FOUNDATIONS – Integrating Evidence-based Teaching and Learning Practices into the Core Engineering Curriculum: Student Perceptions of the Instructional Practices

Dr. Gail P Baxter, Stevens Institute of Technology

Gail P. Baxter is the Co-Director, Center for Innovation in Engineering and Science Education (CIESE) at Stevens Institute of Technology. Baxter leads CIESE research and evaluation efforts and manages a program to support faculty adoption of evidence-based teaching practices in the core courses in the School of Engineering at Stevens. Before joining CIESE, Baxter was a Senior Survey Researcher at Mathematica Policy Research, Inc., Senior Research Scientist at Educational Testing Service, and an Assistant Professor in the Graduate School of Education at the University of Michigan. In addition, she served on National Academy of Sciences Committees on Foundations of Educational and Psychological Assessment and Evaluation of National and State Assessments of Educational Progress. She earned a PhD in Educational Psychology from UC Santa Barbara.

Dr. Keith G. Sheppard, Stevens Institute of Technology (School of Engineering and Science)

Dr. Keith G. Sheppard is Senior Adviser to the Dean in the Charles V. Schaefer, Jr. School of Engineering and Science and a professor in the Department of Chemical Engineering and Materials Science. His research interests have included electrochemical aspects of materials synthesis and environmental degradation of materials. His education in the U.K. included B.Sc. (University of Leeds) and Ph.D. (University of Birmingham) degrees in Metallurgy and a diploma in Industrial Administration (Aston University). He was the recipient of the Henry Morton Distinguished Teaching Professor Award in 2009. As Associate Dean, Prof. Sheppard had a leading role in the development of the undergraduate engineering curriculum at Stevens, including innovations in design education and initiatives to include entrepreneurship, sustainability, and global competency for undergraduate students.

Dr. Frank T Fisher, Stevens Institute of Technology (School of Engineering and Science)

Frank T. Fisher is a Professor of Mechanical Engineering at Stevens Institute of Technology, where he served as the Interim Department Director / Department Chair from April 2013 to August 2018. He earned BS degrees in Mechanical Engineering and Applied Mathematics from the University of Pittsburgh, and Masters degrees in Mechanical Engineering and Learning Sciences (School of Education and Social Policy) and a Ph.D. in Mechanical Engineering from Northwestern. His research interests include characterization of multifunctional nano-reinforced polymer systems, multiscale modeling of nanocomposites and materials, vibration energy harvesting/scavenging, and engineering pedagogy and instructional technologies. Awards that he has received include the NSF CAREER award, the 2016 Alexander Crombie Humphreys Distinguished Teaching Associate Professor award (Stevens), the 2014 Distinguished Faculty Mentor Award from the Stevens Student Government Association, the 2009 ASEE Mechanics Division Outstanding New Educator Award, and the 2009 Outstanding Teacher Award from the Stevens Alumni Association.

Dr. Patricia J. Holahan, Stevens Institute of Technology (School of Engineering and Science)

Patricia J. Holahan is an Associate Professor of Management in the School of Business, Stevens Institute of Technology, Hoboken, NJ, USA. She has served as PI/PD on several NSF funded projects that target large-scale institutional change and transformation where she oversaw the organizational research related to modelling organizational change and transformation processes. Dr. Holahan holds a PhD in organizational behavior and theory from Purdue University's Krannert Graduate School of Management. She teaches courses on organizational behavior and design and organizational change. Her work has been work published in several leading academic journals including, Journal of Applied Psychology, Journal of Management, Journal of Management Studies, and Journal of Product Innovation Management.

Dr. Susan Lowes, Teachers College, Columbia University

Dr. Susan Lowes is Director of Research and Evaluation at the Institute for Learning Technologies at Teachers College, Columbia University. She has conducted research at both university and K-12 levels, with a focus on STEM learning and on the impact of different technologies on teaching and learning. She has directed evaluations of multi-year projects funded by the U.S. Dept. of Education and the National Science Foundation, and served on Dept. of Education and NSF Advisory and Review panels. Dr. Lowes has worked extensively with Columbia University's Fu Foundation School of Engineering and Stevens Institute of Technology's School of Engineering and Science. She has co-authored papers and presentations on STEM learning in the sciences, engineering, and mathematics. Dr. Lowes is also Adjunct Professor in the Program in Computers, Communication, Technology, and Education at Teachers College, teaching courses on methodologies for researching technology in education and on online schools and schooling.

Ms. Susan S. Metz, Stevens Institute of Technology

Susan Metz is Executive Director of Diversity and Inclusion and Senior Research Associate at Stevens Institute of Technology. Metz is a founder of WEPAN, Women in Engineering ProActive Network. She is a recipient of the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring, the Maria Mitchell Women in Science Award and a Fellow of the Association for Women in Science.

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Introduction

Active and collaborative instruction coupled with various means to encourage student engagement lead to better student learning outcomes irrespective of academic discipline [1],[2]. Despite decades of research and efforts to change instructional practices, traditional, content-centered, didactic teaching is still the norm in higher education STEM classrooms especially for large-size core courses. The purpose of this project is to draw on the significant body of research on teaching and learning to effect change in teaching practices in all core mathematics, science, and engineering-science courses taken by students in their first two years, with approximately 600 students entering engineering each year. The project provides support to enable the faculty who teach these critical core courses to target deep and transferable learning within and across disciplinary domains, iteratively redesign their courses to move from faculty-led lectures to more active student engagement, and assess the impact of pedagogical changes on student outcomes. Strategies to support faculty change include ongoing discussions of the principles of teaching & learning [3],[4], and discipline-based education research [5],[6]; trained peer assistants to facilitate active-learning pedagogies in lectures and recitations; midterm course evaluations as formative feedback; and advocacy with colleagues to catalyze diffusion beyond these early courses.

Approach

The Foundations project has engaged three cohorts of faculty, with each cohort receiving summer support for three years beginning summer 2016 (N=9), 2017 (N=5), and 2018 (N=5). These are faculty members who teach the core Calculus, Chemistry, Physics and Biology courses, together with the foundational computer programming, and engineering science courses in Engineering Thermodynamics, Engineering Mechanics, and Electrical Circuits. All thirteen of the core courses have at least one Foundations faculty teaching one or more sections. The faculty engaged to date are heavily weighted towards teaching faculty, but our theory of action anticipates these being the champions to effect diffusion through sharing their experiences and successes with the tenured or tenure-track faculty who tend to teach upper-level courses.

A central goal of the project is to understand student perceptions of the teaching environments that lead to improved learning. Each semester, student feedback is sought at the midpoint and at the end of the course. In this paper, we report results of student feedback (midterm and end-of-course) for all core courses taught by faculty group: Group 1--Those who completed their 3-year commitment; Group 2--Those who have participated for less than three years; and Group 3--Non participants. If the project is successful with respect to faculty adopting evidence-based teaching practices, then we might expect to see differences among the three faculty groups; It is expected that students of Group 1 faculty will perceive their learning experiences more positively than their peers taught by Group 2 or Group 3 faculty. Gender differences were also explored. Because faculty group status changes from year to year, we focus on data collected in the Spring of 2019 when the first cohort of faculty completed their 3-year commitment and Group 2 participating faculty had completed at least 1 full year of their 3-year commitment.

Results and Discussion

Midterm

At approximately the midpoint of the semester, students were asked, via a five-minute on-line survey, the extent to which they agree on a scale from 1 (strongly disagree) to 5 (strongly agree) with statements about professor and course relevance (e.g., It is clear to me how this course is related to my other courses), active learning opportunities (e.g., Students have opportunities to work in pairs or groups to solve problems during class), and strategies for help seeking (e.g., Talk to instructor, look online, talk to my friends).

Table 1. Mean ratings for professor and course relevance by faculty group.

To what extent do you agree or disagree with the following?	Faculty Group	N	Mean	SD	Sig.
A. The professor is interesting and brings the material to life	1	102	4.17	0.93	*
	2	134	4.14	1.09	
	3	69	3.36	1.29	
B. The professor is accessible outside the classroom	1	102	4.12	0.86	*
	2	134	4.10	0.84	
	3	69	3.74	0.87	
C. It is clear to me how this course is related to my other courses	1	102	4.03	1.02	ns
	2	134	3.92	1.13	
	3	69	4.03	.92	
D. It is clear to me why I need to take this course	1	102	3.90	1.14	ns
	2	134	3.90	1.16	
	3	69	3.96	0.96	

*p < 0.05; **p < 0.01; ***p < 0.001; ns = not significant

On average, students from all faculty groups generally agreed with statements about professor and course relevance (see Table 1). Results of Faculty Group by Gender two-way ANOVA shows significant mean differences by faculty group for items A and B. For each of these items, students of Faculty Group 3 (non participants) gave significantly lower ratings than did students of Faculty Groups 1 and 2. There was a gender main effect for item B. Females agreed more strongly (mean = 4.02) than did males (mean = 3.93) that "*the professor is accessible outside the classroom*."

Table 2. Mean ratings for active learning opportunities by faculty group.

I like/appreciate that students have opportunities during class to…	Faculty Group	N	Mean	SD	Sig.

A. Explain the course material to other students in the class	1	102	2.67	1.93	ns
	2	133	2.81	1.84	
	3	69	2.65	1.88	
B. Work in pairs or groups to solve problems	1	102	3.38	1.64	*
	2	132	2.55	1.94	
	3	69	2.77	1.93	
C. Discuss responses to clicker questions with other students	1	102	2.78	1.96	*
	2	133	2.07	1.96	
	3	69	1.81	1.87	
D. Ask the in-class student assistant for help to solve problems.	1	102	2.24	2.12	ns
	2	133	1.78	1.95	
	3	69	1.80	1.97	

*p < 0.05; **p < 0.01; ***p < 0.001; ns = not significant

On average, students generally were neutral or disagreed with statements about active learning opportunities (see Table 2). Large standard deviations (approximately 2 on a 5-point scale) highlight the variation in student responses within faculty group. Results of Faculty Group by Gender two-way ANOVA shows significant mean differences by faculty group for items B and C. For item B (work in pairs to solve problems), students of Faculty Group 1 (completed commitment) more strongly agreed that they appreciate having these opportunities during class than did students of Faculty Group 3 (Nonparticipants). There were no significant mean differences between males and females on any of the items.

When seeking help, students on average agreed that they talked to their friends or talked to others in the class and disagreed or were neutral (neither agree nor disagree) about seeking help from a tutor at the academic support center (see Table 3). Mean student responses varied by faculty group on items A (talk to the course instructor) and F (talk to the course TA or student assistant). On average, students neither agreed nor disagreed that they sought help from the course instructor. Responses varied by faculty group. Students of Faculty Group 2 (those who participated in the project for 1 or 2 years) gave significantly higher ratings on average than did students of Faculty Group 1 or Faculty Group 3. For item F (talk to the course TA or student assistant), students of Faculty Group 1 (completed 3-year commitment) provided higher mean ratings than did students of Faculty Group 2 (those who completed 1 or 2 years). There were no gender differences in ratings for any of the items.

Table 3. Mean ratings for student help-seeking strategies by faculty group.

When I have trouble understanding the course material, I typically…	Faculty Group	N	Mean	SD	Sig.
A. Talk to the course instructor	1	102	3.07	1.23	*
	2	134	3.40	1.26	
	3	69	2.94	1.14	
B. Look online for similar courses or content	1	102	4.15	0.76	
	2	134	4.09	0.82	*
	3	69	4.38	0.64	
	Total	305	4.17	0.78	
C. Talk to my friends	1	102	4.02	0.89	ns
	2	134	4.02	0.91	
	3	69	4.22	0.80	
D. Talk to others in the course	1	102	3.88	0.97	ns
	2	134	3.89	0.94	
	3	69	4.04	1.02	
E. Meet with a tutor from the academic support center	1	102	2.36	1.11	
	2	134	2.46	1.15	ns
	3	68	2.40	1.13	
F. Talk to the course TA or student assistant	1	102	3.29	1.21	*
	2	133	2.86	1.17	
	3	69	2.96	1.29	

*p < 0.05; **p < 0.01; ***p < 0.001; ns=not significant

End of Course

Six items were added to the university-administered end-of-course evaluation for each of the core courses. The items are intended to provide feedback to faculty on student perceptions of the course. The first four items asked students about their motivation to learn the course material (i.e. Interest, professor made it interesting, prerequisite, good grade), and the remaining two items asked about opportunities for active participation and awareness of cross-course connections (a primary focus of the Foundations project).

Table 4. Mean ratings for end-of-course items by faculty group.

1. I was motivated to learn the course material because:	Faculty Group	N	Mean	SD	Sig.
A. I am interested in the subject	1	280	3.68	1.13	ns
	2	233	3.68	1.20	
	3	174	3.90	0.95	
B. The professor made the subject interesting	1	276	3.95	1.05	*
	2	230	3.72	1.15	
	3	173	3.46	1.15	
C. This subject is a prerequisite for other courses in my major.	1	277	4.30	0.97	ns
	2	233	4.19	1.09	
	3	173	4.46	0.71	
D. I wanted to get a good grade in the class.	1	278	4.58	0.61	*
	2	231	4.49	0.67	
	3	170	4.68	0.49	
2. Opportunities to actively participate in class (e.g., individual or group problem solving, polling, peer-to-peer activities) helped me understand the course material.	1	280	3.94	0.97	ns
	2	233	3.89	1.06	
	3	174	3.78	1.02	
3. It is clear to me how this course is related to my other courses.	1	280	4.06	0.99	*
	2	233	3.83	1.25	
	3	174	4.16	0.89	

*p < 0.05; **p < 0.01; ***p < 0.001; ns = not significant

Results of Faculty Group by Gender two-way ANOVA shows significant mean faculty group differences on items IB, ID, and 3. Students of Faculty Group 1 agreed more strongly that the professor made the subject interesting than did students of Faculty Group 3. Further, males agreed more strongly (3.84) than did females (3.66). For item 1D, students of Faculty Group 3 agreed more strongly that they were motivated to learn the course material because they wanted to get a good grade in the class than did students of Faculty Group 2. For item 3, Students of Faculty Groups 1 and 3 more strongly agreed that it is clear how this course is related to my other courses than did students of Faculty Group 2. There were no gender differences on these items.

Summary and Conclusions

The project's efforts to change teaching practices and support student-centered learning has been met with mixed results. Faculty groups, including those involved in the Foundations project, vary in their use of active learning strategies. For example, those who teach the large lecture core

courses are less likely than those who teach smaller sections (< 55 students) to use peer leaders and/or to use polling and group discussion to support student learning. Second, some Group 2 and 3 faculty have benefited from mentoring by Group 1 faculty. For example, one faculty coordinates the efforts of five faculty as part of a large lecture course reorganization. All of these faculty use peer leaders to promote in class discussion, engage students in problem solving, and provide pre-class worksheets and weekly quizzes to scaffold learning. Third, gender differences are minimal which is indeed welcome news on a campus whose student body is less than 30% female. Females agreed more strongly than did males that "*the professor is accessible outside the classroom*" and males agreed more strongly than did females that they were motivated to learn the course material because "*the professor made the subject interesting."* Finally, although there have been important changes in practice, and students seem to be positive about many of them, it will be important to: (1) consider additional strategies to increase student response rates across courses/sections and (2) examine midcourse and end-of-course responses across semesters to provide evidence of the generalizability of the findings.

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