

Diverse Teams Build Better Forecasts

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Abstract

Is having a diverse team most useful for hard problems? This paper presents prior literature and results from a classroom activity that explores individuals versus homogeneous groups versus heterogeneous groups for solving complex problems. The forecasts from a classroom activity with 246 undergraduate and graduate students showed that the Random Groups (Heterogeneous Groups) forecasts were statistically better than Homogeneous Groups forecasts and Individual forecasts using the Mann-Whitney test. Combining this classroom exercise with a lecture focused on building diverse teams for forecasting (and other difficult problems), showed a statistically significant difference in pre-lesson perceptions versus post-lesson perceptions of the students using a test of marginal homogeneity.

Introduction

It is a well-held belief that diverse teams lead to better conclusions for complex problems. There have been numerous studies, from a variety of contexts, which have studied this premise. Recently, an article described using a linearized maximally diverse grouping problem formulation to create diverse teams within University of Michigan's Engineering Global Leadership Honors Program. Their results were implemented with minimal changes [1].

Work in homogeneous teams ("Group of Same") versus heterogeneous teams ("Group of Different") has shown that heterogeneous teams encounter more challenges as the diverse teammates learn how to work together; however, they often overcome their homogeneous team counterparts with better results [2, 3]. Extensive research by Ned Herrmann has evaluated both homogeneous teams and heterogeneous teams [4]. The advantages of homogenous teams are typically: less conflict, better coordination, advantage of cohesion, and higher satisfaction. The advantages of heterogeneous teams are typically: diverse thinking, better performance on complex tasks, and more creativity. The disadvantages of homogeneous teams are: groupthink, decisions are one-dimensional (i.e., no contingency planning), and limited innovation. The disadvantages of heterogeneous teams are: difficulty agreeing, more conflict, and hard to coordinate/manage. It has also been shown that homogeneous teams tend to reach a conclusion (albeit an inferior one) faster than heterogeneous teams [4]. This work has been corroborated and expanded by other studies [5-9].

Traditionally, diversity has included gender, race, ethnicity, and nationality. However, workplace literature also extends workplace diversity to include additional factors such as: age, work experience, educational background, time with organization, values, and goals [10-12]. Unfortunately, these aspects of diversity are not tested in this paper since the activity will be limited to an in-class activity since the sample of students is limited by the class and university demographics.

Classroom Activity

Forecasting is a major topic within the Industrial Engineering curriculum. Thus, the classroom activity presented will be applicable to the Industrial Engineering division and its membership.

Note, for the second phase and third phase the order will be alternated for different class sections.

The classroom activity will include forecasting a problem in three phases:

- The first phase will be forecasting the problem as individuals.
- The second phase will be forecasting the problems in homogeneous groups.
- The third phase will be forecasting the problem in heterogeneous groups.

The hypothesis of the activity is that the forecast of the heterogeneous groups will be superior to the homogeneous groups, and both groups will be better than the individual forecasts.

The activity is planned to last one 75-minute session. Forecasting, as a general topic, has already been discussed in a previous lesson; including mathematical formulas, performance metrics, and applications. The students begin the lesson by taking the pre-assessment survey. Then the students, individually, forecast the problem. Then students complete Phase 2 and Phase 3 (order alternates depending on section). A lecture on diverse teams is presented to the students with some real applications, and then a post-assessment survey is taken. Finally, the answer to the forecasting problem is revealed. The surveys are provided in the Appendix.

Research Questions

The research questions and hypothesis tests include the following, for perceptions and forecasts. The hypothesis tests were computed using the open-source R statistical software [13].

Perceptions:

A before-and-after survey was conducted with the students to test their perceptions on 12 different characteristics as they relate to teams, diverse workforces, and diverse executive boards.

For each of the 12 characteristics:

H₀: The means of the paired samples are equal (i.e., no significant change has occurred). H₁: The means of the paired samples are unequal (i.e., a significant change has occurred). Statistical Test: Test of marginal homogeneity (McNemar's test)

McNemar's test is useful here because it is non-parametric (i.e., it does not assume normality) and it is for dependent testing (i.e., before-and-after) of paired samples. It is useful when comparing whether participants learned something (Yes or No) from a pre-assessment to a post-assessment [14].

Forecasts:

- Question 1: Do heterogeneous groups outperform homogeneous groups?
- Question 2: Do homogenous groups outperform individuals?

Question 3: Do heterogeneous groups outperform individuals?

H₀: The distributions of both populations are equal.H₁: The distributions are not equal.Statistical Test: Mann-Whitney Test

The Mann-Whitney test is useful here because it is non-parametric (i.e., it does not assume normality) and it works with unequal sample sizes [15]. The performance of the forecasts were evaluated using both Mean Squared Error and Mean Absolute Deviation. Where, in both cases, the smaller the better. These are two common measurements of forecasts; suitable for instruction at both the undergraduate and graduate levels.

Results

Perceptions:

For both surveys, the students included their names; which allowed for a paired statistical test to be performed. Since the data was dependent (pre then post) and the underlying distribution was not assumed to be normal; thus, a test of marginal homogeneity (McNemar's test) was preformed to evaluate differences between pre-assessment and post-assessment responses for each student. The sample size was 246 students (93 undergraduates and 153 graduates), across eight sections of courses in statistics (undergraduate), operations management (graduate), lean (graduate), and big data [analytics] (graduate). It should be noted that no significant differences in the hypotheses were observed between the undergraduate and graduate student populations. The results are included in Exhibit 1.

The results indicate that the pre-assessment and post-assessment yielded a statistically significant difference except for the second question, seventh question, and eleventh question. For the second question, ("Do you think that having a diverse workforce will improve customer relationships for an organization?") when evaluating the responses for that question, the pre-assessment indicated 96.5% of students indicated a "Yes" therefore not leaving much room for change on the post-assessment (98.2%). For the seventh question, ("Do you think an individual subject matter expert will have a superior forecast to a group of experts?") the pre-assessment indicated 7% of the students indicated a "Yes" therefore only leaving a little room for change in the post-assessment (i.e., all students said "No" in the post-assessment). For the eleventh question, ("Do you think an individual's forecast will out-perform a group of similar individuals?") the pre-assessment indicated 17% of the students indicated a "Yes" and a post-assessment of 5% of the students indicating "Yes."

The two major questions regarding teams and groups (questions 8 and 9) were among the most significant. Question 8 asked "Do you think an individual subject matter expert will have a superior forecast to a group (of experts and non-experts)?" and the pre-assessment indicated that 53% of the students indicated a "Yes" but on the post-assessment only 1.75% indicated a "Yes." Question 9 asked "Do you think a group of experts will have a superior forecast to a group (of experts and non-experts)?" and the pre-assessment indicated that 84% of the students indicated a "Yes" but on the post-assessment indicated that 84% of the students indicated a "Yes" but on the post-assessment only 21% indicated a "Yes." Thus, these two questions were significant in the difference between pre-assessment and post-assessment.

With regards to the post-assessment, question 10, 93% of the students recognized that Heterogeneous Groups provided a better forecast, with 3.5% selecting Similar Groups (Homogeneous) and 3.5% selecting Individual forecasts. It should be noted that these post-assessments were distributed and collected before the final results (i.e., the answers) to the forecasting exercise were shared with the class.

Exhibit 1: Test of marginal homogeneity (McNemar's test) results for the pre-assessment versus post-assessment surveys for 246 students with $\alpha = 0.05$. Note that question 10 is reported separately since that was the individual forecast question.

Survey Questions:	Significance (p-value)
Do you think that having a diverse workforce will (Questions 1-4)	
1 enhance performance in sales for an organization?	0.008
2 improve customer relationships for an organization?	Not Significant
3 improve market share for an organization?	< 0.001
4 improve profitability for an organization?	< 0.001
Do you think that having a diverse Executive Board will (Questions 5-6)	
5 improve Return on Equity (ROE)?	0.001
6 improve Earnings Before Income Taxes (EBIT)?	< 0.001
7. Do you think an individual subject matter expert will have a superior forecast to a group of experts?	Not Significant
8. Do you think an individual subject matter expert will have a superior forecast to a group (of experts and non-experts)?	< 0.001
9. Do you think a group of experts will have a superior forecast to a group (of experts and non-experts)?	< 0.001
11. Do you think an individual's forecast will out-perform a group of similar individuals?	Not Significant
12. Do you think an individual's forecast will out-perform a group of diverse individuals?	0.031
13. Do you think a group of similar individuals will out-perform a group of diverse individuals?	0.002

Forecasts:

The results for the forecasts (Pre-assessment survey Question 10) along with the homogeneous group results and random group results are provided in Exhibit 2. Note that since we were confined to the members of the class, we are not able to claim purely heterogeneous groups; however, the students were randomly assigned to groups.

Exhibit 2: Forecasts for Individual, Homogeneous Groups, and Random Groups. The group size was 3 or <u>4 students</u>. Note that the target had an average of 2.8 and a median and mode of 3.

	Individual	Homogeneous Groups	Random Groups
Average	3.24	3.13	3.08
Standard Deviation	1.32	0.78	0.67

To test between the different forecasts the Mann-Whitney test on the means was used. The Mann-Whitney test is useful because it is non-parametric (i.e., it does not assume normality) and it works with unequal sample sizes. For Individual forecasts versus the Homogeneous Groups the p-value for the Mann-Whitney test was less than 0.001; thus, the two means are different. For the Homogeneous Groups versus the Random Groups the p-value for the Mann-Whitney test was less than 0.001; thus, the two means are different. The Homogeneous Groups versus the Random Groups the p-value for the Mann-Whitney test was less than 0.001; thus, the two means are different. The difference between Random Groups and Individual yielded a p-value less than 0.001; thus, the two means are different. Therefore, we can conclude that the Individual forecasts were different (worse) than the Homogeneous Groups forecasts, and the Homogeneous Groups forecasts were different (worse) than the Random Groups forecast. Thus, the Random Groups forecasts were superior. The Random Groups forecast and the two other categories based on means. Furthermore, the Random Groups forecast and the Homogeneous Groups forecasts alternated which was first or second depending on the class section. The order in which these forecasts were completed was not statistically significant.

Conclusions

This paper has two overarching conclusions. First, it is another example that Random Groups (Heterogeneous Groups) forecasts are superior to Homogeneous Groups and Individual forecasts. There was a statistically significant difference in the means of those data. Second, the students' perceptions did change for almost all of the questions, with statistical significance. These were tested using a test of marginal homogeneity (McNemar's test) to compare an individual student's before perception versus his or her after perception. Finally, 93% of students recognized that the "Group of Different" (Heterogeneous Group) forecast was superior to the "Group of Same" (Homogeneous Group) and their Individual forecast.

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Appendix

Note: Yes/No questions were coded Yes = 1 and No = 0 for the purposes of data analysis.

Pre-Assessment Survey

Do you think that having a diverse workforce will (Questions 1-4)				
1 enhance performance in sales for an organization?	Yes	No		
2 improve customer relationships for an organization?	Yes	No		
3 improve market share for an organization?	Yes	No		
4 improve profitability for an organization?	Yes	No		
Do you think that having a diverse Executive Board will (Questions 5-6)				
5 improve Return on Equity (ROE)?	Yes	No		
6 improve Earnings Before Income Taxes (EBIT)?	Yes	No		
7. Do you think an individual subject matter expert will have a superior forecast to a group of experts?	Yes	No		
8. Do you think an individual subject matter expert will have a superior forecast to a group (of experts and non-experts)?				
	Yes	No		
9. Do you think a group of experts will have a superior forecast to a group (of experts and non-experts)?	Yes	No		
10. What is your forecast for the problem?				
11. Do you think an individual's forecast will out-perform a group of similar individuals?	Yes	No		
12. Do you think an individual's forecast will out-perform a group of diverse individuals?	Yes	No		
13. Do you think a group of similar individuals will out-perform a group of diverse individuals?	Yes	No		

Pre-Assessment Survey

Note: Yes/No questions were coded Yes = 1 and No = 0 for the purposes of data analysis.

Do you think that having a diverse workforce will (Questions 1-4)					
1 enhance performance in sales for an organization?	Yes	No			
2 improve customer relationships for an organization?	Yes	No			
3 improve market share for an organization?	Yes	No			
4 improve profitability for an organization?	Yes	No			
Do you think that having a diverse Executive Board will (Questions 5-6)					
5 improve Return on Equity (ROE)?	Yes	No			
6 improve Earnings Before Income Taxes (EBIT)?	Yes	No			
7. Do you think an individual subject matter expert will have a superior forecast to a group of experts?	Yes	No			
8. Do you think an individual subject matter expert will have a superior forecast to a group (of experts and non-experts)?					
	Yes	No			
9. Do you think a group of experts will have a superior forecast to a group (of experts and non-experts)?	Yes	No			
10. Which forecast do you believe was better?Individual (Your Own)Group of Similar	Group of Dif	fferent			
11. Do you think an individual's forecast will out-perform a group of similar individuals?	Yes	No			
12. Do you think an individual's forecast will out-perform a group of diverse individuals?	Yes	No			
13. Do you think a group of similar individuals will out-perform a group of diverse individuals?	Yes	No			