Not Your Grandma's Lecture: Interactive Lecture in Calculus I in the CSPCC Two-Year Cases

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Calculus I is a gateway course for STEM majors and, according to 2010 data, taken by nearly one in five students nationwide in a two-year college (Blair, Kirkman, & Maxwell, 2013). Identifying features of successful Calculus I programs was the primary goal of *Characteristics of Successful Programs in College Calculus* (CSPCC) (Bressoud, Rasmussen, Carlson, Mesa, & Pearson, 2010). As part of the CSPCC study, four two-year colleges were selected for in-depth case study. The Calculus I instructors in the two-year cases described their typical method of instruction as a mix of lecture and opportunities for students to engage in the course content (e.g., fielding questions, working problems in class). Some instructors felt compelled to defend their use of lecture and contrasted it with traditional lecturing. Thus, we came to refer to this instructional method as *interactive lecture* (Burn, Mesa, & White, 2015).

The study we report herein sought to provide a detailed description of the features of an interactive lecture, as described by CSPCC participants, and to examine whether interactive lecture shares features associated with high-quality instruction, such as active learning or validation strategies. The findings can guide mathematics instructors in using this instructional method more effectively. In addition, developing a more nuanced understanding of interactive lecture may help stave off potential criticism leveled at oversimplified conceptions of lecturing that portray it as detrimental to student learning and engagement. We begin with a review of relevant literature, followed by our methods, presentation of findings and, finally, implications for practice and research.

Relevant Literature

Our field continues to debate the merits of different instructional methods, although research does not support an exclusive reliance on any single approach (National Mathematics Advisory Panel [NMAP], 2008). Instead, high levels of learning result from a combination of factors, including engaging in meaningful mathematics, spending time on task, and receiving supportive feedback on learning (Kuh, Kinzie, Buckley, Bridges, & Hayek, 2006; NMAP, 2008; Saxe & Braddy, 2015). Many forms of instruction can create these conditions for learning.

Traditionally, "lecture" is a term that describes a set of behaviors: instructors standing at the front of a classroom, writing the content of the day on the board (e.g., examples, definitions, theorems, and proofs), and occasionally turning to ask or answer student questions in a "sage-on-the-stage" approach. The resilience of this instructional method, however, suggests that this stereotypical description obscures other important dimensions of instruction. For example, Hora and Ferrare (2013) found that, relative to other STEM faculty, mathematics instructors used lecture with chalkboard at a higher rate but were more likely to engage students in desk work, had higher rates of responding to student questions, and a higher amount of in-class problem solving.

In this study, we do not seek to defend lecturing. Rather, we seek to identify features of interactive lecture and to understand whether interactive lecture, as enacted in the CSPCC two-year case study institutions we visited, shares features of active learning or other practices associated with high-quality instruction. *Active learning* is an umbrella term for a set of instructional strategies ranging from in-class worksheets to flipped classes that seek to engage students with the content in the classroom so the instructor can monitor their understanding. Active learning is key in this discussion, because a meta-analysis of over 250 studies revealed that student performance increased by nearly half a standard deviation in classes that used any form of active learning compared to traditional lecture classes (Freeman et al., 2014).

Further, research suggests that historically underserved students—particularly first-generation college students who are unfamiliar with college culture—benefit from instruction that incorporates *validation strategies* (Rendon, 1994), strategies that help affirm students' contributions as valuable to learning, such as calling students by name, working one-on-one, praising students, and encouraging students to see themselves as capable of learning. Indeed, analysis of student-survey data from the CSPCC study revealed that higher levels of confidence, enjoyment, and interest in Calculus I were linked to classroom interactions that acknowledge students (e.g., showing multiple methods to solve problems, listening, explaining, fielding questions) and having encouraging and available instructors (e.g., comfort asking questions, shows how to work problems, makes class interesting, and believes students are capable of understanding) (Mesa, Burn, & White, 2015).

Given this information, we set out to answer the following research questions:

1. What are the defining features of an interactive lecture in the selected CSPCC two-year colleges?
2. In what ways does interactive lecture share features of active learning or other practices associated with high-quality instruction in two-year colleges?

Methods

Data for the study derive from faculty interviews, student focus groups, and classroom-observation data collected during site visits to four two-year colleges selected for case study in the CSPCC study (see Table 1). The selected colleges were identified as having larger gains in students' confidence, interest, and enjoyment of mathematics over a semester of Calculus I and higher retention rates into Calculus II based on faculty and student survey data collected in fall 2010 across a stratified random sample of two- and four-year colleges and universities. For a full account of the major findings of the CSPCC two-year cases and details of case-study selection, see Burn and colleagues (2015) and Hsu, Mesa, and The Calculus Case Collective (2014), respectively.

Three of the four calculus programs studied ran on a 16-week semester with roughly 250 minutes of instruction per week spread over two class periods. The fourth program ran on a 14.5-week semester and met for 150 minutes per week on a 2- or 3-class per week schedule with an additional 75-minute mandatory computer lab.

The instructors interviewed were all full-time tenured or tenure-track faculty (5 women, 10 men) and held either a PhD in mathematics $(n = 5)$ or educational leadership $(n = 1)$, or a master's degree in mathematics $(n = 5)$ or computer science $(n = 1)$. The remaining instructors held an MAT $(n = 3)$. The instructors ranged in experience, with two-thirds $(n = 10)$ having more than 10 years of experience teaching math and 3 with over 25 years of experience.

We analyzed faculty-interview and student focus-group questions that asked about what occurred during a typical class, the use of technology, and how instruction supported and motivated students. The findings and interpretations emerged through case-study methods employing an iterative process of thematic coding and reflective memo writing, influenced by grounded theory approaches (Emerson, Fretz, & Shaw, 1995; Yin, 2003).

Classroom observation data included problems solved in the lesson (Problem Logs) and the type of interaction between instructors and students collected in 5-minute blocks (Activity Log), (see White & Mesa, 2012). These data were subjected to quantitative analyses that included the average duration of lessons and problems and the frequency of various problem features (e.g., who performed the problem—instructor, individual student, students at the board, or students working in pairs or groups—frequency of technology use).

Table 1
Two-year college cases and data analyzed in the present study[a]

College	US Region (FTE)	Calculus I Sections/Term (Class Size)	Instructor Interviews[b]	Student Focus Groups
City College	Southeast (<5000)	2 (30–35)	1[c]	4, 43 students
Urban College	Midwest (<10,000)	3–4 (30)	5	1, 26 students
Rural College	West (<3000)	1 (30)	1	1, 42 students
Suburban College	Southeast (>10,000)	10 (30)	8	3, 39 students

[a] Other interview data collected during site visits but not analyzed in this study included department chairs, deans, and learning center staff $(n = 28)$.

[b] All instructors were full-time tenured or tenure track.

[c] Two additional Calculus I instructors were interviewed using a different protocol and they are excluded from this analysis.

Findings

We begin by presenting four common features of interactive lecture described by the majority of instructors and corroborated by student focus groups: (a) lecturing, (b) using technology, (c) fielding student homework questions, and (d) providing time during class for students to work problems. Following this, we present findings from the classroom observation data related to the number of problems solved during a typical class session and who was involved in solving the problems. Lastly, we present findings on how faculty described that their instructional method supported and motivated students.

Four Common Features of Interactive Lecture

First, all 15 instructors said their typical class included lecturing, although the amount of time spent lecturing varied by instructor. Three said they lectured the entire class period, ten said they lectured from a minimum of 15 to 20 minutes and sometimes for an entire class period, and two said they limited their lecture to 15 to 20 minutes. A second feature of interactive lecture described by 12 instructors (80%) was to use technology during class to demonstrate or motivate Calculus I concepts. The most popular technology for such demonstrations was the graphing calculator, which was the preferred technology for students as well. In addition, six instructors (40%) mentioned using more advanced software for classroom demonstrations, such as Maple, Geogebra, or Wolfram Alpha. A third feature of interactive lecture described by 10 instructors (75%) was to field student homework questions at the start of class. We remind the reader that, in the programs studied, classes met two or three times per week, which could influence the need to field student homework questions.

A final feature of interactive lecture described by 12 instructors (80%) was providing time during class for students to work problems. Eight instructors said they ended class (10 to 15 minutes) with students working in informal pairs, and four interwove lecture with student work throughout class. Almost all instructors $(n = 11)$ described that interacting with students during class was the main way they had to assess whether students were learning. For example, one instructor described walking around and looking at students' work, stating, "Then if I find something, I talk to the student and discuss the problems." Instructors also cited concerns about students' ability to seek help outside of class due to either a dearth of qualified Calculus I tutors at the campus learning center or students' busy work schedules. The in-class practice time was also valued by students who described that it provided space to reflect on their learning in a classroom where the pace was typically characterized as brisk.

Problems Solved during Class

Classroom observation data $(n = 8$ unique instructors) confirmed that significant class time was spent solving problems. In a 60-minute segment of class, an average of 7 problems $(SD = 1.52)$ were solved and each problem took roughly 9 minutes $(SD = 1.85$ minutes). On average, instructors were involved in solving 88% of the problems, followed by students working individually $(M = 19\%)$, in pairs $(M = 8\%)$, or in groups of three or more $(M = 6\%)$. It is noteworthy that there was wide variation by instructor. For example, one instructor solved all problems alone, while in another class there was a mix of participants involved in problem solving: instructor (82%), whole class (55%), students in pairs (18%) and students in groups (18%). Technology use in the observed classes was relatively low, with the scientific calculator used on average in 10% of the problems, following by the graphing calculator (6%). The overall low use of technology could be due to the topic covered on the day of the observation, such as l'Hôpital's Rule, which may not be conducive to technology use.

Supporting and Motivating Students during Class

Instructor responses to how their instructional method supports and motivates students fell naturally into three categories: (a) engaging, motivating and connecting with students, (b) teaching for understanding, and (c) leveraging personal attributes to support student learning.

In the first category, instructors described engaging and motivating students by bringing in relevant and interesting topics, by helping students see that mathematics is "great stuff," or by demonstrating the "wow factor" of mathematics. Instructors also described different ways they connected with students during class, such as trying to meet students where they are, building a culture of support for all students (especially struggling students) through group work, providing lecture notes that make the ideas more manageable to students, having clarity and organization in presentation to the benefit of students, lecturing less and making the students do the bulk of the work in class, and having students reflect on their learning. Consider the description of the classroom environment provided by one student:

> I've taken a couple math classes already to get here and, uh, some teachers … they don't really ask questions or encourage when students ask questions. They kind of … not attack but they [are] like, 'What do you mean why?' But the teacher I have right now, I think he's probably one of the best ones I had that makes me feel comfortable [laughs].

In the second category, instructors described supporting students by teaching for understanding: emphasizing "whys," focusing on the logic of mathematics over memorizing, leveraging multiple representations of mathematical concepts, and ensuring students had the basics to be prepared for the follow-on course. In focus groups, students were asked how important it was that they memorize what their instructor did in class—a question many students struggled to answer. The general sentiment was captured by one student who said, "It's basically about being able to do this process rather than memorizing something and then having the same answer on a test."

In the third category, instructors described their personal attributes as supporting and motivating student learning, including their approachability, knowledge of mathematics, personal charisma, high expectations, presentation style, and effective in-class questioning patterns. Half of the instructors $(n = 8)$ cited using their interpersonal skills to establish relationships and build trust with their students, to lighten the mood in class, to excite the class about mathematics, and to give students positive feedback. One instructor described that she frequently let students know "they're going the right way" by giving them "a miniature pat on the back." In her experience, students "feed off that really well." Another instructor stated that his excitement for the subject of mathematics "can open a door and perhaps motivate a student" and that he gladly plays the role of "this weirdo who is teaching the class [and] likes it so much."

Table 2
"Lecture" and "Interactive" Features of Interactive Lecture

Lecture Features
Instructors lecture for various amounts of time (minimum ~15–20 minutes).
Instructors solve problems (average of 7 problems in 60 minutes, 88% solved by the instructor at the board).
Instructors use technology to demonstrate or motivate concepts and in problem solving (instructors reported higher levels of use than was observed).
Instructors motivate students through content relevance and "wow factor."
Interactive Features
Instructors field student homework questions (75% of instructors started class with this).
Instructor and students interact during lecture (e.g., whole-class discussion during lecture, in-class problem solving interwoven with lecture).
Students solve problems in class individually, in pairs, or in groups (~53% of instructors ended class with this).
Instructors interact with students during problem solving (used to evaluate learning, establish relationships with students, and provide feedback).

Discussion

This study sought first to identify the defining features of an interactive lecture in the CSPCC two-year cases. Table 2 displays the features of interactive lecture, separated by features that are "lecture" and those that are "interactive."

Our second research question sought to understand whether interactive lecture shares features of active learning or other practices associated with high-quality instruction in two-year colleges. The main form of active learning associated with interactive lecture was to have students work problems during class. Of the 15 instructors interviewed, eight stated they routinely ended class with students working problems at least in pairs, which was sometimes facilitated by the use of worksheets. While this activity may lack the intensity of formal group work or problem-based learning, it does qualify as a legitimate form of active learning in the Freeman and colleagues' (2014) study.

Lastly, there was evidence that interactive lecture in this sample included validation strategies (Rendon, 1994). More specifically, instructors stated that in-class interactions with students served the purpose of connecting with students partly to provide timely feedback on their learning but also to build a culture of trust and support, to create a classroom atmosphere where students are comfortable asking questions, and to give students positive feedback.

Implications for Practice

The findings of this study suggest that mathematics instructors in two-year colleges may be mischaracterizing or oversimplifying when they describe their method of instruction simply as "lecture." Only three instructors (20%) described lecturing the entirety of the class session. The remaining 12 instructors used a combination of lecture and activities that are legitimate forms of active learning: in-class problem solving involving individual, pair, and group work, demonstrations, and fielding student homework questions (Freeman et al., 2014). Thus, we encourage instructors who routinely use all the features in Table 2 in their classes to steer away from describing their instructional method as simply "lecture" and to enhance the description, particularly when under pressure to provide evidence of the quality of their instruction. Instructors should instead describe what they do in the classroom in ways that highlight dimensions of instruction that attend to active learning, student engagement with mathematics, and student–instructor interactions that promote relationship building, opportunities for feedback, and validation strategies. This description is especially appropriate for instructors who interweave the interactive features throughout a class period as opposed to "bookending" their instruction with interactive features (e.g., starting with fielding homework questions, ending with students working problems and lecturing for the majority of time in between).

That said, the features of interactive lecture we identified suggest opportunities for professional development in the two-year context that can be useful in helping faculty improve their interactive lecture approach. For example, in the present study, the main forms of student–instructor interactions were fielding student homework questions; in-class questions; facilitating individual, pair, or group problem solving; and supporting and motivating students. This suggests the potential benefit of professional development focused on effective classroom questioning techniques to ensure that questions are opportunities for instructors to probe and monitor students' understanding (Mesa, 2011), appropriate use of praise (Dweck, 1986), and facilitating small-group problem solving, including the development of challenging academic tasks (Dubinsky, Matthews, & Reynolds, 1997; Rogers, Reynolds, Davidson, & Thomas, 2001). In addition, incorporating research-based notions such as *validation strategies* (Rendon, 1994) into faculty professional development activities can help mathematics instructors more fully understand their active role in fostering validation and enhance a practice that the instructors in this study only implicitly described.

Implications for Research

In this study, we sought to flesh out what "interactive lecture" means in the context of Calculus I classrooms in the two-year college setting. We invite the field to adopt this phrase or to provide an alternative descriptor of this instructional method. In addition, the study is important in providing a rich description of two factors previously identified in the CSPCC study as positively contributing to student outcomes: (a) classroom interactions that acknowledge students and (b) encouraging and available instructors (Mesa et al., 2015). Lastly, this study revealed two important dimensions of classroom instruction that should be further explored in future research in the two-year context: (a) pedagogical strategies intended to bolster students' perception of relevance and excitement towards mathematics and (b) student–instructor interactions that effectively incorporate validation strategies and use of praise.

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Conclusion

This study provides a detailed description of the interactive lecture that prevailed in Calculus I classrooms in the two-year colleges selected as case studies in a national study of calculus. The study revealed that the classroom instruction in the selected colleges included traditional lecture and other features of high-quality instruction, such as active learning and student–instructor interactions aimed at providing corrective and timely feedback and building relationships. Overall, the findings are important toward helping two-year college mathematics instructors develop a richer understanding of interactive lecture and one they can communicate to stakeholders in a climate where lecturing is typically cast in a negative light.

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