

R E S E A R C H R E P O R T



# Findings from classroom observations of 58 math and science faculty

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# S U M M A R Y

A new classroom observation instrument, the Teaching Dimensions Observation Protocol (TDOP), was used to observe 58 math and science faculty teaching undergraduate courses at three universities in the spring of 2012. This report is intended to provide a broad-brush summary of the institution and discipline specific findings of our observations. In addition, we discuss the advantages that data obtained with the TDOP pose over other existing instruments, as well as challenges associated with using the TDOP. Finally, we discuss future developments that will address these limitations and plans for future research.

## Background

In the spring of 2012 a team of three researchers conducted classroom observations of 58 math and science faculty in three public research universities as part of the Culture, Cognition and Evaluation of STEM Higher Education Reform (CCHER) project based at the Wisconsin Center for Education Research at UW-Madison.<sup>1</sup> The CCHER study is investigating the cognitive, socio-cultural, and organizational factors that shape instructional decision-making and practices in postsecondary institutions.

A core theoretical proposition guiding this study is that teaching is best understood as a multi-dimensional phenomenon in which various elements interact with one another over time. Thus, the common approach of conceptualizing postsecondary teaching solely as the regularity with which certain teaching methods are used (e.g., lecturing, small group work) is an overly reductionist approach that obscures the complexity of classroom practice. This stance is partially an artifact of the reliance on questionnaires with which to study postsecondary teaching, and we argue that classroom observations are a far more appropriate way to measure this complex phenomenon.

Research universities were selected for this study due to the large number of undergraduates being trained in STEM disciplines at these institutions. The three study sites had similar undergraduate enrollment, external research funding, and pedagogical improvement initiatives underway at the time of data collection. The disciplines included in this study are math, physics, biology, geology, and chemistry.<sup>2</sup> The course component of interest in this study was the class lesson, popularly known as the “lecture.” That is, laboratory and discussion sections, tutorials, field-work, and online components of courses were not observed. The instructors self-selected into the study and thus the results should not be generalized to the larger population of faculty at these institutions. Most courses observed in this study had between 26 and 200 students and were taught by either full professors or non tenure-track instructors. For more information about the study sample see Appendix A.

Each instructor was observed on two occasions by researchers who sat in the back of the class and coded the instructor’s behaviors every two minutes using the Teaching Dimensions Observation Protocol (TDOP). The TDOP is a classroom observation protocol that contains five categories of codes that represent important facets of instructional practice: teaching methods, pedagogical moves or strategies, teacher-student interactions, cognitive engagement of students, and the use of instructional technology.

Importantly, the TDOP is not designed to measure the quality or efficacy of instruction, but results in a nuanced portrayal of the actual classroom behaviors of faculty. Thus, the instrument does not measure any underlying scales related to instruction. Prior to gathering data in the field, the three researchers underwent a rigorous training program in order to establish inter-rater reliability (IRR). For more information about inter-coder IRR see Appendix B.

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<sup>1</sup> This study is supported by the National Science Foundation (Award DRL-0814724).

<sup>2</sup> For institutions where different departments could be included in these broad disciplinary classifications, multiple departments were included in the study. For example, Departments of Mathematics and Applied Mathematics would be included under the single descriptor of “math” in this study.

## Major Findings

### **Different types of lecturing are the dominant teaching methods currently in use**

Teaching methods as conceptualized in the TDOP are those overt, observable pedagogical techniques that constitute either modes of delivering course material and/or discrete instructional activities.

- The most commonly observed teaching methods across the three study sites was lecturing, with different types of lecturing observed in over 40% of all two-minute intervals. Among the various forms of lecturing, the most prevalent are the use of lecturing with pre-made (e.g., slides) and hand-made (e.g., writing or drawing on the chalkboard) visuals. The use of these latter forms of lecturing exceeds that of other forms, such as “straight” lecturing (i.e. no visuals or interactions), lecturing with demonstrations, or interactive lecturing through extensive Q&A with students.
- The use of lecturing is relatively consistent across all institutions and disciplines, suggesting that a repertoire of teaching methods, with lecturing at its core, exists across the study sites. However, considerable variation exists across institutions and disciplines in regards to the other dimensions of instruction, indicating that relying on teaching methods alone to describe instructional practice masks important differences.
- After lecturing, the most observed teaching method is small group work. This variation is evident in the cognitive engagement often associated with small group work (i.e., students articulating their own ideas).

### **Different pedagogical strategies or “moves” are being utilized**

In contrast to teaching methods, pedagogical strategies or moves are distinct instructional behaviors that are independent from any particular pedagogical technique or curriculum, and instead refer to personal mannerisms or stylistic features of instruction.

- The use of humor by the instructor, as measured by audible laughter by students in response to jokes or anecdotes, varies among the institutions and disciplines in the study.
- Illustrations are extended anecdotes or metaphors that translate abstract principles from the course into real-world phenomenon that can be understood through experience and/or without content expertise.
- Research suggests that effective instruction includes clear verbal markers of transitions between topics (i.e., organization) and particularly important points (i.e., emphasis) that students should remember (Perry & Smart, 1997). Organization and emphasis were observed in 8% and 5% of all observed 2-minute intervals, respectively.

### **Question types characterize the nature of many teacher-student interactions**

- Faculty pose many different types of questions to students throughout a class period, with the most frequent ones being display questions that seek new information (e.g., What is combustion?).
- Other question types include rhetorical questions to which no student responses are expected or received and comprehension questions (e.g., Do you understand?).

- When students pose their own questions they primarily ask for clarification about the course material (i.e., comprehension questions), with very few instances of students asking new, original questions of their own (i.e., novel questions).

### **Cognitive engagement sheds light on student experiences in the classroom**

Cognitive engagement refers to the types of intellectual activity students may experience in the classroom as inferred by trained researchers. Since three codes in this category were revised after data collection at Institution A, data are reported for these codes only for Institutions B and C. The default mode of cognitive engagement in the observed classes was where students are in a mode of “passive listening.” Thus, the TDOP codes for cognitive engagement capture those observed instances where other types of engagement were taking place.

- Receiving, recalling, or memorizing information was the most prominent form of cognitive engagement that was observed directly at Institutions B and C. In these instances students were clearly presented with definitions, formulas, or terminology with the intent that they remember these facts.
- Problem-solving occurs when students are explicitly asked to engage in working out problems or equations through desk work, small group work, or display questions posed to the entire class.
- Very few instances of students being asked to create their own ideas were observed across all institutions.
- Making connections to the real-world through illustrations and/or demonstrations was observed consistently across all study sites.

### **Chalkboards and PowerPoint slides are the dominant instructional technologies in use**

Instructional technology refers to all digital and non-digital tools that are used by faculty during their classroom instruction.

- The most dominant technologies in use include the chalkboard (38% across all institutions) and PowerPoint slides (47% across all institutions).
- Hand-held clicker response systems were observed regularly at Institution C (13%) but far less so at Institutions A (1%) and B (1%). This is largely due to a campus-wide initiative at Institution C to outfit classrooms with clicker technology and to teach faculty how to integrate them into their teaching.
- New digital technologies including digital tablets and movies/simulations were also observed. Movies and simulations were observed far less frequently.

**TABLE 1.** Proportion of 2-minute intervals each teaching practice was observed by institution.

	Total Sample (n=58)	Institution A (n=20)	Institution B (n=18)	Institution C (n=20)
<b>Teaching Methods</b>				
Lecturing	.21	.23	.20	.19
Lecturing w/pre-made visuals (e.g., PowerPoint)	.48	.54	.43	.46
Lecturing w/hand-made visuals (e.g., chalkboard)	.44	.43	.49	.41
Lecturing w/demonstration	.03	.02	.06	.02
Interactive lecture (i.e., 2+ questions posed)	.02	.05	.00	.02
Small group work	.09	.11	.02	.15
Desk work	.06	.03	.03	.09
Multi-media	.01	.01	.01	.01
<b>Pedagogical Moves</b>				
Humor	.07	.11	.06	.06
Illustration or anecdote	.10	.14	.09	.08
Organization	.08	.11	.07	.06
Emphasis	.05	.08	.06	.03
Assessment	.05	.00	.02	.12
<b>Teacher-Student Interactions</b>				
Rhetorical questions	.09	.15	.09	.04
Display questions (i.e., seeking new information)	.36	.40	.20	.48
Comprehension questions	.11	.13	.07	.12
Student novel question	.01	.01	.00	.01
Student comprehension question	.09	.10	.05	.13
Student response to teacher question	.13*	N/A	.13	.26
<b>Cognitive Engagement</b>				
Articulating	.06*	N/A	.03	.14
Receiving and memorizing	.18*	N/A	.34	.21
Problem-solving	.12	N/A	.06	.13
Creating	.01	.00	.00	.01
Connecting to real-world	.09	.11	.09	.08
<b>Instructional Technology</b>				
Chalkboard	.38	.30	.49	.35
Overhead projector	.07	.09	.03	.08
PowerPoint	.47	.48	.42	.52
Clickers	.05	.01	.01	.13
Demonstrations	.03	.02	.06	.02
Digital tablet	.07	.13	.00	.07
Movies or simulations	.01	.00	.01	.01

\* = These proportions only include data from Institutions B and C. The version of the TDOP used to collect data at Institution A either did not contain these codes, or contained different definitions of the codes from the other research sites.

### **Disciplinary differences in teaching are important to take into account**

Faculty teaching behaviors vary considerably by disciplinary affiliation (see Table 2), which indicates that data aggregated by institution masks important variations among departments.

- Different types of lecturing vary by discipline. Lecturing with pre-made visuals was observed regularly among biology (69%) and geology (76%) faculty, with math (18%), chemistry (36%) and physics (35%) faculty using this approach much less frequently. Lecturing with hand-made visuals (e.g., chalkboard writing) was used regularly by math faculty (78%), followed by chemistry (59%) and physics faculty (55%), and finally by biology (17%) and geology (18%) faculty.
- Small group work was observed more frequently among biology (16%) and physics faculty (13%), with other groups utilizing this method less regularly. Desk work was mostly observed in math classrooms (12%).
- The use of illustrations and anecdotes also varies across disciplines. Physics (17%), geology (15%) and biology (12%) faculty used this pedagogical move the most frequently, whereas math (3%) and chemistry (6%) faculty infrequently used illustrations in their teaching.
- Math faculty pose more display questions (51%) and comprehension questions (22%) than faculty in other disciplines. Similarly, students' responses to instructor questions were observed most often in math classrooms (38%).
- Types of cognitive engagement also vary by discipline. Problem-solving was regularly observed in math classrooms (27%), while connecting to the real-world was seen most often in physics (16%) and geology (13%) classrooms.
- Finally, instructional technology use varies considerably among disciplinary groups. Chalkboards are used most often by math faculty (70%), whereas PowerPoint appears to be the tool of choice for biology (74%) and geology (70%) faculty. Physics faculty are the most regular users of clickers (10%) and demonstration equipment (13%), while digital tables were used mostly by math (13%) and chemistry faculty (14%).

It is important to point out that the highest degree of clicker use was observed among physics faculty at Institution C, where a campus-wide initiative advocating for the use of this technology had taken place recently. While clickers were used by some physics faculty at Institution A, and to a far lesser degree at Institution B, neither group of physicists used the technology with the same regularity as those at Institution C.

**TABLE 2.** Proportion of 2-minute intervals each teaching practice was observed by discipline..

	Math n=14	Biology n=14	Chemistry n=9	Geology n=12	Physics n=9
<b>Teaching Methods</b>					
Lecturing	.11	.25	.20	.28	.20
Lecturing w/pre-made visuals (e.g., PowerPoint)	.18	.69	.36	.76	.35
Lecturing w/hand-made visuals (e.g., chalkboard)	.78	.17	.59	.18	.55
Lecturing w/demonstration	.00	.01	.04	.01	.13
<b>Interactive lecture</b>					
(i.e., 2+ questions posed)	.02	.06	.01	.01	.01
Small group work	.06	.16	.08	.03	.13
Desk work	.12	.06	.04	.01	.07
Multi-media	.00	.02	.00	.02	.01
<b>Pedagogical Moves</b>					
Humor	.08	.12	.07	.06	.03
Illustration or anecdote	.03	.12	.06	.15	.17
Organization	.07	.07	.11	.09	.07
Emphasis	.04	.06	.08	.06	.03
Assessment	.02	.06	.06	.04	.08
<b>Teacher-Student Interactions</b>					
Rhetorical questions	.13	.07	.08	.08	.09
Display questions (i.e., seeking new information)	.51	.38	.30	.24	.35
Comprehension questions	.22	.07	.09	.04	.11
Student novel question	.01	.02	.00	.01	.01
Student comprehension question	.13	.11	.08	.06	.06
Student response to teacher question	.38 *	.11 *	.17 *	.12 *	.15 *
<b>Cognitive Engagement</b>					
Articulating	.08 *	.10 *	.06 *	.03 *	.16 *
Receiving and memorizing	.26 *	.31 *	.24 *	.29 *	.22 *
Problem-solving	.27	.06	.09	.02	.16
Creating	.00	.02	.00	.01	.00
Connecting to real-world	.03	.10	.05	.13	.16
<b>Instructional Technology</b>					
Chalkboard	.70	.14	.41	.12	.57
Overhead projector	.01	.07	.09	.15	.03
PowerPoint	.13	.74	.40	.70	.37
Clickers	.02	.05	.06	.05	.10
Demonstrations	.00	.01	.04	.01	.13
Digital tablet	.13	.05	.14	.00	.00
Movies or simulations	.00	.02	.00	.01	.00

\* = These proportions only include data from Institutions B and C. The version of the TDOP used to collect data at Institution A either did not contain these codes, or contained different definitions of the codes from the other research sites.



# Teaching as a multi-dimensional phenomenon

A multidimensional measure of teaching practice must go beyond merely capturing the different dimensions of classroom practice independently. Such a measure should also examine the extent to which these dimensions are inter-related. For instance, it is not only important to know how often lecturing with pre-made visuals was observed among physicists, but also how often this method was observed with the other dimensions of teaching. Here we provide an example of these relationships for math and physics using graphing techniques from social network analysis.

**FIGURE 1.** Affiliation graph for math instructors (n=14).

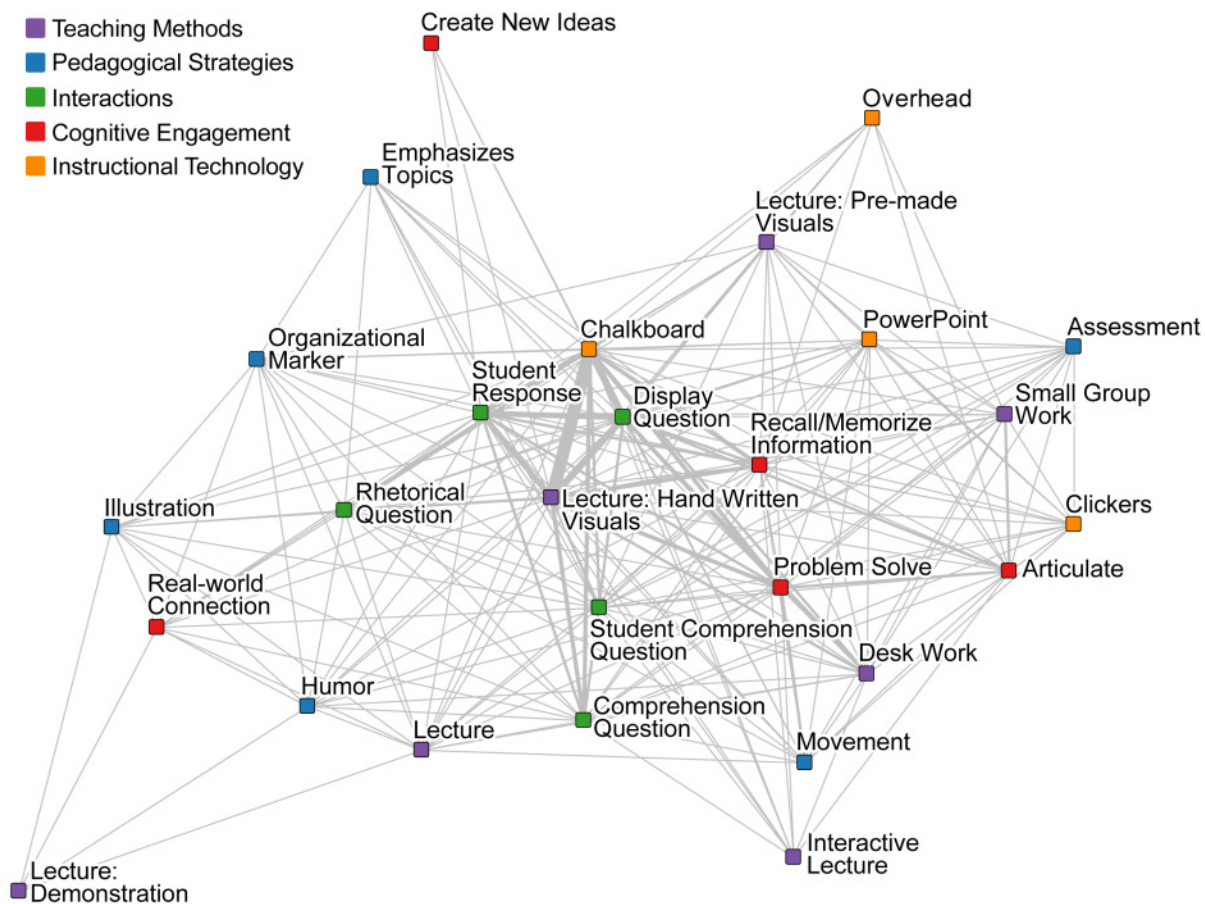


Figure 1 illustrates the inter-relationships within and between each dimension of teaching among the mathematics instructors in our sample. The lines connecting the different TDOP nodes vary in thickness on a scale of 1 – 8 depending on the frequency with which each pair of codes was co-observed in the same two-minute interval. Thus, thicker lines represent more frequently co-observed teaching practices. However, the positions of the nodes are not completely arbitrary. Using an iterative “spring embedding” procedure, the nodes are moved to locations in the graph that minimize the variation in line length.

From the graph in Figure 1 it can be seen that the mathematics instructors—as an aggregated group—had a core repertoire of practice that frequently made use of lecturing with hand written visuals at the chalkboard while posing display questions prompting student responses. The primary forms of cognitive engagement during these activities were problem solving and recalling/memorizing definitions and equations. Secondly, these instructors supplemented their core repertoire with desk work, comprehension and rhetorical questions, and responding to student-posed conceptual questions. Less frequently, these instructors utilized pedagogical moves such as organization, emphasis, illustrations, and humor. Occasionally instructors engaged students in articulating ideas, making real-world connections, and creating, as well as lecturing with slides using PowerPoint or the overhead projector.

**FIGURE 2.** Affiliation graph for physics instructors (n=9)

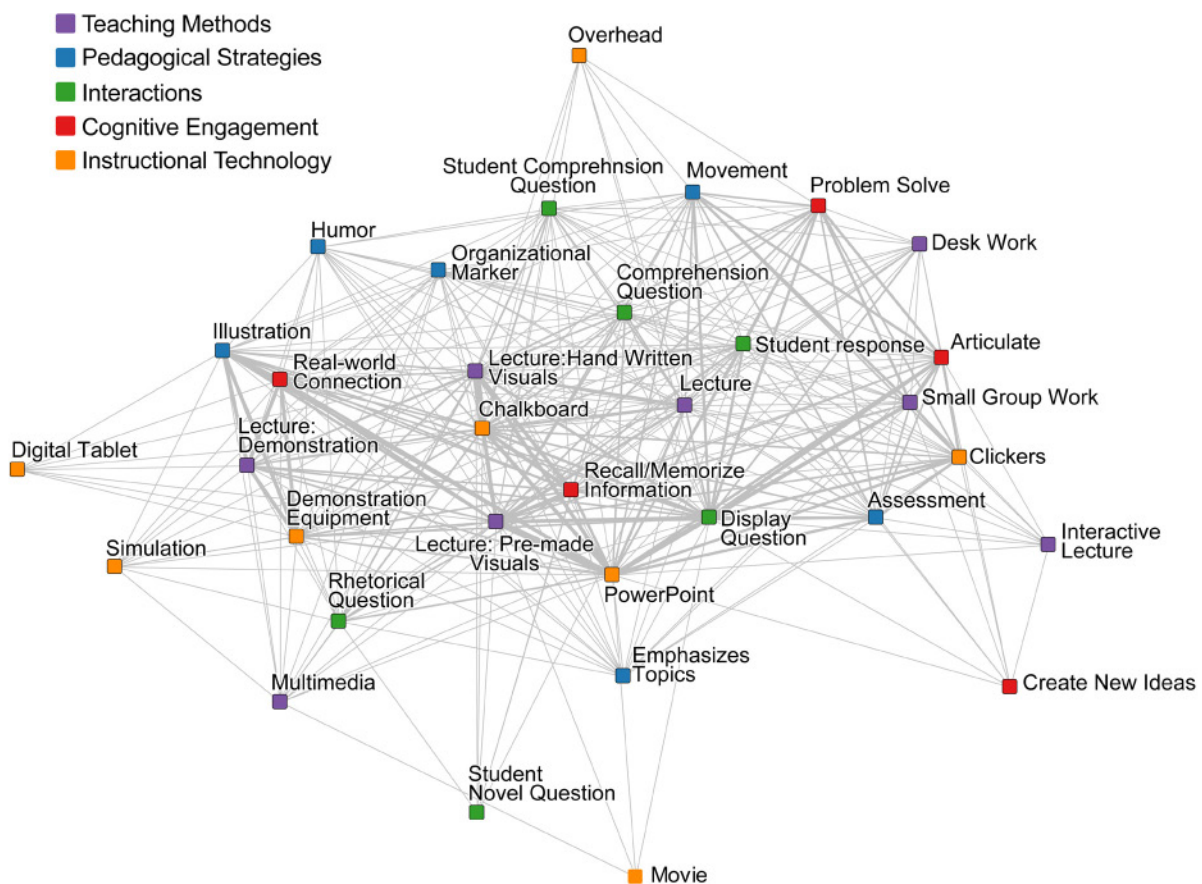


Figure 2 illustrates the graph for physicists, which is considerably more “dense” than the mathematics instructors’ graph in Figure 1. Rather than a core/periphery structure, the physics instructors’ graph reveals a wider variety of relationships within and between the different dimensions of instruction. There are three relatively distinct repertoires at work. First, on the left side of the graph, it can be seen that these instructors frequently lectured with demonstrations that involved illustrations and engaging students in real-world connections. Second, the instructors used a combination of other lecturing styles (hand-written visuals, pre-made visuals, and “straight” lecture) while engaging students in recalling/

memorizing information and posing display and comprehension questions that prompted student responses. Third, these physics instructors frequently used clickers to engage students in articulating ideas and problem solving in small group situations. In each case the core practices were supplemented with additional pedagogical moves, interactions, and technologies.

To be clear, there are no rigid boundaries separating the three repertoires in Figure 2. Nevertheless, the positions of the nodes suggest a degree of distinctness to these different sets of relationships. More importantly, the graphs help to visualize disciplinary differences and the relational specificity to these differences. The graphs can also be used to examine practices among individual instructors. Indeed, such graphs are significantly easier to interpret due to the reduction of lines and nodes.

## Conclusions

In this research report we presented findings from the classroom observations of 58 math and science faculty at three public research universities. The data obtained through the use of the TDOP provides a detailed account of faculty teaching that opens up the “black box” of what kind of instruction happens in postsecondary settings. Since prior studies of faculty teaching have relied primarily on self-reported survey and/or interview data, while also focusing exclusively on a single dimension of teaching (i.e., teaching methods), very little detailed information is known about the types of instruction that students actually experience in the classroom.

With the TDOP instrument a more nuanced portrayal of faculty teaching is possible. For example, faculty teaching is often critiqued for relying too heavily on the “lecture,” which is a common descriptor for the entirety of an individual’s classroom behaviors. Yet the data reported here clearly demonstrate that teaching is actually comprised of multiple dimensions of practice and cannot be adequately described through a sole focus on teaching methods alone.

The heterogeneity of lecturing styles speaks to the more general relational framework in which these data should be interpreted.<sup>3</sup> That is, faculty’s instructional actions in the classroom are not only comprised of teaching methods, but also strategic pedagogical moves, interactions with students, cognitive engagements, and the use of instructional technology. The regular combinations of actions within and between dimensions constitute “pedagogical repertoires” that can be examined individually or through distinct groupings (e.g., institutions, disciplines, tenure rank, etc.). Thus, a math instructor may have a repertoire that consists of the regular use of lecturing through handwritten visuals on a chalkboard. These teaching techniques and use of instructional technology may be interspersed with occasional humor and emphasis, as well as posing questions that engage students in problem solving. Another math instructor may also regularly lecture with handwritten visuals on the chalkboard, but may never pose questions or place emphasis on certain aspects of the curriculum.

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<sup>3</sup> Note that here we are only speaking of describing teaching-related actions in the classroom, and not the relations that influence how instructors teach.

Another way in which pedagogical repertoires can (and should) be examined is at the disciplinary level. Instructional behaviors such as the use of desk work, question-posing, problem-solving cognitive engagements, and chalkboards appear to be more widely used by math faculty than by others. Similarly, lecturing with PowerPoint, using illustrations, and asking students to make connections to the real world was observed more often among biology, geology, and physics faculty than other groups. These results support prior research suggesting that different disciplines have unique approaches to teaching.

It is important to acknowledge limitations to the TDOP instrument and the data reported here. For example, since the instrument focuses on 2-minute intervals there are instances in which some codes appear to be used in combination with others when it may not necessarily be true. This is especially problematic when examining combinations of codes or comparing the proportion of instructional time across codes. Another limitation is the extensive effort required to establish inter-rater reliability. While many codes require very little training to ensure reliability, some of the pedagogical moves (e.g., emphasis and organization) and cognitive engagements proved to be quite challenging in this regard. Finally, the TDOP does not capture levels of student engagement or the “quality” of instruction. There are many instances in which different instructors use the same techniques but with dramatically different results. In part, this is because the TDOP is focused on the instructor’s observable behaviors and does not account for the engagements and motivations of students. Yet this limitation merely suggests that the TDOP should be used in combination with other data collection tools, such as student interviews, surveys, and focus groups. More specific curricular features may also be integrated into the TDOP, but this would require a high level of content expertise. For the time being, the TDOP emphasizes those aspects of pedagogical action that can be directly observed regardless of the observer’s level of familiarity with the content.

## Next steps

At the present time the TDOP is being digitized into a website-based format that will enable users to more easily collect, manage, and analyze data. Accompanying the website will be a TDOP User’s Manual that will describe the development of the instrument, technical information, how to use the instrument, and how to analyze and interpret resulting data. In the near future the TDOP will be used in studies to examine data driven decision-making in academic departments as well as the role of instructional practice in studying student persistence in STEM disciplines. Additional plans for the instrument include developing a database of “coding rules” that specify concrete examples and situations in which certain codes should be applied. These rules will be accompanied by video examples of faculty teaching so that analysts can see what TDOP codes look like in practice. While these rules will not exhaust all possible scenarios in which certain codes should be applied, we hope that it provides users with a foundation to conduct their own reliability training. With the TDOP website and improve training procedures, we then hope to train teams of analysts as part of a large-scale effort to study faculty teaching on regional, national, and international scales.

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<sup>4</sup> See Becher, T., & Trowler, P. R. (2001). *Academic tribes and territories*. Open University Press; Saroyan, A. & Snell, L.S. (1995). Variations in lecturing styles. *Higher Education*, 33, 85-104; Marincovich, M. (1995). Concluding remarks: On the meaning of disciplinary differences. *New Directions for Teaching and Learning*, 1995(64), 113-118.

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## APPENDIX A. Description of sample

	n	Percentage
<b>Sex</b>		
Female	23	40%
Male	35	60%
<b>Discipline</b>		
Math	14	24%
Physics	9	16%
Chemistry	9	16%
Biology	14	24%
Earth/space science	12	20%
<b>Level of course</b>		
Lower division	36	62%
Upper division	22	38%
<b>Size of Course</b>		
25 or less	4	7%
26-50	18	31%
51-100	8	14%
101-200	21	36%
201-300	4	7%
300 or more	3	5%
<b>Position type</b>		
Lecturer/Instructor (non tenure-track)	25	43%
Assistant Professor	9	16%
Associate Professor	3	5%
Professor	21	36%

## Appendix B. Inter-rater reliability results from TDOP training

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	Teaching Method	Pedagogical Moves	Interaction	Cognitive Engagement	Instructional Technology
Analyst 1/Analyst 2	0.850	.789	.652	0.833	0.926
Analyst 1/Analyst 3	0.905	.834	.700	0.727	0.888
Analyst 2/Analyst 3	0.889	.815	.850	0.621	0.728

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Note: These data reflect inter-rater reliability tests for data collected at Institutions B and C. Results from the inter-rater reliability tests for data collected at Institution A were comparable, with the exception of lower scores for the pedagogical moves category. Overall, scores improved with the revised version of the TDOP due to improved code definitions and analyst familiarity with the instrument.



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