122nd ASEE Annual
Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society

Paper ID #11666

Examining Relationships and Patterns in Pedagogical Beliefs, Attitudes and Classroom Practices for Faculty of Undergraduate Engineering, Math and Science Foundational Courses

Prof. James A Middleton, Arizona State University

James A. Middleton is Professor of Mechanical and Aerospace Engineering and Director of the Center for Research on Education in Science, Mathematics, Engineering, and Technology at Arizona State University. For the last three years he also held the Elmhurst Energy Chair in STEM education at the University of Birmingham in the UK. Prior to these appointments, Dr. Middleton served as Associate Dean for Research for the Mary Lou Fulton College of Education at Arizona State University for 3 years, and as Director of the Division of Curriculum and Instruction for another 3 years. He received his Ph.D. in Educational Psychology from the University of Wisconsin-Madison in 1992, where he also served in the National Center for Research on Mathematical Sciences Education as a postdoctoral scholar for 3 years.

Jim's research interests focus in the following areas where he has published extensively: Children's mathematical thinking; Teacher and Student motivation in mathematics; and Teacher Change in mathematics. He is currently developing methodologies for utilizing the engineering design process to improve learning environments in Science, Engineering and Mathematics. He has also written on effective uses of educational technology in mathematics and science education as a natural outgrowth of these interests. To fund his research, Jim has garnered over $20 million in grants to study and improve mathematics education in urban schools. He just finished a $1.8 million research grant to model the longitudinal development of fractions, rational number and proportional reasoning knowledge and skills in middle school students, and is currently engaged in a project studying the sustainability of changes in urban elementary teachers' mathematics practices. All of his work has been conducted in collaborative partnerships with diverse, economically challenged, urban schools. This relationship has resulted in a significant (positive) impact on the direction that partner districts have taken, including a significant increase in mathematics achievement in the face of a rising poverty rate.

Dr. Stephen J Krause, Arizona State University

Stephen Krause is professor in the Materials Science Program in the Fulton School of Engineering at Arizona State University. He teaches in the areas of introductory materials engineering, polymers and composites, and capstone design. His research interests include evaluating conceptual knowledge, misconceptions and technologies to promote conceptual change. He has co-developed a Materials Concept Inventory and a Chemistry Concept Inventory for assessing conceptual knowledge and change for introductory materials science and chemistry classes. He is currently conducting research on NSF projects in two areas. One is studying how strategies of engagement and feedback with support from internet tools and resources affect conceptual change and associated impact on students' attitude, achievement, and persistence. The other is on the factors that promote persistence and success in retention of undergraduate students in engineering. He was a coauthor for best paper award in the Journal of Engineering Education in 2013.

Ms. Kendra Rae Beeley
Dr. Eugene Judson, Arizona State University

Eugene Judson is an Associate Professor of for the Mary Lou Fulton Teachers College at Arizona State University. His past experiences include having been a middle school science teacher, Director of Academic and Instructional Support for the Arizona Department of Education, a research scientist for the Center for Research on Education in Science, Mathematics, Engineering and Technology (CRESMET), and an evaluator for several NSF projects. His first research strand concentrates on the relationship between educational policy and STEM education. This provides policymakers and the educational community an improved understanding of how changes in educational policies impact STEM teaching and learning. His second research strand focuses on studying STEM classroom interactions and subsequent effects on student understanding.

John Ernzen
Dr. Ying-Chih Chen, Arizona State University

Ying-Chih Chen is an assistant professor in the Division of Teacher Preparation at Mary Lou Fulton Teachers College at Arizona State University in Tempe, Arizona.

His research takes two distinct but interrelated paths focused on elementary students' learning in science and engineering as well as in-service science teachers' professional development. The first focus involves how language as a learning tool improves students' conceptual understandings, literacy, and representation competencies in science. His second research focus is on how in-service teachers develop their knowledge for teaching science and engineering in argument-based inquiry classrooms. This research is aimed at developing measures of teachers' Pedagogical Content Knowledge (PCK) for adopting the argument-based inquiry approach, as well as developing tools to capture the interactive nature of PCK.

Examining Relationships and Patterns in Pedagogical Beliefs, Attitudes and Classroom Practices for Faculty of Undergraduate Engineering, Math and Science Foundational Courses

Abstract

The beliefs and practices of 21 faculty engaged in the STEM instruction of freshmen engineering students were examined in this study. Specifically, the degree to which faculty beliefs conformed to a Student-centered approach versus a Teacher-centered approach, and the degree to which these orientations were related to learner-centered classroom practice, was assessed. Four data collection methods were employed: faculty interviews, faculty surveys, observation protocol scores and qualitative classroom observations. Hierarchical Cluster Analysis of faculty responses to the Approaches to Teaching Inventory revealed three coherent groups of faculty who held common beliefs: Faculty who displayed Student-centered beliefs, faculty who displayed Teacher-centered beliefs, and faculty who displayed non-discriminatory beliefs. These beliefs corresponded closely to assessment of their classroom practice. Student-centered faculty engaged in more learner centered practices than either Teacher-centered faculty or non-discriminating faculty. Results showed that the Freshman Engineering departments and the Mathematics department had the most within-department consistency in their teaching delivery and environment. Instruction delivery ranged from mostly lecture with pauses for questions in one of the physics classes, to shared problem solving in one of the mathematics classes, to student led activities in engineering. Student interactions with each other during class ranged from very little, particularly in the large lecture halls, to almost constant collaboration in classes with laboratory formats. Implications for faculty development for the improvement of freshman engineering programs are discussed.

Introduction

This study examines the relationship between the pedagogical beliefs and practices of faculty teaching required freshman courses for engineering students. Research shows that faculty may hold beliefs about teaching that, in the ideal, are learner-centered, but in reality their practice may be teacher-centered due to constraints such as class size, time, technology and their beliefs about students' abilities[1].

Much has been written about Learner- or Student-centeredness over the years in education research. The first attempt for defining Learner-Centeredness was put forth in 1949 by Faw, when he applied Rogerian client-centered clinical therapy techniques to the undergraduate psychology classroom[2]. These ideas smoldered in academia over the years, and it wasn't until the early 1990s that a comprehensive framework for Learner Centered instruction was proposed by the American Psychological Association (see Table 1)[3].

Table 1. American Psychological Associated Learner Centered Psychological Principles

Cognitive and Metacognitive Factors
Nature of the learning process: The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience. **Goals of the learning process:** The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge. **Construction of knowledge:** The successful learner can link new information with existing knowledge in meaningful ways. **Strategic thinking:** The successful learner can create and use a repertoire of thinking and reasoning strategies to achieve complex learning goals. **Thinking about thinking:** Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking. **Context of learning:** Learning is influenced by environmental factors, including culture, technology, and instructional practices.
Motivational and Affective Factors
Motivational and emotional influences on learning: What and how much is learned is influenced by the learner’s motivation. Motivation to learn, in turn, is influenced by the individual's emotional states, beliefs, interests, and goals, and habits of thinking. **Intrinsic motivation to learn:** The learner’s creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, relevant to personal interests and providing for personal choice and control. **Effects of motivation on effort:** Acquisition of complex knowledge and skills requires extended learner effort and guided practice. Without learners’ motivation to learn, the willingness to exert this effort is unlikely without coercion.
Developmental and Social Factors
Developmental influence on learning: As individuals develop, they encounter different opportunities and experience different constraints for learning. Learning is most effective when differential development within and across physical, intellectual, emotional, and social domains is taken into account. **Social influences on learning:** Learning is influenced by social interactions, interpersonal relations, and communication with others.
Individual Differences Factors
Individual differences in learning: Learners have different strategies, approaches, and capabilities for learning that are a function of prior experience and heredity. **Learning and diversity:** Learning is most effective when differences in learners’ linguistic, cultural, and social backgrounds are taken into account. **Standards and assessment:** Setting appropriately high and challenging standards and assessing the learner and learning progress - including diagnostic, process, and outcome assessment - are integral parts of the learning process.

To be Learner-centered under this framework, a classroom must at least make an attempt to account for effective approaches to enhancing students’ cognitive abilities, incorporate students’ motivational and emotional sets into the instructional process, target instruction to the developmental stage where students are at, and understand that the social and individual characteristics students bring to the table will shape their learning process and outcomes.

Weimar's framework[4,5] for Learner-centered teaching effectively summarizes the literature in a concise depiction of what learner-centered practice looks like, in the ideal:

1. The actions of the instructor focus on students learning as opposed to presenting material.
2. In ethically responsible ways, instructors share decision making about learning with students. Teachers control less, but students are involved more.
3. Content is used to build a knowledge base, to develop learning skills and to foster learner self-awareness of their abilities. Teaching approaches account for students' learning modes and strategies.
4. Instructors and students, together, create learning environments that motivate students to accept responsibility for learning.
5. Assessment activities are used to promote learning and to develop self and peer assessment skills, not to evaluate performance primarily.

In a recent meta-analysis of 119 studies, across grades K-20, Cornelius-White, found that learner-centered variables such as non-directive verbal interactions, incorporation of higher-order thinking, encouraging learning and challenge, and adapting to individual and social differences correlate significantly with cognitive and affective student outcomes (e.g., mathematics achievement, science achievement, participation, motivation, and others). Relationships among these variables average r=.34, indicating that the overall influence of learner centered practices accounts for about ten percent of desired outcomes--a significant relationship.[6]

When learner centered practices are broken out by cognitive outcomes, we find that critical/creative thinking is most strongly related to learner-centered practices (r=.45), with mathematics achievement running a close second (r=.34). Grades as an outcome show a much lower relationship (r=.25). Affective/motivational variables showed higher association, typically, than cognitive outcomes. Student participation, for example, is strongly related to learner-centeredness (r=.55), closely followed by satisfaction (r=.44), drop-out prevention (r=.35), self-efficacy (r=.35), positive motivation (r=.32), and social connection/skills (r=.32).

Given these affective/motivational variables are causally and reciprocally related to student achievement in mathematics and science[4], we propose that faculty learner centered attitudes and practices put in place a positive feedback cycle of student motivation and success (see Figure 1).

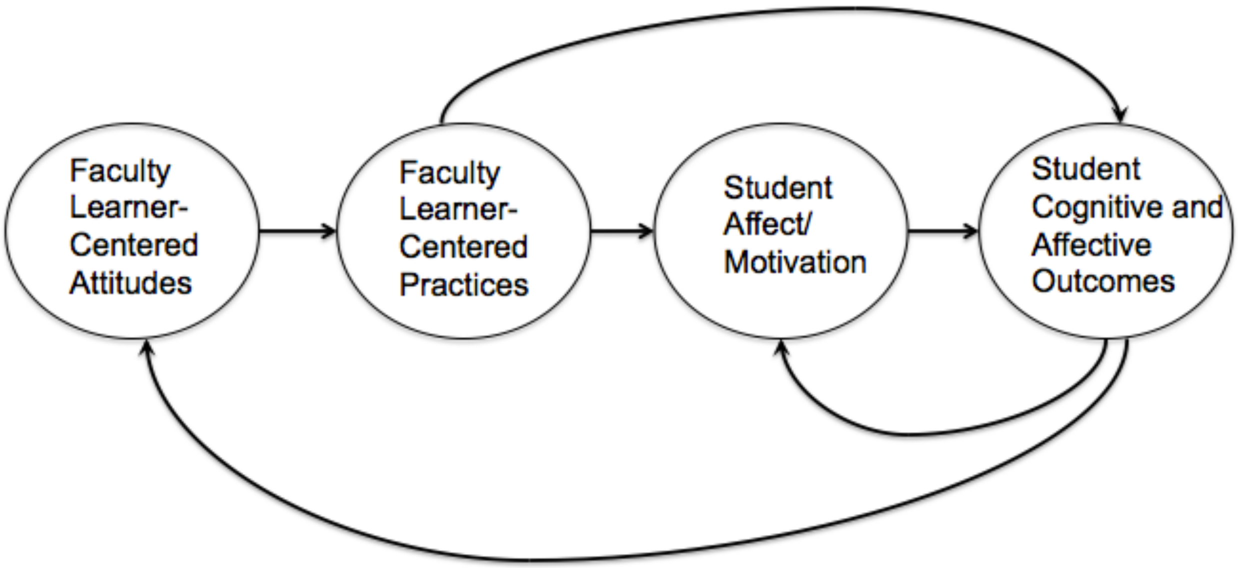

Figure 1. Relationship among faculty attitudes and practices, and student attitudes and outcomes

It is important to note that it is faculty *practices* that drive potential changes in student motivation and performance. Faculty attitudes help guide their practice, and are reinforced by successful student outcomes, but attitudes per se are only indirectly responsible for student achievement, persistence, and motivation. But sadly, Learner-centered practices are used infrequently by post-secondary faculty.[7] Part of the problem concerns the fact that an instructor's perception of student-centered pedagogy may not align with the reality of their classroom practice. Ebert-May et al., for example, reported on results of a national biology professional development program consisting of 6-12 days of workshops on scientific teaching over three years[8]. Faculty teams designed instructional units that included learning objectives, learning assessments, and student-centered learning strategies, such as cooperative learning. While there was a significant increase in pedagogical knowledge, and the majority self-reported they were using a student-centered learning strategy, in reality 75% were found to be lecturing with instructor-centered teaching, as found from rating videos of their classrooms. It was suggested that the professional development was not sufficient to change the nature of their teaching practice. So the majority of participants, in practice, had not actually progressed into a true adoption of innovation[9], possibly because of opportunity to collaborate and create a community to support their burgeoning knowledge and attitudes of learner-centered practice.

Drilling down to engineering, in a recent study by McKenna et al., engineering faculty worked in collaboration with learning scientists to develop student-centered conceptual change instructional methods. They determined the extent to which engineering faculty felt they were changing their pedagogy toward student-centered learning and found that the greater the extent of collaborative reflection between engineering faculty and learning scientists, the greater the shift toward student-centered practices[10]. This agrees with the model developed by Rogers over 3 decades of research on the diffusion of innovation[9]. Briefly, Rogers suggests that adoption and implementation of an innovation in a field goes through five stages:

1. Knowledge or Awareness - occurs when an individual is exposed to an innovation and its functioning

2. Persuasion or Interest – occurs when interest is growing and an individual seeks additional information

3. Evaluation and Decision – occurs when an individual decides to adopt or reject an innovation

4. Implementation or Trial – occurs when an innovation is tested by putting it into use

5. Confirmation or Adoption – occurs when use of an innovation is continued and sustained

Borrego et al. cite findings of other researchers that change agents, who have used this model for faculty development strategies, have been successful at the first two stages of *awareness* and *interest*, but are not as successful at the *trial* stage, which they say can lead to discontinuing use of an innovation or changing it in ways that decrease its effectiveness [11, 12]. However, they also cite evidence that suggests that providing support for implementing innovation in the third and fourth *decision* and *trial* stages, with personal or small group interactions, can provide a more successful progression to the higher stages of diffusion of innovation[13].

Summary

In sum, research on faculty attitudes and practices suggest that Learner-centered practice is the instructor variable representing the most direct route to improving student motivation and performance outcomes. Yet, engineering faculty do not tend to incorporate Learner-centered practices in their instruction. Faculty attitudes are important, providing impetus and support for change in practice, but can be inconsistent with, and lag behind, development of Learner-centered practices. Professional development can help faculty become aware of, and interested in, Learner-centered practice. Yet, moving beyond mere awareness and interest, faculty need to collaborate with others involved in innovating their own practice to make sustained positive change.

The study reported in this manuscript paints a picture of a faculty, distributed across STEM departments in a large, urban university, struggling with issues of engineering motivation, persistence, and retention, and in various stages of implementation of learner-centered practices. We specifically examined the relationship between faculty learner-centered attitudes, their actual classroom practices, and their connectedness within and between others undergoing the same struggle. Three research questions were addressed:

1. What commonalities (if any) exist among faculty teaching first and second year engineering core content regarding their learner centered versus instructor-centered attitudes and practices?
    a. Are there groups of faculty who tend to be more learner centered than others, and if so, are their attitudes and practices more consistent than faculty who tend to be teacher centered?

2. If faculty attitudes and practices were compared, would there be a "pedagogy gap" between the perception of self-assessed student-centered pedagogy and the reality of an objective observation of an instructor's classroom practice?
3. What commonalities (if any) exist among faculty within departments in terms of their attitudes, practices, and resources upon which they rely to help them improve their practice?

Method

This study utilized four data collection methods: faculty interviews, faculty surveys, observation protocol scores and qualitative classroom observations.

Participants

Twenty-one different instructors (13 Engineering, 4 Physics, 2 Mathematics, and 2 Chemistry) across nine departments were chosen for the study. All instructors teach at a large, urban, Southwestern University in the United States. Faculty participants were randomly selected from the list of faculty teaching required STEM courses for freshman engineering students. Two participants hailed from the Mathematics Department, four from Physics, four from Chemistry, four from Biomedical Engineering, two each from Freshman Engineering, Electrical Engineering, and Civil Engineering, and on each from Materials Science, Computer Systems, and Mechanical/Aerospace Engineering. Faculty were provided small stipends as compensation for their time.

Interviews

Each faculty member in the study participated in one one-hour semi-structured interview. Interviews consisted of twenty-four questions focusing on topics of teaching practices, teaching resources used, teaching environment, course and departmental policies, self and departmental evaluations, and departmental and interdepartmental collaboration. Interviews were audio-recorded upon permission.

The Glaser and Laudel approach to qualitative content analysis was chosen to analyze the interview data. Qualitative content analysis is a theory-guided methodology that extracts qualitative content using units of meaning originating from the same theoretical framework that guided the quantitative data collection. The goal of this analysis was to determine contextual and potentially causal factors in the qualitative data that "mirrors" the quantitative[14]. Specifically, we used this method to ascertain the common resources faculty used to support instruction, and then determine the extent to which use of resources supported Learner-centered instruction.

Approaches to Teaching Inventory (ATI)

In addition to the interview, each instructor completed a twenty-two item revised edition of the Approaches to Teaching Inventory survey to measure the faculty perceptions about their own teaching. The ATI is a self-reporting tool designed by Trigwell and Prosser that is a valid and reliable tool that measures the extent to which faculty teach with an approach toward instructor-centered knowledge transmission versus student-centered conceptual change. Items on the ATI fall into four dimensions: 1) Conceptual Change Intention, measuring the degree to which instructors are aware of, and support the development of student understanding in the class (e.g., I see teaching as helping students develop new ways of thinking in this subject); 2) Student-Centered Strategies, measuring the extent to which instructors utilize pedagogical strategies that focus on student learning (Teaching in this subject should help students question their own understanding of the subject matter); 3) Information Transmission, the extent to which the instructor emphasizes getting information to the student (e.g., I think an important reason for running teaching sessions in this subject is to give students a good set of notes); and 4) Teacher-Focused Strategies (e.g., My teaching in this subject focuses on delivering what I know to the students). The first two dimensions promote Student-Centered classroom practice, while the latter two promote Teacher-centered classroom practice. Reliabilities of the subscales range from alpha = .73 to .75. Of course, it is expected that all instructors will incorporate some beliefs from each of these 4 dimensions to more or less degree in their own teaching perspective[13].

Classroom Observation Protocol and Qualitative Observations

For each course, three classroom observations were conducted for a total of 63 observations. Sections to be observed were randomly selected from the list of required freshman engineering courses taught in each department. The Reformed Teaching Observation Protocol (RTOP) was used after each observation to identify specific teaching practices associated with reformed teaching. The RTOP is a classroom observational protocol that quantitatively characterizes the extent to which faculty implement student-centered behaviors in their own classroom practice. It has high reliability and validity[16]. Published reliabilities of RTOP subscales are: Lesson Design and Implementation (alpha = .915), Propositional Knowledge (alpha = .670), Procedural Knowledge (alpha = .946), Communicative Interactions (alpha = .907), and Student/Teacher Relationships (alpha = .872). The overall RTOP has a reliability of alpha =.954. As classroom practice can vary across days and specific learning objectives, RTOP scores for each participant’s three observations were averaged to gain a typical view of their practice, resulting in a single set of scale scores for each participant. In addition to RTOP scores, qualitative classroom observation field notes were gathered during each course observation including details about class environment and student-instructor interactions. The classroom observation field notes were used to provide relevant information in conjunction with the reformed protocol results and to provide any needed context when examining the relationship between the classroom teaching practices as reflected in the RTOP score and the teaching beliefs reflected in the instructor interviews and survey responses.

Results

Faculty surveys and observation protocol scores were used as the main focus for analysis and discussion in this paper. Interview responses and classroom observation results were used as supportive material for the context of this paper.

Relationships among ATI and RTOP dimensions

ATI Dimensions

As expected, correlations among ATI variables showed that the ATI Student-centered dimensions (conceptual change intention and student-focused strategies) were strongly related to each other (r = .657, p=.002). Likewise, Teacher-centered attitudes (information transmission and teacher-focused strategies) were significantly related to each other (r = .543, p = .013). Student-centered attitudes and Information Transmission showed low correlations, close to zero, indicating that these factors are both meaningful and distinct from each other. However, there was a small correlation between both Student-centered dimensions and Teacher-focused Strategies, indicating that some Teacher-focused Strategies are consistent with Student-centered attitudes.

Table 2. Pearson Correlations among ATI dimensions

	CCI	SFS	IT	TFS
Conceptual Change Intention	1	.657**	.018	.266
Student-Focused Strategies	.657**	1	.045	.265
Information Transmission	.018	.045	1	.543*
Teacher-Focused Strategies	.266	.265	.543*	1

*(p<.01)

**(p<.001)

RTOP dimensions

Scores across dimensions of the RTOP were highly related to each other, as expected. Correlations ranged from .57 (p = .006) between Procedural Knowledge and Propositional Knowledge aspects of the classroom, to .91 (p <.001) for Procedural Knowledge, and Classroom Culture. All subscales on the RTOP correlated with the total score very highly (from .74 (p <.001) for Propositional Knowledge, to .96 (p < .001) for Procedural Knowledge). These findings are consistent with published psychometric data for the RTOP[16].

Because the RTOP is so heavily aligned with Learner-centered practice, it was hypothesized that scores on the protocol would show a significant positive relationship with Conceptual Change/Student Centered attitudes (per Figure 1). Indeed, the correlation between total RTOP score and CCSF scale score was .342, while the correlation between total RTOP score and ITTF score was -.072.

Research Question 1: Commonalities Across All Faculty

Faculty Clusters

To determine the extent to which patterns of faculty learner-centered beliefs distinguished different classroom practices and behaviors, hierarchical cluster analysis was performed, clustering faculty participants by their ATI beliefs. Twenty of the 21 participating faculty were clustered across their average ATI beliefs on each of the 4 subscales. One participant was eliminated from the analysis due to missing data.

Cluster analysis techniques examine the distances between each participant, represented as a point in a multidimensional space. Participants who are simultaneously close to each other, but farthest away from other points are considered a cluster. The algorithm for joining pairs of closely-related participants to other pairs is iterative, examining each potential pairwise combination exhaustively, then moving to larger groups of participants. A squared Euclidean distance metric was used to determine intercluster distances because ATI beliefs constructs are averages across several dimensions, approximating a continuous scale. Wards method, a technique that minimizes the variance of total intra-cluster distances was chosen to determine true cluster membership. The dendrogram presented in Figure 1 shows a clear distinction for three groups of faculty. Subjects MAE 1, Math 1, Civil 2, and EE 1 make up Cluster 1. Subjects MSE 1 and Math 2 make up Cluster 2, and the remainder of the participating faculty make up Cluster 3. Some caution must be taken here, as, due to the small sample, determining "true" clusters from error clusters is not straightforward. There may be more true groups of faculty than we have chosen, but to be conservative, we limited the number of clusters to three.

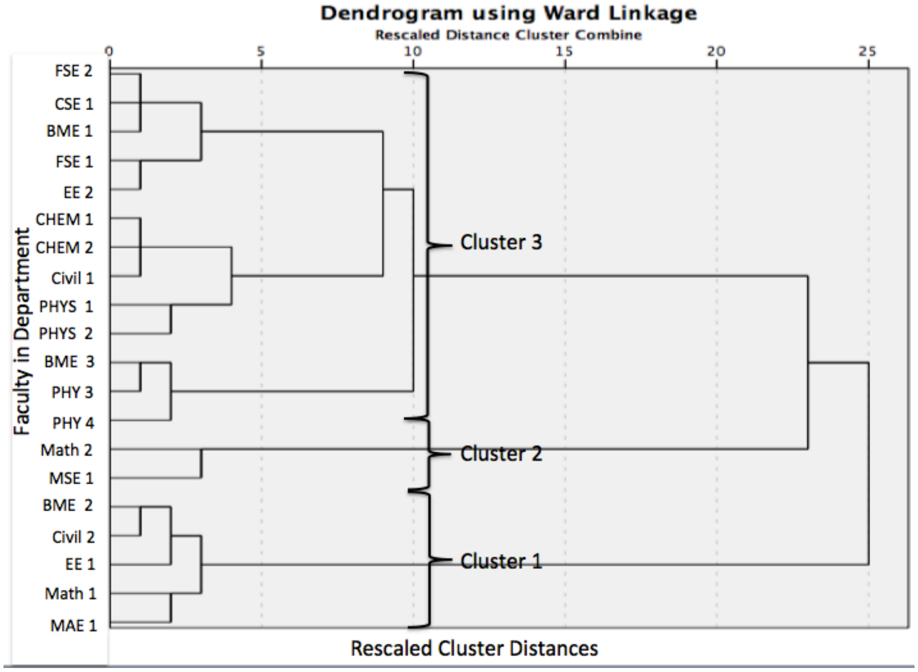

Figure 2. Faculty classification across ATI dimensions

How Faculty Clusters Are Distinguished by Attitudes and Practices.

From the Cluster Analysis, there appear to be three distinct profiles of faculty whose beliefs are differentiated on the ATI. Cluster 3 consists of those who tend to have more positive beliefs regarding conceptual change intention and student-focused strategies, while showing less positive beliefs regarding information transmission with teacher-focused strategies (a Student-centered approach). Cluster 2 consists of faculty who tend to have less-positive views towards conceptual change intention and student focused strategies, and more positive views towards information transmission and Teacher focused strategies (A Teacher-centered approach). Cluster 1 consists of faculty who appear to not distinguish much among these seemingly competing approaches to instruction (A non-discriminating approach). Figure 1 illustrates these different profiles, comparing the mean scores for faculty in each cluster across each of the ATI subscales.

It is interesting to note that faculty tend to cluster around their departmental peers. All four participating physics instructors, for example, appear in Cluster 3. Both Chemistry professors, both freshman engineering professors, and two of the three Biomedical Engineering professors show similar profiles of attitudes towards Student-Centered instruction.

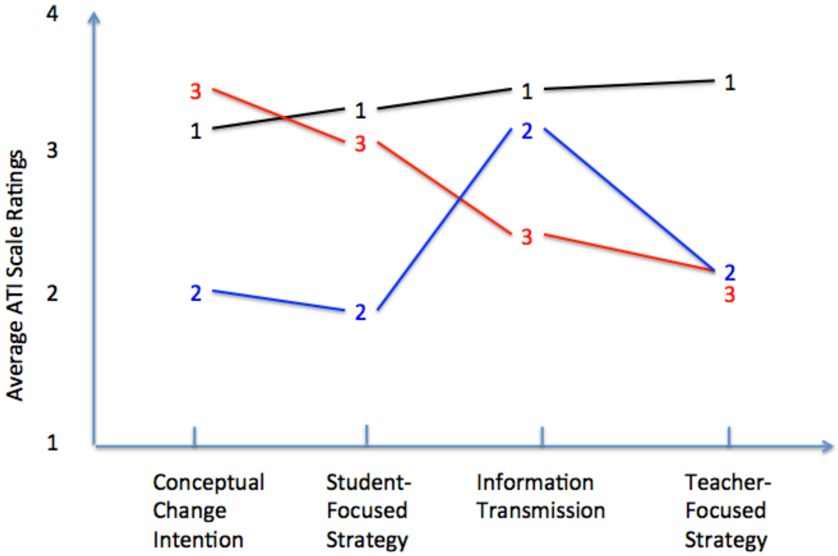

Figure 3.Profiles of Faculty Clusters Across ATI Dimensions

Comparing faculty clusters with outcomes their classroom practice, we find very little differences in instructors' approaches to design and implementation of lessons, and their attention to both propositional and procedural knowledge. Where differences in attitudes *do* seem to differentiate across classroom practice concerns the classroom culture, and student-teacher relationships. Here, Cluster 3 (Student-centered faculty) tended to practice what they preached. They scored higher on these two dimensions of practice than faculty in Cluster 2 (Teacher-centered faculty), or Cluster 1 (non-discriminating faculty) (see Figure 2).

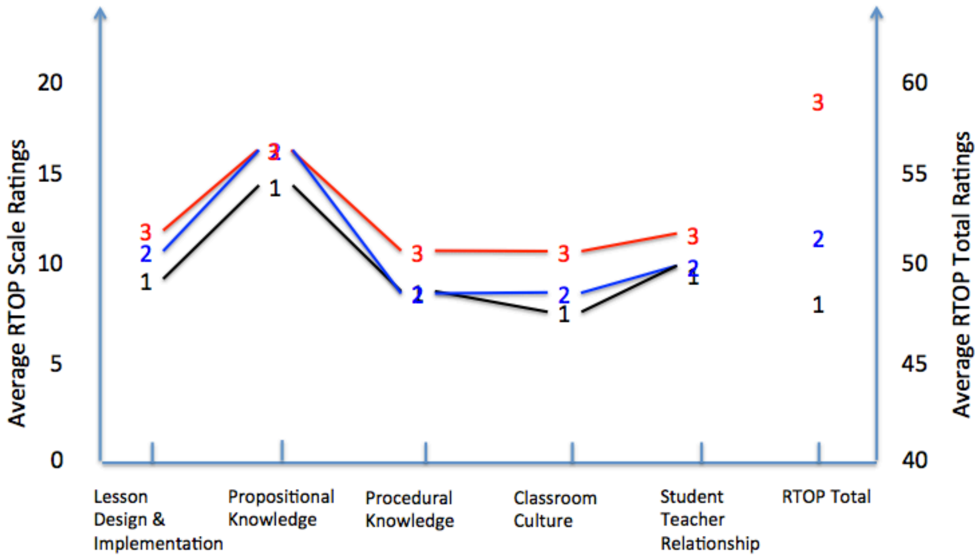

Figure 4. Profiles of Faculty Clusters across RTOP Dimensions

As expected, faculty with more Student-centered beliefs (Cluster 3) scored higher than faculty with more Teacher-centered beliefs (Cluster 2) across all RTOP dimensions. However, what is most interesting is the fact that non-discriminating faculty (Cluster 1) showed the lowest level of reform-oriented practices.

Research Question 2: Is There a "Pedagogy Gap?"

When RTOP dimensions are combined to form an overall score on reformed teaching, Student-centered faculty showed markedly better practices than either Teacher-centered faculty or Non-discriminating faculty (See Tables 3 and 4).

Table 3. Mean RTOP score by faculty cluster

Cluster	**RTOP Score Mean (SD)**	**Effect Size (SD units)**
1. Non-discriminating faculty	47.9 (19.6)	.71
2. Teacher-centered faculty	51.7 (12.7)	.58
3. Student-centered faculty	59.1 (12.1)	--

Research Question 3: Commonalities Across Academic Departments

Table 4. Mean RTOP Total Score by Department

Department	N	Mean RTOP Total	SD
Mathematics	2	60.33	.47
Freshman Engineering	2	73.83	5.89
Chemistry	2	57.67	7.54
Physics	4	60.79	10.83
Biomedical Engineering	4	54.17	18.36
Mechanical/ Aerospace	1	25.33	.
Electrical Engineering	2	56.17	11.08
Computer Systems	1	60.00	.
Materials Science	1	42.67	.
Civil Engineering	2	54.33	1.41
Total	**21**	**56.79**	**13.21**

Note here how the values of the Freshman Engineering faculty practices are very high—reform-oriented practices overall. There exists considerable variability, across departments, and even within departments (BME, for example), in the quality of instructional practices.

What is important to note here, is that these practices are congruent with faculty members' Student-centered attitudes (see Table 5). Freshman Engineering instructors showed a clear Student-centered set of attitudes and intentions. Mathematics, in particular, shows a more Teacher-centered attitude, while Physics seems a bit mixed in attitudes. Caution must be taken, again, when interpreting these data, due to small numbers of faculty surveyed in each department.

Table 5. Mean ATI Scale Scores by Department

Department		Dept. N	Conceptual Change Intention	Student-focused Strategies	Information Transmission	Teacher-focused Strategies	CCSF	ITTF
Math	Mean		2.65	2.35	3.30	3.20	2.39	3.27
	SD	99	.21	1.34	.00000	.85	.86	.38
Freshman Engineering	Mean		3.8	3.15	2.5	2.6	3.33	2.5
	SD	12	.00	.21	.28	.57	.16	1.3
Chemistry	Mean		3.15	2.80	2.75	2.70	2.83	1.91
	SD	77	.21	.14	.07	.14	.08	.13
Physics	Mean		3.03	2.70	1.63	2.25	2.83	1.91
	SD	38	.46	.85	.22	.72	.56	.40
Biomedical Engineering	Mean		3.20	3.30	2.47	2.60	2.42	1.91
	SD	25	.17	.30	.76	.69	1.6	1.4
Mechanical/ Aerospace	Mean		3.50	3.70	4.00	4.00	3.56	4.00
	SD	35	.	.	.	.	.	.
Electrical Engineering	Mean		4.00	3.70	2.95	2.80	3.78	2.86
	SD	69	.00	.00	.35	.85	0.00	.58
Computer Systems	Mean		4.00	3.60	2.30	2.80	3.67	2.55
	SD	79	.	.	.	.	.	.
Materials Science	Mean		1.30	1.90	3.20	1.80	1.33	2.55
	SD	18	.	.	.	.	.	.
Civil Engineering	Mean		3.40	3.00	2.95	2.90	3.00	2.91
	SD	56	.57	.14	1.06	.14	.31	.51
Total	**Mean**		**3.23**	**3.00**	**2.62**	**2.69**	**2.87**	**2.52**
	N	508	20	20	20	20	20	20
	SD		.66	.68	.74	.66	.91	.84

CCSF: Conceptual Change *and* Student Focused Scale Score
ITTF: Information Transmission *and* Teacher Focused Scale Score

Interview and Observation

Each interview coincided with three classroom observations of the required undergraduate engineering course the instructor was teaching that semester. Teaching environment and delivery was inconsistent from department to department. Learning environments observed varied from workshops, small lecture halls to large lecture halls. Instruction delivery ranged from mostly lecture with pauses for questions in one of the physics classes, to shared problem solving in one of the mathematics classes, to student-led activities in engineering. In general, lectures were "traditional" with instructor having the majority of the speaking time. Student interactions with each other during class ranged from very little, particularly in the large lecture halls, to almost constant collaboration in classes with laboratory formats.

In conjunction with the quantitative RTOP scoring analysis and ATI cluster analysis, interview data was used in a qualitative content analysis to determine patterns across departments and colleges regarding instructors' self-reported practices and beliefs. This interview response analysis centered on the following topics: teaching practice in relation to instructors' teaching resources used, instructors' beliefs about student impediments to learning, and instructor practice about self-assessment. Faculty members' interview responses were consistent, overall, with their classification by the cluster analysis. Student-centered faculty tended to proffer more strategies that were learner-centered, and tended to use more and more innovative tools for instruction in their classes.

In terms of utilizing student-centered teaching tools and resources to facilitate instruction, there is some evidence that Student-Centered faculty tend to incorporate more resources (such as formative assessment, use of videos and multimedia, and interactive course materials). Both the mean number of resources utilized, and minimum number of resources utilized was higher for Student Centered faculty than Teacher Centered faculty. Non-discriminating faculty varied considerably on the number of resources they utilized.

Table 6. Number of Learner-Centered Teaching Resources Utilized

Teaching Resources Used			
ATI Cluster	Mean number of teaching resources used	Range in number of teaching resources regularly used	RTOP Score Mean (SD)
Cluster 1 Student-centered faculty	6	4 to 10	59.1 (12.1)
Cluster 2 Teacher-centered faculty	4.5	3 to 6	51.7 (12.7)
Cluster 3 Non-discriminating faculty	5.3	2 to 10	47.9 (19.6)

The instructor's self-reported teaching resources used reflected their beliefs about what are valuable teaching tools and what is required for best teaching practice. The resources the instructors reported using were sorted into the three broad categories of Personnel, Technology and Materials, and Classroom Environment. The instructors that valued Personnel as a resource named at least one of the following: undergraduate teaching assistants, undergraduate learning assistants, graduate teaching assistants, graders, lab staff, teaching team, and other faculty.

Instructors that valued Technology and Materials as a resource named software, textbook, online materials and videos as their primary resources.

Instructors that valued Classroom Environment as a resource discussed their desire for group interactions, and how it was dependent on the seating and space in the room. Faculty that had rooms with tables or labs that allowed for students to be grouped together rated their classrooms as a highly valuable source. Instructors that taught in a large stadium or auditorium style lecture hall frequently commented on the limitations of this classroom environment. Large class sizes, in traditional environments, for most faculty, compounded the difficulty of shifting to student-centered practices.

Being situated in a collaborative, teaching team resulted in a higher likelihood to have similar beliefs and practices within their own group and with other co-teaching groups in other departments with which they had no regular contact. Four departments had pairs of faculty co-teaching sections. These include the introductory Engineering courses; part of the Physics department; a course in a sequence of three courses planned in the Civil Engineering department, and three co-teachers in the Biomedical Engineering department.

The co-teaching groups more were more like to value their teaching assistants as instructional aides than other faculty. For example, one BME instructor explained their most valuable teaching tool: *"The undergraduate teaching assistants. There's no way we could do this class without them. Students feel more comfortable asking them questions, sometimes, than the instructor."* While individual instructors were more likely to name Technology and Materials, such as handouts or video links, as commonly used teaching resources, faculty situated within a co-teaching team *all* reported using co-instructors and other Personnel as a valuable resource for collaborate and improving their teaching practice. For example, the freshman Engineering faculty regularly meet (approximately once per month), coordinating curriculum, and sharing activities and assessments. They have a website devoted to sharing tools and strategies amongst their "team," and are encouraged by the Associate Dean for Academic Affairs and Student Services to engage in professional development related to learner-centered instruction.

Across faculty and across college departments, when the instructors were asked to identify specific impediments to their students' success, the most frequent responses were 1) time management, and 2) gaps in foundational knowledge. Specifically, instructors observed students were unaware of the high time commitment their entire course load required. Another frequent response was that students took courses without the foundational knowledge they needed to easily access the material presented. Several instructors expressed concern about better advising for their students in this regard, but were also unsure about the details of the current advising system for their students. In addition, many faculty members shared the belief that their students come into class with gaps in foundational knowledge and their course is not adaptable for catching them up.

When asked about evaluation of their practices, faculty across departments all reported minimal self-assessment, but an interest in improving in that area. Each noted that the departments evaluated them based on student surveys; however, many of them indicated the surveys were a problematic. Homework assignment grades were also dismissed as an unreliable representative of successful teaching as homework as grades were reported as much higher than test grades or final course grades. Several instructors mentioned, ideally they would like to see how their student did in future related courses, but acknowledged this would be difficult to track. Some said they can tell their instruction is effective by test scores alone, some added they can tell by questions asked, eye contact, or just a feeling. No instructor reported they believed they currently had access to a quality method to measure of their own teaching.

Discussion

In education research, many interacting variables contribute to faculty and student attitudes, classroom practices, and outcomes. Because of these interactions, most bivariate measures of relationship among innovative interventions and student outcomes are rather small, in the r=0.1 to 0.3 range. Fraser, Wahlberg, Welch, & Hattie, for example, synthesized 134 meta-analyses of nearly 8,000 studies and found an average correlation between intervention variables and outcomes to be around .20. Given the range of correlations, and the typical values found, they suggest that any correlation above .20 be considered potentially informative, and any correlation above .30 to be worth pursuing for potential implementation of the innovation[17]. It is in the aggregate—in the complex system that includes the feedback loops from student to instructor, student to student, and instructor to department—that the impact of changes in pedagogy are manifest.

In the study reported in this paper, we found this to be the case. Faculty attitudes are not uniform. There were no faculty who were exclusively student-centered in their beliefs, nor were any faculty completely teacher-centered. Different pedagogies were applied that correlated significantly with faculty attitudes, but all faculty were observed in occasional information transmission modes, and most attempted to establish helpful relationships with their students. In particular, the faculty in the non-discriminating cluster present an interesting case. These faculty appear to hold contradictory beliefs, either: 1) not yet having enough experiences to be able to differentiate learner-centered practices from more teacher-centered ones; or 2) responding to constraints and barriers to implementation of their beliefs presented by large class sizes, departmental inertia, and in particular, lack of connections with other faculty with which to share best practices.

In particular, the relationships between each individual's beliefs and practices were seen to be related, in part, by the context within which the faculty member worked. The interviews, surveys and observations reveal that the course and department context greatly impacts teaching behavior, even when faculty have more learner-centered attitudes. Thus, department culture and norms (including physical plant, available technology, ability to collaborate, etc.) constrain what even well-intentioned and informed faculty can do within boundaries set by these norms. Some attempt to collaborate across departments and develop shared goals for courses engineering students take, and the expectations for their learning environments seems like a fruitful next step in our evolution.

We have raised caveats regarding the statistical significance of the relationships we tested in this study. While the total sample size is adequate for establishing the most important overall relationships among attitude and practice variables, attempts to compare departments are, at best, conjecture at this time. However, the *consistency* of relationships across faculty clusters and academic departments in the aggregate, suggests that a subtle, but significant influence exists among these variables that, over time, may contribute to an effective model of the influences on faculty practice. Armed with such a model, more effective professional development can perhaps be designed to move more faculty along Rogers' diffusion of implementation taxonomy[9].

As we gain more data, the structure of these variables and their mutual contributions can be examined in a manner more consistent with Figure 1. That is, through Structural Equations Modeling, or other ways of depicting a dynamical, causal relationship among variables, can be performed. We are currently also examining student attitudes, performance, and persistence to graduation. We hope to develop a more predictive model connecting faculty attitudes and practices, and their interaction on these key student outcomes.

Implications

The picture we have painted of faculty beliefs and practices is a familiar one[16]. Echoing back to Borrego and colleagues' findings that a supportive social system is critical for sustained change, programmatically[11], our own work suggests that there are commonalities within departments that constrain individual faculty from going too far out of bounds in their instruction, and that some kind of collaborative effort both within and between departments that impact freshman success in engineering, is warranted.

The results of this study suggest several potential avenues for improving undergraduate Engineering faculty and student success. These include improved communication between faculty and student advising units, additional tools for faculty self-assessment, increased interdepartmental communication regarding course sequence and student content knowledge expectations, collaborative self-assessment across departments and colleges to monitor improvements and changes.

Instructors across departments identified a need for communication between faculty and student advising. Most instructors expressed concerns about students entering a class without the requisite prior knowledge and students underestimating the workload and taking too many classes. Several faculty also expressed concern that they themselves were not sure of how the advising was organized or conducted. Improved communication between faculty and advising could be an effective way to also approach a broader issue: communication and coordination between departments. While every engineering student traverses several different colleges and departments to complete their required coursework, the faculty who team them are situated in different departments with vastly variable practices regarding interdepartmental communication and coordination in teaching the courses. Those who are teaching the same particular course might communicate voluntarily, might be part of regular meetings, might co-teach the course, or might not interact with one another beyond social encounters in hallways. Several faculty reported an interest and concern their student's future performance in related courses. However, discussions between instructors of different course topics was very rarely reported by any of the faculty interviewed.

In their interviews, many faculty expressed the belief that the material they were teaching should prepare their students for future coursework at the very least, but had no sense of whether that was in fact happening; they didn't know if success in their class predicted higher performance in future courses and they also didn't know which future courses might be impacted by the course they were teaching. This concern about the students' performance and understanding both before and after their courses indicated that some faculty, across departments and colleges, held a belief that part of their student's success and their own success was interdependent on the larger community involved in the requirements their students needed to pass.

It appears, faculty are each singular gatekeepers in a series of gatekeepers for their student's success, but rarely are any of the previous or future gatekeepers communicating. The coursework and knowledge their students' had already learned (or not) are not only out each individual faculty member's control, but the ways that students are practically applying the material in future courses is unclear as well to most instructors. Although some faculty could clearly articulate what skills they hoped their students would be able to use later and in what contexts, some were actually able to name ways their class might help their student's in future engineering courses. Currently, there is little means for instructors to know about the other "gates" or courses their students already passed or still need to prepare for.

Increased communication between instructors and departments regarding teaching and specific courses would seem to be a logical first step. However, it cannot be assumed that beginning the conversation will in and of itself improve instructor or student outcomes. Efforts for regular and effective interdepartmental and inter-collegial communication – whether in person or virtually - would be needed to both initiated and maintained. Such efforts could also begin a more clear understanding amongst instructors across departments of how their courses impact one another. For example, it would be beneficial to faculty, students and advisors if the concepts and knowledge a student needed for a particular course were clearly mapped out. The time and effort needed to create and disseminate this information, as well as, keep it up to date would require a commitment of resources from all the departments involved in teaching core requirements for Engineering students. Departmental and college level support for faculty to focus on teaching, while not required for improved individual improvement, is needed to impact a maximum number of undergraduate students each year and consistently influence overall trends in student success and retention.

It is important to note, perhaps the most significant deficit identified by faculty was a lack of quality and breadth in tools to self-assess effective instruction. Providing faculty with tools for self-reflection and data collection on their own terms could provide a strong foundation for meaningful and productive communication with other faculty. Additionally, it would be essential to begin coordinated self-assessment beyond the individual faculty. For example, this may mean: 1) identifying two course sequences, 2) locking students into the same sections moving forward, 3) regularly collecting data on student performance as they move forward in the sequence, and 4) regularly changing course teaching practices and content based on the self-assessment processes built into the delivery of the class. It is doubtful that any suggested strategy for improvement will be effective without a built in self-assessment.

In terms of effective change, the results of this study suggest that undergraduate programs would benefit from the identification and use of more self-assessment across departments and colleges. In addition to initiating changes, there is a need for simultaneously measuring the effectiveness of larger collaborative efforts, advising and other interventions chosen to solve reoccurring problems as a means of ongoing collaborative self-assessment beyond the individual classroom. This could not only facilitate awareness as individuals about teaching practices, but could extend to the regular practice of collaborative self-assessment to identify common problems and coordinate solutions to support the success of undergraduate students on their trajectory to graduation and beyond.

References

1. Blanton, Maria L., Susan Westbrook, and Glenda Carter. "Using Valsiner's zone theory to interpret teaching practices in mathematics and science classrooms." *Journal of Mathematics Teacher Education* 8.1 (2005): 5-33.

2. Faw, Volney. "A psychotherapeutic method of teaching psychology." *American Psychologist* 4.4 (1949): 104.

3. American Psychological Association. *Learner-centered psychological principles: A framework for school redesign and reform*. ERIC Clearinghouse, 1995.

4. Weimer, Maryellen. *Learner-centered teaching: Five key changes to practice*. John Wiley & Sons, 2002.

5. Weimer, Maryellen. "Focus on learning, transform teaching." *Change: The Magazine of Higher Learning* 35.5 (2003): 48-54.

6. Cornelius-White, Jeffrey. "Learner-centered teacher-student relationships are effective: A meta-analysis." *Review of Educational Research* 77.1 (2007): 113-143.

7. Walczyk, Jeffrey J., and Linda L. Ramsey. "Use of learner-centered instruction in college science and mathematics classrooms." *Journal of research in science teaching* 40.6 (2003): 566-584.

8. Ebert-May, Diane, et al. "What we say is not what we do: effective evaluation of faculty professional development programs." *BioScience* 61.7 (2011): 550-558.

9. Rogers, Everett M. "Diffusion of Innovations Vol 5". New York: Free Press, 2003.

10. McKenna, Ann F., Bugrahan Yalvac, and Gregory J. Light. "The role of collaborative reflection on shaping engineering faculty teaching approaches." *Journal of Engineering Education* 98.1 (2009): 17-26.

11. Borrego, Maura, Jeffrey E. Froyd, and T. Simin Hall. "Diffusion of engineering education innovations: A survey of awareness and adoption rates in US engineering departments." *Journal of Engineering Education* 99.3 (2010): 185-207.

12. Henderson, Charles, Melissa Dancy, and Magdalena Niewiadomska-Bugaj. "Use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process?." *Physical Review Special Topics-Physics Education Research* 8.2 (2012): 020104.

13. Prince, Michael, et al. "Use of research-based instructional strategies in core chemical engineering courses." *Chemical Engineering Education* 47.1 (2013): 27-37.

14. Glaser, Jochen, and Grit Laudel. "Life with and without coding: Two methods for early-stage data analysis in qualitative research aiming at causal explanations. *Forum Qualitative Sozialfroschung / Forum: Qualitative Social Research* 14.2. Retrieved from http://qualitative-research.net/index.php/fqs/article/view/1886/3528.

15. Trigwell, Keith, and Michael Prosser. "Development and use of the approaches to teaching inventory." *Educational Psychology Review* 16.4 (2004): 409-424.

16. Sawada, Daiyo, Michael Piburn, Eugene Judson, Jeff Turley, Kathleen Falconer, Russell Benford, & Irene Bloom. "Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol." School Science and Mathematics, vol. 102, pp. 245-253, 2002.

17. Fraser, Barry J., et al. "Syntheses of educational productivity research." *International journal of educational research* 11.2 (1987): 147-252.