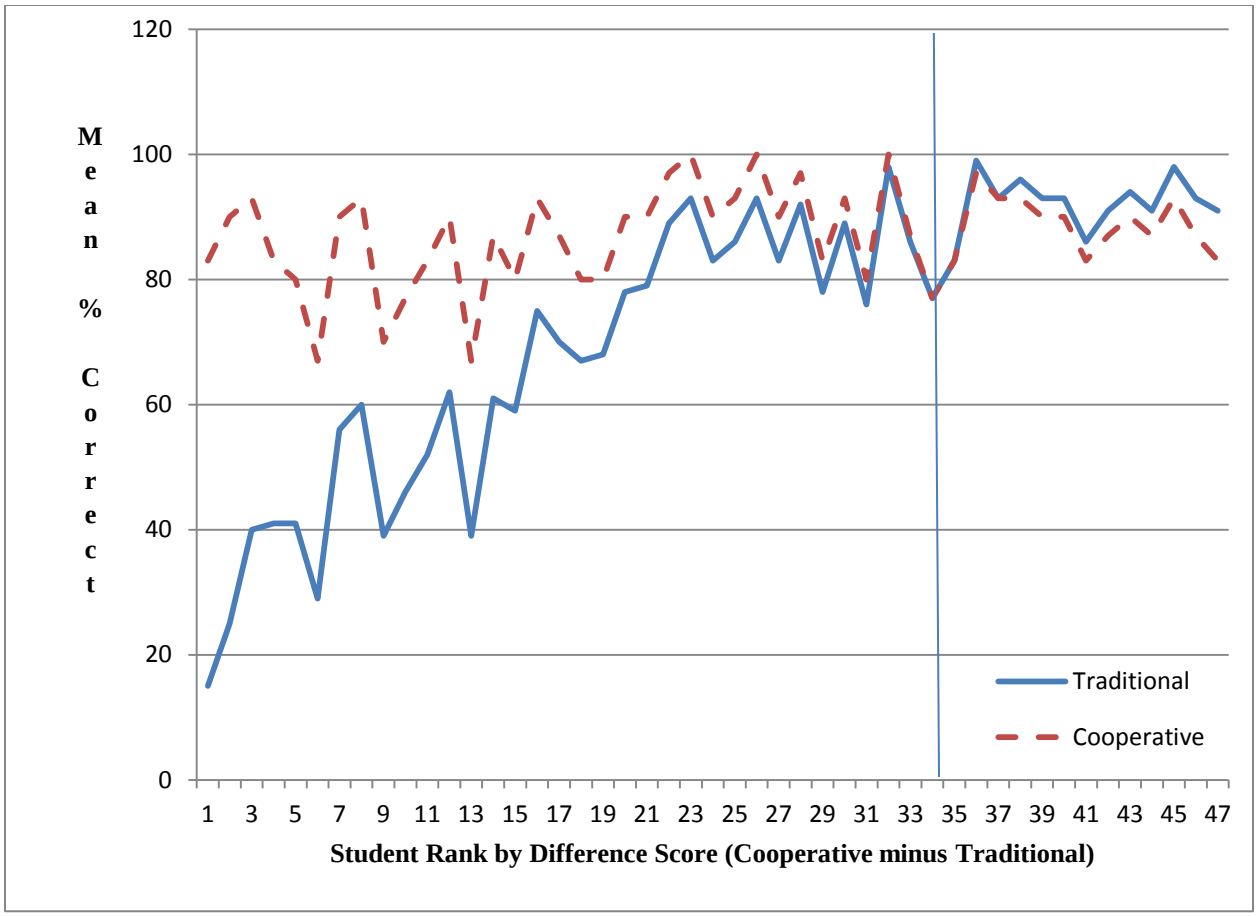

Figure 2. Comparison of Student Homework Score Means for Traditional vs. Cooperative Methods Ranked From Greatest Increase to Greatest Decrease

Quizzes

For quizzes, the mean (sd) for the traditional method was 60.0 (21.3) compared to 68.7 (21.4) for the cooperative learning method ($t = 2.85$, $df = 58$, $p = .006$). Forty (40) out of 59 students increased their average, three stayed the same and 16 decreased. The amount of increase ranged from three points to 81 points. The amount of decrease ranged from one point to 53 points. This is illustrated in Figure 3 where students were ranked from largest increase to greatest decrease. For clarity purposes, the lines were smoothed by eliminating some students from the graph.

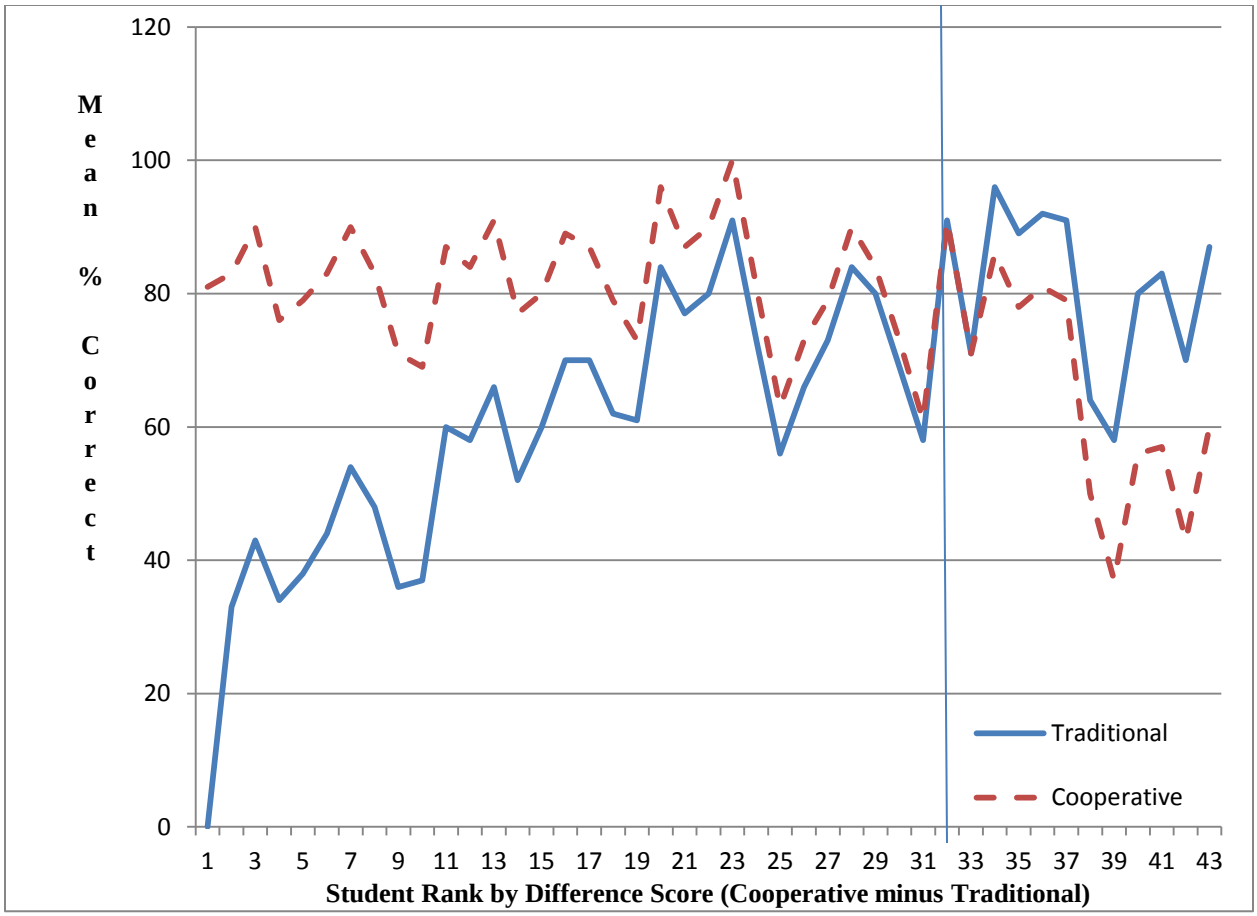

Figure 3. Comparison of Student Quiz Score Means for Traditional vs. Cooperative Methods Ranked From Greatest Increase to Greatest Decrease

Examinations

For examinations, the mean (sd) for the traditional method was 66.1 (19.5) compared to 77.3 (20.4) for the cooperative method ($t = 4.00$, $df = 58$, $p < .001$). Forty (40) out of 59 students increased their average, one stayed the same and 18 decreased. The amount of increase ranged from two points to 46 points. The amount of decrease ranged from one point to 54 points. This is illustrated in Figure 4 where students were ranked from largest increase to greatest decrease. For clarity purposes, the lines were smoothed by eliminating some students from the graph.

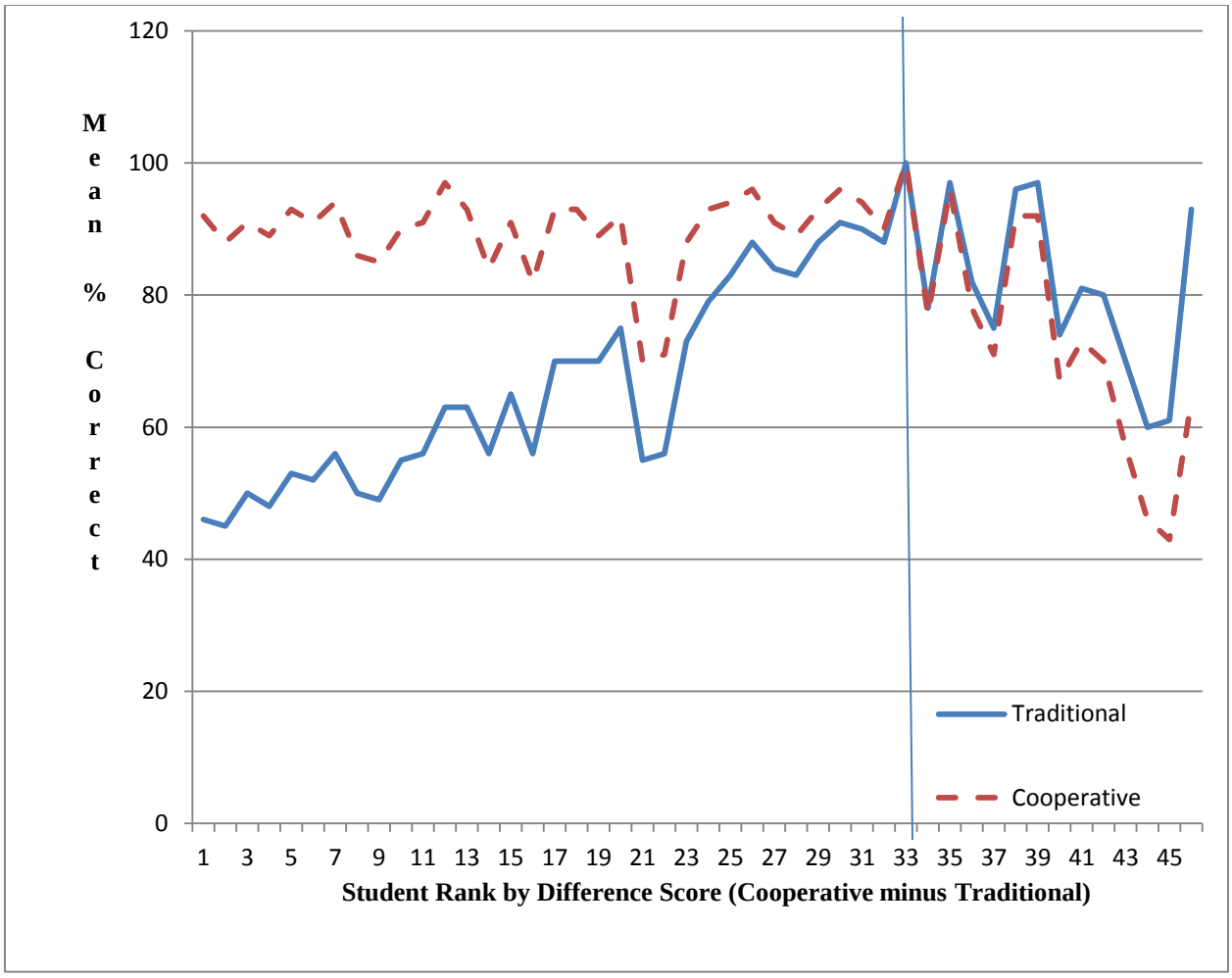

Figure 4. Comparison of Student Examination Score Means for Traditional vs. Cooperative Methods Ranked From Greatest Increase to Greatest Decrease

Student Opinion

The student opinion survey showed that a majority of students liked the cooperative learning approach: 70% agreed it helped them understand class material, 54% agreed it made the course more interesting, 61% agreed it improved their performance, 73% agreed it was overall effective and 79% agreed it should be continued next semester.

CONCLUSIONS

On average, engineering undergraduate students performed better after switching to the cooperative learning method, which is consistent with findings in other disciplines [Johnson, 11]. This was true in all elements of the course, i.e. homework, quizzes and examinations. The majority of students liked the cooperative learning method. It appears cooperative learning helps lower performing students more than higher achieving students. This is too be expected, if for no other reason than good students have less room for improving (the ceiling effect).

Some students did score lower after the change to cooperative learning (31% on homework, 27% on quizzes, 31% on examinations). This observation was supported by Weltman and Whiteside's [Weltman, 18] report on interaction between teaching method and student GPA. They found that when hybrid and "fully active" approaches were used,

students with high, medium, and low GPAs performed equally. In both conditions the performance of the high GPA students was significantly less than their performance under the lecture method. They concluded that active learning is not universally effective and further concluded that "It is possible that students with high GPA achieve a deeper level of learning when experiencing exposure to the maximum amount of instructor expertise and direction." One of the reasons for the inconsistent results in the active learning is the way the experiments were conducted. Pfaff and Weinberg [Pfaff, 14] concluded that active learning activities are effective to the degree that they encourage students to think about the underlying statistical concepts. It is also not uncommon for students who perform well in the first half of a course to decrease their efforts during the second half because they feel assured of a passing grade in a course that they do not consider central to their engineering education.

Williamson and Rowe [Williamson, 19] observed reduced withdrawals in the group-problem-solving section. The withdrawal rate was about one-half (17.3 %) the rate in the control group (33.5 %). They observed a similar difference in withdrawal rate though the two groups had similar scores in the given Test of Logical Thinking (TOLT). The authors mention that a feeling of comradeship developed in the cooperative group enabled students to persist whereas feeling of isolation of the control group led to withdrawal more frequently. This is particularly important in cases where a University is trying to attract and retain more students in engineering majors. Group problem solving should be a part of the arsenal of teaching strategies [Williamson, 19]. It appears that students of lower ability improved their performance significantly in the cooperative learning method in this study. This observation is supported by Williamson and Rowe's [Williamson, 19] observations. It may be due to the fact that the students in co-operative learning were obliged to apply more effort and time in solving problems compared to that used by the students in the lecture method. Another reason may be due to the fact that students are less intimidated while discussing with peers.

Overall, it appears that the cooperative learning method of teaching may be a way to augment student's learning in introductory statistics as well as retaining students in an engineering major. However, the teaching method and experiment have to be designed using activities to explain the underlying concepts and requiring students to demonstrate their understanding of these concepts.

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