The Nexus of Knowledge Production and Acquisition: Integrating Research and Teaching in STEM Classrooms

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Abstract

The prevailing thought in academia is that faculty cannot be both productive researchers and excellent teachers. Using data from the Higher Education Research Institute's (HERI) 2013-2014 Faculty Survey, the purpose of this study is to examine the relationship between scholarly productivity, student-centered teaching, and discipline-based teaching activities, controlling for select demographic and contextual factors. Structural equation modeling (SEM) was used on a national sample of 4,548 STEM faculty across 262 institutions to simultaneously estimate the relationships among confirmed latent constructs. Findings show that the simple relationship between scholarly productivity and the use of student-centered teaching practices is significantly negative but becomes significantly positive after introducing authentic forms of research in teaching (the nexus of knowledge production and dissemination) as a mediator between scholarly productivity and student-centered teaching. The relationship between scholarly productivity and student-centered teaching also varies across institutional type. This study changes the discourse around teaching and research, which currently seem to be at odds. Institutional leadership and other educational stakeholders will be interested in seeking ways to both increase research outputs and improve teaching quality, both of which encompass the bedrock of higher education.

A great deal of national interest has focused on not only improving STEM teaching in colleges and universities, but also creating the next generation of scientists that meet projected national needs for research excellence (PCAST, 2012). Unfortunately, the prevailing thought in academia is that faculty who are highly productive scholars are not master teachers who use engaged teaching practices. In a work environment wherein promotion and tenure considerations privilege research over teaching, classroom practices that lead to authentic learning experiences for students are often left to the wayside (Lord & Orkwiszewski, 2006). Encouragingly, scholars have suggested that STEM faculty who perceive that they are valued constituents of their respective institutions, provided with incentives to cultivate innovation within the classroom or having their concerns legitimized by administrators, tend to have a greater likelihood of using teaching practices that are student-centered (Zhu & Engels, 2014).

Moreover, there may be a positive association between undergraduate research and effective teaching, with faculty who spend more time engaging undergraduate students in research possibly having the most effective teaching practices (Elsen et al., 2009). Indeed, award-winning science professors contend that a synergy between teaching and research can be achieved wherein it is possible to increase the effectiveness of both at research universities (Anderson, et al., 2011). Findings on this relationship are conflicted, however, with research showing a non-existent relationship between engaged teaching and standard measures of research productivity (Hattie & Marsh, 1996). Conflicting findings may be a result of how researchers conceptualize the connection between research and teaching (Elsen et al., 2009) or may be because previous work separately examined the factors that contributed to student-centered pedagogy and scholarly productivity, which limits the potential to assess the reciprocal relationship between research and teaching. As such, additional research is needed to determine if there are other factors that change the relationship between research productivity and faculty use of student-centered teaching practices.

The purpose of this paper is to empirically investigate faculty behavior in integrating discipline-based research activity into the classroom (via class assignments that are research-oriented and research-based) and to determine if this changes the relationship between scholarly productivity and the use of student-centered teaching practices. Specifically, we investigate the relationships between scholarly productivity, student-centered teaching, and discipline-based research activities, controlling for select demographic and contextual factors. The goal is to determine the extent to which knowledge production can be linked with knowledge dissemination, or the nexus of research and teaching in practice. To this end, this study can capture faculty practice and foster transformation in STEM teaching and learning in interesting ways that have yet to be fully documented, thereby improving STEM degree production. This research may additionally change the nature of the discourse around teaching and research, which currently seem to be at odds when considering the pressures faculty face to show impact for rewards in their work-life. Institutional leadership and other educational stakeholders will be interested in these findings as they seek ways to both increase research excellence and improve teaching quality, both of which encompass the bedrock of higher education.

Conceptual Framework

Traditional frameworks used to conceptualize the relationship between teaching and research are limiting (Mutemeri & Chetty, 2013), as they often frame the relationship as existing within a binary. Fortunately Jones (2013) offers a counter narrative to the dominant discourse about teaching and research by instead focusing on the nexus between the two. Her conceptual framework titled, “Scholarship Teaching Action Research” (STAR), posits that the underlying tension within the discourse around teaching and research is structural, as research and teaching are commonly placed on opposite ends of a continuum. Instead, Jones argues that there is the possibility for a synergy or nexus to exist between the two. Useful to this study, the STAR framework identifies three possible relationships that Jones posits are multi-directional and mutually supportive: 1) research and teaching; 2) scholarship and teaching; and 3) scholarship and research.

The first interactional relationship in the STAR framework is between research and teaching. This relationship refers to research that is integrated within the classroom setting wherein teaching is used as a tool for students to engage in authentic learning opportunities and requires that students use existing disciplinary knowledge to explore new knowledge. Here, students are challenged to apply the discipline-based content learned in class to inform additional discovery research, wherein research is meant to be an “inquiry-based activity” that includes innovation and creativity and adds to new knowledge. Students then teach their peers by disseminating the knowledge they have gained via their research, which allows for further discussion and knowledge construction. The mixture of conducting research and then teaching what one has learned optimizes learning. Thus, Jones (2013) argues that research and teaching co-exist in interdependence rather than in opposition.

The second multi-directional relationship referenced in the STAR framework, which is a less applicable to our study but informative nonetheless, is the interaction between scholarship and teaching. Embedded within this interaction are scholarship-for-teaching and scholarship-from-teaching. Scholarship-for-teaching refers to a methodical study of existing pedagogy of learning. Scholarship-from-teaching requires that students reflect upon the classroom experience in an effort to inform future teaching pedagogy. Indeed faculty ought to cultivate a more scholarship-oriented approach to their teaching so that gaps and links between theory and practice are identified in an iterative process (Couper & Stoakes, 2010).

The third and final multi-directional relationship within STAR is the interaction between scholarship and in-class research activities. Here, teachers create learning opportunities that require students to apply existing knowledge learned from discipline-based scholarship to explore interdisciplinary practices. In this way students can identify problems that they foresee and generate innovative solutions. Any discoveries (i.e. new knowledge) gained from this explorative research exercise is publishable.

As applied to this study, the first and third interactional relationships described above, inform how we conceptualize the nexus between research and teaching. Specifically in this study, it encompasses activities that teach students how to think and act like scientists via assignments that are research-oriented (i.e. have an emphasis on learning how knowledge is produced in the field by practicing research related skills) and research-based (i.e. contains activity in which students actually conduct research/ engage in the processes of inquiry) (Elsen et al., 2009). In other words, these assignments have an emphasis on the research process and problems, even though students are technically participating in research in a restricted manner (Elsen et al., 2009; Healey, 2005). Further, although Jones (2013) makes a firm case for linking research and teaching, the STAR framework has not currently been empirically tested for it utility as a tool to reconcile the age-old separation between engaged teaching and research productivity.

In testing the STAR framework, and in an attempt to yield robust findings, we decided to control for three demographic/context variables: sex, faculty rank, and the number of courses the faculty member was teaching the term the survey was taken. Our justification for choosing to control for faculty sex is due to evidence suggesting that men tend to report higher levels of research productivity than women (Sax et al,. 2002). Indeed, although gender disparities in scholarly productivity are not as distinct at lower productivity levels, visible gender disparities still remain among high-producing faculty (i.e. those who produce five or more publications within a two-year period). Further, this gender gap in research production appears to be most notorious at research-intensive institutions (Sax et al., 2002). We controlled for faculty rank, as it makes intuitive sense that more senior faculty would generally have higher scholarly productivity than junior faculty as a result of having had been in academia longer. Finally, we control for the number of courses the faculty member was teaching the term the survey was taken because faculty who teach several classes are likely have less time to conduct research than faculty teaching fewer classes. This study will be among the first to test the utility of the STAR conceptual framework, paying particular attention to how the relationship between research productivity and student-centered teaching changes after adding the nexus mediating variable and controlling for select variables.

Literature Review

Academia's reward structure places a great emphasis on research publications, which essentially perpetuates the long-standing dichotomy between research and teaching – that is, engaged teachers do not have time to be productive researchers and vice versa (Bozeman & Boardman, 2013; Braxton, 1996; Diamond, 1999). Concerned that this dichotomy is damaging to faculty work-life balance and student learning, scholars have extensively investigated the relationship between research and teaching, which yields mixed findings. Though some research studies suggest a negative relationship (Cage, 1991; Massy & Zemsky, 1994), others have indicated a positive one (Bowen & Schuster, 1986). Even still, other literature suggests that research productivity does not significantly affect the likelihood that an instructor uses student-centered pedagogy and vice versa (Braxton, 1996; Feldman, 1987; Milem, Berger, & Dey, 2000). The subsequent sections discuss the relationship between teaching and research, and integrating discipline-based research activity into the classroom.

Relationship Between Teaching and Research

STEM scholars (Anderson, et al., 2011) and researchers examining the teaching and research behavior of university faculty (Hattie & Marsh, 1996) contend that it is possible to improve teaching excellence at post-secondary institutions, even those that have a primary focus on the production of knowledge (i.e. Research I Institutions). At minimum, there is research that supports a zero relationship between the proportion of time spent on research and teaching effectiveness of faculty working at research extensive universities (Braxton, 1996). More optimistically, at the conclusion of their meta analysis of previous research, Hattie and Marsh (1996) stated that there may well be a happy "marriage between teaching and research" and "the aim is to increase the circumstances in which teaching and research have occasion to meet, and to provide rewards not only for better teaching or for better research but for demonstrations of the integration of teaching and research" (p.533-534). Since the time that seminal piece was published, a handful of institutions and a select few individuals have successfully found synergistic modes of research and teaching.

Further, Elsen et al. (2009) investigated the connection between institutional policy that dealt with the research-teaching nexus, and the practices actually occurring within college courses across a variety of universities, with the intent of exploring effective possibilities for improving the relationship between research and teaching. Findings revealed that students benefited from learning environments where faculty were allowed the flexibility to structure their own classes and to use pedagogy that supported a tight linkage between teaching and research, rather than being forced to operate from a prescribed class structure. Elsen and colleagues (2009) recommended that policy concerning research and teaching include active input from faculty and that efforts be made to effectively disseminate new policy throughout the institution.

Discipline-Based Research Activities in Higher Education Communities

Current trends in education suggest a growing interest in activities that are characterized by a nexus of teaching and research in practice. The Howard Hughes Medical Institute, for example, recently gave funds to more than 70 institutions for the purpose of improving science education by engaging students in authentic research experiences in introductory STEM classes (http://www.hhmi.org/programs/science-education-alliance). The research emerging from these classes have the potential to also result in publications. Doing science in the classroom as science is done, allows for the convergence of research and teaching. Similarly, many institutions across the country are directing increased attention towards discipline-based research of teaching in STEM, using more evidence-based practices (e.g. cooperative learning strategies) and shifting from teaching students *what* scientists know to *how* scientists think (NRC, 2012; 2015).

Indeed, it is essential to develop students' research dispositions in their field as such skills help students prosper in college (Elsen et al., 2009). There is a host of knowledge and skills students ought to acquire upon graduating high school because it helps them be academically successful in college, as identified by David Conley (2005) who interviewed college faculty teaching entry level courses. The "habits of mind" essential of entering freshmen college students, according to Conley, include being able to critically think and problem solve; having an inquisitive nature; being open to possible failures; and being able to cope with frustrating and ambiguous learning tasks. Students also must be able to discern the applicability and credibility of information, draw inferences and reach conclusions independently, and effectively use technology to assist in their learning.

Encouragingly, there are a number of studies that demonstrate the impact research-based approaches to activity within the classroom have on student outcomes. Benefits include improved grades, greater student engagement in the course, and better long-term retention of information (Horta, Dautel, & Veloso, 2012). Inquiry-based teaching is more effective than traditional instruction which is heavily reliant on lecture, as revealed in a controlled study that compared the two methods of instruction in a science laboratory and then assessed student performance within those classes (Lord & Orkwiszewski, 2006). In addition to improved academic performance, being in a class characterized by discipline-based research activities drove other positive outcomes like having more positive perceptions of science compared to peers in traditional science courses (Lord & Orkwiszewski, 2006). Students also reported more positive evaluations of their skills and abilities at the conclusion of taking a course taught with inquiry-based practices (Malcolm, 2014).

A recent study found that the number of publications made, was not a barrier to using research-based instructional strategies (or not), but having a large number of publications was a barrier to high-level use of such instructional practices (Henderson, Dancy, & Niewiadomska-Bugaj, 2012). Other measures of research productivity, such as having external funding for research and the number of research presentations made, were not significantly correlated to the extent of which a faculty member used research-based instructional strategies.

Previous studies have largely failed to investigate this phenomenon on a national level using data from faculty across a large number of institutions and across different campus contexts. This study overcomes that limitation. We hypothesize that more productive research scientists will use discipline-based research practices more frequently in their teaching. We also hypothesize that such practices mediate the relationship between research productivity and student-centered teaching practices. In an effort to address the limitations of the extant literature base and to extend previous work, this study plans to investigate the relationships between use of *student-centered pedagogy*, *research productivity*, and teaching that emphasizes inquiry research (i.e. what we term *research-teaching nexus*), controlling for factors that seem to matter such as faculty rank, number of courses taught, and sex. An additional purpose of this study is to determine whether the model of the relationship between *scholarly productivity* and *student-centered pedagogy* is distinct across institutions of different types (i.e. liberal arts institutions, master's comprehensive institutions, and research institutions).

Methods

Data Source and Sample

Data from this study come from the Higher Education Research Institute's (HERI) 2013-2014 Faculty Survey, which gathers information on the teaching, research, and service practices of faculty, their perceptions of campus and departmental climates, goals related to undergraduate education, and their personal values. HERI employed a stratified institutional sampling scheme for the faculty survey to ensure representation that reflects all nonprofit, postsecondary institutions. Before sampling occurred, four-year colleges and universities identified as part of the national population were divided into 20 stratification groups based on type (four-year college, university), control (public, private nonsectarian, Roman Catholic, other religious), and selectivity in admissions defined as the median SAT Verbal and Math scores (or ACT composite score) of first-time, first-year students. The methodology for the surveys is described in two reports on nationally normed data by institution type, gender, and rank (Hurtado et al., 2012b; DeAngelo et al., 2009).

CIRP invited campuses to participate in the faculty survey and provided them with guidelines for survey administration; the survey instrument was then administered via the internet. In cases, where institutional stratification cells were insufficient for drawing conclusions, CIRP supplemented the sample by identifying faculty at those institutions and sending surveys to augment the sample. Funding from the National Institutes of Health and Howard Hughes Medical Institute allowed for a supplemental sample of STEM faculty to participate in the survey. After filtering out faculty who did not teach STEM courses and faculty who were not tenure-track professors, we had a final analytic sample of 4,548 STEM faculty across 262 institutions.

With respect to the faculty demographics of the STEM faculty sampled, 40.2% were full professors, another 30.5% were associate professors, and 29.3% were assistant professors. Men were more highly represented in the sample (58.1%) than women (41.2%). Further, 5.2% of the faculty identified as coming from underrepresented racial/ethnic background. With respect to discipline, 4.5% were in agriculture or forestry, 22% in the biological sciences, 9.9% in engineering, 22.5% in a health-related field, 12.7% in mathematics or statistics, 21.3% in the physical sciences and 7.2% were in a technical-related field. Notably, of the faculty included in this study, 39.4% were employed at research universities, 33.8% at master's comprehensive universities, and the final 25.4% employed at liberal arts institutions. Finally 40.7% of faculty surveyed were from public universities.

In terms of the 262 institutions that were represented in the survey, a majority were private institutions (67.9%) with the other 32.1% being public. Further, 35.8% of the institutions surveyed were liberal arts institutions, another 44.7% were master's comprehensive universities, and the last 19.5% were research universities. Although institutions ranged in size from as little as 396 students to many as 53 thousand, the average size – as measured by the full-time student equivalent for fall enrollment − was 7,129 students.

Measures

Primary dependent variable. The outcome variable of interest in this study is *research-teaching nexus*. For the purposes of this study, it is a five-item latent factor comprised of STEM faculty responses to the question, "how frequently in the courses you taught in the past year have you given at least one assignment that required students to..." The five items included in this factor include: "engage deeply with a significant challenge or question within your discipline," "use research methods from your discipline in field or applied settings," "apply learning from both academic and field settings," "describe how different perspectives would affect the interpretation of a question or issue in your discipline," and "weigh the meaning and significance of evidence." Participants could choose one of three response options for each item: "not at all," "occasionally," or "frequently." A higher score on research-teaching nexus therefore indicated that the faculty member more frequently used research discipline-based assignments as a teaching tool in their classes.

Hypothesized endogenous variables. Excluding the primary dependent latent variable, there were two additional hypothesized latent constructs: *scholarly productivity* and the other being a measure of *student-centered pedagogy*. *Scholarly productivity* is indicated by three items (i.e. number of published articles in academic and professional journals, number of published chapters in edited volumes, and number of professional writings published or accepted for publication in the last two years). A higher score on *scholarly productivity* therefore indicated that the faculty member was more productive in terms of research outputs. In examining the extent to which faculty utilized student-centered pedagogical practices within their classrooms, faculty indicated the proportion of courses they taught that they used each of the following practices: class discussions; cooperative learning (small groups); experiential learning/field studies; group projects; student-selected topics for course content; reflective writing/journaling; student inquiry to drive learning; real-life problems; and performances/demonstrations. Faculty had the option of selecting “none,” “some,” “most,” or “all” as responses to each item. Thus a higher score on *student-centered pedagogy* therefore indicated that the faculty member used these instructional methods in a greater number of their classes.

Hypothesized exogenous variables. The remaining three variables are related to demographic and situational influences that likely matter in the frequency with which a faculty member uses research-based assignments as a teaching tool in their classes (i.e. *research-teaching nexus*): sex; faculty rank; and the number of courses the faculty member taught during the term he or she took the survey. See Appendix A for the entire list of variables included in the study and their corresponding coding scales.

Missing Data

By default, Mplus uses full information maximum likelihood estimation (FIML) for datasets with missing data, which uses the raw data as input and hence can use all the available information in the data for substituting estimates for missing values. Under ignorable missing data conditions (missing completely at random and missing at random), FIML parameter estimates and standard errors are unbiased and more efficient than listwise deletion, pairwise deletion, and similar response pattern imputation (Enders & Bandalos, 2001). Further, FIML yields the lowest proportion of convergence failures and decreases Type 1 error rates.

Analyses

Structural equation modeling (SEM) was used to simultaneously estimate the relationships among our confirmed latent constructs and the three variables we wanted to control for, which helped account for measurement error (Bentler, 2005; Bentler & Wu, 2002). SEM was useful in that it provided coefficients that estimated the statistical significance and magnitude of the relationships between our theoretical constructs (i.e., *research-teaching nexus*, *scholarly productivity*, and *student-centered pedagogy*). Mplus 7.4 was the primary statistical software package used to test the validity of the hypothesized models and illustrates via both numerical output and picture diagrams the interrelationships between the exogenous variables and endogenous constructs.

Building the final hypothesized SEM model occurred in a series of steps. First, we ran descriptive statistics and tested for the non-normality of the data. Descriptive statistics for the variables included in the analysis are located in Appendix B. Correlations among all the variables can be found in Appendix C. With respect to kurtosis of the data, the more a value deviates from zero, the more of a concern it is because it impacts tests of variances and covariances, which is what structural equation modeling essentially uses (DeCarlo, 1997). Descriptives demonstrated that the highest kurtosis value for any variable was 1.718. Although there is no clear consensus regarding how far a kurtosis value must deviate from zero before it can be regarded as problematic, some say possible departure points of non-normality start at plus or minus 2.0 (Boomsma & Hoogland, 2001; Muthén & Kaplan, 1985); others state plus or minus 7.0 (West et al., 1995) as a standard. We therefore proceeded to use FIML as the estimator during analysis because the data were within the range of multivariate normality.

Second, we tested for the validity of the three latent constructs using confirmatory factor analysis in MPlus. As mentioned above, the measurement models included the observed indicator variables and their associated underlying latent constructs, accounting for measurement error. It was necessary to know that the indicators adequately loaded onto their corresponding latent constructs before we could have confidence in the findings related to the assessment of the hypothesized SEM model. For each of these constructs, we constrained the variance for the factor at one, leaving the paths for the items comprising the factor free to vary. For all three factors, we hypothesized that indicators would loading strongly (at least above a .45 loading) for the factor it was designed to measure, and this was the case. Appendix D shows the standardized factor loadings and R^2's of the observed indicator variables on their respective underlying latent factors across the entire sample.

Third, we created a structural model beginning with correlation model between *scholarly productivity* and *student-centered pedagogy* to determine the baseline relationship between the two constructs and later added the controls. Next, we developed the structural model with the hypothesized paths (without the controls) to determine the relationships between the three latent constructs and to determine if *research-teaching nexus* changed the relationship between *scholarly productivity* and *student-centered teaching*. The final SEM model included the three latent constructs and the three control variables.

We used goodness-of -fit indices to determine the adequacy of the SEM models (Laird, Engberg, & Hurtado, 2005). Prior research and theory, along with the modification indices identified possibly misfitting parameters in the model and suggested the deletion or addition of causal paths to improve model fit. Several fit indices were used to assess model fit during confirmatory factor analysis and structural equation modeling, which included the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). Based on minimum thresholds, a CFI value above .90 indicates adequate model fit, while RMSEA and SRMR scores below .06 indicate an appropriate level of fit (Raykov, Tomer, & Nesselroade, 1991). Models considered to be extremely well fitting have CFI scores above .95 (Hu & Bentler, 1999). We didn't rely on the chi-square test statistic as a measure of wellness-of-fit because the chi-square likelihood ratio test is sensitive to sample size (Byrne, 2012), and we had a fairly large sample with several thousand cases. We used the chi-square tests, however, when conducting chi-square difference tests to determine significant improvement of model fit.

We followed Byrne's (2012) sequence of steps for determining whether or not components of the measurement and structural models were invariant (i.e., equivalent) across faculty employed at different institutions (liberal arts, master's comprehensive, and research institutions). In particular we were interested in determining whether the covariance between *scholarly productivity* and *student-centered pedagogy* in our specified SEM model containing controls was equivalent across faculty teaching at different institutional types.

Testing for factorial equivalence encompasses a series of steps that build upon one another and that begins with the determination of a separate baseline model for each group. To do so, we started with the final SEM model containing controls (that was created using the entire sample) and made adjustments for each of the three faculty groups based on model fit and statistical modification indices coupled with theoretical justification. Equality constraints were then tested simultaneously across the three groups. In this process, factor reliability and loadings are calculated for each groups, whereas fit indices are calculated only for the overall model using the entire sample. In testing for invariance, the first step is to test for configural invariance to examine the basic factor structure. Next, measurement invariance examined the equality of factor loadings and measurement error variances and covariances. Partial measurement invariance was tested when full invariance was not confirmed across groups by releasing constraints between errors and between factors and variables (Byrne, 2012). In each of the substeps, fit indices and statistical modification guided theoretically sound model modification. The final model for partial measurement invariance was confirmed by calculating the change in the chi-square for FIML between the previous and final models and confirming the change was not significant. Since group differences in the latent means were of no particular interest in this study, tests for invariant intercepts were not conducted.

Limitations.

This study is limited by the use of secondary data, meaning it is restricted to the questions and measures of the existing data set, which was not designed from a STAR framework perspective. Thus relationships that we expected to find between latent constructs and with endogenous variables and the strength of those relationships may not be as robust as we would have liked. Another limitation is that although data collection on faculty was focused on undergraduate teaching faculty, we have observed over the years that the most vulnerable populations may not respond to surveys and others neglect to provide identifying information (rank, race/ethnicity or department). Thus although we hope we are capturing relationships from a nationally representative sample of STEM faculty, we may be underestimating relationships for individuals who do not want to risk being identified by their own institution. Further we typically use weights to represent the national population of men and women faculty for all HERI reports; we did not weigh the responses in this study because the exact numbers within STEM fields were not available in IPEDS. In the future, NSF data could be instrumental in helping to weigh responses obtained using HERI surveys.

Findings

Model Estimation and Assessment of Fit

Our analysis focused on the relationships between a set of three latent variables: *research-teaching nexus*, *scholarly productivity*, and *student-centered teaching practices.* When conducting the confirmatory factor analyses, the residuals associated with each indicator variable were initially constrained to zero. However, a review of the modification indices for the baseline models for *research-teaching nexus* and *student-centered pedagogy* revealed some evidence of model misfit. Indeed for both latent constructs, there was some overlap of item content within the subscales. We decided therefore to re-specify the models for these two factors allowing the residuals of some items to correlate (per the suggestion of the modification indices) to account for the item overlap. Residuals of indicator items were allowed to correlate one-at-a-time, and the model was re-ran after each modification. This was done in an iterative process until model fit reached optimum levels for both latent constructs

Overall, the confirmatory factor analysis showed that the hypothesized measurement models fit the data well. In terms of the *research-teaching nexus* factor model, the chi-square statistic was 30.676 (df= 6, N = 4,464, p = 0.000), and the fit indices were CFI = 0.997, RMSEA = 0.030, and SRMR=0.010. The *student-centered teaching practices* factor model had a chi-square statistic of 269.908 (df= 28, N = 4,490, p = 0.000), and the fit indices were CFI = 0.980, RMSEA = 0.044, and SRMR = 0.022. Since *scholarly productivity* was comprised of only three indicators, it was just-identified and could not be tested, because it would always perfectly reproduce the data (Mulaik, 2009, p. 144).

The third step involved determining the baseline relationship between *scholarly productivity* and *student-centered teaching practices*. See Table 1 for a summary of model fit and χ^2 difference test statistics for the correlation model between these two constructs. After adding several residual co-

Table 1.

Correlation Model with No Controls: Research-Teaching Nexus and Scholarly Productivity

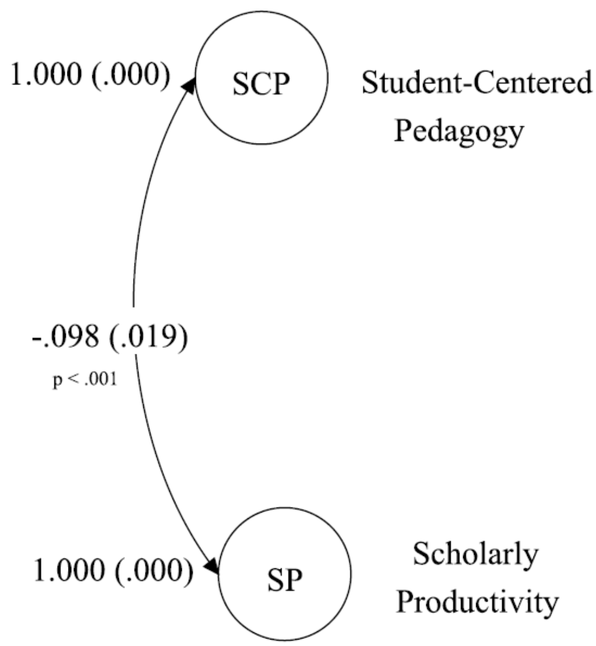
Summary of Model Fit and χ^2 Difference Test Statistic

Model	Post Hoc Residual Co-Variances Added to the Model	χ^2	df	CFI	RMSEA	SRMR	Model Comparison	$\Delta \chi^2$
1		2116.10	64.00	0.875	0.084	0.052		
2	Group projects ***WITH*** Cooperative learning (small groups)	1581.97	63.00	0.908	0.073	0.047	Model 2 compared to Model 1	534.14
3	Student presentations ***WITH*** Group projects	1301.84	62.00	0.925	0.066	0.045	Model 3 compared to Model 2	280.13
4	Using student inquiry to drive learning ***WITH*** Using real-life problems	1070.52	61.00	0.939	0.060	0.042	Model 4 compared to Model 3	231.32
5	Performances/Demonstrations ***WITH*** Experiential learning/Field studies	928.51	60.00	0.056	0.947	0.040	Model 5 compared to Model 4	142.02
6	Cooperative learning (small groups) ***WITH*** Class Discussions	829.31	59.00	0.054	0.953	0.039	Model 6 compared to Model 5	99.19
7	Student presentations ***WITH*** Student-selected topics for course content	763.86	58.00	0.957	0.052	0.039	Model 7 compared to Model 6	65.45
8	Using student inquiry to drive learning ***WITH*** Student-selected topics for course content	702.72	57.00	0.961	0.050	0.038	Model 8 compared to Model 7	61.14
9	Reflective writing/journaling ***WITH*** Student-selected topics for course content	658.04	56.00	0.963	0.049	0.037	Model 9 compared to Model 8	44.68
10 (final model)	Student presentations ***WITH*** Cooperative learning (small groups)	622.68	55.00	0.966	0.480	0.037	Model 10 compared to Model 9	35.37

Note: n=4,548 STEM faculty across 262 institutions.

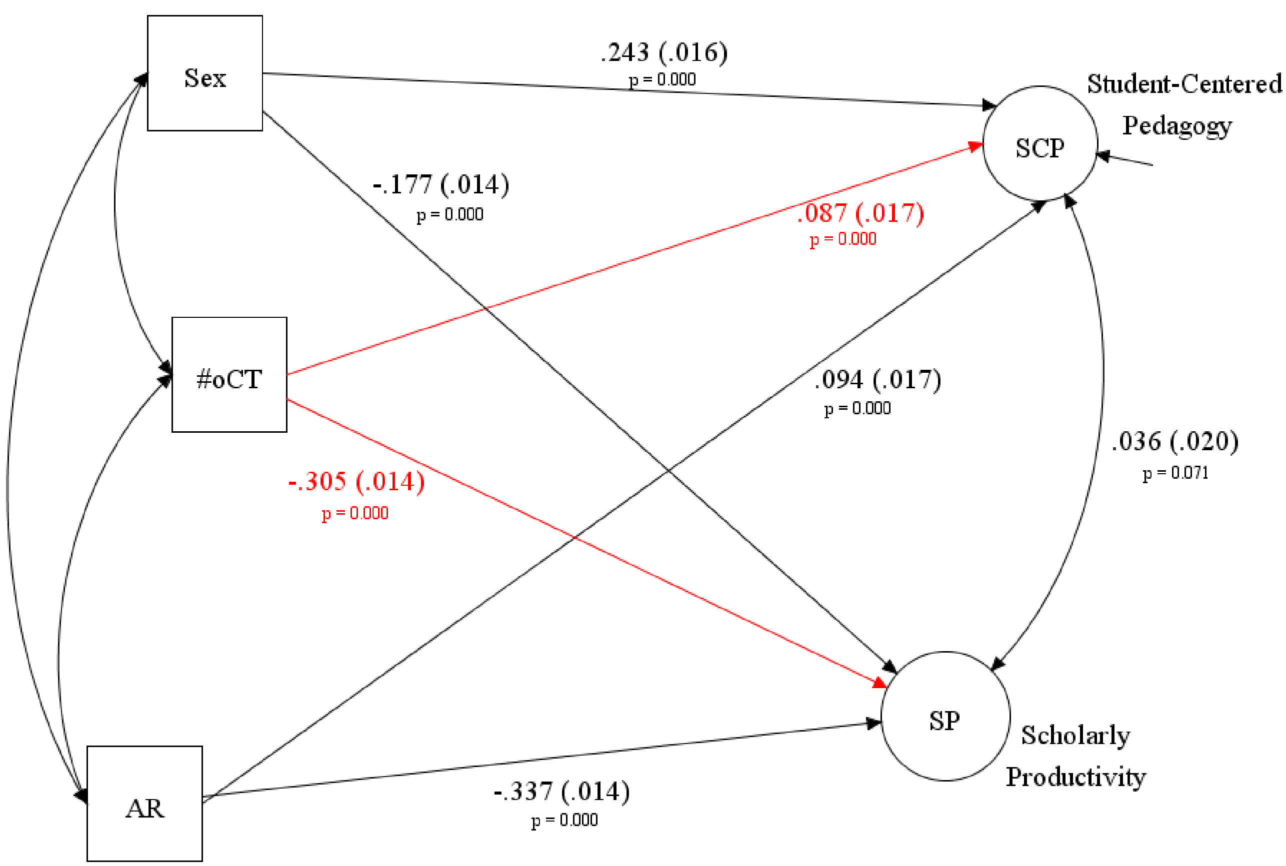
variances to the model per the modification indices, the final correlational model had a chi-square statistic of 622.675 (*df*= 55, *N* = 4,548, *p* = 0.000), and the fit indices were CFI = 0.966, RMSEA = 0.048, and SRMR = 0.037. Findings show that the covariance value between the two latent constructs was negative (β = -.098, SE=.019, p < .001). See Figure 1 for a diagram showing the correlation model. In other words, without controlling for other faculty characteristics, there is a negative relationship between *scholarly productivity* and use of *student-centered pedagogy* – the more publications faculty completed in the last two years, the less likely they are to use student-centered teaching practices in the classroom.

Figure 1. Correlation Model with No Controls



Before determining the mediating effect of *research-teaching nexus* to the relationship between *student-centered pedagogy* and *scholarly productivity* (which will be discerned in subsequent models), we added the three exogenous variables we wished to ultimately control for to this correlational model to understand how the introduction of controls tempered the relationships between the use of *student centered-pedagogy* and *scholarly productivity*. Goodness-of-fit statistics related to this model were $\chi^2_{(89)}$ = 1039.355, CFI = 0.948, RMSEA = 0.049, and SRMR = 0.037. The addition of controls – sex, faculty rank, and number of courses taught at the time the survey was taken – changed the covariance value between the two latent construct from negative (β = -.098) to positive (β =.036, SE=.020, p = 0.071), but the positive estimate was *not* significant. See Figure 2 for a diagram showing the correlation model with controls. Controlling for sex, faculty rank, and number of courses taught at the time the survey was taken, there is a zero relationship between *scholarly productivity* and use of *student-centered pedagogy*. In other words, the number of publications faculty members have has no effect on the likelihood that faculty use student-centered teaching practices in their classes and vice versa, which is a finding similar to that concluded by Hattie and Marsh (1996).

Figure 2. Correlation Model with Controls

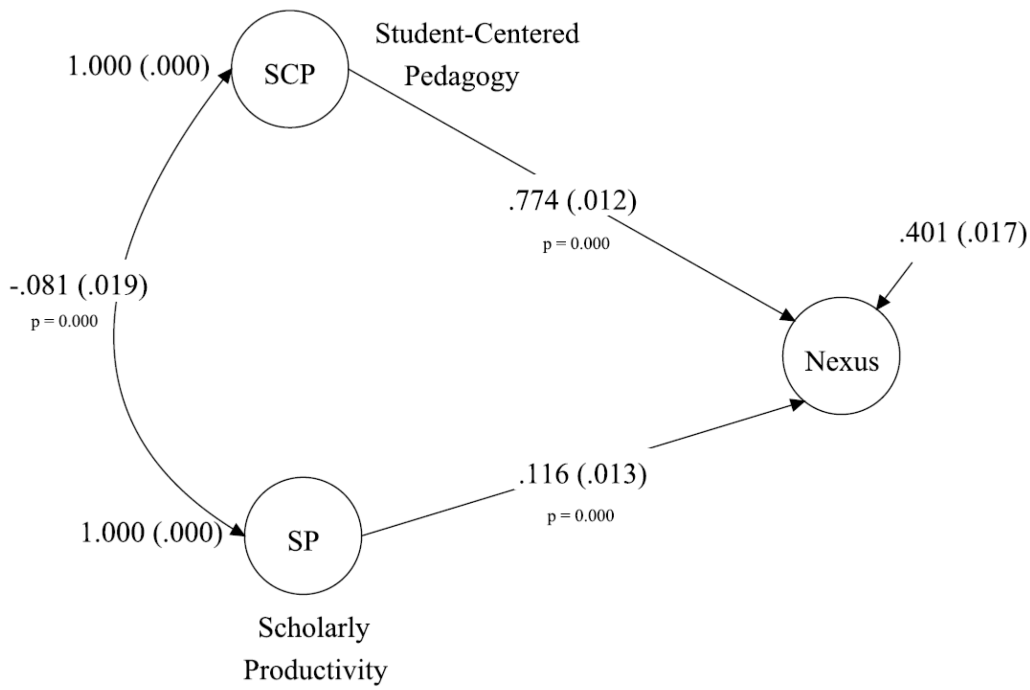


The fourth step involved putting the three latent constructs into a model (without the controls) to see if *research-teaching nexus* changes the relationship between *scholarly productivity* and *student-centered teaching practices*. For this model we hypothesized that faculty who more often use *student-centered pedagogy*, would be more likely to utilize *research-teaching nexus* in their classes, so we allowed a path going from *student-centered pedagogy* pointing toward *research-teaching nexus*. Similarly, we hypothesized that those who are more productive when it comes to scholarly output, are more likely to infuse activities that involve research in class assignments as a mode of teaching, so we allowed a path going from *scholarly productivity* pointing toward *research-teaching nexus*. Since the directional relationship between *scholarly productivity* and *student-centered pedagogy* remains unclear, we allowed this relationship to covary and did not specify a specific directional path.

After running the baseline SEM model, the fit indices revealed poor model fit and post-hoc modifications suggested a need for several correlations between residuals of indicator variables across constructs. For example, in looking at the modification indices (MI), the residual covariances related to the items "experiential learning/field studies" and "apply learning from both academic and field settings" suggested overlap. After making the appropriate change, we ran the newly specified model and reviewed the fit indices and modification indices. These steps were done in an iterative process, with changes made one at a time. Our knowledge of theory and empirical research on this topic was used to determine if suggested changes of parameters were substantively meaningful. Refer to Table 2 of a step-by-step process of respecifying the SEM model containing no control variables. Notably, the addition of two cross-loadings of indicators items was deemed necessary: 1) giving an assignment that required students to use research methods from one's discipline in an applied setting was also associated with the factor for *student-centered pedagogy*; and 2) using cooperative learning in class was also associated with *research-teaching nexus*. The first connection indicates that the introduction of disciplinary methods in the classroom is associated with more active learning practices; the second connection indicates that using research in teaching may also involve cooperative learning practices that demonstrate how science is actually conducted.

After refitting the model and making appropriate changes, the final SEM model containing no control variables (i.e. Model 15 in Table 2) revealed adequate fit: the chi-square statistic was 1,087.715 (df= 126 N = 4,548, $p < 0.000$), and the fit indices were CFI = 0.964, RMSEA = 0.041, and SRMR = 0.033. Further, not controlling for any other factors, the relationship between student-centered teaching practices and scholarly productivity was still negative (β = -0.081, S.E. = 0.019 p = 0.000) and significant. See Figure 3 for the estimates of causal paths, covariances, and significance values of those estimates from this model.

Figure 3. SEM for Research-Teaching Nexus: No Control Variables Added



Results with Respect to the Control Variables

Finally in the fifth step of model building, we added the three exogenous variables – sex, faculty rank, and number of courses being taught the term the survey was taken – to the SEM model to determine if the introduction of controls better tempered the relationships between use of *student centered-pedagogy*, *research-teaching nexus*, and *scholarly productivity* as it did in the correlation model depicted in Figure 2. The chi-square statistic for the final SEM model containing controls was 1,612.284 (*df* = 174, N = 4,485, $p < 0.000$), and the fit indices were CFI = 0.95, RMSEA = 0.043, and SRMR=0.035, indicating a well-fit model.

Of particular interest were the relationships between the three latent factors in the SEM model

Table 2.

SEM for Research-Teaching Nexus - No Control Variables Added

Summary of Model Fit and χ² Difference Test Statistic

Model	Post Hoc Residual Co-Variances Added to the Model	χ^2	df	CFI	RMSEA	SRMR	$\Delta\chi^2$
1	Final Correlation Model + Nexus Mediating Factor	2263.56	140.00	0.921	0.058	0.043	
2	Experiential learning/Field studies ***WITH*** Apply learning from both academic and field settings	2020.15	139.00	0.930	0.055	0.041	243.41
3	Describe how different perspectives would affect the interpretation of a question or issue in your discipline ***WITH*** Apply learning from both academic and field settings	1836.42	138.00	0.937	0.052	0.041	183.73
4	Describe how different perspectives would affect the interpretation of a question or issue in your discipline ***WITH*** Use research methods from your discipline in field or applied settings	1713.70	137.00	0.942	0.050	0.041	122.72
5	Using real-life problems ***WITH*** Apply learning from both academic and field settings	1604.74	136.00	0.946	0.049	0.040	108.97
6	Use research methods from your discipline in field or applied settings ***WITH*** Write in the specific style or format of your discipline	1547.35	135.00	0.948	0.048	0.039	57.39
7	Performances/Demonstrations ***WITH*** Apply learning from both academic and field settings	1502.64	134.00	0.949	0.047	0.038	44.71
8	Reflective writing/journaling ***WITH*** Describe how different perspectives would affect the interpretation of a question or issue in your discipline	1462.87	133.00	0.951	0.047	0.038	39.77
9	Experiential learning/Field studies ***WITH*** Use research methods from your discipline in field or applied settings	1426.35	132.00	0.952	0.046	0.038	36.51
10	Reflective writing/journaling ***WITH*** Apply learning from both academic and field settings	1333.28	131.00	0.955	0.045	0.037	93.08
11	Student Centered Pedagogy ***BY*** Use research methods from your discipline in field or applied settings	1243.81	130.00	0.959	0.043	0.035	89.47
12	NEXUS ***BY*** Cooperative learning (small groups)	1207.85	129.00	0.960	0.043	0.035	35.96
13	Weigh the meaning and significance of evidence ***WITH*** Write in the specific style or format of your discipline	1170.68	128.00	0.961	0.042	0.034	37.17
14	Write in the specific style or format of your discipline ***WITH*** Engage deeply with a significant challenge or question within your discipline	1124.35	127.00	0.963	0.042	0.034	46.33
15	Reflective writing/journaling ***WITH*** Experiential learning/Field studies	1087.72	126.00	0.964	0.041	0.033	36.64

Note: n=4,548 STEM faculty across 262 institutions; Modifications ceased at Model 15 containing controls. (Figure 4 diagrams the causal paths of this final model and Table 3 contains the standardized and unstandardized estimates of these paths.) As hypothesized, both *scholarly productivity* (β = 0.163, S.E. =0.017, p =.000) and *student-centered pedagogy* (β = 0.754, S.E.= 0.013, p =.000) were significant positive predictors of faculty's subsequent use of *research-teaching nexus* practices in class assignments. Further, there was a significant relationship between *scholarly productivity* and the utilization of *student-centered pedagogy*. Most importantly, the relationship went from being significantly negative in the correlation model (Figure 1) (β = -.094) to significantly positive (β = 0.054, S.E. = 0.020, p = 0.007) in the SEM model (Figure 4) that included controls and wherein *research-teaching nexus* mediated the relationship between *scholarly productivity* and *student-centered teaching*. These results lend some empirical support to the STAR theory under certain conditions, and help understand previous results on faculty productivity and teaching practices.

With respect to the direct effects for the final SEM model containing the three control variables, there are a number of interesting findings. Table 3 shows the unstandardized and standardized coefficients and significance values for variables that we controlled for in this model. Two of the three exogenous variables had a significant relationship with the factor *research-teaching nexus*. First, teaching a higher number of courses during an academic term is positively and significantly related to r*esearch-teaching nexus* practices (β = 0.116, S.E.=.014, p = 0.000). In layman's terms, faculty more frequently integrate inquiry-based research activities within the scope of the classroom setting when they spent more hours in the classroom. This relationship is likely indicative of the great value of having more hours dedicated to the practice of teaching — indeed teaching may very well be an art form, with inquiry-based teaching being a skill that evolves and that is refined via practice. The sex of faculty also matters, with women more frequently using assignments that infuse *research-teaching nexus* practices than their male counterparts (β = .049, S.E. = .013, $p < 0.001$). Interestingly, the findings suggest no significant differences between a faculty member's rank and their use of *research-teaching nexus* in the classroom (β = -.016, S.E. = .014, p =.249); in other words, junior faculty (i.e. assistant professors) use *research-teaching nexus* practices as much as senior faculty (i.e. associate professors and full professors).

Figure 4. SEM for Research-Teaching Nexus: Control Variables Added

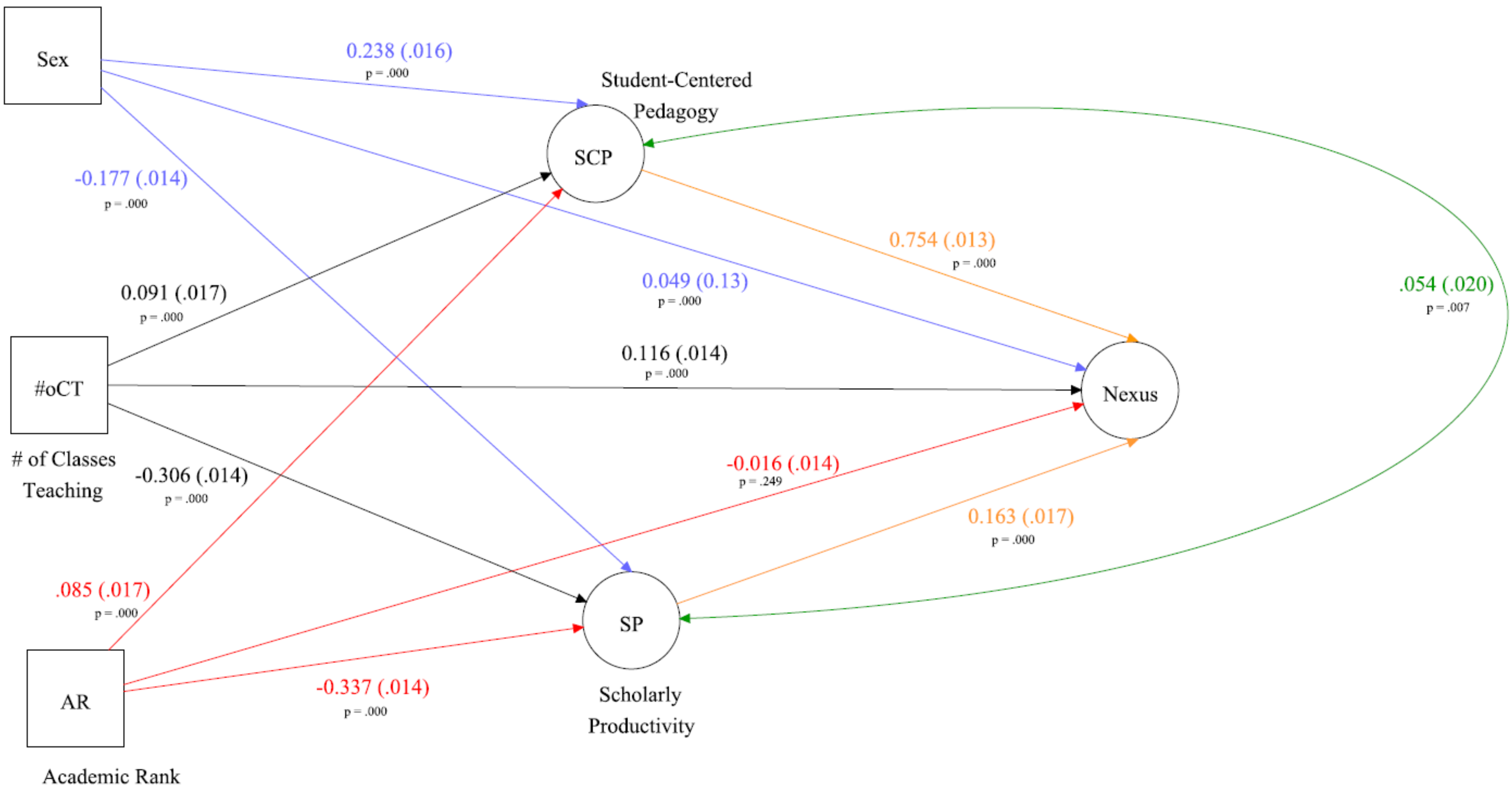


Table 3.

SEM for Research-Teaching Nexus - Control Variables Added

Parameter Estimates for Direct Effects & Covariance

	b	β	Sig.	S.E.
Teaching-Research Nexus				
Student-Centered Pedagogy	1.155	0.754	***	0.013
Scholarly Productivity	0.219	0.163	***	0.017
Sex of Faculty	0.160	0.049	***	0.013
Number of courses teaching the term survey was taken at all institutions in which the individual teaches (e.g., 0, 1, 2, 3)	0.128	0.116	***	0.014
Academic Rank (Higher number indicating more junior faculty)	-0.030	-0.016	n.s.	0.014
Scholarly Productivity				
Sex of Faculty	-0.429	-0.177	***	0.014
Number of courses teaching the term survey was taken at all institutions in which the individual teaches (e.g., 0, 1, 2, 3)	-0.252	-0.306	***	0.014
Academic Rank (Higher number indicating more junior faculty)	-0.487	-0.337	***	0.014
Student-Centered Pedagogy				
Sex of Faculty	0.505	0.238	***	0.016
Number of courses teaching the term survey was taken at all institutions in which the individual teaches (e.g., 0, 1, 2, 3)	0.066	0.091	***	0.017
Academic Rank (Higher number indicating more junior faculty)	0.108	0.085	***	0.017
Covariance: Scholarly Productivity & Student-Centered Pedagogy	0.054	0.054	**	0.020

Note: n=4,548 STEM faculty across 262 institutions.; χ^2=1612.284 df=174; CFI=.95; RMSEA=.043 SRMR=.035

**p<.01 ***p<.001

With respect to the latent factor measuring the use of student-centered teaching practices, findings show that more junior faculty have a higher propensity of adopting practices in their classes that are known to engage students in the learning process (β = .085, S.E. = .017, $p < 0.001$). Likewise, the number of courses faculty teach during a term positively and significantly predicts the use of *student-centered pedagogy* in the classroom (β = .091, S.E. = .017, $p < 0.001$). In other words, the more courses a faculty teaches over the course of a term, the more they infuse *student-centered pedagogy* in their classes as they teach. Finally, female faculty more frequently use *student-centered pedagogy* in their classes than their male counterparts (β = .238, S.E. = .016, $p < 0.001$).

With respect to *scholarly productivity*, the three exogenous are all significant negative predictors, with the strongest predictor being academic rank (β = -.337, S.E. = .014, $p < 0.001$). This finding suggests that more senior faculty (i.e. full professors) have a greater tendency to be drivers of *scholarly productivity*. It makes sense that full professors would have produced more scholarship than assistant professors, because full professors would have likely been in academia longer and assembled research teams to be highly productive. Echoing other research (Fairweather & Beach, 2002), the model shows that the number of courses taught during a given term negatively impacts *scholarly productivel*y (β = -.306, S.E. = .014, $p < 0.001$). Indeed, time and energy exerted towards carrying a heavier course load, must affect the time and energy available to conduct research. Confirming previous studies (Sax et al,. 2002), women tend to have lower levels of *scholarly productivity* than men (β = -.177, S.E. = .014, $p < 0.001$) in the last two years.

Invariance Testing to Determine Equivalency of Factorial Structure across Institution Types

One of the goals of this study is to determine whether the relationship between *scholarly productivity* and *student-centered teaching* varies across institutional type. To determine this, we conducted invariance testing using a series of nested models; the steps we took to conduct the invariance testing is discussed next.

Establishing baseline models across the faculty at three institutional types. The initial SEM model containing control variables was created using the entire sample of faculty. This model was next tested separately across three groups of faculty (those at liberal arts institutions, those at master's comprehensive institutions, and those at research institutions) to establish baseline models for each faculty group. With respect to the model for faculty at liberal arts institutions, the initial fit indices revealed that the model could be improved. The modification indices helped identify where improvements could be made. Changes were made one at a time so that model fit could be determined after each parameter modification.

Overall, the model for liberal arts institutions differed in three ways from the initial SEM model that was established using the entire sample: First and second, the liberal arts model was re-specified so that the residual associated with "using student inquiry to drive learning" and "cooperative learning (small groups)" was allowed to covary as was the residual associated with "using student inquiry to drive learning" and "class discussions." Third, it was necessary to cross-load the indicator item "reflective writing/journaling" onto the factor *research-teaching nexus*. The justification for this is based on the theoretical importance ascribed to reflection of one's learning experiences for the development of further knowledge (Carr & Kemmis, 1986). Indeed engaging in reflection as part of the learning and research processes is also highlighted in the STAR framework because it is necessary when contemplating the multi-directional relationships between scholarship, teaching, and research (Jones, 2013). The final model for faculty at liberal arts institutions was strong: the chi-square statistic was 524.722 (df= 171, N = 1,231, p = 0.000), and the fit indices were CFI = 0.949, RMSEA = 0.041, and SRMR=0.038. We decided not to continue to modify this model (even though the CFI did not quite reach the .95 value we were striving towards) because balancing model fit and model parsimony required that we choose a model that fit the data well but also had minimal parameter specification (Bryne, 2012).

With respect to the model for faculty at master's comprehensive institutions, the initial fit indices revealed that this model could also be improved. Again modification indices helped identify where improvements could be made. Changes were made one at a time so that model fit could be determined after each change. In all, the model for master's comprehensive institutions is different from the initial SEM model based on the entire faculty sample in two ways: First, the model was re-specified so that the residual associated with "student presentations" and "reflective writing/journaling" was allowed to correlate. Second, it was necessary to cross-load the indicator item "weigh the meaning and significance of evidence" onto the factor *student-centered pedagogy*. This cross-loading was deemed acceptable considering the fact that exercises that engage students in analysis, processing information, applying knowledge, and making meaning of what they have learned is by definition what student-centered pedagogy does (Asch, 1951; McKeachie, 1954;). The final model for faculty at liberal arts institutions was adequate: the chi-square statistic was 604.873 ($df = 172$, N =1,333, p = 0.000), and the fit indices were CFI = 0.942, RMSEA = 0.043, and SRMR = 0.041.

Finally, with respect to the model for faculty at research institutions, no departures from the original SEM model containing controls were made because the fit indices revealed good model fit: the chi-square statistic was 754.752 ($df=174$, N =1,857, p = 0.000), and the fit indices were CFI = 0.953, RMSEA = 0.042, and SRMR = 0.037. This indicates that the original hypothesized model fit the faculty behaviors in a research university context, and slight differences in practices could be identified in other institution types.

Because the estimation of baseline models involved no between-group constraints, the data was analyzed separately for each group. However, in testing for invariance, equality constraints had to be imposed on particular parameters making it necessary for the data for all groups to be analyzed simultaneously to obtain efficient estimates (Bentler, 2005; Jöreskog & Sörbom, 1996). The model under test in this multigroup application is the same postulated three-factor structure in the SEM model containing controls that was created for the entire faculty sample. Further it is important to note that we knew *a priori* that although the originally hypothesized factor structure for each group is similar, it is not identical as faculty employed in different contexts had slightly different baseline models. By implementing a condition of partial measurement invariance, we continued with the multigroup analysis.

Testing invariance: The configural model. The configural model (Model 1) is a multigroup representation of the baseline models for each group of faculty with no equality constraints imposed on any of the parameters that are shared across the three groups. This configural model provided the baseline value against which the first comparison of models was made. The chi-square statistic for the configural model was 1984.12 (*df = 523*, *N* = 4,484, *p* = 0.000), and the fit indices were CFI = 0.946, RMSEA = 0.043, and SRMR = 0.041. See Table 4 for the summary of model fit and the chi-square difference test statistics for this model and subsequent models created during the invariance testing steps.

Testing invariance: The measurement model. With respect to the measurement model, the key parameters of interest in this step of invariance testing were the factor loadings and residual covariances that were commonly specified for each faculty group. In Model 2, all factor loadings were constrained equal. Goodness-of-fit statistics related to this model were $\chi^2_{(559)}$ =2240.32, CFI = 0.938, RMSEA = .045, and SRMR = 0.049. As indicated by the higher χ^2 value and slightly lower CFI value, compared with the configural model (Model 1 in Table 4), results suggest that Model 2 does not fit the data quite as well as it did with no factor-loading constraints imposed. Thus we could expect to find some evidence of non-invariance related to the factor loadings. In reviewing the results from this analysis, the factor loading of "the number of published chapter in edited volumes" on the latent factor *scholarly productivity*, appeared to be the most problematic in terms of its equivalence across groups. Presented with this information, our next step was to relax the equality constraint related to this factor loading. Analysis of this partial invariance model (Model 3 in Table 4) resulted in a chi-square of 2116.79 with 557 degrees of freedom. The other fit indices were CFI = .0.942, RMSEA = 0.043, and SRMR = 0.046.

A review of the relaxed factor loading of "the number of published chapter in edited volumes" on the latent factor *scholarly productivity* for the three groups revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being .394, for master's comprehensive institutions being .406, and for research institutions being .742. (To make comparisons across groups, we report unstandardized coefficients because different groups may have different covariate variances; thus standardized values can differ across groups even when the unstandardized do not.) Given that the p-value for Model 3 was significant, we once again looked for evidence of possible additional non-invariant factor loadings. We continued this process of modifying the model such that the estimation of factor-loading parameters were freed one-by-one in an iterative process until we arrived at a model (Model 6) wherein

Table 4.

Tests for Invariance of Model Across Liberal Arts Institutions, Master's Comprehensive Universities, and Research Universities

Summary of Model Fit and χ^2 Difference Test Statistics

Model		χ^2	df	CFI	RMSEA	SRMR	Model Comparison	$\Delta \chi^2$	Δdf	p-value	Review of the relaxed parameter
Configural Model											
1	No Constraints.	1984.12	523.00	0.95	0.04	0.04	na	na	na	na	na
Measurement Parameters											
2	All factor loadings invariant/constrained equal	2240.32	559.00	0.94	0.05	0.05	2 versus 1	256.20	36.00	0.01	na
3	All factor loadings invariant except for **"# of published chapters in edited volumes"**	2116.79	557.00	0.94	0.04	0.05	3 versus 1	132.67	34.00	0.01	A review of the relaxed parameters for "# of published chapters in edited volumes" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being .394, for master’s comprehensive institutions being .406, and for research institutions being .742.
4	All factor loadings invariant except for "# of published chapters in edited volumes" & **"# of professional writings published or accepted for publication in the last two years"**	2059.70	555.00	0.95	0.04	0.05	4 versus 1	75.59	32.00	0.01	A review of the relaxed parameters for "# of professional writings published or accepted for publication in the last two years" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being .529, for master's comprehensive institutions being .543, and for research institutions being .791.
5	All factor loadings invariant except for "# of published chapters in edited volumes," "# of professional writings published or accepted for publication in the last two years," & **"reflective writing/journaling"**	2038.80	553.00	0.95	0.04	0.05	5 versus 1	54.68	30.00	0.01	A review of the relaxed parameters for "reflective writing/journaling" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being .563, for master's comprehensive institutions being .493, and for research institutions being .379.
6	All factor loadings invariant except for "# of published chapters in edited volumes," "# of professional writings published or accepted for publication in the last two years," "reflective writing/journaling," & **"write in the specific style or format of your discipline"**	2020.81	551.00	0.95	0.04	0.05	6 versus 1	36.69	28.00	**N.S.**	A review of the relaxed parameters for "write in the specific style or format of your discipline" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being .169, for master's comprehensive institutions being .213, and for research institutions being .239.
7	Model 6 plus 21 residual covariances invariant	2153.01	593.00	0.94	0.04	0.05	7 versus 6	132.20	42.00	0.01	na
8	Model 6 plus all residual covariances invariant except for the residual covariance for **cooperative learning (small groups) WITH class discussions**	2139.35	591.00	0.94	0.04	0.05	8 versus 6	118.54	40.00	0.01	A review of the relaxed parameters for the residual covariance for "cooperative learning (small groups) WITH class discussions" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being .082, for master's comprehensive institutions being .062, and for research institutions being .142.
9	*Model 6 plus all residual covariances invariant except for the residual covariance for cooperative learning (small groups) WITH class discussions; &* ***using student inquiry to drive learning WITH using real-life problems***	*2120.95*	*589.00*	*0.94*	*0.04*	*0.05*	*9 versus 6*	*100.14*	*38.00*	0.01	A review of the relaxed parameters for the residual covariance for "using student inquiry to drive learning WITH using real-life problems" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.114, for master's comprehensive institutions being 0.099, and for research institutions being 0.196.
10	*Model 6 plus all residual covariances invariant except for the residual covariance for cooperative learning (small groups) WITH class discussions; using student inquiry to drive learning WITH using real-life problems; &* ***write in the specific style or format of your discipline WITH engage deeply with a significant challenge or question within your discipline***	*2107.04*	*587.00*	*0.94*	*0.04*	*0.05*	*10 versus 6*	*86.23*	*36.00*	0.01	A review of the relaxed parameters for the residual covariance for engage deeply with a significant challenge or question within your discipline" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.026, for master's comprehensive institutions being 0.014, and for research institutions being 0.058.

Table 4.

Tests for Invariance of Model Across Liberal Arts Institutions, Master's Comprehensive Universities, and Research Universities

Summary of Model Fit and χ^2 Difference Test Statistics

11	*Model 6 plus all residual covariances invariant except for the residual covariance for Cooperative learning (small groups) WITH class discussions; using student inquiry to drive learning WITH using real-life problems; write in the specific style or format of your discipline WITH engage deeply with a significant challenge or question within your discipline; &* ***student presentations WITH student-selected topics for course content***	*2095.33*	*585.00*	*0.94*	*0.04*	*0.05*	*11 versus 6*	*74.52*	*34.00*	0.01	A review of the relaxed parameters for the residual covariance for "student presentations WITH student-selected topics for course content" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.042, for master's comprehensive institutions being 0.106 , and for research institutions being 0.099.
12	*Model 6 plus all residual covariances invariant except for the residual covariance for cooperative learning (small groups) WITH class discussions; using student inquiry to drive learning WITH using real-life problems; write in the specific style or format of your discipline WITH engage deeply with a significant challenge or question within your discipline; student presentations WITH student-selected topics for course content; &* ***reflective writing/journaling WITH student-selected topics for course content***	*2084.49*	*583.00*	*0.95*	*0.04*	*0.05*	*12 versus 6*	*63.68*	*32.00*	0.01	A review of the relaxed parameters for the residual covariance for "reflective writing/journaling WITH student-selected topics for course content" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.012, for master's comprehensive institutions being 0.062, and for research institutions being 0.076.
13	*Model 6 plus all residual covariances invariant except for the residual covariance for Cooperative learning (small groups) WITH Class discussions & Using student inquiry to drive learning with Using real-life problems & Write in the specific style or format of your discipline WITH Engage deeply with a significant challenge or question within your discipline & Student presentations WITH Student-selected topics for course content & Reflective writing/journaling WITH Student-selected topics for course content; &* ***Experiential learning/Field studies WITH Apply learning from both academic and field settings***	*2074.29*	*581.00*	*0.95*	*0.04*	*0.05*	*13 versus 6*	*53.48*	*30.00*	0.01	A review of the relaxed parameters for the residual covariance for "Experiential learning/Field studies WITH Apply learning from both academic and field settings" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.213, for master's comprehensive institutions being 0.144, and for research institutions being 0.156.
14	*Model 6 plus all residual covariances invariant except for the residual covariance for cooperative learning (small groups) WITH class discussions ; using student inquiry to drive learning WITH using real-life problems; write in the specific style or format of your discipline WITH engage deeply with a significant challenge or question within your discipline; student presentations WITH student-selected topics for course content; reflective writing/journaling WITH student-selected topics for course content; & experiential learning/field studies WITH apply learning from both academic and field settings.* ***Further, one additional factor loading freed: weigh the meaning and significance of evidence***	*2062.05*	*579.00*	*0.95*	*0.04*	*0.05*	*14 versus 6*	*41.24*	*28.00*	**N.S.**	A review of the relaxed parameters for "weigh the meaning and significance of evidence" revealed a slight discrepancy with the unstandardized estimate for liberal arts institutions being 0.244, for master's comprehensive institutions being 0.296, and for research institutions being 0.290. This smaller model (Model 14) can now be accepted.

Table 4.

Tests for Invariance of Model Across Liberal Arts Institutions, Master's Comprehensive Universities, and Research Universities

Summary of Model Fit and χ^2 Difference Test Statistics

11	*Model 6 plus all residual covariances invariant except for the residual covariance for Cooperative learning (small groups) WITH class discussions; using student inquiry to drive learning WITH using real-life problems; write in the specific style or format of your discipline WITH engage deeply with a significant challenge or question within your discipline; &* ***student presentations WITH student-selected topics for course content***	*2095.33*	*585.00*	*0.94*	*0.04*	*0.05*	*11 versus 6*	*74.52*	*34.00*	0.01	A review of the relaxed parameters for the residual covariance for "student presentations WITH student-selected topics for course content" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.042, for master's comprehensive institutions being 0.106 , and for research institutions being 0.099.
12	*Model 6 plus all residual covariances invariant except for the residual covariance for cooperative learning (small groups) WITH class discussions; using student inquiry to drive learning WITH using real-life problems; write in the specific style or format of your discipline WITH engage deeply with a significant challenge or question within your discipline; student presentations WITH student-selected topics for course content; &* ***reflective writing/journaling WITH student-selected topics for course content***	*2084.49*	*583.00*	*0.95*	*0.04*	*0.05*	*12 versus 6*	*63.68*	*32.00*	0.01	A review of the relaxed parameters for the residual covariance for "reflective writing/journaling WITH student-selected topics for course content" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.012, for master's comprehensive institutions being 0.062, and for research institutions being 0.076.
13	*Model 6 plus all residual covariances invariant except for the residual covariance for Cooperative learning (small groups) WITH Class discussions & Using student inquiry to drive learning with Using real-life problems & Write in the specific style or format of your discipline WITH Engage deeply with a significant challenge or question within your discipline & Student presentations WITH Student-selected topics for course content & Reflective writing/journaling WITH Student-selected topics for course content; &* ***Experiential learning/Field studies WITH Apply learning from both academic and field settings***	*2074.29*	*581.00*	*0.95*	*0.04*	*0.05*	*13 versus 6*	*53.48*	*30.00*	0.01	A review of the relaxed parameters for the residual covariance for "Experiential learning/Field studies WITH Apply learning from both academic and field settings" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.213, for master's comprehensive institutions being 0.144, and for research institutions being 0.156.
14	*Model 6 plus all residual covariances invariant except for the residual covariance for cooperative learning (small groups) WITH class discussions ; using student inquiry to drive learning WITH using real-life problems; write in the specific style or format of your discipline WITH engage deeply with a significant challenge or question within your discipline; student presentations WITH student-selected topics for course content; reflective writing/journaling WITH student-selected topics for course content; & experiential learning/field studies WITH apply learning from both academic and field settings.* ***Further, one additional factor loading freed: weigh the meaning and significance of evidence***	*2062.05*	*579.00*	*0.95*	*0.04*	*0.05*	*14 versus 6*	*41.24*	*28.00*	**N.S.**	A review of the relaxed parameters for "weigh the meaning and significance of evidence" revealed a slight discrepancy with the unstandardized estimate for liberal arts institutions being 0.244, for master's comprehensive institutions being 0.296, and for research institutions being 0.290. This smaller model (Model 14) can now be accepted.

Table 4.

Tests for Invariance of Model Across Liberal Arts Institutions, Master's Comprehensive Universities, and Research Universities

Summary of Model Fit and χ^2 Difference Test Statistics

Structural Parameters											
15	Same as 15b, but here all structural paths between latent factors fixed to equal	2106.02	586.00	0.94	0.04	0.05	15 versus 14	43.97	7.00	0.01	
16	Same as 15b, but here all structural paths between latent factors fixed to equal with the exception of the **path going from "scholarly productivity" to "nexus"**	2074.01	583.00	0.95	0.04	0.05	16 versus 14	11.96	4.00	0.05	A review of the relaxed parameters for the residual covariance for "using student inquiry to drive learning WITH using real-life problems" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.077, for master's comprehensive institutions being 0.211, and for research institutions being 0.227.
17	Same as 15b, but here all structural paths between latent factors fixed to equal with the exception of the path going from "scholarly productivity" to "nexus" and **the covariance between "scholarly productivity" and "student centered pedagogy"**	2066.82	581.00	0.95	0.04	0.04	17 versus 14	4.77	2.00	**N.S.**	A review of the relaxed parameters for the residual covariance for "using student inquiry to drive learning WITH using real-life problems" revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.106, for master's comprehensive institutions being -0.018, and for research institutions being 0.096. The smaller model (model 17) can now be accepted.

Note: n=4,548 STEM faculty across 262 institutions. Of the faculty included in this study, 39.4% were employed at research universities, 33.8% at master's comprehensive universities, and the final 25.4% employed at liberal arts the chi-square difference test with the configural model was not significant. Non significance indicates that this smaller model (Model 6) is an improvement over Model 1 and can therefore be accepted. Up to this point, all factor loadings in the model were operating equivalently across the three faculty groups with the exception of those factor loadings that we allowed to be estimated freely. (See Table 4 for a step-by-step description of the specific factor loadings that were freed and the corresponding fit indices and chi-square difference tests.)

Of interest next was the commonly specified residual covariances and the extent to which they were invariant across the groups. For Model 7, we therefore constrained all 21 covariances to be equal across the three groups. Model fit results deviated a bit from Model 6 and were as follows: $\chi^2_{(593)}$ = 2153.01, CFI = 0.942, RMSEA = 0.042, and SRMR = 0.047. Comparison of this model with Model 6, which represents the final model in the test for invariant factor loadings, yielded a corrected $\Delta\chi^2_{(42)}$ value of 132.20. Because this difference in the chi-square was significant, we knew that there was a residual covariance that was not operating equivalently across the groups. An examination of the modification indices revealed that the residual covariance between the items “cooperative learning (small groups)” and “class discussions” were the practices that differed across contexts. We therefore released the constraint on that residual covariance for Model 8, and then conducted a chi-square difference test between Model 8 and Model 6. These steps were repeated in an iterative process until non-significance was established with Model 14, indicating that this smaller model could be accepted because it was an improvement over Model 6. (See Table 4 for a step-by-step description of the residual covariances that were freed.)

Testing invariance: The structural model. Having established invariance related to the measurement model, we then moved to testing for the invariance of structural parameters in the model; in the present case this simply includes the path from *scholarly productivity* to *research-teaching nexus*, the path from *student-centered pedagogy* to *research-teaching nexus*, and the covariance between *scholarly productivity* and *student-centered pedagogy* which were all constrained to equal. Goodness-of-fit for the testing of Model 15 were $\chi^2_{(586)}$ =2106.02, CFI = 0.944, RMSEA = 0.042 , and SRMR = 0.045. Comparison of Model 15 with Model 14 yielded a corrected difference value that was significant ($\Delta\chi^2_{(7)}$ =

43.97, $p < .01$) indicating evidence of possible non-invariant paths. An examination of the modification indices revealed that the path going from *scholarly productivity* to *research-teaching nexus* appeared to be the most problematic in terms of its equivalence across groups. Thus we relaxed the equality constrained related to this path for Model 16; a review of the relaxed parameter for the path going from *scholarly productivity* to *research-teaching nexus* revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being 0.077, for master's comprehensive institutions being 0.211, and for research institutions being 0.227. This indicates that incorporating research in teaching was more likely to happen at research universities and master's comprehensive institutions than at liberal arts colleges.

Comparison of Model 16 with Model 14 yielded a corrected difference value that was significant ($\Delta\chi^2_{(4)} = 11.96$, $p < .01$), indicating that we needed to once again looked for evidence of possible additional non-invariant paths. In Model 16, we found that the next problematic parameter was the covariance between *scholarly productivity* and *student-centered pedagogy* so we relaxed the equality constrained related to this covariance in Model 17. A review of the relaxed parameter for the covariance between *scholarly productivity* and *student-centered pedagogy* revealed a fairly substantial discrepancy with the unstandardized estimate for liberal arts institutions being positive and significant 0.106 (S.E. = 0.039, p = .006), for master's comprehensive institutions negative and nonsignificant -0.018 (S.E. = 0.037, p = .634), and for research institutions being positive and significant 0.096 (S.E. = 0.030, p = .001).

To statistically test for whether the discrepancy of values above were different from a statistical standpoint, we used the equation offered by Paternoster and colleagues (1998) for the equality of unstandardized estimates across independent samples with unequal sample sizes. This test revealed no significant difference between the estimate of the covariance parameter for liberal arts institutions and the estimate derived for research institutions. The value of the covariance parameter for master's comprehensive institutions however was significantly different than the value derived for liberal arts institutions ($z = -2.307$, $p <.05$) and the value derived for research institutions ($z = -2.393$, $p <.05$). This finding indicates that the relationship between *scholarly productivity* and *student-centered pedagogy* works in a positive and similar way for research institutions and liberal arts institutions. In contrast, there in no relationship between *scholarly productivity* and *student-centered* for faculty teaching at master's comprehensive institutions, and this zero relationship is statistically different than the estimates derived for faculty at liberal arts institutions and research institutions. This is a relatively new finding, since it is previously thought that liberal arts colleges are much more different than research universities. At least compared to peers within their own institutional contexts, the link between *scholarly productivity* and *student-centered practices* is positive.

Finally a comparison of Model 17 with Model 14 yielded a corrected difference value that was significant ($\Delta\chi^2_{(2)} = 4.77$) indicating that Model 17 was the best fitting model and could be accepted.

Discussion and Conclusion

The purpose of this paper was to empirically investigate faculty behavior in integrating discipline-based research activity into the classroom via class assignments that are research-oriented and research-based (what we call research-teaching nexus practices) and to determine if this changes the relationship between research productivity and the use of student-centered teaching practices. Specifically, we investigated the relationships between research productivity, student-centered teaching, and discipline-based research activities, controlling for select demographic and contextual influences. By doing so, we also empirically test the STAR framework proposed by Jones (2013) for its utility as a tool to reconcile the age-old separation between teaching and research.

The relationships among variables in the hypothesized model were confirming and lend empirical support to Jones' STAR framework. Indeed, in the final SEM model, there were positive relationships between all three of our latent construct. This indicates that: using different kinds of student-centered pedagogy in a greater frequency in one's classes predicted more frequent use of research discipline-based assignments as a teaching tool in one's classes; having more research publications predicted more frequent use of research-based assignments as a teaching tool in one's classes; and finally, having more research publications was associated with more frequent use of student-centered pedagogy in one's classes. Instead of teaching and research being at odds, this research shows that they can work in unison to elevate both the research production and engaged teaching of faculty. These findings support previous work wherein faculty who more frequently use student-centered teaching practices were also the same people to more frequently engage undergraduate students in research (Elsen et al., 2009). Our findings contrast with the work of other scholars that found no relationship between scholarly productivity and the frequency with which an instructor uses teaching-centered pedagogy (Braxton, 1996; Feldman, 1987; Milem, Berger, & Dey, 2000; Hattie & Marsh, 1996). The main distinction in this study is capturing new measures of introducing research discipline-based practices that are linked with research excellence and student-centered teaching, a relatively new practice gaining momentum across many STEM disciplines (Singer et al., 2012). Moreover, we show that there can be greater synergy between research and teaching as faculty in research universities engage in inquiry-based, student-centered teaching.

To dispel the prevailing notion that engaged, student-centered teaching equates to being a less productive researcher, faculty and the administration need to identify real life examples of the synergy that can be created between research and teaching. In other words, STEM faculty need to see positive role-models of ‘synergy’ and ‘nexus practices’ so that faculty can re-imagine what is possible as teachers and researchers. To make this reimagining happen, department chairs may want to invite speakers, who have a strong record of both synergy and nexus, to showcase their journey in this process and the results they have seen as a result. In some cases, introductory classrooms have even produced publications of original research as part the Science Education Alliance initiative sponsored by HHMI. The foundation has spearheaded campus innovation by introducing original research in introductory classrooms for engaging students in knowledge production and acquisition.

Institutions also need to do a better job of supporting the professional development of faculty when it comes to using research-based instructional strategies and giving them time to revise courses and practice these strategies. Indeed, in a study that examined the relationship between knowledge of research-based instructional strategies and implementation of such practices among a national sample of faculty teaching introductory physics classes, 12% of faculty reported having no knowledge of any research-based instructional strategies and only 16% were aware of these instructional practices, but had not tried any (Henderson, Dancy, & Niewiadomska-Bugaj, 2012). Another 23% of faculty had stopped using research-based instructional strategies after a period of initially trying them out. Clearly additional efforts must be made to support faculty in their implementation of inquiry-based research activities in the classroom, so that faculty are aware of the essential features of these instructional methods, have realistic expectations of student learning gains, and become knowledgeable of the core issues (including potential problems) related to using these practices. In order to encourage academics to take advantage of these professional development opportunities, reward policies and promotional considerations must value research-teaching nexus practices (Elsen et al., 2009).

Considering the finding that, other things being equal, teaching a heavier course load negatively impacts the scholarly productivity of faculty, institutions should find additional ways of supporting faculty who teach large course loads. Indeed, being overwhelmed with teaching may negatively impact faculty's ability to conduct research and publish. Excellence in both is needed considering faculty's role in not only teaching students, "how to learn from known sources in the classroom, but also how to create new knowledge" (Anderson, et al., 2011, p. 152). Institutions should therefore try to provide faculty teaching large course loads with more graduate teaching assistants and/or undergraduate learning assistants to help with the facilitation of class activities, the grading of assignments, and office hours, so that faculty have more time to plan for excellent teaching and to engage in research and publishing. Interestingly, teaching more classes in the term the survey was administered did not seem to get in the way of using student-centered pedagogy or infusing research into the teaching.

Although this study stands counter to the misconception that productive researchers cannot be engaging teachers and vice versa, the study unfortunately does not reveal much about the individuals who excel at being both great teachers *and* great researchers, nor do we offer any description about the conditions across campus contexts that allowed for these outcomes to occur. A good place to start filling this gap in the knowledge base would be to collect qualitative information about those individuals and institutions that are already exhibiting signs of synergy between engaged teaching, research, and scholarly productivity. Are there any unique incentives that drive research-based inquiry in the classroom? Do these institutions have structures in place that support faculty (especially junior faculty) in balancing their numerous responsibilities? This research is especially important given that faculty will always be expected to teach even though research is regarded with utmost importance in promotion and tenure considerations, particularly at research universities.

Further, because highly regarded scholars passionately purport that a synergy between teaching and research is possible (Anderson, et al., 2011), perhaps having more survey data about the institutional and departmental environment in which faculty teach, and identifying these factors will strengthen the rationale supporting a positive relationship between scholarly productivity and engaged teaching practice. Longitudinal data would also help to establish how teaching and research practices change over time for individual faculty across the course of a career. Future research should also test for model invariances across different STEM faculty groups (e.g. by race/ethnicity, by discipline, etc.). Given findings of inadequate fit, researchers can propose and test alternative factorial structures and cross-validate this structure over independent samples within each faculty group.

In conclusion, if colleges are to produce the next generation of scientists, a far greater focus must be placed on improving STEM teaching in colleges and universities so that students can successfully complete their intended STEM degrees, join the workforce, and advance research agendas that meet projected national needs. To improve teaching, academia must move away from the conception that faculty must choose between being productive researchers or master teachers (Chetty & Lubben, 2009). Indeed the faculty role is a multifaceted one, and with the proper supports, faculty do not have to sacrifice stellar performance in one area to boost performance in another. In addition, research inherently has a dual role in the academic enterprise: it is both a tool that enhances the learning environment and also is an integral piece of the educational process itself (Simons & Elen, 2007). In this way the relationship between teaching and research ought to more appropriately be conceptualized as being fluid and bi-directional and necessary to help students ask new questions to advance research. A fluid relationships is necessary because 21st century problems require that students not only have acquired the requisite knowledge relating to their domain of study, but also that students possess metacognitive skills whereby they know how to find, assess, and apply information (Biggs, 2003). In this way graduates of STEM programs become knowledge creators and critically contribute to solving rapidly changing national and global problems.

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Appendix A.
Variables and Scale

Variable	Scale
Control Variables	
Sex	1=Male; 2=Female
# of courses teaching the term survey was taken at all institutions in which the individual teaches (e.g., 0, 1, 2, 3)	Continuous
Faculty member academic rank	1=Professor; 2=Associate Professor 3=Assistant Professor
Research-Teaching Nexus	
How frequently in the courses you taught in the past year have you given at least one assignment that required students to:	
Engage deeply with a significant challenge or question within your discipline	1=Not at all; 2=Occasionally; 3=Frequently
Write in the specific style or format of your discipline	"
Use research methods from your discipline in field or applied settings	"
Apply learning from both academic and field settings	"
Describe how different perspectives would affect the interpretation of a question or issue in your discipline	"
Weigh the meaning and significance of evidence	"
Student-Centered Pedagogy	
In how many of the courses that you teach do you use each of the following?	
Class discussions	1=None; 2=Some; 3=Most; 4=All
Cooperative learning (small groups)	"
Experiential learning/Field studies	"
Performances/Demonstrations	"
Group projects	"
Student-selected topics for course content	"
Method: Reflective writing/journaling	"
Method: Using real-life problems	"
Method: Using student inquiry to drive learning	"
Method: Student presentations	"
Scholarly Productivity	
# of published articles in academic and professional journals	1=None; 2=1-2; 3=3-4; 4=5-10; 5=11-20; 6=21-50; 7=51+
# of published chapters in edited volumes	"
# of professional writings published or accepted for publication in the last two years?	1=None; 2=1-2; 3=3-4; 4=5-10; 5=11-20; 6=21+

Note: n=4,548 STEM faculty across 262 institutions.

Appendix B.
Descriptive Statistics for STEM faculty

	Mean	S.D.	Kurtosis	Min	Max
Control Variables					
Sex (female=2)	1.42	0.47	-1.88	1.00	2.00
# of courses teaching the term survey was taken at all institutions in which the individual teaches (e.g., 0, 1, 2, 3)	2.30	0.51	1.51	0.00	13.00
Faculty member academic rank	40.2% full professors; 30.5% associate professors; and 29.3% assistant professors			1.00	3.00
Research-Teaching Nexus					
How frequently in the courses you taught in the past year have you given at least one assignment that required students to:					
Engage deeply with a significant challenge or question within your discipline	2.34	0.63	-0.78	1.00	3.00
Write in the specific style or format of your discipline	2.41	0.56	-0.68	1.00	3.00
Use research methods from your discipline in field or applied settings	2.32	0.47	-0.97	1.00	3.00
Apply learning from both academic and field settings	2.20	0.93	-1.31	1.00	3.00
Describe how different perspectives would affect the interpretation of a question or issue in your discipline	1.98	0.98	-1.21	1.00	3.00
Weigh the meaning and significance of evidence	2.46	1.11	-0.42	1.00	3.00
Student-Centered Pedagogy					
In how many of the courses that you teach do you use each of the following?					
Class discussions	3.08	1.09	-0.93	1.00	4.00
Cooperative learning (small groups)	2.76	0.98	-1.09	1.00	4.00
Experiential learning/Field studies	2.08	0.72	-0.95	1.00	4.00
Performances/Demonstrations	2.10	0.79	-0.94	1.00	4.00
Group projects	2.54	0.84	-1.05	1.00	4.00
Student-selected topics for course content	1.89	0.92	0.25	1.00	4.00
Method: Reflective writing/journaling	1.66	0.88	0.67	1.00	4.00
Method: Using real-life problems	3.18	1.81	-0.60	1.00	4.00
Method: Using student inquiry to drive learning	2.68	3.82	-1.04	1.00	4.00
Method: Student presentations	2.52	1.50	-0.90	1.00	4.00

Appendix B.

Descriptive Statistics for STEM faculty

Scholarly Productivity					
# of published articles in academic and professional journals	2.47	0.24	-0.31	1.00	6.00
# of published chapters in edited volumes	4.19	2.11	-1.18	1.00	7.00
# of professional writings published or accepted for publication in the last two years?	1.91	0.68	1.70	1.00	7.00

Note: n=4,548 STEM faculty across 262 institutions.

Appendix C.

Correlation Table of all the Variables in the SEM Models

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Engage deeply with a significant challenge or question within your discipline	1.00																					
2	Write in the specific style or format of your discipline	0.39	1.00																				
3	Use research methods from your discipline in field or applied settings	0.49	0.46	1.00																			
4	Apply learning from both academic and field settings	0.38	0.30	0.45	1.00																		
5	Describe how different perspectives would affect the interpretation of a question or issue in your discipline	0.44	0.33	0.38	0.53	1.00																	
6	Weigh the meaning and significance of evidence	0.43	0.39	0.47	0.37	0.45	1.00																
7	Class discussions	0.34	0.20	0.24	0.33	0.37	0.26	1.00															
8	Cooperative learning (small groups)	0.25	0.21	0.19	0.21	0.23	0.23	0.47	1.00														
9	Experiential learning/Field studies	0.27	0.22	0.32	0.46	0.29	0.26	0.31	0.31	1.00													
10	Performances/Demonstrations	0.17	0.12	0.17	0.28	0.23	0.17	0.30	0.28	0.39	1.00												
11	Group projects	0.28	0.24	0.25	0.27	0.25	0.23	0.37	0.60	0.33	0.29	1.00											
12	Student-selected topics for course content	0.28	0.20	0.24	0.26	0.32	0.24	0.33	0.28	0.27	0.22	0.30	1.00										
13	Method: Reflective writing/journaling	0.22	0.21	0.19	0.34	0.36	0.20	0.30	0.26	0.35	0.28	0.28	0.34	1.00									
14	Method: Using real-life problems	0.26	0.16	0.23	0.36	0.31	0.25	0.34	0.28	0.28	0.26	0.29	0.23	0.26	1.00								
15	Method: Using student inquiry to drive learning	0.33	0.20	0.25	0.28	0.36	0.29	0.43	0.36	0.28	0.28	0.30	0.38	0.32	0.47	1.00							
16	Method: Student presentations	0.31	0.26	0.31	0.31	0.31	0.27	0.40	0.41	0.34	0.29	0.53	0.42	0.35	0.28	0.34	1.00						
17	# of published articles in academic and professional journals	0.11	-0.02	0.09	0.01	0.03	0.03	0.04	-0.02	-0.01	-0.03	0.00	0.07	-0.09	-0.03	-0.01	0.04	1.00					
18	# of published chapters in edited volumes	0.05	-0.02	0.06	-0.10	-0.06	0.03	-0.05	-0.06	-0.09	-0.12	-0.06	0.01	-0.21	-0.12	-0.08	-0.02	0.63	1.00				
19	# of professional writings published or accepted for publication in the last two years?	0.09	-0.02	0.06	0.05	0.09	0.05	0.06	-0.02	0.00	-0.05	-0.01	0.09	-0.03	-0.02	0.00	0.08	0.48	0.56	1.00			
20	Sex	0.08	0.18	0.13	0.18	0.16	0.13	0.14	0.17	0.14	0.08	0.13	0.11	0.24	0.15	0.12	0.17	-0.16	-0.26	-0.12	1.00		
21	# of courses teaching the term survey was taken at all institutions in which the individual teaches (e.g., 0, 1, 2, 3)	0.09	0.13	0.09	0.15	0.11	0.12	0.03	0.05	0.07	0.10	0.06	0.02	0.12	0.14	0.09	0.02	-0.29	-0.32	-0.23	0.07	1.00	
22	Faculty member academic rank	-0.01	0.05	0.02	0.08	0.05	0.03	0.08	0.10	0.10	0.12	0.08	0.03	0.12	0.11	0.10	0.03	-0.19	-0.39	-0.35	0.20	0.15	1.00

Note: n=4,548 STEM faculty across 262 institutions.

Appendix D.

Factor Items and Loadings

Item	Standardized Factor Loading	R^2
Research-Teaching Nexus		
Engage deeply with a significant challenge or question within your discipline	0.65	0.43
Write in the specific style or format of your discipline	0.59	0.35
Use research methods from your discipline in field or applied settings	0.75	0.57
Apply learning from both academic and field settings	0.57	0.33
Describe how different perspectives would affect the interpretation of a question or issue in your discipline	0.68	0.46
Weigh the meaning and significance of evidence	0.64	0.41
Student-Centered Pedagogy		
Class discussions	0.63	0.40
Cooperative learning (small groups)	0.58	0.34
Experiential learning/Field studies	0.54	0.29
Performances/Demonstrations	0.48	0.23
Group projects	0.59	0.34
Student-selected topics for course content	0.51	0.26
Reflective writing/journaling	0.54	0.29
Using real-life problems	0.50	0.25
Using student inquiry to drive learning	0.58	0.34
Student presentations	0.63	0.40
Scholarly Productivity		
# of published articles in academic and professional journals	n/a	n/a
# of published chapters in edited volumes	n/a	n/a
# of professional writings published or accepted for publication in the last two years?	n/a	n/a

Note: n=4,548 STEM faculty across 262 institutions.