Exploring the Adoption of Research-Based Instructional Strategies in Undergraduate Mathematics with the Teacher Centered Systematic Reform Model

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Studies show that Research-Based Instructional Strategies (RBIS) help students learn, however their adoption has been slow. The Teacher Centered Systematic Reform Model (TCRM) is a general model for organizing enablers and barriers to adoption of new teaching methods that includes departmental, personal and teacher thinking factors. We used the TCRM model as a framework to assess the amount of formal lecture reported by 634 mathematics instructors in their undergraduate courses. Regression analyses found that instructors who participated in Project NExT (a professional development workshop) during their early careers were less likely to use lecture than non-participants. Other significant predictors of lecture less included evaluation expectations emphasizing active teaching methods, involvement in equity and diversity efforts, and prior experience with RBIS. Factors with a positive correlational association with lecture included evaluation efforts by departments where lecture was expected. Results confirmed some prior models in different disciplines.

Keywords: Undergraduate Education, Adoption of New Teaching Practices, Research Based Teaching Strategies, Mathematics Education, Inquiry-Based Learning

Reaching back over twenty years, many studies show that Research-Based Instructional Strategies (RBIS) help students learn in college, but that adoption and integration into undergraduate classrooms is stubbornly limited (American Association for the Advancement of Science, 2013; Laursen et al., 2019; Stains et al., 2018). While the use of RBIS can help provide student understanding of STEM (and other disciplines), their effectiveness is limited if their use is constrained. The Teacher Centered Systematic Reform Model (TCSR) provides a general structural model to assess incentives and barriers to adoption of RBIS (Gess-Newsome, 2003). The broad categories of enablers and barriers to adoption in this model include contextual, personal, and teacher thinking; these factors have been researched in studies that assess the relative contribution of factors in the implementation of active learning in college classrooms (Yik et al., 2022).

The departmental context is an important focus of many adoption studies. Departmental norms and expectations, both supporting and hindering active learning, have been studied as one factor for instructors adopting active teaching methods (Hora & Anderson, 2012). Some of the factors constraining adoption were related to teaching load and a lack of time to prepare lessons, perhaps related to prevailing practices in university departments (Henderson & Darcy, 2007). Pressures to achieve tenure and to publish, found in more research-intensive universities, act to constrain the amount of effort instructors can devote to course design (Lund & Stains, 2015). Prevailing norms and expectations linked to academic evaluation can also encourage or limit adoption of RBIS; if teaching is not valued or if alternative teaching methods are discouraged, instructors may be less willing to take risks with new teaching methods. More practically, classroom context, mainly large class sizes and classroom layout (e.g., places designed for group work), have also worked against adoption (Yik et al., 2022).

The personal characteristic of university instructors also plays into implementation decisions. These can include prior experience with active teaching, participation in professional development and beliefs and values related to teaching. Instructors who experienced or practiced inquiry-based teaching as graduate students were more likely to teach the same way later (Fukawa-Connelly et al., 2016), as are instructors who experienced RBIS as students (Yik et al., 2022). Participation in larger professional development initiatives such as Chem Connections, National Academies Summer Institutes on Undergraduate Education, or POGIL have been linked to greater use of active teaching methods (Dertling et al., 2016). Our current study used data from Project NExT (PN), a teaching initiative in mathematics. Participation in more short-term professional development efforts, usually conducted on college campus, have also been linked to greater adoption and implementation of alternative pedagogies.

While many studies have been conducted on factors influencing adoption, there are few that focus on teaching undergraduate mathematics. Yik et al. (2022) conducted the largest quantitative study to date on adoption, testing a wide range of factors from the TCSR model. These researchers compared the amount of lecture used by instructors in mathematics to chemistry and physics. While physics instructors spent significantly less time lecturing than mathematics instructors, instructors in mathematics lectured at similar rates to those who taught chemistry. However, no separate or interactive models were made to learn how other factors worked within the mathematics discipline. Johnson et al. (2019) examined many of the same factors found in the TCSR model with survey data from 219 algebra instructors, although they did not incorporate a regression model in their analysis. The researchers made comparisons between high, medium and low lecturing groups on a range of variables from the TCSR model. Significant group comparisons were found in teacher beliefs about student learning (e.g., "I think students learn better when they struggle with the ideas prior to me explaining the material to them."). Johnson's team found only small differences for departmental support between lecture groups, with instructors who were given more latitude in course design lecturing at lower rates than instructors whose teaching was more constrained by their departments.

Rationale for Study & Research Questions

Widespread adoption and implementation of RBIS provide the key to their effective use. Understanding what helps and hinders this adoption may spur adoption by addressing policies and practices that may encourage or stymie the use of more active instruction. Our research questions included:

1) What factors related to the TCRM model are associated with the amount of time instructors engage in formal lecture in their mathematics courses?
2) Is participation in the professional development workshop Project NExT associated with the amount of time instructors engage in formal lecture in their mathematics courses?

Method

Participants

Six-hundred-thirty-four (634) mathematics instructors answered the Alumni Survey, 492 former participants in Project NExT and 142 from a comparison group. On the survey, participants were asked to choose one course they had taught recently and report on their teaching practices. Calculus was the most frequently chosen course (31%), followed by Special Topics (e.g., higher division mathematics), Algebra (12%), and Other courses (28%). Demographically, participants were white (79%), with Asian (4.6%), Hispanic (3%) and Black instructors (1.1%) making up only a small percentage of respondents. Gender representation was nearly even with 50% of those answering the survey identifying as male, 44% as female and another 6% non-binary or preferring not to answer. Instructors reported teaching at the college level from three to 44 years with an average teaching career of 18 years. Of those instructors responding, 28% of respondents had been department chairs at one time during their time teaching, but only 3% had been deans. Having an advanced degree was a requirement for entering Project NExT; 96% indicated their terminal degree was a Ph.D.

Instrument

The Project NExT Alumni Survey was administered to a list of 1532 Project NExT Alumni obtained from the project with a response rate of (71%). The sampling frame for the Alumni Comparison Group Survey contained 882 names with response rate of 28%. While 902 mathematics instructors answered the survey, the current analyses used only 643 responses of those providing complete information about their teaching and described in-person and non-virtual classes. The survey was administered during the winter and spring of 2022.

The survey contained 47 items (many items with long lists of choices) asking about a range of topics related to careers as math instructors. These included: 1) the benefits of Project NExT or an alternate professional development project, 2) academic career activities, 3) participation in professional development, 4) participation in professional societies, 5) involvement in receiving grant money and research, and 6) expectations for evaluation of their work from their department, and a parallel section asking about the activities that brought respondents personal career fulfillment. The teaching component of the survey was based on the TAMI-S survey developed by our research team (Hayward et. al., 2017) and asked instructors to choose a course they had taught recently and estimate the amount of time they spent in a range of teaching activities (e.g., Lecture or Group Work). We also asked basic demographic questions as well as questions about time spent teaching at the college level, and the characteristics of their institution.

Analysis

Ordinary Least Squares (OLS) Linear Regression was used to estimate the individual contribution of variables on instructor responses to the item: *Please choose a course you have taught that represents your best teaching. What approximates the amount of time you spend in Formal lecture? (1, Did not use this activity, 1/3 or less, 1/3 to 2/3, 2/3 to all of class time).* The dependent variable was similar to that used in Yik et al. (2022) which asked instructors to report percentages of time spent in lecture.

The final regression model used 564 listwise responses from 26 variables. These variables were included as representing components of the TCSR model. For the sake of space, we reported only statistically significant predictors, and listed other variables tested but which were not statistically significant. We also compared both raw and adjusted mean differences for Project NExT using a simple ANCOVA procedure, adjusting the means for each group with the propensity covariate. We used the covariate in this manner only after checking the assumptions of the ANCOVA procedure.

The survey took place in the context of research on professional development at project NExT. As well as selection of PN Alumni, we selected a comparison group of instructors. These respondents were chosen through the Math Genealogy Project, a website that tracks the history of mathematics Ph.D's and their advisors. Instructors were chosen for the sampling frame by matching PN alumni with their graduate school colleagues who shared the same advisor and attended the same university program at the nearly the same time.

For comparisons between PN Alumni and the comparison group mentioned below, we used a propensity matching analysis to control for differences between groups (Benedetto et al., 2018). The propensity model provided information on how groups differed along many of the same variables used in the main analysis.

Results

Fifteen variables entered the regression model; the resulting R-squared value was $R^2 = 0.34$. Five-hundred and sixty-four (564) cases were used in the regression model. The greatest inverse predictors of time spent lecturing were academic evaluation expectations to use techniques other than lecture (Beta= -0.22) and participation in Project NExT (Beta = -0.19). Evaluation expectations to lecture (Beta= 0.15) and to use a variety of teaching methods were associated with greater use of formal lecture. Lecture was used less frequently in courses for education majors or non-majors (Beta = -0.13), and instructors who used active or inquiry-based methods during their early career tended to lecture less (Beta = -0.09). Other inverse predictors of lecture included involvement in equity and diversity in department or institution (Beta = -0.12) and collaborating with other instructors to promote changes in math teaching practices (Beta = -0.12). The number of campus professional development workshops instructors participated in predicted greater use of lecture (Beta = 0.08). Table 1 presents the Linear Regression Model for class time spent in formal lecture.

Other variables were tested from the TCSR model but did not enter our regression model. Non-significant variables included: Years teaching at college/university level, Department head or chair (past or present), Gender, Academic Department Expectation: Receiving High Evaluations of Teaching from Students (as evaluation criterion), Tenure Track Position, Teaching Load, Member of Minoritized Population, Highest Degree Offered at Institution, Member of (Specific) Professional Societies, and Participation in (Specific) Campus Professional Development efforts.

To better assess the association of participation in Project NExT with formal lecture we created a propensity matching model. This model used logistic regression to predict group membership in PN or the comparison group. The resulting probabilities of group membership derived from the logistic model were then used as a covariate in an Analysis of Covariance model (ANCOVA) that tests the differences in the mean estimates of time spent lecturing between groups and adjusts each mean to reflect the logistic probabilities. The propensity logistic model found statistically significant differences between groups favoring the PN group for the following variables: Served on National Committee, and Participation in Campus Professional Development. The variables favoring the comparison group in the propensity model included Highest Degree Offered, Receiving an Endowed Professorship or Other Honorary Post, and Years Teaching at University Level.

The ANCOVA comparison returned a statistically significant result for the main effect for program status (PN or Comparison) of $F = 16.02$, df 1,497, $p < .0001$**. This result tested the difference in means for Formal Lecture between groups with PN = 2.01 and Comparison = 2.94. These means were adjusted by the covariate to PN = 2.09 and Comparison = 2.62. As effect sizes, the difference between raw means was ES = -0.88; for adjusted means the effect size was

ES = -0.50. The result indicated that having participated in Project NExT was associated with less use of formal lecture in the classroom.

Table 1 Linear Regression Model Predicting Class time Spent in Formal Lecture

	B	SE	Beta	t	p
(Constant)	2.72	0.46		5.89	<.001**
Participated in Project NExT	-0.48	0.10	-0.19	-4.86	<.001**
Collaborated with colleagues to promote changes in math teaching practices	-0.27	0.09	-0.12	-3.06	.002**
Agree/Disagree: I am involved in efforts at my institution to promote equity and inclusion in teaching practice	-0.20	0.08	-0.09	-2.42	.016*
Personal Expectation: Teaching in more active and engaging ways	-0.22	0.07	-0.12	-2.98	.003**
Personal Expectation: Promoting equity and diversity in your department and institution	-0.15	0.06	-0.12	-2.72	.007**
Academic Department Expectation Giving academic talks at conferences	0.13	0.05	0.10	2.60	.010*
Academic Department Expectation: Expectation to use techniques other than lecture	-0.21	0.06	-0.22	-3.47	<.001**
Academic Department Expectation: Expectation to use a variety of teaching methods	0.17	0.07	0.16	2.55	.011*
Academic Department Expectation: Expectation to lecture	0.16	0.04	0.15	3.98	<.001**
Sum of professional development involvement at institution	0.05	0.02	0.08	2.13	.034*
Agree/Disagree: “In my department, I am mostly free to teach however I want.”	-0.15	0.07	-0.08	-2.16	.031*
Agree/Disagree: “I taught using active or inquiry-based methods during my early career”	-0.20	0.08	-0.09	-2.35	.019*
Agree Disagree: “I taught large introductory-level courses during my early career”	0.17	0.08	0.08	2.18	.030*
Content: Education and Non-Major	-0.46	0.13	-0.13	-3.65	<.001**
Content: Geometry	-0.41	0.18	-0.08	-2.33	.020*

R^2 (Adjusted) = .34, p<.05* p < .01** , N for model = 564

Discussion

The analysis of the Project NExT Alumni Survey data found significant effects predicting the amount of time instructors reported using formal lecture for a range of variables related to departmental expectations, personal expectations, campus professional development, course content and equity and diversity. The results support some of the previous findings related to the TCSR model (Gess Newsome, 2003).

The large attenuated effect seen for participation in the workshop professional development Project NExT reflected those seen in Yik et al. (2022) and various other research about teacher focused professional development (Dertling et al., 2016). Although this comparison cannot be considered causal in any way, the effect for participation in the PN program suggests that those who have participated in NExT tend to lecture less than those from the matched comparison group. This counters a previous assessment of the program that found little or no benefits for the PN program (Fukawa-Connelly et al., 2016). Participation in campus wide professional development was not predictive of lecture time by specific program although those participating in more types of professional development were slightly more likely to lecture. This countered findings from Benabentos et al. (2021) who found higher uptake of research-based methods for those using campus professional development services. Our result may have been related to the type of professional development we asked about including training in non-teaching activities such as grant writing.

Perceived departmental expectations for active teaching were also predictive of less time spent lecturing. Instructors who reported that their department evaluated them with the "expectation to use techniques other than lecture" lectured less. Conversely, departments with expectations for lecture reported lecturing more. Johnson et al. (2019) found only small effects for departmental expectations for instructors in designing their own courses, with those having more latitude less likely to lecture. This was similar to the small effect for our agree/disagree survey item: "In my department, I am mostly free to teach however I want". The findings that departmental evaluation criteria are predictive of time spent lecturing was seen in work by Seymour et al. (2011), generally with instructors feeling blocked from implementing active learning due to a lack of incentives for doing so and pressure to publish for tenure. Items asking about activities that instructors find personally fulfilling were also predictive of time spent lecturing including valuing "Teaching in more active and engaging ways". Other practical teaching expectations such as teaching load, tenure status and the importance of student teaching evaluations did not enter into our regression model, a result mostly consonant with the Yik et al. study (2022).

Collaboration with others was also found to be predictive of lecture time. Those who collaborated with colleagues to promote changes in math teaching practices were less likely to lecture. This reflects other studies on professional development and teaching practices (Bressoud & Rasmussen, 2015) where instructors shared experiences with innovative pedagogical practices. This perhaps extends to other areas of collaboration such as promoting student equity and diversity; those instructors who were involved in these efforts with colleagues were also less likely to lecture. Early career experiences seemed to impact current teaching for those who took our survey. Those agreeing with the statement : "I taught using active or inquiry-based methods during my early career" tended to lecture less, and those who agreed with "I taught large introductory-level courses during my early career" lectured more. The influence of early career experiences on teaching style is found in studies by Yik et al.(2022) and Lund and Stains (2015).

Like many models ours is under-identified. Because of constraints on data collection, we were not able to gather information about teaching thinking related to student growth mindset, an important part of the TCSR model (Gess Newsome, 2003) and a significant predictor of less lecture time in Yik et al. (2022). Similarly, variables of class size and class layout were not included in our model but were found to predict greater use of lecture in previous studies (Lund & Stains, 2015; Yik et al.,2022). Inclusion of these factors in future research would provide a more complete picture of enablers and barriers to implementation of active learning.

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