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Analyzing Student Achievement to Measure the Effectivenss of Active Learning Strategies in the Engineering Classroom

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From the fall of 2016 through the spring of 2019, Kara worked with the JTFD Project, an NSF grant working to improve active learning in engineering education. She has completed 300 RTOP classroom observations in ASU engineering courses (civil, environmental, construction, chemical, aero/mechanical, materials, transportation, and biomedical engineering). The RTOP or Reformed Teaching Observation Protocol, is a rubric designed to assess student centered instruction in math and science. Kara also provided instructional coaching for 37 engineering faculty grant participants, after their teaching observations.

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Analyzing Student Achievement to Measure the Effectiveness of Professional Development for Active Learning Strategies in the Engineering Classroom

Abstract

This Evidence-Based Practice Paper examines how integration of active learning affects student achievement. There is a significant body of research that has illustrated the positive impact of active learning on student achievement and engagement, and this paper delves into the process of how student achievement can indicate the success of active learning as a best practice. When paired with a classroom observation rubric, like the Reformed Teaching Observation Protocol (RTOP), student achievement can provide evidence that active learning is present and impacting how students are performing and interacting with their coursework.

This paper is an extension of research conducted through the Just-in-Time-Teaching with Two Way Formative Feedback for Multiple Disciplines (JTFD) grant, an NSF-funded IUSE grant that started in the fall of 2015. The grant used a model of year-long faculty development project that consisted of eight biweekly workshops and six subsequent biweekly Communities of Practice (CoPs) to share best practice strategies in active learning and engagement style teaching with over 80 engineering faculty from multiple disciplines at a large southwestern university.

This paper provides information on how student achievement can measure the effectiveness of active learning in the engineering classroom. While students have historically perceived traditional lecture methods as more effective, research has emerged showing the opposite: student achievement is higher when active learning is integrated into the classroom. This paper also discusses past findings as they relate to student achievement and how the data associated with this five-year project aligns with the research that student achievement is increased in classrooms that utilize active learning and engagement-style strategies. Results show an increase in persistence along with an overall positive shift in grade distribution.

Introduction and Background

This large-scale faculty development program was implemented at a large, research-focused Southwestern university and had participants from 7 different disciplines from its engineering college: aerospace, biomedical, chemical, civil, construction, materials, and mechanical. The five year program, ending this year, was funded and supported through the National Science Foundation’s Improving Science Education (IUSE) initiative.

The goal of this paper is to share student achievement data and trends as they relate to active learning in the classroom and to provide a discussion on how active learning affects student achievement. The overall goals of the project, increasing the awareness and use of student-centered, or active learning, pedagogical practices amongst a multi-disciplinary group of engineering faculty, along with a complete analysis on its findings, can be found in previous papers and other papers being presented at this conference [1].

Active Learning

Active learning is an evidenced-based pedagogical tool that shifts learning from teacher-centered to student-centered. The strategies that fall under this umbrella help instructors engage their students through different means with the ultimate goal of increasing learning and improving student outcomes [2]. Active learning provides an alternative to traditional lecture-based instruction that has long been identified as largely ineffective for a majority of students [3]. As such, there is ample research that supports greater student outcomes when active learning is embedded into classroom instruction, including a widely-cited meta-analysis of over 200 students by Freeman et al. [4] that found students who were enrolled in courses that utilized active learning illustrated higher learning and comprehension on concept inventories. This is similar to the work of John Hattie who identified different factors in education that had the most significant effect on student achievement; those strategies with the highest percentage of impact with regard to classroom and instructional practices were all examples of active learning [5]. Another compelling case for active learning is found in Prince's work, where he reviews the evidence for how effective active learning can be in the engineering classroom [6].

While active learning is not a new strategy, it has not been as thoroughly adopted at the higher education level compared to its permeation into K12. Despite this slow adoption, emerging studies are starting to support the idea that infusing curriculum with active learning strategies can have a positive impact on student outcomes at the university level. In response, this grant was developed to create a robust faculty development program aimed at teaching engineering faculty how to utilize active learning in their classes. This was done through a series of workshops, coupled with classroom observations and instructional coaching, ultimately resulting in a Community of Practice (CoP) to help sustain the overall program.

Classroom Observations

Classroom observations are a form of formative feedback that can also be used to measure the effectiveness of a faculty development program [7]. Although there are different forms of classroom observations, this study utilized trained observers with extensive pedagogical background.

Structure and Data Collection

Sample

As noted earlier, this NSF-funded IUSE grant program was aimed at increasing active learning practices in engineering classrooms. In its last year, the grant has now shifted its focus from the active PD program to examining factors that contributed to the results. The initial program, using a train-the-trainer model, included eight bi-weekly workshops and six bi-weekly Communities of Practice (CoP) sessions. This year-long faculty development program was followed up with four classroom observations and coaching sessions. Faculty participants were also afforded the opportunity for individual coaching calls and emails in addition to the observation and instructional coaching sessions. This provided real-time classroom practice of new instructional strategies following the workshops as a way to solidify new concepts and provide early wins for faculty participants.

Classroom Observation

Classroom observations were scheduled with the participants to evaluate the presence of active learning in the observed classroom. Each participant had four observation opportunities. Trained observers with extensive pedagogical expertise and experience sat through classes and identified the presence or absence of active learning activities using the Reformed Teaching Observational Protocol (RTOP) Evaluation Framework [8], a tool comprised of five dimensions and a five-point Likert scale for a total of 100 possible points, as noted in Appendix A. Given this scale, a classroom can be characterized on a scale from 0 to 100, where 0 indicates traditional, lecture-based and 100 indicates a reformed, student-driven class. Lecture-based classes fall within a 0-29 point range, active lecture classes between 30 and 49, and active learning classes constitute a score of 50 to 100. Following the initial program, a third round of observations were conducted in the spring of 2019. The round was open to JTFD participants and was completely voluntary. Twenty-six faculty responded to the opportunity for an additional observation and coaching session.

Classroom Observation Tool

The RTOP tool measures what is identified within the observed course; there are no outside assumptions made about the level of active learning integration in previous or subsequent courses. Because of this, a faculty member can have different scores for different observations if active learning activities are built into different lessons. What can be deduced, however, is that if a faculty member is consistently scoring in the range of active learning, then she is regularly utilizing active learning practices within the classroom. Each faculty member was given four RTOP observations; instructional coaching sessions followed the observations.

Each classroom observation was conducted by two trained observers. Following the observation, the observers met with each faculty member to discuss each person's goals as they pertain to the RTOP rubric. An individualized follow-up plan was devised among the participants and observers and was also used to guide subsequent observations and instructional coaching. In order to examine how the active learning strategies that were presented in the workshops impacted student achievement, course-level data for undergraduate engineering classes between the academic years of 2012-2013 (before the faculty development program) and 2017-2018 (after the faculty development program) was gathered. Seven disciplines of engineering were sampled: aerospace, biomedical, chemical, civil, construction, materials, and mechanics.

Data Treatment

In order to gather the information needed to analyze student achievement, queries were used to amass data from several electronic archives within the university repository. The archives utilized here included class -level data: discipline, course number, and instructor name. Longitudinal information from academic years 2012-2013 (pre-intervention) and 2017-2018 (post-intervention) was selected to account for implementation lag time [9]. The original cleaning process for the overall program evaluation involved merging grade distribution data for cross-listed courses to determine if the discipline, course number, and instructor were aligned. Then, the team removed any +/- grade letters to help streamline them into their letter category: A-/A+ were categorized into the A group, etc. We followed this classification system for A, B, C, D, E, and W. [10] The cleaning process for this examination included removing any course that didn't have an RTOP score associated with the pre and post, as well as courses that didn't match those that were observed. Similarly, courses that had higher than 75% As in the pre were removed. We also removed any courses with fewer than 10 A-E grades. After all of these classifications, we ended with a sampling of 108 courses.

Data Analysis Results

The original data analysis involved a two-step process. Initially, SPSS was used to find the average grade distribution for A,B, C, D, E, and W. Then, multiple linear mixed effects models were run in R to evaluate differences found in student percentages of the grades A, B, C, D, E, and W. [11]

The initial results of this process illustrated a decline in As but an increase in Bs and Cs. While Ds and Es also increased slightly, there was a decrease in Ws for the fall semesters and a slight increase in Ws for the spring semester. More detailed statistics are available in previous papers. [12]

Students' grades were examined to assess if there were significant differences before and after instructors participated in JTFD workshops. Courses which had more than 75% of the students earning an A prior to JTFD workshops were filtered out from analyses because it was judged that these courses, largely small project-based courses, were not representative of the targeted course types which have a wider distribution of grades. Data were further filtered to include only courses assigning typical A-F grades (i.e., not pass/fail courses) and with an enrollment of at least 12 students both pre- and post-JTFD participation.

Course grades were identified as administered either *before* (pre) or *after* (post) an instructor's JTFD workshop participation. Data were then aggregated by course instructor and course name. Pre-to-post comparisons were made strictly based on *same instructor* and *same course*. Data did not meet tests of normality and therefore a series of nonparametric Wilcoxon signed-rank tests were applied to detect changes in grades from pre- to post-JTFD participation.

Pre-to-post mean GPAs and proportion of each grade type (i.e., A-F), as well as withdrawals and incompletes, per instructor/course were evaluated across all course levels, across undergraduate courses only, and per grade level (100-, 200-, 300-, and 400-levels). There were no significant changes in mean GPA. In examining the percentage of each grade type, though there were a few significant shifts in grade proportions, composite patterns indicated no positive JTFD effect on student grades.

To further this analysis, we took these initial results and further narrowed the scope by applying RTOP scores to compare to student achievement data. We were curious to see what correlation, if any, existed between higher student achievement and a higher RTOP score. Our hypothesis was that there would be a positive correlation among the two. Appendix B shows that, out of the 108 student achievement samples, 61 courses had pre and post RTOP scores. Within that sample, 40 showed improved RTOP scores, 19 showed a decreased RTOP score, and 2 showed no change.

Table 1

Positive, Negative, or Neutral Change in Courses with Pre- and Post-RTOP scores (%; n = 61)

Change Classification	Percentage of Courses with Change
Positive Change	66%
Negative Change	31%
No Change (Neutral)	3%

Discussion

Student Achievement Results

This examination has some limitations. One limitation is that final grades were the only indication provided for student achievement. Knowing what we do about active learning, we realize that there are more complex ways to measure student achievement that are not as easily quantifiable. Another limitation is the scope of the observation tool. The RTOP only measures the presence of active learning on the day of the observation; there are no assumptions made about the degree to which active learning has been infused throughout the entire course outside of the observation period. Other measures of achievement should be examined.

We were surprised that the overall results indicated only a 0.02% positive GPA shift among the 108 samples. Early results had indicated a more positive shift, but once we aligned instructors and courses, the increase was much smaller.

Another consideration is the implementation timeline. Although this faculty development was several years in length, the student achievement data was collected after faculty participants had one semester of implementation. Previous studies have reported full GPA point shifts in student achievement and up to a 50% reduction in Ds and Es when active learning has been implemented and sustained in a course over several years [13].

RTOP Observations and Student Achievement

Because we used the RTOP tool to assess active learning in the classroom, we decided to compare RTOP scores to the student achievement for each of the courses. As aforementioned, RTOP scores improved overall from pre- to post JTFD participation, so we wanted to examine any possible correlations that existed between RTOP scores indicating an “active learning classroom” and a change in student achievement.

We first looked at those faculty who volunteered to be observed a third time post-grant because that gave us an additional data point. Out of the 26 faculty who volunteered, we had 21 faculty with all 3 RTOP observation scores. Table 2 illustrates the number of faculty with positive or negative RTOP score changes between pre and post-post (first and third observations).

Table 2

Positive and Negative RTOP scores among Faculty over 3 Observations

Change Indicator	Percentage of Faculty	Mean GPA Change
Positive Change	43%	
Negative Change	57%	

While more faculty showed a negative RTOP score change from pre to post/post, nearly half of the faculty observed were still implementing active learning in their classrooms without ongoing support. With regard to student achievement, of those who showed a positive change in the RTOP score, 67% had positive GPA shifts in student achievement. This indicates that there is a positive correlation between an infusion of active learning into instruction and an increase in student achievement.

Other trends that indicated a more significant positive shift in student achievement were found in the number of students in a course. Table 3 illustrates that in courses with fewer than 100 students, there was an overall positive GPA shift. All classes over 100 indicated a negative GPA shift. Similarly, courses at the 400 level also showed a positive GPA shift which, as mentioned earlier, could be indicative of the trend to include more problem-based instruction in upper-level courses.

Table 3

GPA Shift by Class Size

Class Size Category	Number of Courses	GPA Shift (in points)
0-100	55	+.21
101-200	27	-.09
201-300	9	-.08
301-400	4	-.04
401-500	6	-.08
501-1050	6	-.06

With regard to RTOP scores, classes that had fewer than 100 students showed a mix of positive and negative RTOP score shifts. Out of the 55 courses with fewer than 100 students, only 14 courses (25%) were taught over all three observation periods. Of those 14 courses, 36% showed a positive RTOP score shift over all 3 observations, and 43% illustrated a positive RTOP score shift over the first two of the three observations. With all of the limitations presented with scheduling courses, including the fact that some courses are taught every other semester, we were not surprised at the number of courses that aligned over the 2 year period in which the observations were conducted. Nor were we very surprised to see some scores decrease between the second and third observation because there was not as much direct support through the active workshop series between the second and third observation rounds.

Conclusion

Significant change takes time and multiple iterations are needed to support the infusion of active learning into the classroom. Each semester a course is taught brings different variables that can impact results on student achievement. Active learning, fortunately, can be adapted to meet those changes, but this ability to shift practices requires a higher level of comfort in working with a new instructional practice. Similarly, the type of active learning strategies, such as formative feedback, incorporated into the class can have more substantial impacts on student achievement than simply segmenting or shortening pre-existing lectures.

While some of the results of this paper didn't fully align with results from substantiated research, limitations and trends discussed here offer some explanation for the contradictory evidence. For example, using the RTOP to measure active learning is highly effective, but only provides a snapshot into the instructor's overall practice. If an instructor is observed during a heavy-lecture class, even when most of the other courses are infused with active learning strategies, the score will still show a lecture-based or teacher-centered classroom. This is a limitation of the RTOP: the lack of instruments designed to measure the overall impact of active learning over the course of a semester restricts the ability to fully measure the impact of active learning in a class overall.

Ultimately, evidence of a positive GPA shift was present in courses with fewer than 100 students, indicating that, along with active learning strategies, other factors can impact student outcomes. One of those factors that cannot be ignored is class size. Implementing engagement strategies into large classes has definitive physical and organizational limitations. Oftentimes, for example, large classes are conducted in lecture halls with stadium seating; this physical space is not conducive to collaboration among students. Additionally, instructors see their time dwindle if they try to use their physical presence to engage students because it ultimately takes them longer to move about the room and address questions than it would in a class with fewer than 100 students.

With ongoing support and implementation over an extended period of time, the results explored in this paper indicate that student achievement would be positively impacted by active learning strategies consistently present in the engineering classroom. However, we feel that an even more valuable lesson contained in this paper is that measuring student achievement in a large-scale study such as this is no easy feat. We have found that aligning schedules and classes can be difficult in order to gain the data needed to measure the impact of active learning on achievement. Furthermore, we acknowledge that significant change takes time; previous studies conducted by the team have indicated up to a four-year time period required for a significant impact on student achievement [14]. In the future, projects that devote several years of active data collection paired with RTOP evaluation and ongoing support should be able to present more optimistic findings in relation to the degree of positive impact that active learning strategies have on student achievement in the engineering classroom.

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References

[1] Author

[2] Hake, R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics* 66, 64.

[3] Jungst, S., Likclider, L. L., & Wiersema, J. (2003). Providing support for faculty who wish to shift to a learning-centered paradigm in their higher education classrooms. *The Journal of Scholarship of Teaching and Learning* 3(3), 69-81.

[4] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS*, 11(23), 8410-8415.

[5] Hattie, J, Biggs, & Purdie, N. (1996). Effects of learning skills interventions on student learning: A meta-analysis. *Review of Educational Research*, 66(2), 99-136. http://www.jstor.org/stable/1170605.

[6] Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-231.

[7] Stephens, J., Battle, D., Gormally, C., & Brickman, P. (2017). “Show me the way: Future faculty prefer directive feedback when trying active learning approaches,” *Journal of College Science Teaching*. 42, 57-65.

[8] Piburn, M., Sawada, D., Falconer, K., Turley, J. Benford, R., Bloom, I. (2000). Reformed Teaching Observation Protocol (RTOP). http://physicsed.buffalostate.edu/AZTEC/rtop/RTOP_full/PDF/.

[9] Author

[10] Author

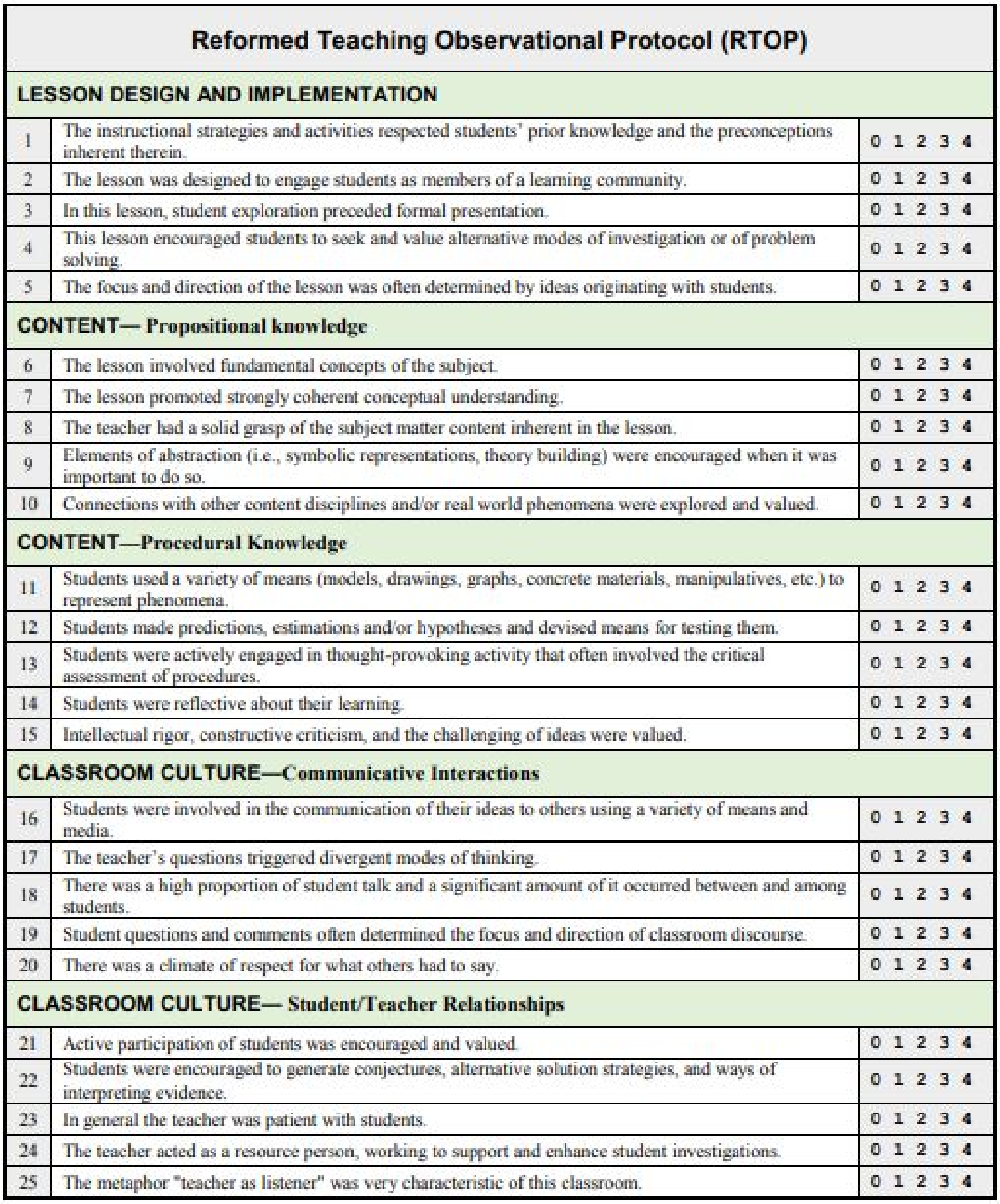
[11] Author

[12] Author

[13] Krause, S., Baker, D., Alford, T., Ankeny, C., Carberry, A., Koretsky, M., Brooks, B., Waters, C., & Gibbons, B. (2015). Effect of implementation of JTF engagement and feedback pedagogy on change of faculty beliefs and practice and on student performance. 2015 ASEE Annual Conference Proceedings.

Appendix A

RTOP Evaluation Framework



	Reformed Teaching Observational Protocol (RTOP)	
	LESSON DESIGN AND IMPLEMENTATION	
1	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0 1 2 3 4
2	The lesson was designed to engage students as members of a learning community.	0 1 2 3 4
3	In this lesson, student exploration preceded formal presentation.	0 1 2 3 4
4	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0 1 2 3 4
5	The focus and direction of the lesson was often determined by ideas originating with students.	0 1 2 3 4
	CONTENT— Propositional knowledge	
6	The lesson involved fundamental concepts of the subject.	0 1 2 3 4
7	The lesson promoted strongly coherent conceptual understanding.	0 1 2 3 4
8	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0 1 2 3 4
9	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0 1 2 3 4
10	Connections with other content disciplines and/or real world phenomena were explored and valued.	0 1 2 3 4
	CONTENT—Procedural Knowledge	
11	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0 1 2 3 4
12	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0 1 2 3 4
13	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0 1 2 3 4
14	Students were reflective about their learning.	0 1 2 3 4
15	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0 1 2 3 4
	CLASSROOM CULTURE—Communicative Interactions	
16	Students were involved in the communication of their ideas to others using a variety of means and media.	0 1 2 3 4
17	The teacher's questions triggered divergent modes of thinking.	0 1 2 3 4
18	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0 1 2 3 4
19	Student questions and comments often determined the focus and direction of classroom discourse.	0 1 2 3 4
20	There was a climate of respect for what others had to say.	0 1 2 3 4
	CLASSROOM CULTURE— Student/Teacher Relationships	
21	Active participation of students was encouraged and valued.	0 1 2 3 4
22	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0 1 2 3 4
23	In general the teacher was patient with students.	0 1 2 3 4
24	The teacher acted as a resource person, working to support and enhance student investigations.	0 1 2 3 4
25	The metaphor "teacher as listener" was very characteristic of this classroom.	0 1 2 3 4

Appendix B

Average GPA change from Pre to Post Professional Development Program

Course Sample 1-36	pre_GPA_avg	post_GPA_avg	GPA_change	Course Sample 37-72	pre_GPA_avg	post_GPA_avg	GPA_change	Course Sample 73-108	pre_GPA_avg	post_GPA_avg	GPA_change
1	2.43	3.80	1.37	37	3.11	3.27	0.16	73	3.36	3.23	-0.14
2	2.73	3.67	0.95	38	3.29	3.43	0.15	74	2.69	2.55	-0.14
3	2.79	3.62	0.83	39	3.69	3.83	0.14	75	3.00	2.86	-0.14
4	2.91	3.61	0.70	40	3.51	3.63	0.13	76	2.64	2.49	-0.15
5	2.90	3.45	0.55	41	2.77	2.87	0.10	77	3.10	2.95	-0.15
6	3.40	3.92	0.53	42	2.39	2.47	0.09	78	3.14	2.96	-0.18
7	3.23	3.75	0.52	43	3.43	3.52	0.08	79	2.45	2.27	-0.18
8	3.43	3.90	0.47	44	2.87	2.93	0.06	80	3.58	3.39	-0.19
9	3.35	3.79	0.44	45	2.41	2.47	0.06	81	2.75	2.55	-0.20
10	3.50	3.93	0.43	46	2.97	3.02	0.05	82	3.55	3.32	-0.23
11	3.16	3.57	0.41	47	2.57	2.62	0.05	83	2.51	2.27	-0.24
12	3.21	3.62	0.40	48	3.33	3.38	0.05	84	2.82	2.57	-0.24
13	2.71	3.08	0.37	49	3.33	3.37	0.04	85	2.90	2.65	-0.24
14	3.26	3.63	0.37	50	3.52	3.56	0.04	86	2.70	2.44	-0.25
15	3.19	3.52	0.33	51	2.67	2.70	0.03	87	3.27	3.00	-0.27
16	3.51	3.84	0.33	52	2.65	2.68	0.03	88	2.77	2.49	-0.28
17	3.04	3.33	0.29	53	3.16	3.18	0.02	89	3.16	2.85	-0.31
18	3.35	3.64	0.28	54	2.99	3.00	0.01	90	2.82	2.50	-0.31
19	3.54	3.82	0.28	55	3.56	3.56	0.01	91	3.23	2.90	-0.33
20	2.49	2.77	0.28	56	2.74	2.73	0.00	92	2.94	2.60	-0.34
21	3.61	3.87	0.27	57	3.34	3.33	0.00	93	3.35	3.00	-0.35
22	3.21	3.47	0.26	58	3.13	3.13	-0.01	94	3.21	2.86	-0.36
23	3.45	3.70	0.25	59	3.45	3.43	-0.01	95	3.29	2.92	-0.37
24	3.61	3.86	0.25	60	3.50	3.49	-0.02	96	3.57	3.18	-0.39
25	3.51	3.76	0.25	61	3.45	3.42	-0.03	97	3.27	2.87	-0.40
26	2.41	2.65	0.23	62	2.57	2.54	-0.03	98	2.92	2.50	-0.42
27	3.33	3.56	0.23	63	3.57	3.53	-0.04	99	3.37	2.94	-0.43
28	3.30	3.53	0.23	64	3.63	3.59	-0.04	100	3.45	3.00	-0.45
29	3.29	3.52	0.23	65	2.87	2.80	-0.07	101	3.72	3.27	-0.45
30	3.62	3.83	0.21	66	2.36	2.29	-0.07	102	2.68	2.23	-0.45
31	3.14	3.35	0.21	67	3.28	3.21	-0.07	103	3.53	3.07	-0.46
32	2.78	2.99	0.21	68	3.48	3.40	-0.07	104	2.98	2.51	-0.47
33	3.16	3.36	0.20	69	3.32	3.23	-0.09	105	3.05	2.50	-0.55
34	3.00	3.19	0.19	70	3.28	3.17	-0.11	106	2.62	1.98	-0.64
35	3.49	3.68	0.19	71	2.77	2.66	-0.11	107	3.19	2.48	-0.71
36	3.62	3.81	0.18	72	3.39	3.26	-0.13	108	2.73	1.81	-0.92