Seating Arrangement, Group Composition and Competition-driven Interaction: Effects on Students' Performance in Physics

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Abstract. We probe the effect of seating arrangement, group composition and group-based competition on students' performance in Physics using a teaching technique adopted from Mazur's peer instruction method. Ninety eight lectures, involving 2339 students, were conducted across nine learning institutions from February 2006 to June 2009. All the lectures were interspersed with student interaction opportunities (SIO), in which students work in groups to discuss and answer concept tests. Two individual assessments were administered before and after the SIO. The ratio of the post-assessment score to the pre-assessment score and the Hake factor were calculated to establish the improvement in student performance. Using actual assessment results and neural network (NN) modeling, an optimal seating arrangement for a class was determined based on student seating location. The NN model also provided a quantifiable method for sectioning students. Lastly, the study revealed that competition-driven interactions increase within-group cooperation and lead to higher improvement on the students' performance.

Keywords: peer instruction method, seating arrangement, group composition, competition, cooperation
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INTRODUCTION

The effectiveness of peer instruction (PI) method in increasing student's learning of Physics concepts has already been established [1]. Studies have shown that PI enhances conceptual understanding, subject mastery, and problem solving skill [2]. In this teaching method, the students are given interaction opportunities (SIOs) to discuss their answers in a given conceptual question. Research showed that the percentage of correct answers typically increases after SIOs [3]. This increase in test scores is not simply due to the influence of knowledgeable peers. Recently, peer discussion has been shown to enhance understanding even when none of the students in a discussion group originally knows the correct answer [4].

In this study, we present a strategy to optimize learning by considering the effect of seating arrangement, group composition, and motivation if deliberate student-student interactions are integrated in a lecture design. We also characterized the information propagation dynamics in a classroom using neural network modeling.

METHODOLOGY

Modified Peer Instruction Method

Sixty-eight (68) experimental lectures framed on Eric Mazur's Peer Instruction Method [5] were conducted in 9 learning institutions to investigate the effect of seating arrangement on students' learning. Of these, 20 lectures were done involving college students and the remaining 48 lectures with high school students.

For each lecture session, the following format was used: main lecture (20 min), first assessment (10 min), student interaction opportunity (SIO) (15 min), and second assessment (10 min). The main lecture consisted of Physics demonstrations and conceptual questions called ConcepTests. After the lecture, a pencil-and-paper test composed of 10 multiple choice questions was administered as the first assessment. During SIO, students were instructed to interact with their neighbors. Accordingly, they were able to do the following: review answers to conceptual questions in the main lecture; discuss prior knowledge on the topic that was not included in the lecture; list and answer

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questions of each group member regarding the lesson. To isolate the effect of SIO, a second assessment with the same number of items and level of difficulty as the first was administered.

The improvement in the performance of each student was measured by calculating the Hake Factor or average normalized gain <g> [6], which has been defined as the ratio of the actual average gain to the maximum possible average gain as given by the formula:

$$\langle g \rangle = \frac{\langle 2^{nd}\, assessment - 1^{st}\, assessment \rangle}{\langle 1 - 1^{st}\, assessment \rangle} \quad (1)$$

Students' improvement was also measured by computing the output/input ratio (O/I), which is the ratio of the second assessment score to the first assessment score. An O/I value greater than 1 indicates an improvement in the students' scores. This measure is more helpful in trending the relative improvement of an ensemble of students but it tends to be biased toward low-scoring students.

Classroom Dynamics Using Neural Networks

Different seating arrangements, based on the students' perceived aptitude level (PAL) were investigated. The PAL of each student was initially qualified by averaging his/her previous performance in the Physics subject. The distribution of PAL was normalized with respect to the highest mark. Four different seating arrangements, each with an 8 x 8 size (total students = 64), were examined. These are referred to as: middle, inner four corners, random and outer four corners SA. The designation is indicative of the initial location of students with high PAL. An optimal seating arrangement was determined by analyzing the actual experimental lecture results and using neural network modeling.

An artificial neural network (NN) composed of three layers was utilized to map the transfer of learning represented by students' performance in the second assessment given their neighbors' and their individual performance in the first assessment. This was in line with the assumption that during interaction the amount of information that a student acquires is dependent on his current information and on the amount of information that his neighbors transmit. Neural network was used in correlating the resulting state of a student (second assessment score) as a function of the state of his/her neighbors and his/her own state before the interaction (first assessment scores). The network from the input (first assessment scores) to the output state (second assessment scores) was mapped. We used a three layer feed-forward NN where each element in the input layer was connected to each element in the hidden layer, and consequently to the output layer. Every connection was represented by a weight. In the training of the network, the weights were updated to minimize the difference between the experimental output and the estimate of the NN, specifically, using the gradient descent back-propagation method [7, 8].

The trained weights were also used to predict the performance of simulated homogeneously- and heterogeneously-sectioned classes. A simulated population of 640 students, with a Gaussian PAL distribution of 0.4 mean and 0.14 standard deviation (consistent with experimental data), is divided into 10 sections.

Incentive-driven Interaction

Thirty lectures were conducted to probe the effect of incentive-driven interaction on classes using the outer-four corners SA. Three learning conditions were observed: competition-driven; interaction-driven and no-motivation. Two-thirds of the total lecture was conducted with college students in either small or large class. Ten lectures were conducted with high school students using an 8x8 SA.

In the competition-driven condition, i.e., peer instruction with intergroup competition, students were informed prior to the SIO that their individual scores would be based on how well their group performed in the second assessment relative to the other groups in the class. Each group consisted of nine members seated in a 3x3 SA. For a large class (N = 72) with 8 groups, the members of the group that had earned the highest average score in the second assessment received an additional 3 points in their individual scores. Those with the second highest average got +2 points, and those with the third highest average obtained +1 point. For a small class (N = 27) with 3 groups, only the members of the group that had earned the highest average score in the second assessment received an additional 3 points in their individual scores. In the interaction-driven condition, i.e., peer instruction with individualized incentives, for every correct answer of a student's four closest neighbors (left, right, front and back), a 0.25-bonus point is added to the score of the student. If the student's four neighbors are correct then he/she increases his/her score by 1 (or 100%) per item.

In the control (no motivation) condition, the students proceed to the SIO without further instruction.

RESULTS AND DISCUSSION

Neural Network Modeling

A visual comparison of the experimental result and the corresponding neural network prediction is shown in Figure 1.

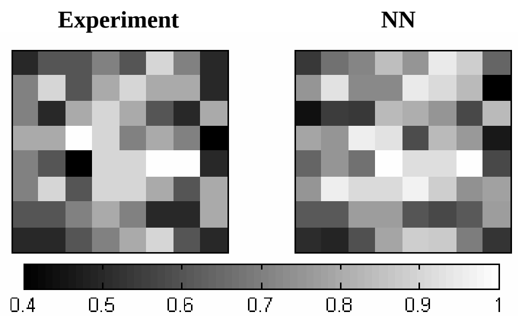

FIGURE 1. Neural network's prediction of the propagated information resulting from student interaction opportunities (SIO). Good agreement is observed between the actual values of the second assessment and the prediction of the NN (test sets) which was verified using Linfoot's criteria.

The similarity between the NN prediction and the actual generated patterns are evaluated using Linfoot's criteria of structural content C, fidelity F, and correlation quality Q [9]. The two states are identical when $C = F = Q = 1$. We obtained a high value of Linfoot's measures (an average of ~0.88) indicating that the NN model was able to characterize the information transfer during the students' interaction.

Effect of Seating Arrangement

Table 1 compares the average score improvement of different SA. It is observed that SA with high PAL students seated at the outer four corners (low PAL at the middle) has the highest O/I and <g>. This is consistent with the fact that SA with high PAL students concentrated at the center (less interaction opportunity for low PAL) has the lowest average <g> and <O/I>.

TABLE 1. Gain in the performance for different seating arrangements.

Seating Arrangement	O/I	<g>
Center	1.04±0.01	0.07±0.01
Inner four	1.08±0.01	0.14±0.02
Random	1.06±0.02	0.11±0.02
Outer four	1.11±0.01	0.18±0.02

In the outer-four corner SA, low PAL students were situated in the middle and more likely engaged with students of similar aptitude during the SIO. Despite this, the said SA resulted in the highest learning gain. This can be explained by a recent finding on the effectiveness of peer discussion even among students in naïve groups [4]. The study pointed out that peer discussion can be effective even when no one in the group initially knows the correct answer. The discussion is deemed more productive as it reinforces students' ability to arrive at conceptual understanding on their own.

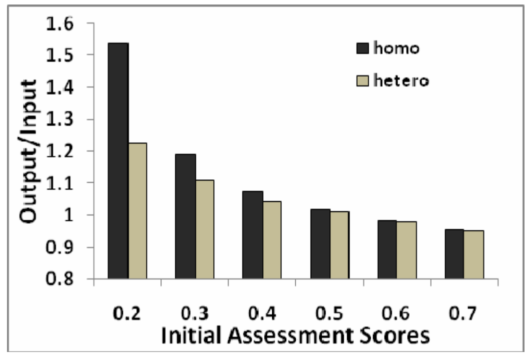

FIGURE 2. Average performance as a result of SIO for homogeneous and heterogeneous sections. Higher improvement is observed for students with low PAL (≤0.5).

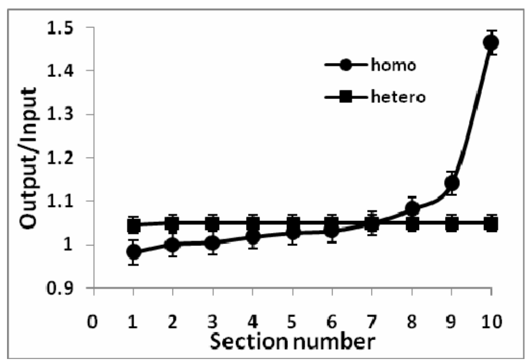

FIGURE 3. Per section improvement for HeS and HoS. Section 1 has the highest average PAL.

Effect of Group Homogeneity

Each section in the simulated population of students is arranged into the outer four corners SA. The trained NN predicts an average improvement for HoS higher than HeS as shown in Figure 2 (HoS: <O/I> ~ 1.11, <g> ~ 0.20; HeS: <O/I> ~ 1.05, <g> ~ 0.14). Higher improvement is observed for students with low PAL (≤0.5), which means that students with low PAL benefit more when grouped and allowed to interact with students of the same level. This in line with the earlier results of Smith et al [4] that peer discussion enhances understanding even when none of the students in the group originally knows the correct answer. Figure 3 further supports this idea. Large output-input ratio was obtained in the homogeneous group with the lowest average aptitude level.

Effect of Incentive-driven Interaction

Table 2 shows the average score improvement of the incentive-driven interaction as compared to the no-motivation condition. It is observed that there is a significant increase in the student's performance for the competition-driven learning condition. This shows that competing with other groups encourages the students to actively participate in the SIO resulting in higher value of <g> and O/I. It can also be observed that improvement of the students in the competition-driven scheme is almost the same for the small and large class sizes which implies that the effectiveness of competition-driven motivation was independent of the number of competing groups in a class. Results also show that similar to competition-driven scheme, a significant increase in the performance of the class is expected to be achievable when interaction–driven incentives are made available during SIO.

TABLE 2. Performance of students in incentive-driven and no-motivation interaction opportunities.

SIO	<g>	O/I
Competition-driven		
Small class (1)	0.42	1.77
Large class (2)	0.40	1.92
Interaction-driven (3)	0.15	1.47
No motivation		
1	0.23	1.30
2	0.13	1.37
3	0.02	1.22

TABLE 3. Average standard deviations of scores for each group before σ_1 and after σ_2 SIO, respectively, for the no-motivation and competition-driven scheme.

No motivation		Competition-driven	
σ_1	σ_2	σ_1	σ_2
0.15	0.14	0.19	0.12
0.15	0.18	0.18	0.16
0.18	0.18	0.21	0.13
0.16	0.17	0.20	0.14
0.12	0.14	0.19	0.15

Another interesting observation on the experimental data, as shown in Table 2, is that there was a decrease in the standard deviation of the group scores after SIO for the competition-driven conditions. No trend could be observed for the no-motivation case. The low variability in the second assessment scores of the competition-driven group is supported by the idea that in the process of building mutually shared cognition, through peer interaction, an agreement is reached for a joint interpretation [10]. The result further implies that cooperation among group members was enhanced by intergroup competition. This agrees with previous findings that between-group competition increases cooperation within a group and the class' overall productivity [11]. The same trend can be observed in the incentive-driven scheme.

CONCLUSION

A neural network can accurately characterize the information propagation in a classroom. Results of experimental lectures and NN model show that outer-four corner seating arrangement provides highest collective performance improvement. Peer instruction method is also proven to have greater benefits for low performing students. Student performance can further be improved through group-based competitions and individual-based incentives.

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