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Faculty Characteristics that Influence Student Performance in the First Two Years of Engineering

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Faculty Characteristics that Influence Student Performance in the First Two Years of Engineering

Abstract

This is an evidence-based paper based on research that has shown faculty beliefs influence their classroom practices and reformed teaching methods like engagement teaching improve student performance and retention in science, technology, engineering, and mathematics (STEM) fields. To better understand the relationships between faculty beliefs and practice and student outcomes such as performance and attitudes, three tools were utilized. The first tool is a 24 question guided interview to gauge general beliefs towards teaching; the second is the Approaches to Teaching Inventory (ATI) that measures faculty beliefs towards instructor-centered knowledge transmission and instructor-centered strategies versus student-centered conceptual change intention and strategies. Lastly, the third tool is the Reformed Teaching Observational Protocol (RTOP) which is an observational protocol that quantitatively measures degree of student-centered classroom behaviors. By combining ATI and RTOP scores with emergent theme (ET) analysis on relevant interview questions, faculty characteristics influencing student outcomes can be determined. This work addressees the research questions, "What is the relationship between faculty beliefs and practice?" and "What is the relationship between faculty practice and student outcomes?"

30 faculty members who teach freshman or sophomore level science, math, or engineering courses at a large, southwestern university were interviewed about their teaching beliefs, were surveyed using the ATI, and were observed using the RTOP. Interview questions were analyzed using emergent theme analysis and related to their ATI responses and RTOP scores. The interview question responses were coded numerically as either teacher-centered (-1), student centered (+1), or mixed/neither (0) using the dimensions of the ATI as a basis. The total RTOP scores, the ATI dimension scores, and the sum of the interview ET analyses for every faculty member were then ranked in ascending order. Using Spearman's rank correlation, the relationships between the ATI, RTOP, and ET analysis were found. It was discovered that two of the four dimensions of the ATI were correlated to the ET analysis at the 90% confidence level and that teacher practice was related to ATI. Finally, the grade distributions were examined for the classes that we observed and were correlated to teacher practice. The ratios of the grades ABC to DEW and ABC to DE were higher for the instructors with higher RTOP scores than for instructors with lower RTOP scores. The findings indicate that faculty beliefs and practices are related and that they relate to student performance. It follows that by shifting the beliefs of faculty members towards student-centeredness, there would likely be a positive change in student outcomes.

Background

This study examines the relationship between pedagogical beliefs and practices of faculty teaching undergraduate level courses for engineering students. Previous research shows that faculty may hold beliefs that, ideally, are student-centered, but in reality may be teacher-centered due to constraints[1].

Much research in student or learner centered instruction has been published. The framework for student-centered instruction presented by Weimar[2,3] effectively summarizes the literature and provides an accurate, brief description of what learner-centered instruction ideally entails:

1. Instructor's actions focus on students learning instead of instructor covering material.
2. Instructors share decision making about learning with students in ethically responsible ways. Students are involved more, and teachers control less.
3. Content is used to build a knowledge base, to develop learning skills, and to foster student self-awareness of their abilities. Teaching approaches accounts for students' learning strategies and prior knowledge.
4. Together, students and teachers create motivating learning environments that encourage students to accept responsibility for their learning.
5. Assessments are implemented to promote learning and to develop self and peer assessment skills, not to evaluate performance primarily.

In a meta-analysis of 119 studies, across grades K-20, Cornelius-White found that learner-centered variables such as incorporation of higher-order thinking, encouraging learning and challenge, non-directive verbal interactions, and adapting to individual and social differences correlate significantly with cognitive and affective outcomes like science achievement, participation, and motivation among others. Relationships among these variables averaged r=0.34, indicating that the influence of learner-centered practices account for about 10% of desired outcomes[4].

Another recent meta-analysis of 225 studies by Freeman et al. demonstrated that active learning (i.e. learner-centered practice) increases performance in science, engineering and mathematics. They found that average examination scores increased by about 6% in active learning courses when compared to traditional lecture courses. Also, students in traditional classes were 1.5 times more likely to fail than in active learning classes. The literature implies that shifting faculty practice towards student-centeredness is a goal worth pursing to increase student outcomes[5].

Middleton et al proposed that faculty learner-centered attitudes and practices put in place a positive feedback cycle of student motivation and success, and this is the model that we will also adopt (see Figure 1 below)[6].

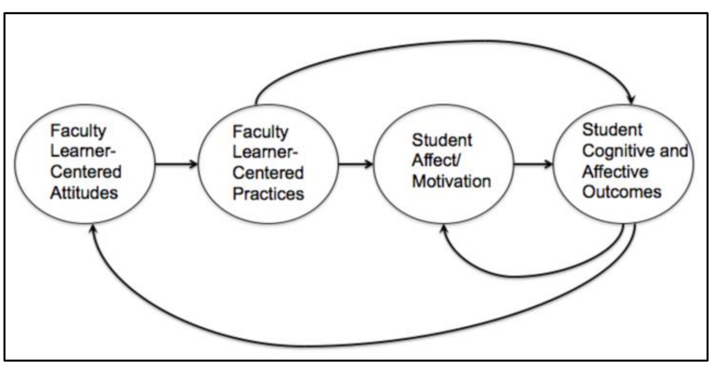

Figure 1. Relationship among faculty attitudes and practices, and student attitudes and outcomes[6]

In the model adopted, it is faculty *practices* that cause potential changes in student motivation and performance. Faculty attitudes help guide their practice, and are reinforced by successful student outcomes, but attitudes are only indirectly responsible for student motivation, persistence, and achievement. Unfortunately, student-centered practices are not used very often by college instructors[7]. Part of the problem is that an instructor may believe they are using student-centered pedagogy but in reality are not. In the aptly titled "What We Say is Not What we Do: Effective Evaluation of Faculty Professional Development Programs" by Diane Ebert-May et al, the group reported that the majority of faculty participants (75%) in a 6-12 day-long workshop series about student-centered strategies still used instructor-centered teaching even though the majority of participants self-reported they were using student-centered learning strategies[8].

In sum, research on faculty attitudes and practices suggest that student-centered practice is the most direct route to improving student motivation and performance. However, engineering faculty do not typically use student-centered practices in their classrooms. Faculty attitudes are important for providing reason and support for change in practice. However, faculty beliefs can be inconsistent with or lag behind visible implementation of student-centered practice. This work addressees the research questions, "What is the relationship between faculty beliefs and practice?" and "What is the relationship between faculty practice and student outcomes?" in order to better understand if faculty beliefs actually relate to visible practice and if faculty practice actually relates to better student achievement.

Methods

This study utilized two data collection methods to gauge faculty beliefs and one tool to gauge the degree of student-centered practice in their classrooms. The two tools to measure faculty beliefs were the Approaches to Teaching Inventory (ATI) survey and a semi-guided interview, and the tool to measure extent of student-centered practice was the Reformed Teaching Observational Protocol (RTOP); all three metrics are described in detail below. 30 different instructors (22 engineering. 4 physics, 2 math, and 2 chemistry) were selected for the study. All instructors teach at a large, southwestern university in the US. Faculty participants were randomly selected from the list of faculty teaching STEM courses for engineering underclassmen and were provided small stipends as compensation for their time.

Each instructor completed a 22 item revised edition of the Approaches to Teaching Inventory (ATI) survey to measure faculty beliefs about their own teaching. Developed by Trigwell and Prosser, the ATI is a valid and reliable self-reporting tool that measures the extent to which faculty teach with an approach toward instructor-centered knowledge transmission vs. student-centered conceptual change. Items on the ATI fall into 4 dimensions:

1. Conceptual Change Intention (CCI) – measures 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 (SCS) – measures the extent to which instructors utilize strategies that focus on student learning (e.g. Teaching in this subject should help students question their own understanding of the subject matter)
3. Information Transmission (IT) – measures the extent to which instructors emphasize 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)
4. Teacher-Focused Strategy (TFS) – measures the extent to which instructors utilize traditional, teacher-centered 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 practices, while the latter two promote teacher-centered classroom practices. Reliabilities on the dimension subscales range from alpha = 0.73 to 0.75. Of course, it is expected that all instructors will incorporate some beliefs from each of the four dimensions to more or less degree in their teaching perspectives[9].

In addition to taking the ATI, each faculty member participated in a one-hour semi-structured interview. The interview consisted of 24 questions focusing on teaching practices, teaching environment, departmental policies, self and departmental evaluations, teaching resources used, course and departmental policies, and departmental and interdepartmental coordination. Interviews were audio-recorded upon permission. Emergent theme (ET) analysis techniques were used to analyze interview responses[10]. Each interview question was coded numerically using the ATI as a basis. A +1 was assigned to each response deemed student-centered (i.e. falling into the categories of CCI or SCS); a -1 was assigned to each response deemed teacher-centered (i.e. falling into the categories of IT or TFS), and a 0 was assigned to each response deemed mixed or neither student nor teacher-centered. The sum of the ET analysis for each instructor was then correlated to the 4 dimensions of the ATI.

Finally, each instructor had their classroom observed three times for a total of 93 classroom observations. Instructors selected which class periods would be observed. The Reformed Teaching Observational Protocol (RTOP) was used after each observation to identify specific teaching practices associated with reformed (i.e. student-centered) teaching. The RTOP is a classroom observational protocol that quantitatively characterizes the extent to which faculty implement student-centered behavior in their classroom practice. It has 25 statements, each ranked on a scale from 0-4, for a maximum score of 100 which corresponds to entirely reformed teaching practice. It has high reliability and validity[11]. The overall RTOP has a reliability of alpha= 0.954. As classroom practice can vary, the RTOP scores for each instructor were averaged. Though the RTOP has subscales, only total RTOP scores will be reported in this paper. Throughout the course of this study, there were two sets of observers. However, there was about a 10 point discrepancy in the average between the observer sets. In order to ensure proper comparison between instructors, and to err on the side of caution, all total RTOP scores were converted to normalized Z-scores for each set. The assumption of normality implicit in the Z-score conversion was justified because of the central limit theorem[12,13].

For measuring student performance, student grades from the course sections observed for each instructor were pulled from an online database DataWarehouse. The ratio of A's and B's to C's, D's, and E's and the ratio of A's, B's, and C's, to D's, E's, and W's (withdraws) was calculated for each instructor in order to control for variance in instructors grade distributions. The two ratios were correlated to total RTOP scores. Certain instructors had to be dropped from this analysis because of missing data.

Results

The ATI data was first checked to see if it was normally distributed. The Shapiro-Wilk W test was used to check for normality. Table 1 below shows the results of the Shapiro-Wilk W test for the four ATI dimensions for all instructors.
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ATI Dimesion	Shapiro-Wilk W Value	Prob<W
Conceptual Change Intention (CCI)	0.90	0.0306*
Student-Focused Strategy (SFS)	0.92	0.0835
Information Transmission (IT)	0.98	0.9436
Teacher-Focused Strategy (TFS)	0.96	0.6209

Table 1. Results of the Shapiro-Wilk W test for the four ATI dimensions. The only dimension that was not normally distributed was CCI.

At the 95% significance level, CCI was not normally distributed because the p value was less than 0.05. Because of the non-normality, Spearman's correlation was applied to all of the data instead of Pearson's correlation which is typically used in social science research. Pearson's correlation is a measure of the linear relationship between two continuous random variables. When the variables are bivariate normal, Pearson's correlation provides a complete description of the association. On the contrary, Spearman's correlation applies to ranks and so provides a measure of a monotonic relationship between two continuous random variables. It is also useful with ordinal data and is robust to outliers (unlike Pearson's correlation) [14,15]. Therefore, the rest of the data was analyzed using Spearman's correlation because of the non-normality. In order to apply Spearman's correlation, the 4 ATI dimension scores, the interview ET sum, and the total RTOP Z-scores for each instructor were ranked from lowest to highest. Table 2 shows the results of Spearman's correlation analysis of the 4 ATI dimension scores to the interview ET sum in order to understand the relationship between the two measures of beliefs for faculty.

Variable	by Variable	Spearman ρ	Prob>|ρ|
Conceptual Change Intention (CCI)	ET TOTAL SCORE	0.0454	0.8117
Student-Focused Strategy (SFS)	ET TOTAL SCORE	0.3279	0.077**
Information Transmission (IT)	ET TOTAL SCORE	-0.4001	0.0285*
Teacher-Focused Strategy (TFS)	ET TOTAL SCORE	-0.1404	0.4595

Table 2. Spearman correlations for each of the four ATI dimensions by interview ET total score. **: 90% confidence level; *: 95% confidence level

From Table 2, one can see student-focused strategy (SFS) and ET total score were positively correlated at the 90% confidence interval (p-value less than 0.1). Also, information transmission (IT) and ET total score were negatively correlated at the 95% significance level (p-value less than 0.05). These results are not surprising because ET data was coded with student-centeredness as positive. One would therefore expect the correlations between SFS and ET total score and CCI with ET total score to be positive and the correlations between IT and ET total score and TFS to be negative, which is what occurred. The trends seen in Table 2 are as expected, with 2 out of 4 of the correlations being statistically significant at the 90% significance level. Overall one can conclude the interview data matches fairly well with the ATI survey data.

The relationships between the teaching practice as measured by total RTOP Z-score and beliefs as measured by the 4 dimensions of the ATI are recorded in Table 3 below.

Variable	**by Variable**	**Spearman ρ**	**Prob>|ρ|**
Total RTOP- Z Score	Conceptual Change Intention (CCI)	-0.0061	0.9754
Total RTOP- Z Score	Student-Focused Strategy (SFS)	0.1681	0.3926
Total RTOP- Z Score	Information Transmission (IT)	-0.293	0.1303
Total RTOP- Z Score	Teacher-Focused Strategy (TFS)	-0.3624	0.0581*

Table 3. Spearman correlations between total RTOP Z-score and each of the 4 ATI dimensions.

Only one of the four ATI dimensions (TFS) was correlated to Total RTOP Z-score at the 90% significance level. One would expect that Total RTOP Z-score, which measures degree of student-centered practice, would be positively correlated to CCI and SFS and negatively correlated to IT and TFS, which is close to what was found – the CCI Spearman rho was the only inconsistent correlation with this hypothesis, and it was of small magnitude. The results from this set of analysis demonstrates that three of the four ATI dimension scores are not correlated to total RTOP score significantly, which is most likely due to discrepancies between faculty beliefs and actual practice. The interview ET data and Total RTOP Z-score were analyzed using Spearman's correlation, but no significant findings were discovered.

Finally, the relationships between student performance and total RTOP Z-score were analyzed. The total RTOP Z-scores of the instructors were ranked and split down the middle into two groups, high and low, based off of their total RTOP Z-score. Figure 2 shows a comparison of the average AB/CDE and ABC/DEW ratios for both the high and low RTOP Z-score instructor groups.

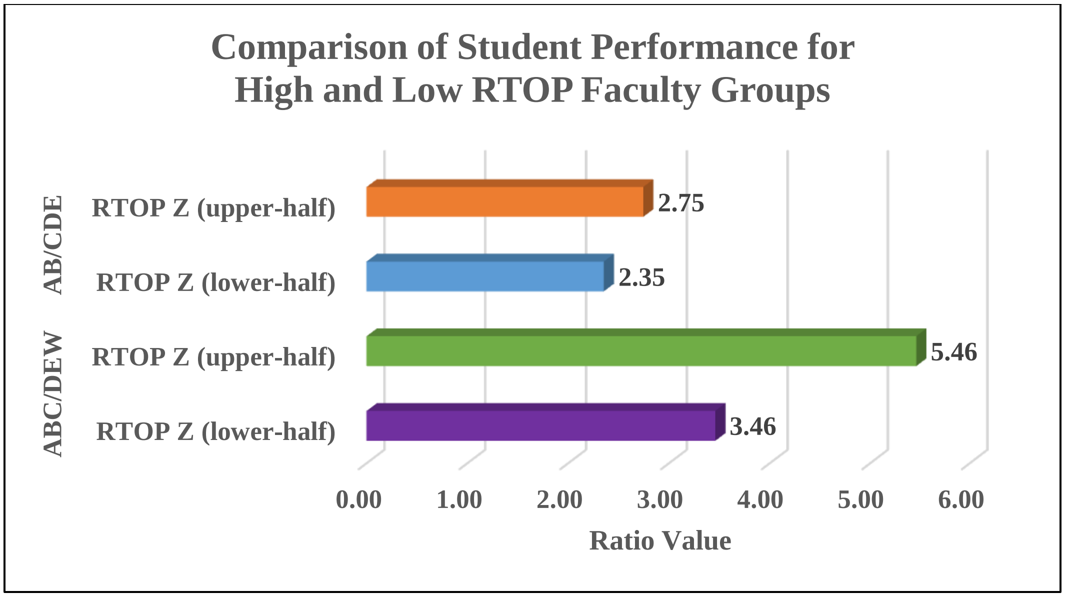

Figure 2. Comparison of average AB/CDE ratios (top two bars) and ABC/DEW ratios (bottom two bars) for high (upper-half) and low (lower-half) RTOP instructor groups.

For outlier detection, the Jack-knife technique was applied to the data. Consequently three points were excluded from the ABC/DEW data, and two points were excluded from the ABC/DE data since their relative distance was far from the data cluster (54% and 40%). Figure 2 demonstrates that the high RTOP group had higher AB/CDE and ABC/DEW ratios than the low RTOP group. This suggests that higher degree of student-centered instruction is correlated to higher student performance. Further summary statistics for the student performance and RTOP analysis is displayed below in Table 4. The low number of data points available for the analyses presented in Figure 1 and Table 4 is the most likely reason for the lack of statistical significance.

	Group	Number of Instructors	Mean	Std Dev	Lower 95%	Upper 95%
ABC/DEW	RTOP Z-score (lower-half)	10	3.5	2.0	2.1	4.9
	RTOP Z-score (upper-half)	8	5.5	3.4	2.6	8.3
AB/CDE	RTOP Z-score (lower-half)	11	2.4	1.8	1.2	3.5
	RTOP Z-score (upper-half)	8	2.7	1.4	1.6	3.9

Table 4. Summary statistics from the comparisons of student performance for the high and low RTOP groups.

One last measure of the relationship between student performance and faculty practice was taken. The average percent of students failing (receiving a D or E grade) was measured for the courses in the low and high RTOP Z-score groups. Figure 3 displays the results from this analysis.

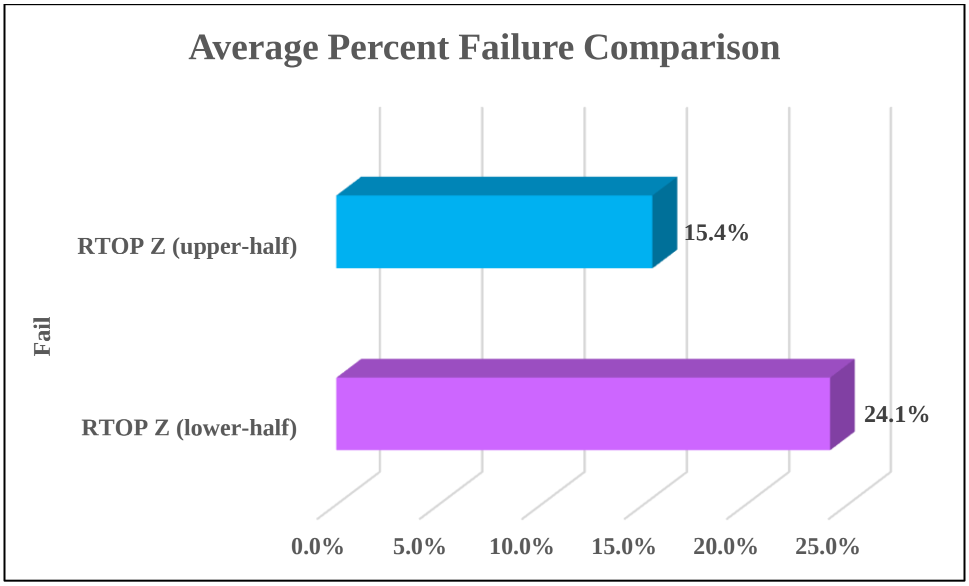

Figure 3. Comparison of average percent of students failing (receiving a D or E grade) for the high RTOP (in blue) and low RTOP (in purple) faculty groups.

The stark difference in average failure rate between the two groups was statistically significant (p value less than 0.05). Figure 3 is further evidence that student-centered instruction leads to better student outcomes.

Discussion

Recall that this work addressees the research questions, "What is the relationship between faculty beliefs and practice?" and "What is the relationship between faculty practice and student outcomes?" The first question concerns the relationships between the beliefs as measured by the ATI and interview ET analysis, and classroom practice as measured by RTOP Z-scores. Table 2 shows the relationship between the four ATI dimensions and the interview ET analysis. The ET and the ATI were correlated in ways that were expected. Total ET score was positively correlated with SFS and CCI and negatively correlated with IT and TFS, which is as expected because the coding scheme used in the ET analysis had student-centeredness as positive. However, only 2 of the 4 correlations between ET analysis and ATI dimensions were statistically significant. There are multiple explanations for this. It is important to note that the interview questions were created without the ATI in mind, and because of this, only a few select questions showed contrast between people. In addition, all faculty members had positive overall interview ET scores, agreeing with Ebert-May's previous work that demonstrates faculty tend to self-report high student-centeredness[8]. In light of these facts, the interview questions used were not congruous to the ATI and also did not show much contrast between participants. The correlations between the ET analysis and ATI dimensions are still important, even with the aforementioned limitations, because they show that faculty beliefs as measured two different ways were similar.

The relationship between faculty beliefs as measured by the ATI dimensions and classroom practice as measured by total RTOP Z-score are displayed in Table 3. Three of the four correlation trends are as expected (i.e. the student-centered ATI dimensions positively correlate with total RTOP Z-score and the teacher-centered ATI dimensions negatively correlate with total RTOP Z-score). The correlation between ATI dimensions CCI and total RTOP Z-score was negative, even though one would expect student-centered beliefs to correlate positively with student-centered classroom practice. Also, none of the correlations between the ET analysis total score and total RTOP Z-score were logical nor were statistically significant (which is why they were not displayed). These two facts combined with the fact that only one of the four ATI dimensions was statistically significantly correlated with RTOP total Z-score suggests that faculty beliefs did not agree with their observed classroom practice. The results presented concerning the lack of congruence between beliefs and practice agree with previous works[8]. Possible reasons for this discrepancy are limitations in implementing student-centered practices from the classroom environment or class size, knowledge gaps in the participants, or just simply the faculty believing incorrectly that they were using student-centered practice when they in reality were not. Many of the participants reported in the interview that they had not received any faculty development opportunities for improving their teaching, so it is likely they may be unaware of student-centered teaching practices. Therefore, providing effective faculty development opportunities is recommended to amend the gap in faculty beliefs and practices.

In addition, the relationships between student performance and faculty classroom practice were examined in Figures 2 and 3 and in Table 4. It is clear that the high RTOP faculty group had better student outcomes than the low RTOP faculty group. Interestingly, the difference between the student outcomes of the faculty groups is more pronounced for the ABC/DEW ratios than for the ABC/DE ratios (see Figure 1). This difference is evidence that faculty practice influences whether a student withdrawals and that student-centered classroom instruction is related to persistence in the course, which is consistent with previous works[4]. However, the small number of faculty in each group is rather low (see Table 4), limiting the strength of the previous claim. Additional participants should be added to the study in the future for more conclusive results.

Finally, Figure 3 shows that faculty with higher RTOP scores had a lower percentage of students failing (receiving a D or E grades) than faculty with lower RTOP scores, and that this finding was statistically significant at the 90% validity level. This indicates that student-centered instruction is related to better student achievement for the participants in our study, which is consistent with the results of Freeman’s meta-analysis that demonstrated active-learning increases student performance[5]. Due to these findings, the overall recommendation is to implement effective faculty development in student-centered instruction at this university because of student-centered practices' relation to positive student outcomes.

Conclusion

In summation, it was discovered that faculty beliefs as measured two different ways (the ATI and the interview) are consistent with each other but are not consistent with observable faculty classroom practice (RTOP Z-score). This study also found that faculty classroom practice is related to student outcomes and that student-centered teaching practices are related to better grades and less course withdrawals. In other words shifting faculty practices towards student-centeredness would likely lead to lower percentages of DEW student grades. Providing effective faculty development opportunities in student-centered instruction is therefore highly recommended in order to mend the gap between faculty beliefs and practice and to promote more positive student outcomes.

Acknowledgement

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