Paper ID #18471

The Variation of Nontraditional Teaching Methods Across 17 Undergraduate Engineering Classrooms

Mr. Kevin A. Nguyen, University of Texas, Austin

Kevin Nguyen is currently a doctoral student in the Science, Technology, Engineering, and Mathematics (STEM) Education program at University of Texas at Austin. He has a B.S. and M.Eng in Environmental Engineering both from Texas Tech University. As an engineering and STEM education researcher, he draws on a variety of social science research methods from ethnography to regression modeling. He is currently working on two projects: engineering faculty's use of active learning and an ethnographic study of a citizen science student community.

Mr. Robert Matthew DeMonbrun, University of Michigan

Matt DeMonbrun is a Ph.D. Candidate at the Center for the Study of Higher and Postsecondary Education (CSHPE) in the School of Education at the University of Michigan. His research interests include college student development theory, intergroup interactions, and teaching and learning practices and how they relate to student learning outcomes in engineering education.

Dr. Maura Borrego, University of Texas, Austin

Maura Borrego is Associate Professor of Mechanical Engineering and Curriculum & Instruction at the University of Texas at Austin. She previously served as a Program Director at the National Science Foundation and an associate dean and director of interdisciplinary graduate programs. Her research awards include U.S. Presidential Early Career Award for Scientists and Engineers (PECASE), a National Science Foundation CAREER award, and two outstanding publication awards from the American Educational Research Association for her journal articles. Dr. Borrego is Deputy Editor for Journal of Engineering Education and served on the board of the American Society for Engineering Education as Chair of Professional Interest Council IV. All of Dr. Borrego's degrees are in Materials Science and Engineering. Her M.S. and Ph.D. are from Stanford University, and her B.S. is from University of Wisconsin-Madison.

Dr. Michael J. Prince, Bucknell University

Dr. Michael Prince is a professor of chemical engineering at Bucknell University and co-director of the National Effective Teaching Institute. His research examines a range of engineering education topics, including how to assess and repair student misconceptions and how to increase the adoption of research-based instructional strategies by college instructors and corporate trainers. He is actively engaged in presenting workshops on instructional design to both academic and corporate instructors.

Dr. Jenefer Husman, University of Oregon

Jenefer Husman received a doctoral degree in Educational Psychology from the University of Texas at Austin, in 1998. She served as an Assistant Professor at the University of Alabama from 1998 to 2002, when she moved to Arizona State University. In 2008 she was promoted by ASU to Associate Professor. She is currently an Associate Professor in the Educational Studies Department at the University of Oregon. Dr. Husman served as the Director of Education for the Quantum Energy and Sustainable Solar Technology Center - an NSF-funded Engineering Research Center from 2011-2016. Dr. Husman is an assistant editor of the Journal of Engineering Education, and is a member of the editorial board of Learning and Instruction. In 2006 she was awarded the U.S. National Science Foundation CAREER grant award and received the Presidential Early Career Award for Scientists and Engineers from the President of the United States. She has conducted and advised on educational research projects and grants in both the public and private sectors, and served as an external reviewer for doctoral dissertations outside the U.S. She publishes regularly in peer-reviewed journals and books. Dr. Husman was a founding member and first President of the Southwest Consortium for Innovative Psychology in Education and has held both elected and appointed offices in the American Psychological Association (APA) and the Motivation Special Interest Group of the European Association for Research on Learning and Instruction.

Dr. Cynthia J. Finelli, University of Michigan

Dr. Cynthia Finelli is Associate Professor of Electrical Engineering and Computer Science, Associate Professor of Education, and Director of Engineering Education Research at University of Michigan. Her research areas include student resistance to active learning, the impact of the classroom space on teaching and learning, the use of classroom technology to increase student learning and engagement, and faculty adoption of evidence-based teaching practices. She recently led an international initiative to develop a taxonomy for the field of engineering education research. Dr. Finelli is a Fellow of the American Society of Engineering Education, Associate Editor for the IEEE Transactions on Education, and past chair of the Educational Research and Methods Division of ASEE. She founded the Center for Research on Learning and Teaching in Engineering at University of Michigan in 2003 and served as its Director for 12 years.

Dr. Prateek Shekhar, University of Michigan

Prateek Shekhar is a Postdoctoral Research Fellow at the University of Michigan. His research is focused on examining translation of engineering education research in practice, assessment and evaluation of dissemination initiatives and educational programs in engineering disciplines. He holds a Ph.D. in Mechanical Engineering from the University of Texas at Austin, M.S. in Electrical Engineering from University of Southern California and B.S. in Electronics and Communication Engineering from India.

Dr. Charles Henderson, Western Michigan University

Charles Henderson is a Professor at Western Michigan University (WMU), with a joint appointment between the Physics Department and the WMU Mallinson Institute for Science Education. He is the co-founder and co-director of the WMU Center for Research on Instructional Change in Postsecondary Education (CRICPE). His research program focuses on understanding and promoting instructional change in higher education, with an emphasis on improving undergraduate STEM instruction. Dr. Henderson's work has been supported by over $7M in external grants and has resulted in a many publications (see http://homepages.wmich.edu/˜chenders). He is a Fulbright Scholar and a Fellow of the American Physical Society. Dr. Henderson is the senior editor for the journal "Physical Review Physics Education Research" and has served on two National Academy of Sciences Committees: Undergraduate Physics Education Research and Implementation, and Developing Indicators for Undergraduate STEM Education.

Dr. Cindy Waters, North Carolina A&T State University

Her research team is skilled matching these newer manufacturing techniques to distinct material choices and the unique materials combination for specific applications. She is also renowned for her work in the Engineering Education realm working with faculty motivation for change and re-design of Material Science courses for more active pedagogies

The Variation of Nontraditional Teaching Methods Across 17 Undergraduate Engineering Classrooms

Abstract

This research paper aims to explore the variation of nontraditional teaching methods (such as inductive teaching methods, active learning, pedagogies of engagement, and research based instructional strategies) in engineering classes in the United States. Numerous articles have demonstrated the effectiveness of nontraditional teaching methods in STEM classrooms, and the adoption of such methods has increased across the nation. But, more work needs to be done to explore how instructors are implementing nontraditional teaching methods. In this research study, we collected data from 17 diverse engineering classrooms across the nation and ask two research questions: (1) What are the perceived predominant types of instruction in undergraduate engineering classrooms that feature nontraditional teaching methods? (2) Is there a statistically significant difference in the perceived amount of traditional lecturing in undergraduate engineering classrooms that feature nontraditional teaching methods?

In our study, we recruited faculty teaching undergraduate engineering courses who employed nontraditional teaching methods and invited all students to complete the Student Response to Instructional Practices Survey (StRIP). Nontraditional teaching methods on the StRIP Survey included items such as individual and group problem solving, previewing concepts and material before class, and discussing questions in class. The StRIP Survey also included traditional teaching methods such as listening to the instructor lecture during class or watching the instructor solve problems. In total, our study collected data from 17 engineering classes, and 997 students during the 2015-16 academic year. To answer our first question, we used descriptive statistics of nontraditional teaching methods displayed in a graphical representation. To answer the second question, we conducted a Kruskal-Wallis H test to test for a statistically significant difference between classes. Even though all classes were sampled for their nontraditional teaching methods, many still incorporated traditional teaching methods alongside their nontraditional teaching methods. Traditional teaching methods such as passive lecture were the most frequently used teaching approach in 10 of the 17 classes. However, alluding to our second research question, there was a statistically significant difference in students' perception of passive lecture based by course, Kruskal-Wallis $\chi^2 = 394.3$, df = 16, $p < 0.001$.

Our results indicate that engineering instructors use multiple types of activities across classrooms, and labeling an entire course as nontraditional or active learning based may be problematic, as there is much variation and nuances that occurs in engineering classrooms. Furthermore, we find that most classes include a mix of traditional and nontraditional teaching methods, and implementing nontraditional teaching methods in the undergraduate engineering classroom does not always imply abandoning lecture. Our future work involves exploring *how* instructors implement these activities, how these teaching methods relate to students' evaluation of the instructor, and how faculty professional development can be used to help instructors implement activities as well as relating perceived use of teaching methods to institutional demographics, instructor's gender, course types, and other characteristics.

Introduction

Towards Nontraditional Teaching Methods in the Engineering Classroom

Recent developments in engineering and STEM education have led the call for more active learning and nontraditional teaching methods in our classrooms (Council on STEM Education, 2013; PCAST, 2012b). We define nontraditional teaching methods as types of instruction that are student-centered and involve student engagement in the classroom. Nontraditional teaching methods have been shown to improve student learning gains, affect or emotions in the classroom, and retention in engineering programs (Freeman et al., 2014; Prince, 2004). Despite the effectiveness of nontraditional teaching methods, the adoption of nontraditional teaching methods has been slow, and many engineering instructors discontinue their use of nontraditional teaching methods or are not aware of such methods (Borrego, Cutler, Prince, Henderson, & Froyd, 2013). We conducted a national research study of engineering instructors and their various teaching methods to provide a better understanding of those faculty that *do* decide to use nontraditional teaching methods in their classrooms. This research paper is then situated upon prior work engaging with nontraditional teaching methods and active learning.

Literature Review

Nontraditional Teaching Methods in Undergraduate STEM Education

Traditional teaching methods used in undergraduate STEM education involve heavy use of lecture. These traditional methods are based on what Barr and Tagg (1995) called the instruction paradigm. Within the instruction paradigm, the goal of the instructor is to transfer knowledge to the students by covering material. In contrast to the instruction paradigm, there are also a set of nontraditional teaching methods that fall within the learning paradigm (Barr & Tagg, 1995). Within the learning paradigm, the goal of the instructor is to elicit knowledge building by constructing an appropriate learning environment. Borrego et al. (2013) identified eleven types of nontraditional teaching methods that are commonly used in undergraduate engineering education: just-in-time teaching, case-based teaching, service learning, think-aloud-paired problem solving, inquiry learning, peer instruction, concept tests, think-pair-share, problem-based learning, collaborative learning, and cooperative learning. With a focus on the shift to the learning paradigm that includes nontraditional teaching methods, we hope to illicit positive outcomes for students.

Outcomes of Nontraditional Teaching Methods and Active Learning

Existing literature has extensively documented the benefits of nontraditional teaching methods such as active learning (Johnson, Johnson, & Smith, 1991), project-based learning (Fang, 2012), collaborative learning (Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001) and problem-based learning (Yadav, Subedi, Lunderberg, & Bunting, 2011) in engineering courses. Responding to calls from national academies to transform engineering education (National Academy of Engineering, 2004, 2005; PCAST, 2012a), researchers have gathered significant evidence supporting the efficacy of nontraditional teaching methods in improving student learning, increasing engagement and fostering interest in engineering (Freeman et al., 2014; Prince, 2004; Smith, Sheppard, Johnson, & Johnson, 2005)

In addition to improving student learning and instilling skills needed in future engineers, researchers have also noted the benefits of nontraditional teaching methods in addressing other issues critical to undergraduate engineering education. Specifically, researchers have shown that these teaching methods are effective in increasing student retention in STEM fields (Angelo & Cross, 1993; Prince & Felder, 2006) and promoting diversity in the student population (Seymour, 2002)

Guided by this research, recent calls from funding agencies have further highlighted the importance of bringing nontraditional teaching methods into practice for further advancing undergraduate engineering education (NSF, 2015). As a result, several dissemination efforts have been initiated to increase the awareness and adoption of nontraditional teaching methods in engineering classrooms, such as teaching workshops and faculty development programs (Finelli, Daly, & Richardson, 2014; Moore et al., 2015). These initiatives promote instructional change by educating engineering instructors on a wide variety of nontraditional teaching methods. Instructors are trained in using various in-class activities that range from simple group discussions to more constructive engagements such as requiring students to seek information on their own to solve assigned problems (Felder & Brent, 2010).

In light of these recent advances in engineering education, assessing the use of nontraditional teaching methods in engineering classrooms has become a logical and necessary step to better inform future engineering education efforts. In this paper, we examine the extent to which engineering instructors are using both nontraditional and traditional teaching methods in their classrooms. We propose a set of research questions to organize our research study.

Research Questions

1. What are the perceived predominant types of instruction in undergraduate engineering classrooms that feature nontraditional teaching methods?
2. Is there a statistically significant difference in the perceived amount of traditional lecturing in undergraduate engineering classrooms that feature nontraditional teaching methods?

Methods

The Student Response to Instructional Practices (StRIP) Survey

This research paper utilizes data from our study analyzing Student Response to Instructional Practices (StRIP). Within the context of this study, efforts to measure instructional practices of teaching methods in classrooms involved us surveying students' perceptions of what teaching methods were used in their classrooms. Although we did not directly ask instructors about their teaching methods, reporting students' perceptions or perceived types of instruction may be more important in discussing how dissemination efforts of nontraditional methods are being perceived by students.

The StRIP survey instrument was designed, validated, and piloted in our previous studies (DeMonbrun et al., 2017; Nguyen, Borrego, et al., 2016; Nguyen, Shekhar, et al., 2016; Shekhar et al., 2015). Through revisions and classroom observations (Shekhar et al., 2015), we chose 14 types of instruction that capture what teaching methods are occurring in engineering classrooms. Table 1 provides the 14 teaching methods items surveyed for this study. These items included both traditional and nontraditional forms of teaching. Although we did not survey all types of nontraditional teaching methods in the engineering education literature, we hoped to capture a variety of the most frequently used nontraditional teaching methods in classrooms.

Table 1

StRIP Survey on Perceived Teaching Methods

A	Listen to the instructor lecture during class.
B	Watch the instructor demonstrate how to solve problems during class.
C	Solve problems in a group during class.
D	Solve problems individually during class.
E	Solve problems during class that have more than one correct answer.
F	Work on problems during class that require me to seek out new information not previously covered in class.
G	Be asked to answer a question during class on material not previously covered in class.
H	Be called on personally by the instructor to answer a question during class.
I	Be given time to think or discuss before answering a question posed by the instructor during class.
J	Discuss concepts with classmates during class
K	Preview concepts before class by reading, watching videos, etc.
L	Receive an individual grade for group work.
M	Be graded on my class participation
N	Be graded based on the performance of my group.

Question Stem: In this course, how often did you…
Likert Scale: 1 - Never; 2 – Seldom (1-5 times/semester); 3 - Sometimes (5-10 times/semester); 4 – Often (Once a week); 5 - Very often (more than once/week)

Population and Sampling

Students' perceptions of teaching methods were sampled at the end of the semester. During Fall 2015 and Spring 2016, 17 instructors/courses participated in our research study. These instructors were chosen based on prior knowledge of their use of nontraditional teaching methods as well as their self-selection into the study. The final study sample represents a mix of gender, institution type, Carnegie type, and discipline, and the demographic and characteristic data are reflected in Table 2. The total number of students used in the analysis was 997, and pairwise deletion was used to handle missing data across survey items.

Table 2

Survey Population and Characteristics of Engineering Instructors

Course label	Instructor gender	Institution type	Carnegie classification*	Course discipline**	Number of students
1	F	Public	R2	CIVIL	51
2	M	Public	R1	INTRO	35
3	F	Public	R1	CBME	131
4	M	Public	R1	DESIGN	51
5	M	Public	M1	ME	45
6	M	Public	R1	EECS	226
7	F	Private	M1	CBME	97
8	F	Public	R1	CBME	41
9	M	Private	M3	EECS	11
10	F	Public	BACC	DESIGN	28
11	M	Public	R1	CBME	119
12	F	Private	R2	INTER	74
13	M	Public	M1	INTRO	286
14	M	Public	M1	ME	36
15	F	Public	R2	CBME	79
16	M	Private	R2	INTRO	140
17	F	Private	M1	INTRO	123

* Carnegie classifications: R1 = Doctoral Universities: Highest Research Activity; R2 = Doctoral Universities: Higher Research Activity; M1 = Master's Colleges and Universities: Larger Programs; M3 = Master's Colleges and Universities: Smaller Programs; B-A/S = Baccalaureate Colleges: Arts & Sciences Focus; and B-DIV = Baccalaureate Colleges: Diverse Fields

** Course disciplines: CBME = Chemical/Biomedical Engineering; CIVIL = Civil and Environmental Engineering; DESIGN = Design; EECS = Electrical Engineering/Computer Science; INTER = Interdisciplinary; INTRO = Introduction to Engineering; MAT = Materials Science and Engineering; and ME = Mechanical Engineering.

Quantitative Methods

To answer our research questions about the types of instruction in nontraditional classrooms, we provided descriptive statistics for each of the 17 undergraduate engineering courses as well as for the sample overall. Representations of descriptive statistics included tables and graphical figures. Across the 17 courses, we also provided information on which methods were used most and least.

To examine the prevalence of traditional teaching methods across our data set, we combined items A ("Listen to the instructor lecture during class") and B ("Watch the instructor demonstrate how to solve problems during class") into one passive lecture construct. Previous work highlighted the reliability of the passive lecture construct across pilot and final survey data (DeMonbrun et al., 2017). In this data set, passive lecture had a construct reliability of 0.71 (two items) and was reliable across the 17 courses. We conducted a Kruskal Wallis test to determine if students' perception of passive lecture were significantly different across courses. An alpha of 0.05 was used to determine if the Kruskal-Wallis H test was statistically significant. A Kruskal-Wallis test is similar to an ANOVA but does not assume normality of the data set nor equal sample sizes (Rheinheimer & Penfield, 2001).

Results

Descriptive Statistics

Overall descriptive statistics of mean, standard deviation (SD), median, skew, and kurtosis for the 14 teaching methods surveyed are provided in Table 3. For this sample of courses, it appears that items related to passive lecture (A and B) occurred the most frequently when compared to the other teaching methods (Table 3). The other types of instructions items appeared to only occur "sometimes" (a corresponding mean or median around 3 on a 5-Point Likert scale that ranged from 1-Never to 5-Very Often).

Table 3

Descriptive Statistics of Overall Teaching Method Items

Item		Mean*	SD	Median*
A	Listen to the instructor lecture during class.	4.14	0.92	4.00
B	Watch the instructor demonstrate how to solve problems during class.	3.96	1.24	4.00
C	Solve problems in a group during class.	3.41	1.31	4.00
D	Solve problems individually during class.	2.95	1.26	3.00
E	Solve problems during class that have more than one correct answer.	3.19	1.29	3.00
F	Work on problems during class that require me to seek out new information not previously covered in class.	3.32	1.27	3.00
G	Be asked to answer a question during class on material not previously covered in class.	2.47	1.25	2.00
H	Be called on personally by the instructor to answer a question during class.	2.68	1.47	2.00
I	Be given time to think or discuss before answering a question posed by the instructor during class.	3.50	1.12	4.00
J	Discuss concepts with classmates during class	3.22	1.28	3.00
K	Preview concepts before class by reading, watching videos, etc.	3.02	1.39	3.00
L	Receive an individual grade for group work.	3.22	1.43	3.00
M	Be graded on my class participation	2.91	1.30	3.00
N	Be graded based on the performance of my group.	3.09	1.29	3.00

*Question Stem: In this course, how often did you…
Likert Scale: 1 - Never; 2 – Seldom (1-5 times/semester); 3 - Sometimes (5-10 times/semester); 4 – Often (Once a week); 5 - Very often (more than once/week)

Due to the large volume of data, usage of the 14 teaching methods across the 17 courses are summarized using a graphical representation presented in Figure 1. Figure 1 contains the 17 courses listed vertically and their median scores for each teaching method listed horizontally. For example, course 17 is at the top of Figure 1, and its median score for teaching method item E is 4. Looking vertically, top to bottom, there appears to be high median scores for passive lecture items and a high variability for the remaining teaching method items.

Comparing the most and least frequent mean scores across all courses and teaching method provided additional information. Ten of the 17 courses used passive lecture (A and B) the most frequent on average. After omitting the two passive lecture items, “Solve problems in a group during class” (C), “Work on problems during class that require me to seek out new information not previously covered in class” (F), and “Be given time to think or discuss before answering a question posed by the instructor during class” (I) were used the most in 9 of the 17 courses. The least used teaching method in 5 of the 17 courses was “Solve problems individually during class” (G).

Kruskal Wallis Test

A Kruskal-Wallis H test was used to test the differences in perceived passive lecture across courses. In alignment with the findings from our descriptive statistics, there was a statistically significant difference in perceived passive lecture by course (Kruskal-Wallis $\chi^2 = 394.3$, df = 16, $p < 0.001$).

Discussion and Limitations

The sampled population in this study was diverse, but by no means representative of all engineering instructors, courses, and students. The sample most likely overestimates adoption levels of nontraditional teaching methods in engineering courses, but nonetheless, gives some insight into the variety of nontraditional teaching methods used by engineering instructors at U.S. institutions. Although the instructors were selected for their use of nontraditional teaching methods, these practices were often used alongside more traditional approaches, such as “Listen to the instructor lecture during class” (A) and “Watch the instructor demonstrate how to solve problems during class” (B). Surprisingly, their students perceived that passive lecture items were the most frequently used teaching method in many courses (10 of the 17 courses). Additionally, passive lecture items had the highest frequency on average for the overall sample.

As researchers continue to encourage instructors to adopt other forms of instruction in their classrooms, it may be comforting to hear that most engineering instructors who identify with using nontraditional teaching methods still incorporate some elements of lecture into their classrooms. Some may interpret calls for increased use of active learning or nontraditional teaching methods as an abandonment of lecture, but our study of indicates this is not the case. Very few active learning techniques rely on abandoning lecture, and most instructors used active learning to add some variety to a classroom while keeping the basic structure of a traditional lecture in place. There are exceptions (PBL, flipped classrooms), but those are the exemplar cases. A variety of methods can serve different instructors and student audiences. As learning scientists Schwartz and Bransford (1998) tell us, there may be a “time for telling” in our classrooms, even though many of us have made the switch to more student-centered instruction.

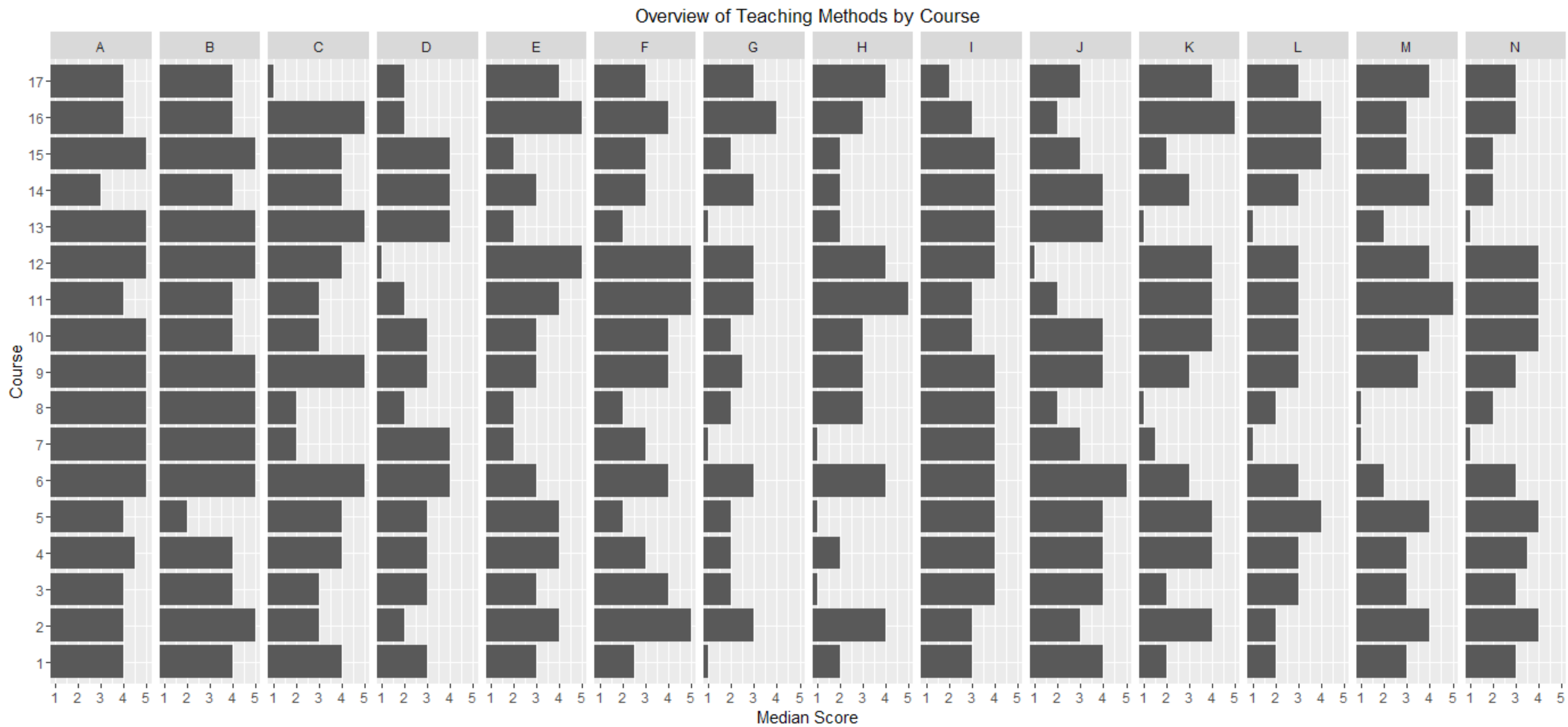

Figure 1 – Median Scores of StRIP Teaching Methods Items of All 17 Courses

However, as shown in this data set, variety of teaching methods and not just lecturing appears to be the common theme. Even though many courses had high occurrence of passive lecture instruction, there was still a statistically significant difference in passive lecture by course, and not all courses surveyed can be categorized as simply using passive lecture instruction. The graphical representation of teaching methods by course (Figure 1) and Kruskal Wallis test results indicate that engineering instructors use multiple types of activities to varying degrees. Further, we find that most classes include a mix of traditional and nontraditional teaching methods.

Conclusion and Future Work

As the nation continued to encourage and disseminate nontraditional teachings methods such as active learning in our STEM classrooms, there appears to be a variation of teaching methods being currently adopted into engineering classrooms. Even in classrooms self-identified as nontraditional, many students perceive a high frequency of traditional instruction. These results provide a baseline for other researchers to identify which nontraditional teaching methods may be most or least common in practice, how instructors' teaching intentions may vary from students' perceptions, and which may be worthy of further study. Also, relating teaching methods to institutional demographics, instructor's gender, course types, and other characteristics remains work to be done. From a researcher's point of view, it is important to remember how nuanced instructors' classrooms can be, as it may be problematic to simply label or categorize an entire classroom semester as passive lecture only or fully nontraditional. This study also serves as a starting point for similar survey studies of instructional practices. Combined with other data, these results enable exploring *how* instructors implement these activities, how these teaching methods relate to students' evaluation of the instructor, and how faculty professional development can be used to help instructors implement activities, and these are the research themes for our future work.

Acknowledgements

This project is funded by the U.S. National Science Foundation through grant numbers 1347417, 1347482, 1347580, 1347718, and 1500309. The opinions are those of the authors and do not necessarily represent the National Science Foundation. The authors would like to thank the instructors and students who agreed to be part of the pilot study, as well as project advisory board members and American Society for Engineering Education reviewers.

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