



**Closing Achievement Gaps: Factors Impacting Student  
Performance in the First General Chemistry Course.**

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**NCAIR 2023 – 50<sup>th</sup> Annual Conference**  
*Back Together Again*

# Introduction and Learning Outcomes

- ▶ Review literature about success in the first general chemistry course
- ▶ Identify significant factors that impact student performance in first semester chemistry with a special focus on students from low-income or under-represented minority groups
- ▶ Discuss the challenges encountered in the research process
- ▶ Discuss finding implications

# Research Questions

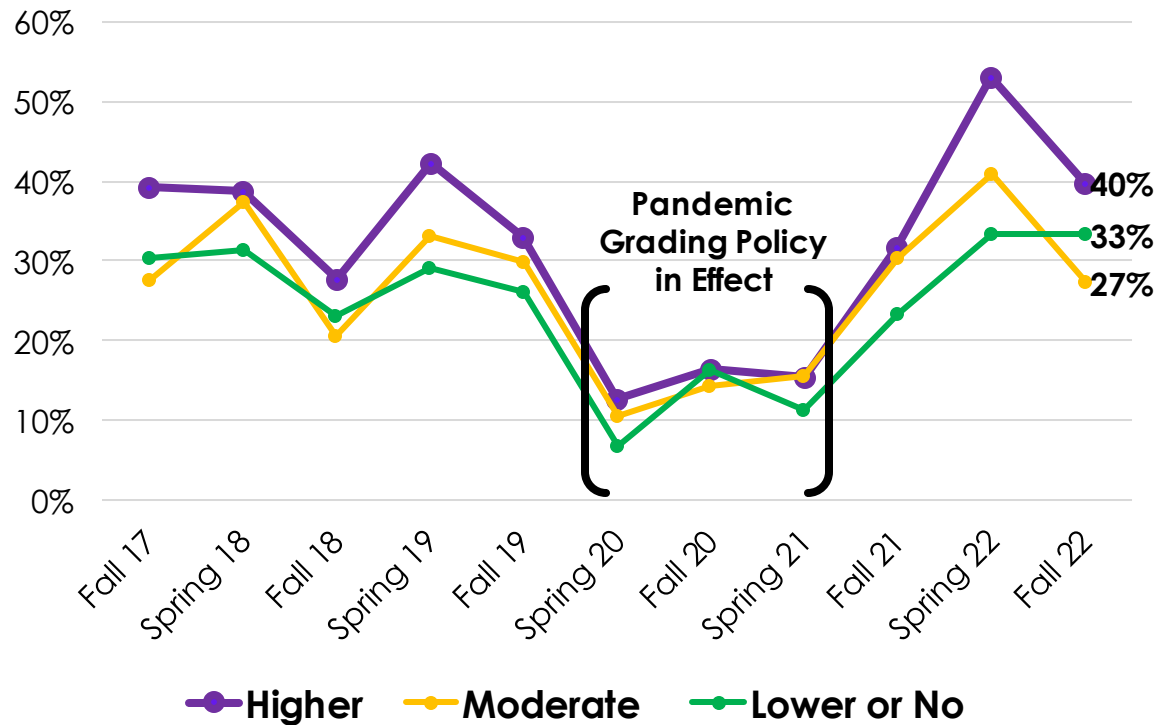
- ▶ What factors impact student performance in CHEM 1150?
- ▶ Does tutoring have a mediating effect on student performance for students with lower high school GPAs?
- ▶ After controlling for schedule difficulty and high school grades, do PEERs perform at the same level as non-PEERs?
- ▶ How do students from high schools with higher proportions of low-income and PEER students perform compared to their peers?

# Literature Review

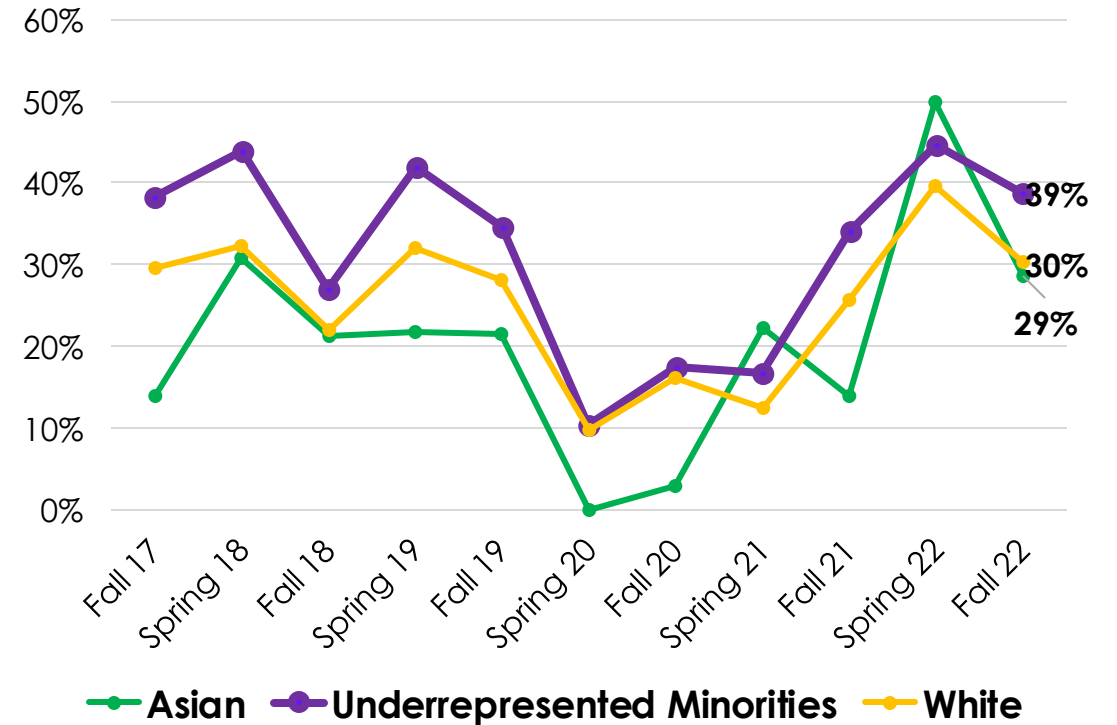
- ▶ **Persons Excluded due to Ethnicity and Race (PEER)** are twice as likely to leave STEM disciplines as Whites and Asian Americans. Most of these departures occur during the introductory STEM experience, typically in the first year of college.
- ▶ Systematic exclusion has resulted in the underrepresentation of people belonging to certain racial and ethnic groups in STEM. (Asai, 2020).
- ▶ STEM's leaky pipeline leads to a lack of diversity. Loss of women, PEERs, first-generation and low-income students with progression through the curriculum (NCES 2014).
- ▶ Relationship between math aptitude and chemistry performance (Ralph and Lewis, 2019)

# ECU Context: CHEM 1150 First-time Taker DFW Rates

## DFW Rates by Financial Need Level



## DFW Rates of Under-represented Minorities\*



*Excluding race/ethnicity unknown.*

# ECU Context: CHEM 1150 Placement

## CHEM 1150 / 1151 PLACEMENT BY SAT/ACT SCORE OR MATH PLACEMENT TEST

SAT MATH	ACT MATH	MATH PLACEMENT TEST	COURSE
0-560 (consider MATH placement exam - see above)	0-22 (consider math placement exam - see above)	0-16 on 1st test	Student CAN NOT take Chemistry. They must pass remedial math with a minimum C-, then pass MATH 1065 with a minimum C before taking CHEMISTRY.
570-590 OR placement into MATH 1065 by exam (see MATH placement section above)	23-24 OR placement into MATH 1065 by exam (see MATH placement section above)	17 or higher on 1st test	Must register for MATH 1065 first; then add CHEM 1150 and 1151 after math is on your schedule
600 or higher	25 or higher	Must pass the first test with 17 or higher; Then must pass 2nd test with 12 or higher	Able to register for CHEM 1150 and 1151 without having a math course on your schedule

- ▶ Chemistry Placement:
  - ▶ **Determined by SAT/ACT Score OR ECU's Math Placement Test (unchanged pre-and-post pandemic).**
  - ▶ **Prerequisite or corequisite for College Algebra (Math 1065) is in place for students with a lower math score.**
- ▶ ECU's math placement method has shifted multiple times for various reasons (the pandemic, admissions requirements, etc.) over the last few years. **A consistent quantitative measure of students' aptitude in Math is not available for the study.**

# Phase I Study

SUMMER & FALL 2022



# Phase I Study Overview

- ▶ Cohort: 1,465 First-time and transfer students who entered ECU between Fall 2012 to Fall 2015 (who had enough time to graduate in six years)
- ▶ Major or Intended Major: Chemistry, Biology, and Biochemistry requiring a 4-course sequence: General Chemistry (2) and Organic Chemistry (2)
- ▶ Research Interests:
  - ▶ Mapping student journey through the four-course sequence
  - ▶ Identifying factors impacting course grades

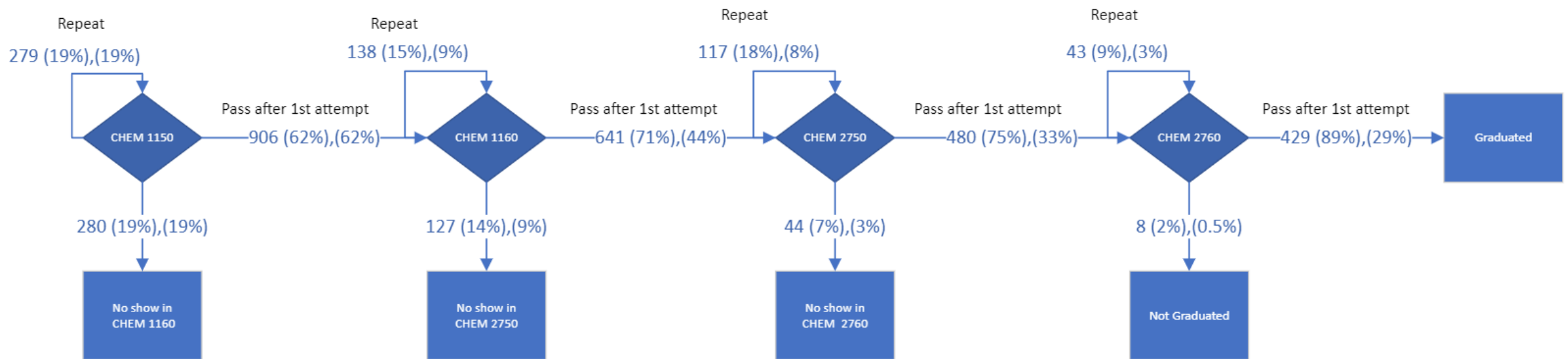


# Four-course Sequence Mapping

(Majors requiring four Chemistry courses)

Total: 1465

Sequence Level - Bio Chem Biochem



# Summary of Findings: Course Sequence Mapping

- ▶ The chart tracks the success of students in their first attempt at each course. The students who repeated the course, even if they eventually passed, were dropped from the subsequent mapping. Therefore, the chart **under reports** the completion and graduation rates of the original student population.
- ▶ Each diamond is a course in the sequence and the path moves from left to right. Students either pass the course on their first attempt and move on to the next course, repeat the course, or drop out from the chemistry sequence.
- ▶ For CHEM 1150, 62% (of the 1,465 students) passed the course in one attempt and moved on to CHEM 1160, 19% repeated the course and 19% dropped out from the chemistry sequence.
- ▶ For CHEM 1160, 71% passed in one attempt, which means 44% of the original population (n=1,465) passed both courses with one attempt. Another 9% of the original population dropped out of the sequence.
- ▶ The first-time pass rate increases and the drop-out rate decreases as the “surviving” students moved through the sequence.
- ▶ In the end, only 29% of the original population completed all four courses on the first attempt and graduated from ECU.

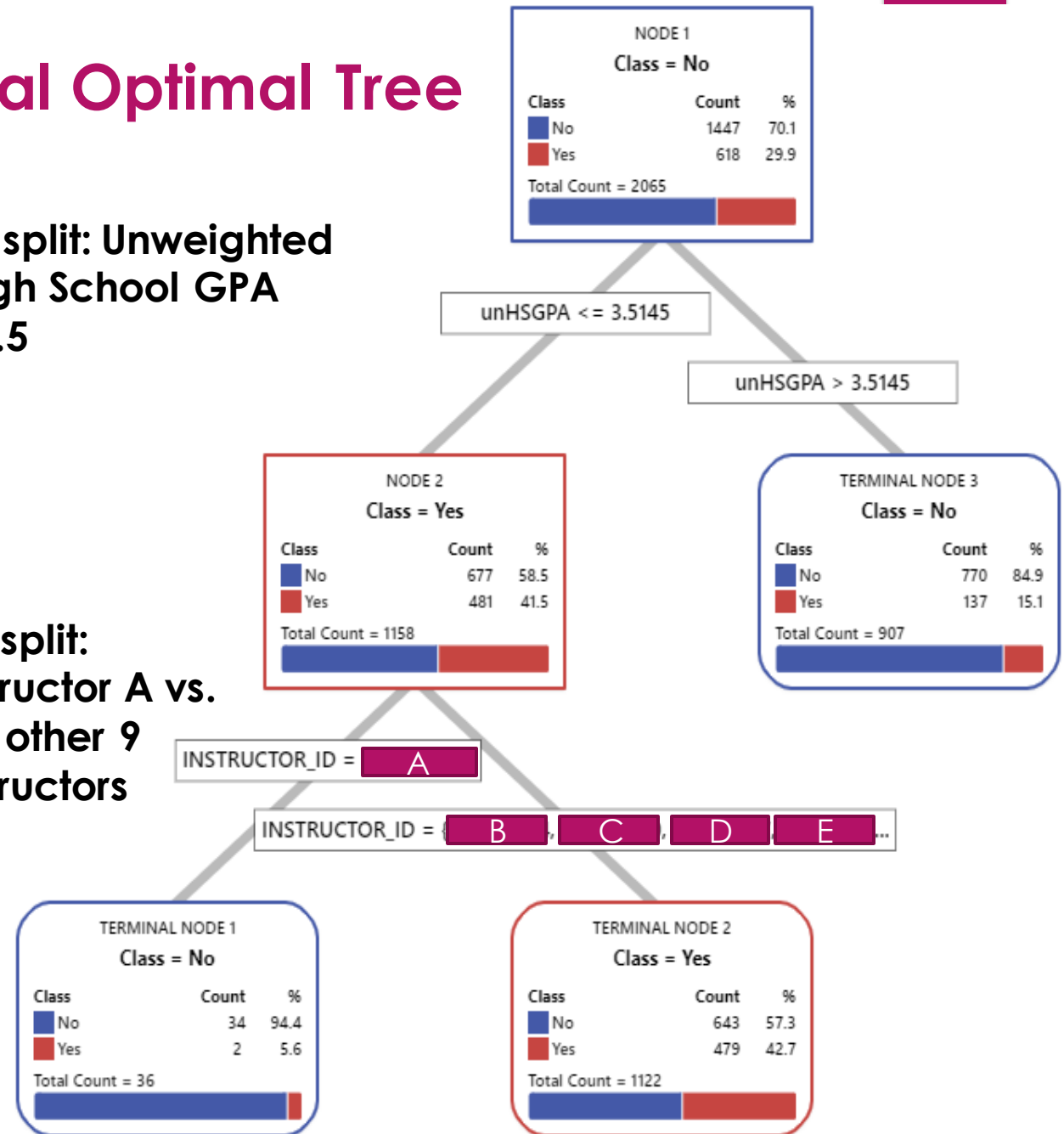
# CART Classification Results: CHEM 1150 DFW Grades

- Student Population: CHEM 1150 first-time takers who were first-time students, Spring 2016 – Fall 2019
- Dependent Variable: DFW Grade (Y/N)
- Independent Variables: gender, PEER, Pell, First-gen, Unweighted HS GPA, SAT/ACT Math Score, Tutoring, Instructor, Course Evaluation Score

## Final Optimal Tree

**1<sup>st</sup> split: Unweighted High School GPA = 3.5**

**2<sup>nd</sup> split: Instructor A vs. the other 9 instructors**



# Lessons Learned from Phase I Study

- ▶ Unweighted High School GPA was the strongest predictor of a DFW grade.
- ▶ Because there were only 10 unique instructors who taught CHEM 1150, the models using instructor demographic variables (gender, race/ethnicity, academic rank, tenure status) were less robust compared to the models using individual instructor as the independent variable.
- ▶ After controlling for all other variables in the model:
  - ▶ Instructor and student being from the same demographic group (gender or race/ethnicity) was not a significant predictor.
  - ▶ Student satisfaction with the overall instruction of the course/section (collected from course evaluations) was not a significant predictor.
  - ▶ Tutoring did not significantly decrease the DFW risk.



# Phase II Study: Preliminary Results

SPRING 2023

IN COLLABORATION WITH CHEMISTRY FACULTY

# Phase II Study Overview

- ▶ All students enrolled in Chemistry 1150 for the first-time during Fall 2018, Spring 2019, and Fall 2022 (will add Spring 2023)
- ▶ Research Questions:
  - ▶ How do students from high schools with higher proportions of low-income and PEER students compare to their counterparts?
  - ▶ Did the curriculum change implemented in Fall 2022 help reduce the performance gap between PEER and non-PEER students?

# Phase II Variables

## Student Background

- Gender
- Race/Ethnicity/PEER
- Pell Recipient
- Entry Status (First-time vs. Transfer)
- Unweighted HS GPA
- Transfer GPA
- ACT/SAT Math Score
- Honors Student

## CHEM 1150 Semester

- Enrolled in CHEM 1150 in First Semester at ECU
- Credit Hours Attempted
- Schedule Difficulty
- Tutoring Center Visits for CHEM 1150 (**excluding office hours**)
- CHEM 1150 Grade Points (0-4)

## Course Variables

- Instructor
- Learning Assistant in Course Section (dropped from analysis)
- Course meeting time (dropped)

## High School Characteristics (For First-time Freshmen Only)

- % Free or Reduced Lunch
- % PEER
- Student to Teacher Ratio



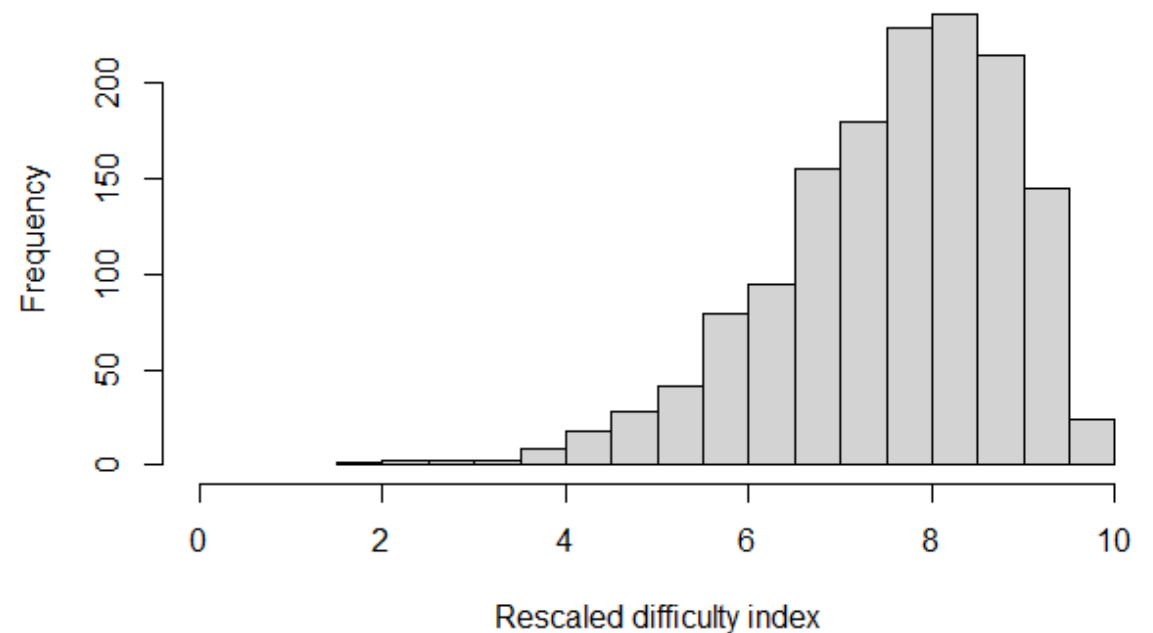
# Schedule Difficulty Indicator

- ▶ A variable representing each student's schedule difficulty. Derived using the ABC grade rates for the courses in which a student was enrolled in the same semester as CHEM 1150. Rescaled by multiplying by 10.

$$\text{Difficulty Index} = 1 - \prod_{i=1}^n a_i$$

Where  $a_i$  is the ABC rate of the course  $i$

Difficulty of schedule based on ABC Rate



# Demographic Information of the Population

## Student Demographics

	Pre-Pandemic	Post-Pandemic
FTFY	86%	84%
Female	56%	61%
PEER	32%	31%
Pell	44%	37%
Honors	10%	10%
Avg HS GPA	3.39	3.42
Avg Transfer GPA	3.03	3.02

## Instructor Demographics

	Pre-Pandemic	Post-Pandemic
Female	14.3%	50%
Race		
Asian	43%	25%
White	57%	50%
Hispanic	None	25%

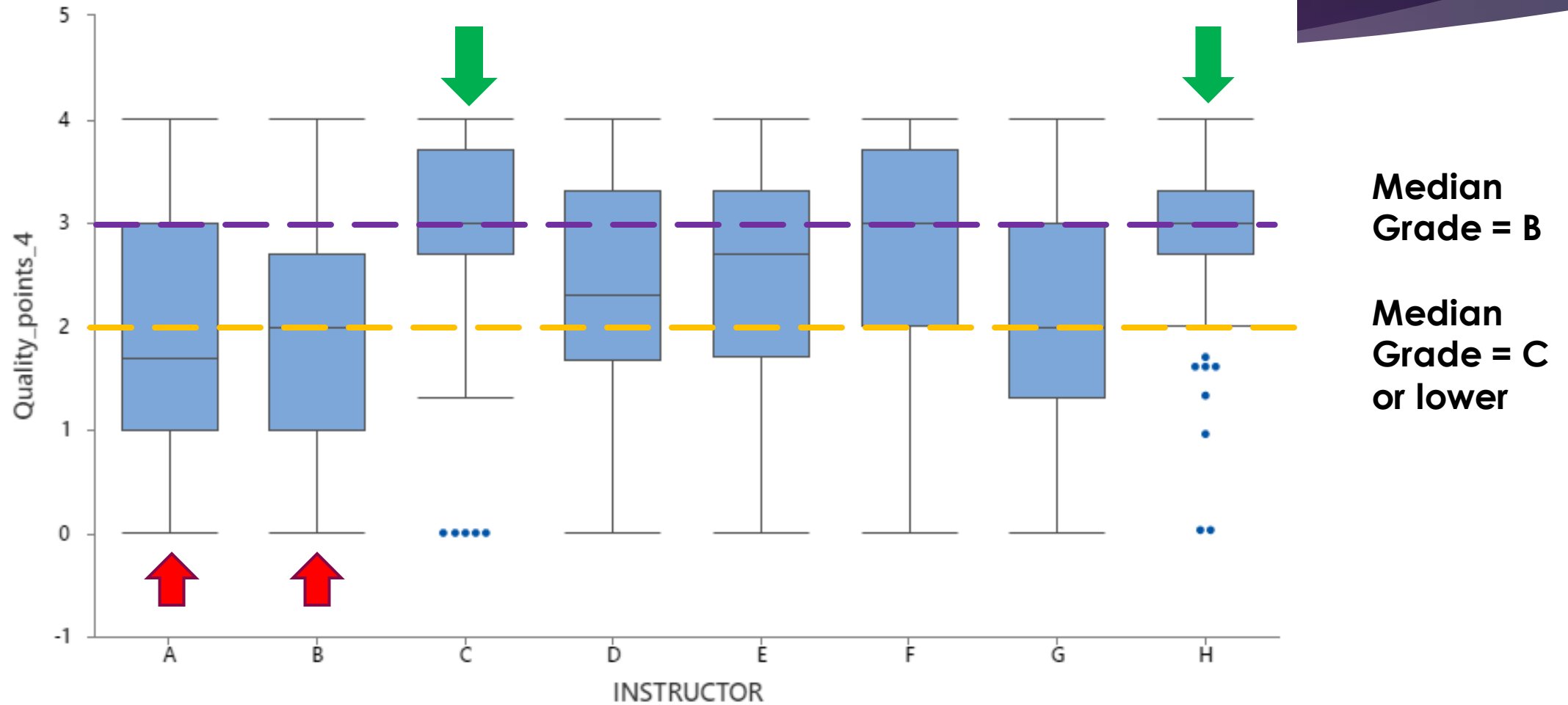
# Course Grade Distribution

	PEER	Non-PEER*	Male	Female*	Pell	Non-Pell*	FTFY*	Transfer
Grade A&B	178 (35%)	536 (50%)	287 (43%)	427 (47%)	246 (37%)	469 (51%)	641 (47%)	74 (33%)
Grade C	150 (30%)	243 (23%)	154 (23%)	239 (26%)	188 (28%)	207 (22%)	338 (25%)	57 (25%)
Grade D&F	132 (26%)	218 (20%)	168 (25%)	182 (20%)	164 (25%)	186 (20%)	288 (21%)	62 (27%)
Grade W**	46 (9%)	77 (7%)	53 (8%)	70 (8%)	63 (10%)	60 (7%)	89 (7%)	34 (15%)

\*Indicates the better performing group.

\*\* Students receiving a W were excluded from the subsequent regression analyses.

# Course Grades by Instructor



# First-time Freshmen: Low-income and PEER Population in High School

20

- ▶ Data Source: NCES Elementary/Secondary Information System
- ▶ CEEB Code to NCES School Code Crosswalk
  - ▶ Mark Davenport at UNC-Greensboro
  - ▶ Office of Data Analytics, CU Boulder
- ▶ Reporting Year: 2019-20 (most recent year available for private schools)
- ▶ % free/reduced lunch for private schools coded as 0

	Average % free/reduced lunch	Average % PEER
PEER	45%	56%
Non-PEER*	33%	37%
Final Grade A&B*	35%	41%
Final Grade C	38%	44%
Final Grade D&F	41%	47%
Final Grade W*	34%	41%

# Methodology

- ▶ **Multiple Linear Regression on Course Grade Points**
  - ▶ Backward elimination ( $p < 0.1$ ) to select final variables
  - ▶ 10-fold cross-validation to examine model fitness, in addition to traditional r-squared
  - ▶ Dependent Variable: course grade points (0-4) with W grades excluded
  - ▶ Separate models for First-time Students (FTFY) and Transfers
    - ▶ Secondary analysis comparing the pre-pandemic FTFY cohorts (Fall 2018 and Spring 2019) with the post-pandemic cohort (Fall 2022)
    - ▶ Due to small Ns, unable to compare pre- and post-pandemic transfer students
- ▶ **CART Classification of DFW Grade Risk**
  - ▶ Dependent Variable: DFW grade
  - ▶ One model for First-time Students (FTFY), one for Transfers

# Results – ALL First-time Students








N = 1,151

Significant Variables:

- Unweighted High School GPA +
- Credits Attempted +
- Schedule Difficulty –
- % Free/Reduced Lunch –
- Tutoring Visits (>5 times) +
- Instructor + or -
- Taking CHEM in the first term +
- Being an Honors Student +

## Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)	10-fold S	10-fold R-sq
0.967457	34.90%	33.92%	32.93%	0.974412	32.91%

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-2.237	0.445	-5.02	0.000	
UNWEIGHTED_GPA	1.2357	0.0833	14.84	0.000	1.23
CREDITS_ATTEMPTED	0.0397	0.0184	2.16	0.031	1.06
schedule_difficulty	-0.0810	0.0263	-3.08	0.002	1.47
% free/reduced lunch	-0.644	0.101	-6.40	0.000	1.04
Tutoring Center					
1= 1 or 2 visits	0.1060	0.0804	1.32	0.188	1.11
2= 3-5 visits	0.128	0.102	1.25	0.213	1.09
3= 6-9 visits	0.392	0.162	2.41	0.016	1.03
4= 10 or more visits	0.449	0.165	2.71	0.007	1.05
INSTRUCTOR					
B 	0.167	0.161	1.04	0.299	3.76
C 	1.107	0.192	5.78	0.000	2.37
D 	0.205	0.160	1.28	0.199	3.43
E 	0.513	0.162	3.17	0.002	3.72
F 	0.504	0.146	3.44	0.001	4.83
G 	0.203	0.147	1.38	0.168	4.24
H 	1.097	0.185	5.93	0.000	2.43
CHEM1150_FIRSTTERM					
Y	0.2206	0.0734	3.00	0.003	1.64
HONORS					
Yes	0.470	0.102	4.62	0.000	1.36



# Highlights of the Results: First-time Students

Grade Point + 1.2

Every point increase in unweighted high school GPA

Grade Point +  $\approx 0.4$

Using Tutoring Center frequently (> 5 times) vs. infrequent or no use

Grade Point + 0.5

Being an Honors Student

Grade Point - 0.64

Every 10 percentage points increase in free/reduced lunch students at high school

Grade Point + 1.1

Taught by instructors C & H, as compared to A, B, D & G

Grade Point + 0.5

Taught by instructors E & F, as compared to A, B, D & G

## Findings: First-time Students

- Unweighted HS GPA is the most significant predictor, followed by instructor, and % free and reduced lunch.
- Student demographic characteristics are not significant factors of course grades.







### Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	17	568.41	33.436	35.72	0.000
UNWEIGHTED_GPA	1	206.05	206.048	220.14	0.000
CREDITS_ATTEMPTED	1	4.37	4.372	4.67	0.031
schedule_difficulty	1	8.86	8.865	9.47	0.002
% free/reduced lunch	1	38.35	38.348	40.97	0.000
TUTOR_CAT	4	12.60	3.151	3.37	0.009
INSTRUCTOR	7	80.47	11.496	12.28	0.000
CHEM1150_FIRSTTERM	1	8.44	8.444	9.02	0.003
HONORS	1	19.96	19.964	21.33	0.000
Error	1133	1060.46	0.936		
Total	1150	1628.87			

# First-time Students – Pre and Post Pandemic Comparison

25

## ▶ Pre pandemic: with ACT-math (n=835)




Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-2.601	0.387	-6.72	0.000	
CONV_ACT_MATH	0.0532	0.0102	5.24	0.000	1.55
UNWEIGHTED_GPA	1.183	0.102	11.64	0.000	1.24
% free/reduced lunch	-0.574	0.123	-4.68	0.000	1.09
HONORS					
Yes	0.339	0.125	2.71	0.007	1.51
INSTRUCTOR					
B 	-0.681	0.132	-5.14	0.000	2.58
C 	0.630	0.156	4.03	0.000	1.68
D 	-0.422	0.132	-3.19	0.001	2.41
F 	-0.172	0.134	-1.29	0.199	2.12
G 	-0.328	0.134	-2.45	0.015	2.40
H 	0.592	0.153	3.87	0.000	1.77
Tutoring Center					
1= 1 or 2 visits	0.0850	0.0877	0.97	0.333	1.14
2= 3-5 visits	0.182	0.106	1.71	0.088	1.14
3= 6-9 visits	0.323	0.175	1.85	0.065	1.03
4= 10 or more visits	0.432	0.175	2.47	0.014	1.07

Reference:  
Instructor E  


### Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)	10-fold S	10-fold R-sq
0.923089	35.53%	34.34%	33.10%	0.933983	32.70%

## ▶ Post pandemic: without ACT-math(n=429)

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-0.855	0.660	-1.30	0.196	
UNWEIGHTED_GPA	1.237	0.146	8.47	0.000	1.32
schedule_difficulty	-0.1479	0.0538	-2.75	0.006	1.36
% free/reduced lunch	-0.533	0.175	-3.04	0.003	1.01
STUDENT_GENDER_IPEDS					
M	0.239	0.113	2.12	0.035	1.10
HONORS					
Yes	0.384	0.186	2.07	0.039	1.36
INSTRUCTOR					
A 	-0.508	0.198	-2.56	0.011	1.79
F 	0.040	0.157	0.26	0.799	2.21
G 	-0.524	0.172	-3.05	0.002	1.97
Tutoring Center					
1= 1 or 2 visits	0.189	0.184	1.03	0.304	1.04
2= 3-5 visits	0.413	0.330	1.25	0.212	1.03
3= 6-9 visits	0.737	0.379	1.95	0.052	1.09
4= 10 or more visits	0.876	0.426	2.06	0.041	1.04
CHEM1150_FIRSTTERM					
Y	0.362	0.125	2.89	0.004	1.36

### Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)	10-fold S	10-fold R-sq
1.01388	39.67%	37.51%	35.10%	1.03477	34.73%

# Analysis of Variance: FTFY

## Pre-pandemic with ACT Math

- Instructor and HS GPA: each account for most of the explained variance.

### Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	14	356.88	25.491	29.92	0.000
CONV_ACT_MATH	1	23.40	23.401	27.46	0.000
UNWEIGHTED_GPA	1	115.41	115.412	135.45	0.000
% free/reduced lunch	1	18.70	18.699	21.94	0.000
HONORS	1	6.28	6.278	7.37	0.007
INSTRUCTOR	6	117.65	19.608	23.01	0.000
TUTOR_CAT	4	8.82	2.206	2.59	0.036
Error	760	647.59	0.852		
Total	774	1004.47			

## Post-pandemic without ACT Math

- HS GPA is the single most important predictor.
- The importance of “Instructor” is reduced.

### Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	13	244.727	18.825	18.31	0.000
UNWEIGHTED_GPA	1	73.728	73.728	71.72	0.000
schedule_difficulty	1	7.764	7.764	7.55	0.006
% free/reduced lunch	1	9.499	9.499	9.24	0.003
STUDENT_GENDER_IPEDS	1	4.614	4.614	4.49	0.035
HONORS	1	4.391	4.391	4.27	0.039
INSTRUCTOR	3	23.250	7.750	7.54	0.000
TUTOR_CAT	4	9.570	2.393	2.33	0.056
CHEM1150_FIRSTTERM	1	8.583	8.583	8.35	0.004
Error	362	372.122	1.028		
Total	375	616.849			

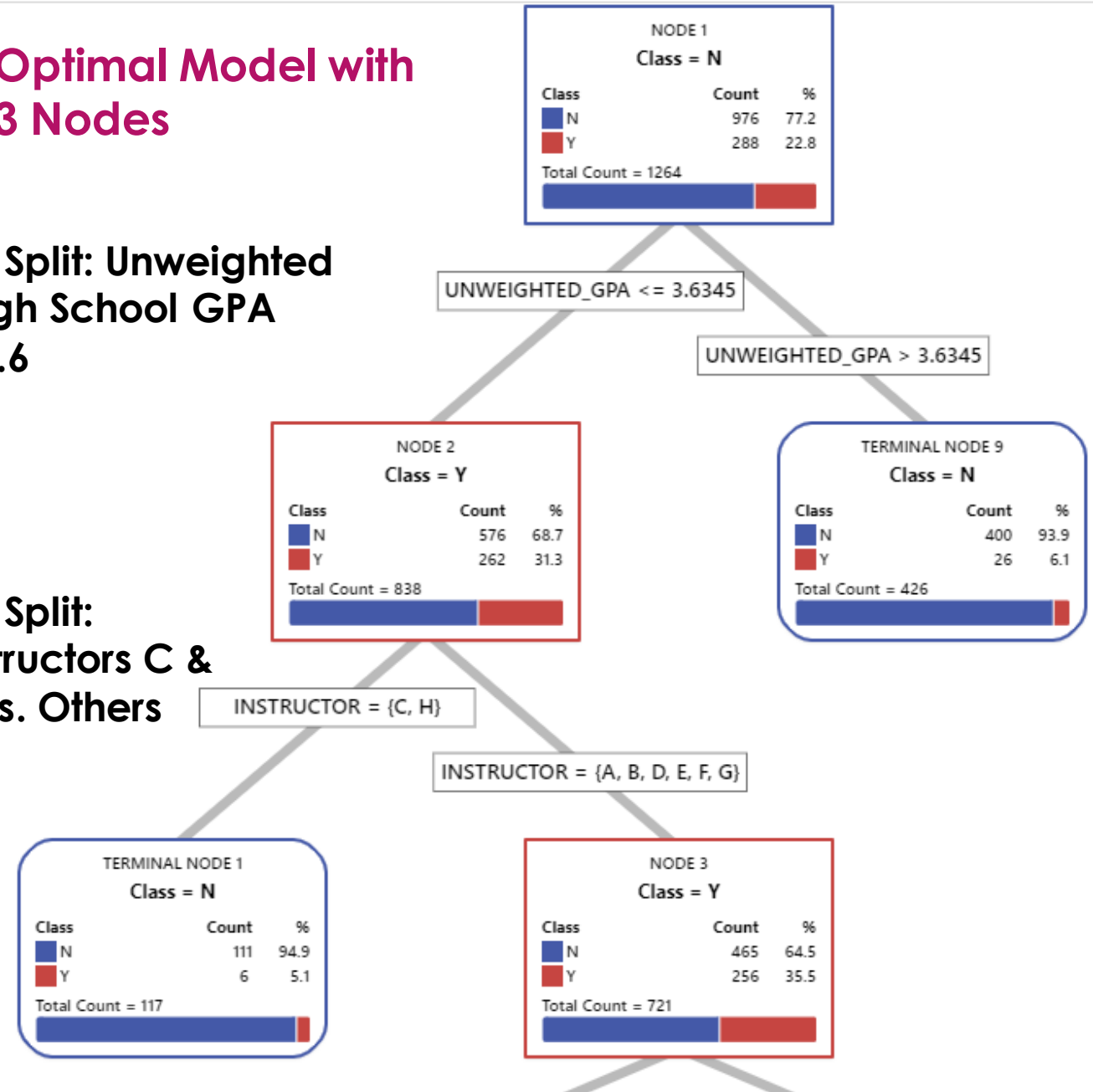
# CART Classification Results: CHEM 1150 DFW Grades

- Population: First-time Students (n=1,264)
- Dependent Variable: DFW Grade (Yes/No)
- Using the same variables as in the regression models

## Optimal Model with 3 Nodes

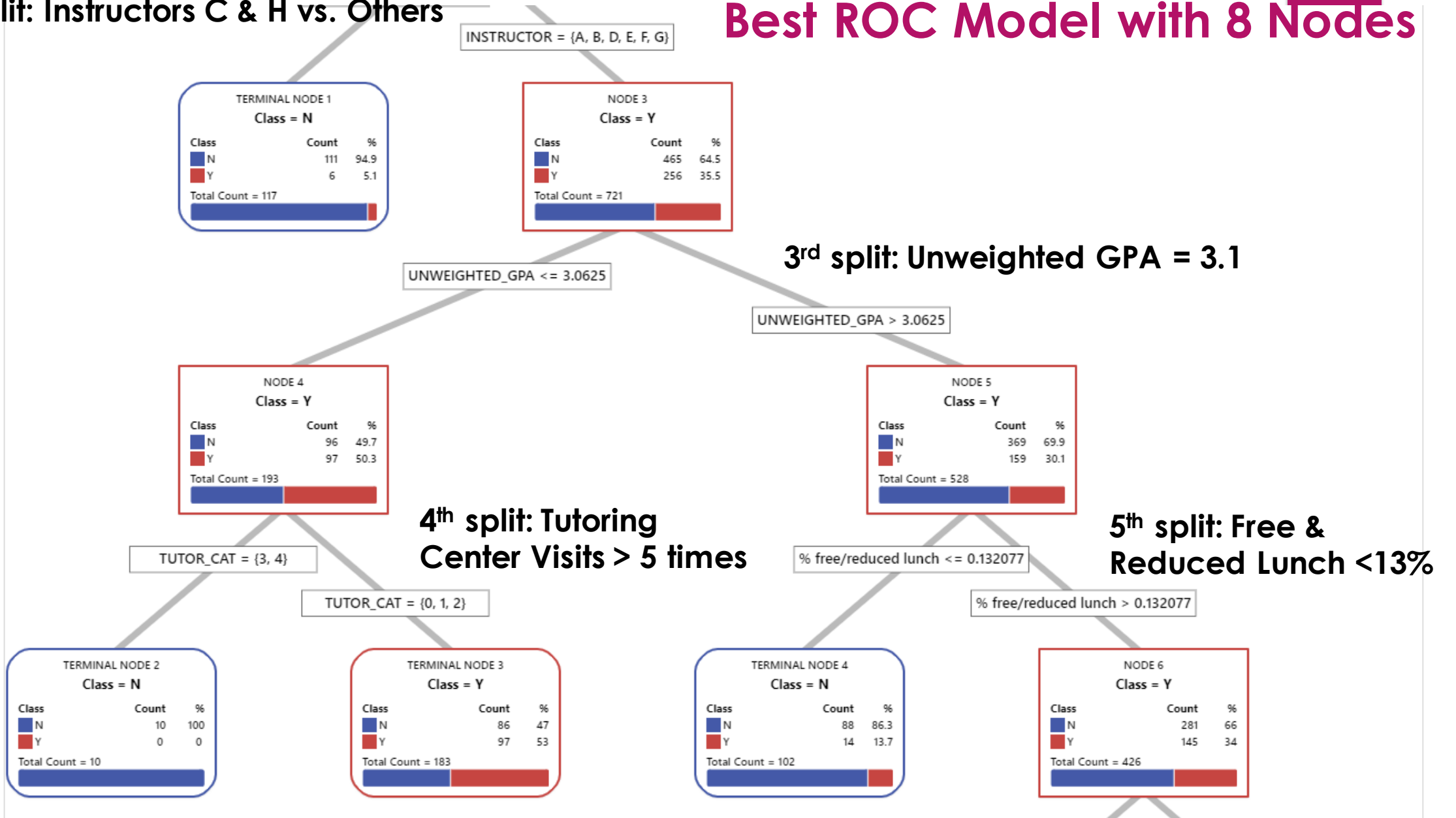
1<sup>st</sup> Split: Unweighted High School GPA = 3.6

2<sup>nd</sup> Split: Instructors C & H vs. Others

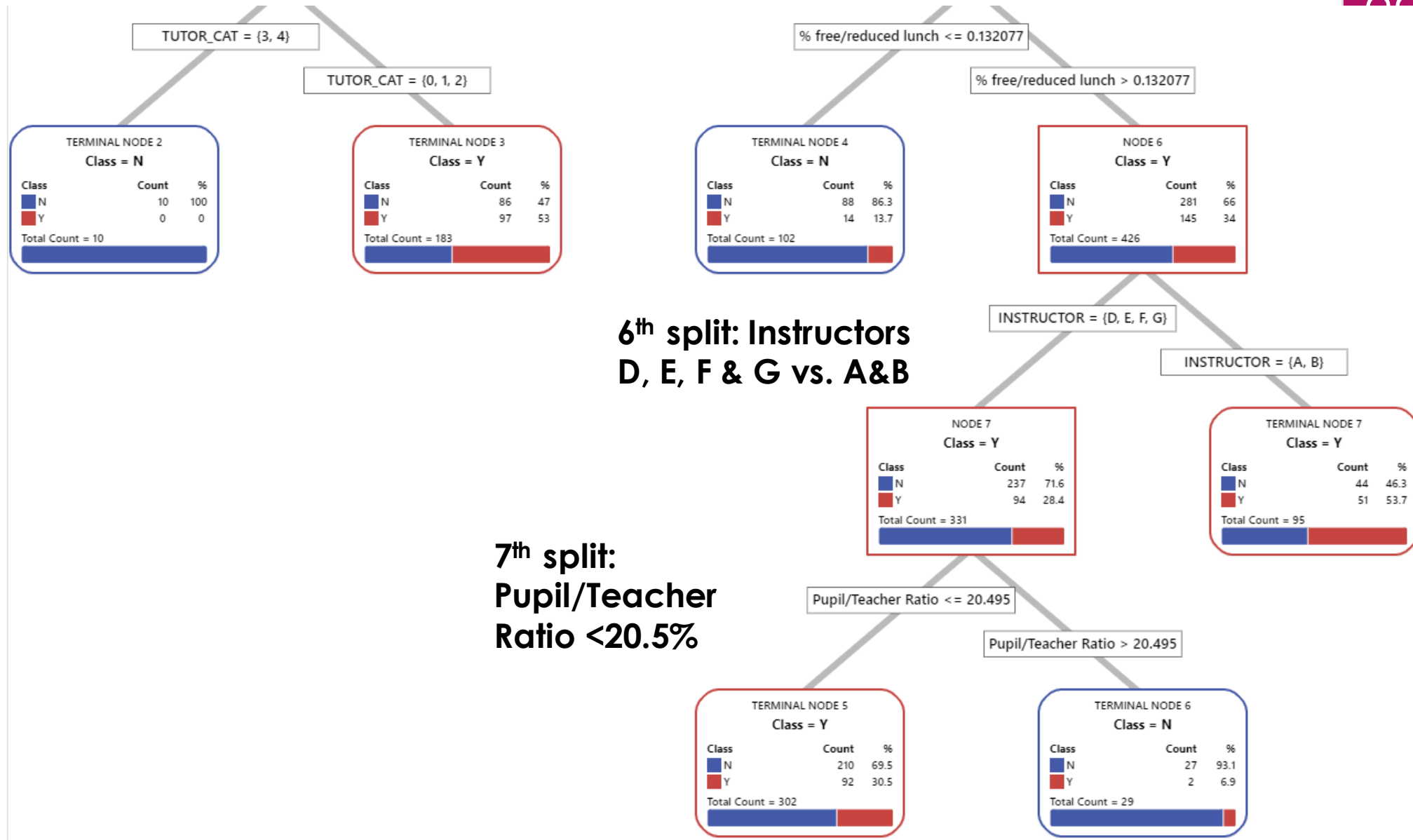


## 2<sup>nd</sup> Split: Instructors C & H vs. Others

# Best ROC Model with 8 Nodes



## 5<sup>th</sup> split: Free & Reduced Lunch <13%

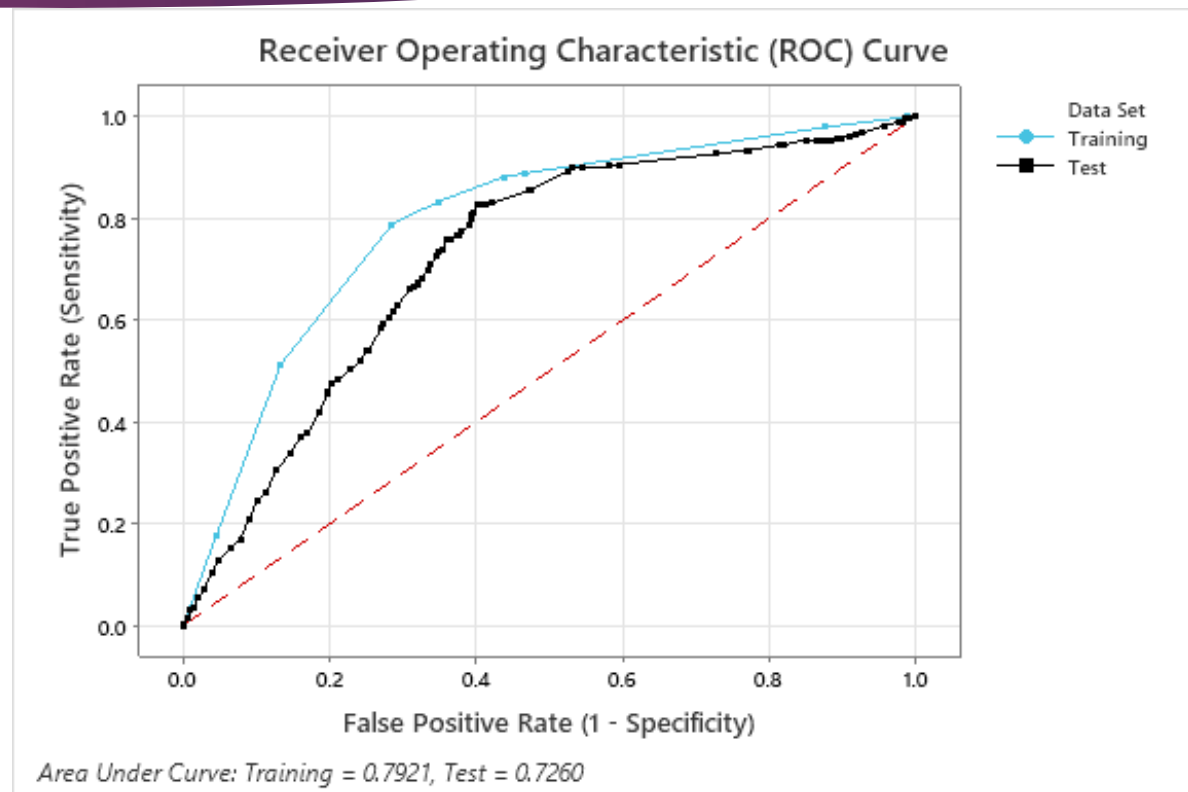
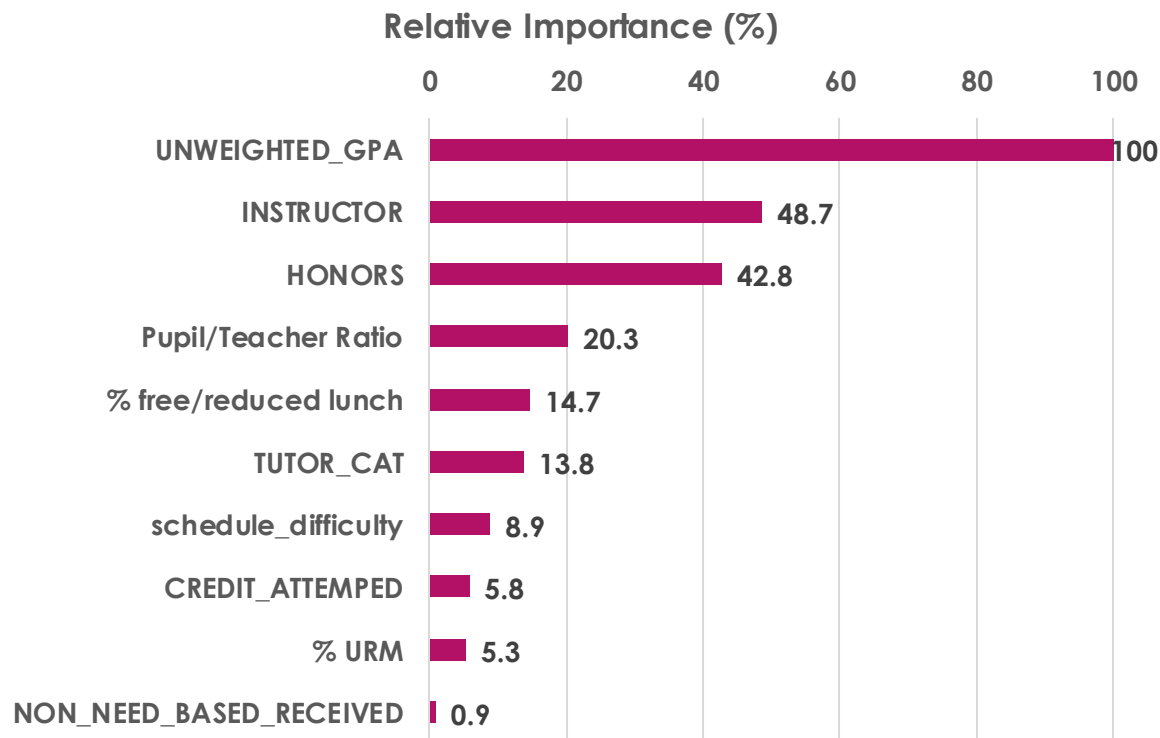




# First-time Student DFW Rate: Summary of Findings

- ▶ Students with an unweighted high school GPA  $> 3.6$  had a 94% probability to pass the course.
- ▶ If high school GPA  $< 3.6$  and taught by instructors C & H, the students had a 95% chance to pass.
- ▶ If high school GPA is  $< 3.1$  and taught by any of the other instructors, the students had a 50% chance to pass unless they frequently used tutoring services.
- ▶ If high school GPA is between 3.1–3.6 and taught by any of the other instructors, the students who came from a wealthier high school (% free/reduced lunch  $< 13\%$ ) had an 86% chance of passing the course.
- ▶ If high school GPA between 3.1–3.6 and taught by instructors A & B, the students who came from less wealthy high school (% free/reduced lunch  $> 13\%$ ) were slightly more likely to fail the course.

# Relative Variable Importance and ROC Curve



# Results – ALL Transfers

N = 180

Significant Variables:

- Transfer GPA +
- Taking CHEM in the first term +
- Instructor + or -

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-1.450	0.570	-2.54	0.012	
TRANSFER_GPA	0.873	0.160	5.46	0.000	1.05
CHEM1150_FIRSTTERM					
Y	0.499	0.189	2.64	0.009	1.28
INSTRUCTOR					
B	-0.065	0.437	-0.15	0.881	1.61
C	1.102	0.360	3.07	0.003	2.04
D	0.697	0.383	1.82	0.070	1.84
E	1.078	0.347	3.11	0.002	2.25
F	0.575	0.332	1.73	0.085	2.59
G	0.318	0.321	0.99	0.322	2.66
H	1.119	0.458	2.45	0.015	1.46

## Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)	10-fold S	10-fold R-sq
1.10675	28.17%	24.37%	19.52%	1.12394	21.57%

# Highlight of the Results: Transfer

Grade Point + 0.87

Every point increase in transfer GPA

Grade Point + 0.5

Took CHEM 1150 in the first semester


Grade Point +  $\approx$  1.0

Taught by instructors C, E, & H vs. the others

# Analysis of Variance table: Transfer

## Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	9	81.678	9.075	7.41	0.000
TRANSFER_GPA	1	36.580	36.580	29.86	0.000
CHEM1150_FIRSTTERM	1	8.555	8.555	6.98	0.009
INSTRUCTOR	7	27.957	3.994	3.26	0.003
Error	170	208.234	1.225		
Total	179	289.911			



# Lessons Learned and Conclusions

# Lessons Learned

- ▶ NCES Data
  - ▶ Crosswalk of CEEB and NCES School Code (federal schools and many early colleges are missing)
  - ▶ Non-reporting issues (private schools)
- ▶ Unable to measure students' academic preparation for CHEM 1150 (missing data issues)
  - ▶ Unable to retrieve high school Chemistry course grades
  - ▶ Few students had taken AP Chemistry
  - ▶ Difficulty in measuring prior knowledge in Math: students no longer submit SAT/ACT scores; ECU's math placement tests are not consistent over the years; grades for College Algebra are not available for all students because some take the two courses together
- ▶ Instructor characteristics: too few instructors included in the study; the course grade variance between the instructors can't be explained by gender/race/ethnicity/academic rank/tenure status



# Conclusions

- ▶ How do students from high schools with a higher percentage of low-income and PEER students compare to others in the cohort?
  - ▶ After controlling for all other variables in the model, students from higher free/reduced lunch high schools tend to have lower CHEM 1150 grades – every 10 percentage points increase in free/reduced lunch reduces the predicted course grade points by .64.
  - ▶ Percent of PEERs in high school is not a significant factor in predicting CHEM 1150 grades.
  - ▶ Pupil/teacher ratio appeared in the CART classification model: students from schools with a lower pupil/teacher ratio had a **higher** chance of earning a D/F/W grade in CHEM 1150.
- ▶ Did the curriculum changes implemented in Fall 2022 help reduce the performance gap between PEER and non-PEER?
  - ▶ In all models, PEER and Pell Status were not significant factors after controlling for the other variables.
  - ▶ In Fall 2022, the grade difference between instructors decreased because the “easier graders” (Instructors C & H) did not teach.

# Future Research

- ▶ Data: add Spring 2023 data to complete the academic year
- ▶ Further explore the relationship between math placement and chemistry performance
- ▶ Further explore reasons for course withdrawals and departures from STEM pathways
  - ▶ Academic reasons, personal interests, or other reasons?
  - ▶ What additional barriers exist for students, particularly PEERs, to continue pursuing STEM majors?

# Contact Us

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# Thank you for attending the 2023 NCAIR Annual Conference!

There's a QR code in your program for a conference evaluation form. You'll also get an e-mail following the conference with a link to the form, which will be available until 4/18.

Please take the opportunity at your earliest convenience to let the planning committee know your thoughts about this year's conference and where you would like to meet next year.

