Team-Based Learning in: "El Eng 447: Information Theory and Coding Theory"

1. Course Situation

- Department: Electrical and Computer Engineering
- Subject: Information Theory and Coding Theory
- Level: Graduate (second-year)
- Students: N = 18, 1 female student, 13 Indian, 3 Chinese, 2 U.S. citizens
- Time Structure: 3 50-minute lectures per week, 45 lectures in a semester (16-week semester)
- Any special course or classroom factors? None

2. Learning Goals for the Course

- Students will understand and remember key concepts from the main content areas listed in the topical outline (below).
- For a given communication channel, students will be able to compute the maximum rate of reliable transmission and design, evaluate, and implement codes that achieve capacity with reasonable decoding complexity.
- Students will build the knowledge and develop the skills necessary to read and understand articles written in journals such as the *IEEE Transactions on Information Theory*.
- Students will learn how to work effectively in a group setting to accomplish goals related to a coding theory project.
- Students will appreciate the importance of coding theory and information theory and its impact on society.
- Students will be able to direct their own learning in understanding, designing and evaluating new codes.

3. Reasons for Changing to Team-Based Learning

- In a previous offering of El Eng 447, the instructor encountered a great deal of student resistance to working difficult math-based problems. Material was conveyed primarily using lectures with mathematically rigorous definition, theorem, and proof sequence. Students seemed to be completely overwhelmed by material, and this difficulty resulted in student frustration, apathy, and low evaluations.
- Methods of incorporating team-based learning were observed at a Course Design Retreat offered through the University of Missouri New Teaching Faculty Scholars' Program. Team-based learning seemed to be an effective and enjoyable way to get students to learn difficult material.

4. Changes Made

- The following educational activities were added to the course:
  - Reading quizzes: included a group-based graded component
  - Reflections: Students were asked to post responses to essay questions about course material
  - Learning portfolios: Students were asked to compile their best work in the course and write a 5-page narrative describing what they learned in the course.
  - Presentations: Students were asked to present research results from articles published in the *IEEE Transactions on Information Theory.*
  - Resubmission of Homework: Students were allowed to resubmit homework problems to improve their score.
  - In-class Group Work: Students worked in groups of 3 or 4 to solve structured in-class assignments.
  - Intraclass Design Challenge: Student teams competed to design and test the best code.
- Results:
  - It was observed that none of the students in the class was apathetic.
  - Students uniformly commented that they were working very hard and enjoying it.
  - Participation of students during class increased dramatically. Students scrutinized proofs and examples obsessively, thus showing increased interest in material.
  - Students interacted extensively with one another during class.

5. Examples of Team Assignments

- **Code Design Challenge**: A major month-long group project was assigned, entitled the Code Design Challenge. Teams of three or four students worked to design the best code for a variety of given communication channels and then produced simulations to back up their claims. When final reports were finished, teams traded work to verify performance. Final grades were based upon completeness of the final report, and teams that had the best demonstrated (and subsequently verified) code performance won reward points. There was enough flexibility in the specifications of the design problem to ensure that every team would have a chance to win some reward points in at least one category. Not all teams claimed these reward points. These group activities fostered cooperation and forced students to apply lecture material to solve difficult problems while also creating student-to-student interactions important to the overall learning experience of the class.
- **Reading Quizzes:** During the semester, several reading quizzes were given. Students were asked to read a chapter in the book, for example, then

given a multiple-choice quiz to solve in class. After the individual quizzes were taken, groups of three or four were formed to solve the same quiz collectively. The students score on the exam was always a function of both the individual and group score. After quizzes were graded, students were allowed to argue their answers with the instructor in class. Students enthusiastically enjoyed the reading quizzes, as reported in the mid-semester survey and learning portfolio.

6. Impact

A. On Student Ratings of the Course:

- The following table shows the impact of these changes on student evaluations. Both offerings of El Eng 447 had the same number of students and similar ethnic composition. The Question column indicates the question being posed to students, e.g. Education Value correspond to the question, "Rate the educational value of this course." Ratings are given on a scale of 0 to 4.

Changes in Student Ratings:

Winter Semester 2001 to Fall Semester 2002

Question	Changes in Average Ratings for All Faculty in Department	Changes in This Instructor's Ratings†
Educational Value	+0.2	+0.7
Assignments/Tests	+0.2	+1.1
Instructor Concern	+0.2	+0.3
Preparedness	+0.2	+0.4
Communicate	+0.3	+0.3
Stimulate/Motivate	+0.3	+0.7
Overall	+0.3	+0.3

†Winter 2001: Before incorporating team-based learning
Fall 2002: After incorporating team-based learning

- For example, the Educational Value line shows that between Winter 2001 and Fall 2002, the ratings for El Eng 448 increased by 0.7 while the

average ratings in the department increased by only 0.2. This increase appears to be statistically significant and may be attributed to the use of TBL strategies.

B. On Student Attitudes

- The following excerpts from the non-anonymous learning portfolio show the power of active learning techniques and team-based learning in transforming students into enthusiastic learners.
  - "On the whole, EE447 Information theory and Coding theory has been an interesting learning experience which I will not forget for the rest of my life. The course has provided me with the requisite knowledge to carry out independent study and possibly some research over my career."
  - "I enjoyed this entire course to the fullest. . . . Being a part of the "Information and Coding Theory class" I learnt lot more than the course work. On the whole being a part of this class was entertaining and at the same time enlightening."
  - "It is hard to single out one enjoyable aspect of the course. The course was packaged in such a way, thanks to the instructor, that it made us really enjoy every aspect of it. Right from the lectures to the group work done in the class and of course, the reading quizzes. Doing the homework, again, was a great revelation."
  - "Reading quizzes were also very helpful because in order to [take] this kind of exams one needs to understand each and every point of the subject. Weekly reflections, I feel is also a good concept, because this gives a chance to the students to express their own ideas."
  - "I am thankful to Dr. Weeks for providing such a good course and also thankful to other students in the class for providing such a great atmosphere in the class. I will probably remember the course and Instructor in particular throughout my life."
  - "Even though I had a lot of fun and good things in the course, my disappointment was not getting the best code design award. Our ultimate goal when we started the project was to get the best project. But things didn't turn out well as we put ourselves in the hole by spending very less time in the documentation. The net result was the bad documentation. My advice to the student who do projects is to spend 30% of the effort for documentation as it counts a lot."

C. On the Teacher

- The changes in the class required some extra effort on my part to construct activities and team-based learning strategies. I had to take my content (info theory/coding theory) and find ways to present design problems and reading quizzes for the student teams.
- The student response was nothing less than phenomenal. I never could have anticipated such drastic improvements in student morale. I was especially surprised that the students were motivated to work so hard. Many students reported to me that they enjoyed the work load in the class.
- Teaching such an excited group of students was an unforgettable experience. It made my job seem worthwhile and very fulfilling. I will be feeding off that student excitement for years.

7. Related Publications

- W. Weeks IV, "Incorporation of Active Learning Strategies in the Engineering Classroom," Proceedings of the 2003 ASEE Midwest Section Meeting, University of Missouri-Rolla, September 2003.

8. Contact Information

William Weeks IV
Department of Electrical and Computer Engineering
University of Missouri-Rolla
1870 Miner Circle
Rolla, MO 65409-0040
Phone: 573.341.6632
Email: weeksw@umr.edu
FAX: 573.341.6671

9. APPENDIX: More Detailed Information about Team Assignments and Products of the Teams' Work

This course had a special assignment that required students to work in groups to design codes of varying rate for reliable transmission of data across various channels.

The assignment sheet for this project is shown below; this description also includes the grading rubric for this assignment (shown at the end).

A description of the report by the student group that won the "Best Code Design" award is included as a separate file.

Special Assignment for this course:

Code Design Challenge, in El Eng 447, Fall 2002

Instructor: Prof. William Weeks

Purpose: The purpose of this group project is to give students an opportunity to design codes of varying rate for reliable transmission of data across various channels. Students will work in groups to solve practical problems in encoder and decoder design. This project will test your knowledge of coding theory as well as your ability to work effectively in groups.

Groups: First you must select a group. In this class, there will be 2 groups of 4 and 3 groups of 3. It is expected that every member of a group will make a contribution to the group project. Groups must be selected by **Friday, November 1, 2002**.

Challenge: Your group's challenge is to design a code for two of the following communication scenarios:

a. Communication across a BSC at a rate $R \geq 1/7$.
b. Communication across a BSC at a rate $R \geq 5/6$.
c. Communication across a binary-input AWGN (BIAWGN) channel at a rate $R \geq 1/3$
d. Communication across an intersymbol-interference (ISI) channel with $\mathbf{c} = [1 \quad 1]$ and AWGN at a rate $R > 1/2$.

The design goal is to minimize signal-to-noise ratio (SNR) at a fixed bit error rate (BER) of 10^{-3} and 10^{-5} while minimizing encoding and decoding complexity (run time).

Implementation: You must specify encoders and decoders completely in the documentation of your project, making liberal use of diagrams and figures. You must also implement your designs using Matlab, and simulate performance of your system over a wide range of the noise parameter of the channel you are using. For a BSC, the noise parameter is the crossover probability ε, and for the AWGN channels the noise parameter is the variance σ^2 of the Gaussian-distributed noise samples. The simulations will involve transmitting long sequences across the given channel model, resulting in an estimate of the bit error rate. Block codes should be able to handle input sequences which are not multiples of the block length. Submit preliminary code design before **November 15, 2002**. All code, documentation, and initial simulation must be completed by **November 25, 2002**.

Verification: After you have completed code design, simulation and documentation, you will hand your Matlab code to another team. Likewise, you will receive the code designs from yet another team. You will verify the performance of the code from the other team and will analyze their designs for improvements and/or weaknesses. This analysis will be part of your group grade. Verification is due by **Friday, December 6, 2002**.

Reward: Your individual grade on this group project will be based on the report, software, simulation results, verification, and peer evaluation of your personal contribution to the group project. A portion of the grade is competitive in that the team with the best SNR and/or running time will receive the most points. Furthermore, there will be prizes for the teams with the best code designs.

Sample Rubric:

Performance (40%)
- BER
- Running Time
- Simulations
- Novelty
- Software

Style and Format (15%)
- Use of Figures
- Neatness
- Organization
- Spelling and Grammar
- Bibliography

Verification and Analysis (15%)

Peer Evaluation (15%)

Reward (15%)
- Smallest SNR
- Best Running Time
- Best Code Design