Leveraging Universal Design for Learning to Scale Inquiry-Oriented Instruction on Sequences and Series

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Although research has shown benefits of inquiry-oriented (IO) instruction for student learning, it has also been reported not to benefit all students equally. In this report, we illustrate how UDL can serve as a generative framework for (re)designing IO instruction in such a way that attends to the individual needs and strengths of students, working toward creating an equitable learning environment. We will also share UDL-aligned teaching practices for IO classrooms, including those fostering relationship-building, multimodal participation, and equitable assessment.

Keywords: Inquiry-Oriented, Universal Design for Learning, Equity

Research shows that inquiry-based (IO) instruction can support student learning, but it does not always benefit all students equally (Johnson et al., 2020). Without intentional instructional design, it may privilege certain voices or patterns of participation. For instance, Reinholz et al. (2022) showed women's (vocal) participation levels correlated with performance; when participation was equal, the gap disappeared. Other studies have similarly shown that IO classrooms can limit meaningful participation for students from groups historically marginalized in mathematics. For example, women can be excluded or dismissed during group work (Brown, 2018; Ellis & Alzaga Elizondo, 2023), and even when women offer valuable insights, their ideas may not surface in whole-class discussions (Ernest et al., 2019). Together, these findings suggest that although IO instruction holds great promise, it must be intentionally crafted to ensure that all students can participate in meaningful ways. Yet, what it means to intentionally craft this teaching remains underexplored.

One place where this issue becomes especially visible is in efforts to scale inquiry-oriented instructional materials. Research on scaling has made progress by focusing on the mathematical learning trajectory, resulting in streamlined task sequences (e.g., Larsen et al., 2013). However, this work has paid less attention to how to build in instructional supports into these materials that also address students' diverse strengths. As Armstrong (2011) notes, "classrooms are social environments, and all social environments are places where inclusivity happens—*or fails to happen*" (p. 53). Inquiry-oriented classrooms require careful attention to inclusivity, as they are structured around social interactions, which can promote inequities when not treated carefully (Battey & McMichael, 2021). Moreover, because IO instructional materials often originate from the work of a small group of students, if not intentionally designed to accommodate a broad range of learners, they risk privileging a narrow subset of the class.

Guided by Universal Design for Learning (UDL), we have been working to address these challenges to scale IO instructional materials on sequences and series in Calculus 2. In this report, we share our instructional (re)design decisions, informed by UDL principles and student interviews, as we scaled a task sequence that originated from the work of two students.

Theoretical Perspective

We engaged in design research (Cobb & Gravemeijer, 2014) to develop our IO instructional materials, following an iterative, cyclic process with three core components: (1) task (re)design, (2) implementation, and (3) data analysis. Each component informs the rest; the analysis of the

data collected during one implementation informs the redesign of the tasks that will be implemented (and subsequently analyzed) in the next. Traditionally, researchers have started with pairs of students and then scaled the tasks to a whole class setting once the tasks seem to appropriately support students in learning the content goals. However, the limited research on scaling the materials to a whole class setting has had a limited focus on streamlining the mathematical learning trajectory, rather than also attending to other social experiences that students might encounter with such learning environments. Because of this, we have adopted Universal Design for Learning (UDL) to help us also focus on other aspects of the environment. UDL complements the theoretical design frameworks that we have used to design the task sequence (e.g., Realistic Mathematics Education, Gravemeijer & Doorman, 1999; Gravemeijer & Terwel, 2000) by extending our focus from not only engaging students in meaningful mathematics but also other factors that might further support their engagement, representations, and strategic action.

We draw on UDL to support instructors to build environments that recognize and respond to the diverse identities, strengths, and needs of learners (Gargiulo & Metcalf, 2023). UDL is not a fixed set of techniques, but a generative framework for instructors that assumes from the outset that all learners are variable: in how they feel engaged in the content, how they communicate, and how they make sense of mathematics (Chardin & Novak, 2020; Tobin & Behling, 2018; Hall, 2012). Lambert (2024) outlined key elements of UDL-aligned math classrooms: (1) promoting engagement through meaningful tasks and supportive environments, and (2) supporting strategic action by helping students understand themselves as learners and offering equitable feedback and assessment, and (3) attending to mathematical representation by valuing multimodality and investing time in core ideas. (See Figure 1.)

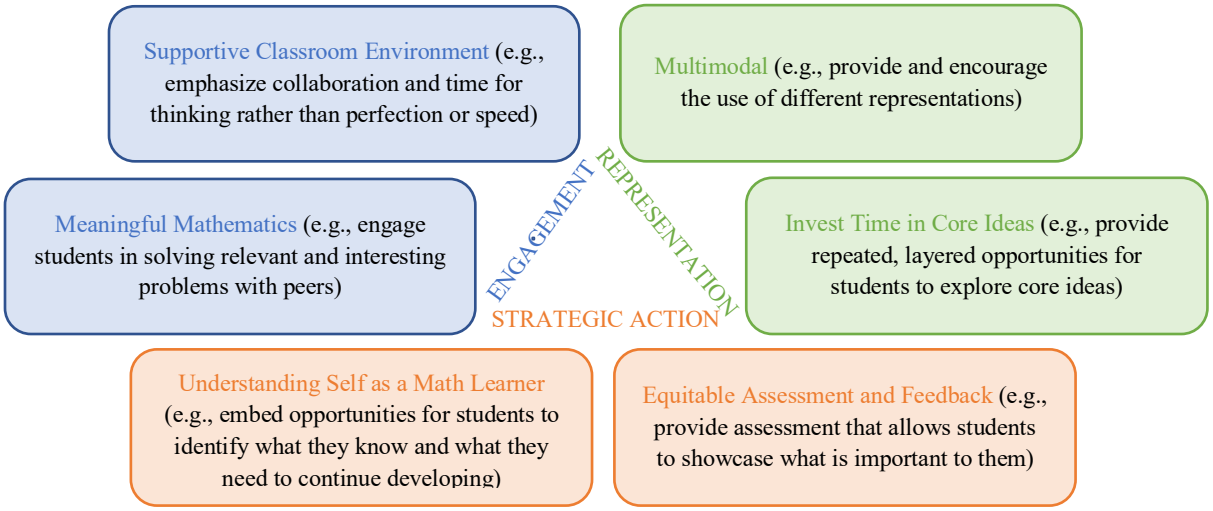

Figure 1. Key Elements of UDL-Aligned Math Classrooms.

We drew on UDL as an analytic tool during our analysis phase of the first whole-class design cycle. In particular, we wanted to (re)design teaching practices that recognize and respond to the diverse identities, strengths, and needs of learners. By teaching practices, we mean both the instructor's goal (i.e., task) and the observable actions taken toward accomplishing their goal (i.e., procedure) (Nachlieli and Elbaum-Cohen, 2021). When planning to scale the materials, we set out to test out the teaching practices that we anticipated would relate to UDL engagement,

representation, and strategic action goals. For instance, we planned to implement standard-based quizzes and portfolios instead of exams (procedure) to allow assessment to be more individualized (task related to understanding self as a math learner).

Together, we use these theories to investigate the following research questions: 1) *What are some UDL-aligned teaching practices for IO classrooms?,* and 2) *How can UDL guide instructional (re)design choices to develop such practices?* Answers to these research questions provide two main contributions. First, practical teaching practices that instructors can adapt to open up their classroom to serve a broader range of students. And, secondly, methodological suggestions for IO designers who want to scale up their materials in an inclusive way that takes into consideration the different strengths and needs of their students.

Methods

The data for this report comes from a larger project in which we are designing an IO calculus 2 unit on sequences and series. We have designed a set of tasks that, with the instructor's support, guide students to reinvent several key theorems of this unit: Monotone Convergence Theorem, all convergent sequences are bounded, and several tests for series convergence (Vroom et al., 2025; Vroom & Davis, 2024; Vroom & Alzaga Elizondo, 2025). Our design research to date has included implementing, analyzing, and revising the instructional sequence first with a pair of students in a laboratory design experiment (Spring 2022) and then in Vroom's calculus 2 class (Spring 2025). In this report, we focus on (a) some of our instructional design choices, informed by UDL and the previous paired-implementation, (b) the calculus 2 students' experiences with the instruction via interviews, and (c) redesigned instructional choices based on UDL and these experiences.

The primary source of data for this redesign relied on individual semi-structured interviews with students (13 of the enrolled 25 students in the Spring 2025 course), which were conducted a week after the course meetings ended. During these interviews, we shared our interpretation of some of the research findings on inequitable outcomes and experiences in IO classrooms (i.e., an elaborated version of the first paragraph of this paper). This was a purposeful decision to attempt to bring students into the conversation that our research aimed to address – to do research *with* the students rather than *on* them (inspired by Stinson, 2008). Following this reading, we discussed how, if at all, the research findings resonated with the students' experience during the sequences and series unit. We also asked students to share aspects (about the instruction, peer interactions, the course structure) that supported and discouraged their participation. See Table 1 for the participants self-reported identity markers (from a survey early in the semester).

Table 1. Self-reported identity markers.

Student	Gender	Race/Ethnicity	Sexuality
Aaron	Man	Chinese/White	Did not report
Alice	Female	White	Straight
Anna	Woman	White	Straight
Caleb	Male	White	Straight
Gabe	Male	Caucasian	Straight
Imran	Male	Indian	Heterosexual
Jack	Man	White	Did not report
Jason	Male	Asian	Straight
Micah	Transmasc/nonbinary	Caucasian	Asexual and Queer

Nina	Woman	White	Bisexual
Oliver	Male	White	Straight
Shaan	Male	Asian	Straight
Trevor	Male	White/Caucasian	Straight

Prior to the classroom implementation, we designed a set of teaching practices that we anticipated would align with UDL principles. For example, we planned to use Padlet, an online platform where students can post (anonymously if they choose), to provide multiple ways to participate. Following the implementation, we began analyzing these practices, initially focusing on interview transcripts from four students who identified with gender identities historically marginalized in mathematics (i.e., "woman," "female," or "Transmasc/nonbinary"). We prioritized these students' perspectives because our instructional design explicitly sought to respond to documented gender inequities in IO classrooms (Brown, 2018; Ellis & Alzaga Elizondo, 2023; Earnest et al., 2019; Johnson et al., 2020; Reinholz et al., 2022). In analyzing these transcripts, we first identified excerpts in which students referred to specific procedures associated with a teaching practice. We used these excerpts to refine our original list of practices. For instance, students commented on the practice of working in self-selected groups. Although the instructor typically uses this strategy to foster peer relationships, students' responses helped us recognize its potential alignment with UDL principles, even though we had not initially framed it that way. After identifying relevant quotes from the four transcripts, we compiled a table linking them to teaching practices. We then open coded the linked excerpts for how students perceived the practices' tasks, grouping responses to identify shared purposes. We compared these student-identified goals with our original intentions and revised (i.e., expanded, created, or maintained) practices accordingly. This process yielded a set of UDL-aligned teaching practices, which we then used to frame our analysis of the rest of the transcripts. We then read the remaining interview transcripts, coding for additional student references to these practices and incorporating their perspectives to elaborate and further refine them. Here we share a subset (eight) of these practices.

Results

Below we describe our (re)design choices. We organize this section by discussing practices that we 1) expanded, 2) created, and 3) maintained after the class implementation. In Table 2, we overview the redesigned teaching practices.

Table 2. UDL-Aligned Teaching Practices.

Revised Practice	UDL Reasoning
1. Incorporate anonymous discussion board to pose questions to provide an alternative way to participate	Representation: multimodal
2. Incorporate anonymous discussion board to create a safe space to take risk and mitigate perceived biases in discussion	Engagement: supportive classroom environment
3. Incorporate discussion board for students to increase peer engagement by providing a space for them to see or respond to each other's contributions	Engagement: supportive classroom environment

4.	Implemented standard-based quizzes and portfolios (instead of exams) to allow students to share *their* mathematics and what *they* find important	Strategic action: equitable assessment and feedback
5.	Implemented standard-based quizzes and portfolios (instead of exams) to support students to focus on their learning on their timeline rather than memorizing or their grades	Strategic action: understanding self as a math learner
6.	Allow students to choose groups that they will stay with throughout semester to build relationships	Engagement: supportive classroom environment
7.	Make sure everyone has a partner, preferable group of 2, to increase opportunities to contribute and reduce possibilities of exclusion	Engagement: supportive classroom environment
8.	Regularly share that the expectation is to share rough draft ideas (rather than perform polished ones) to normalize mistakes and emphasize growth	Engagement: supportive classroom environment

Expanding UDL-aligned teaching practices. Originally, we intended to *incorporate anonymous discussion board to pose questions to provide an alternative way to participate*. This was aligned with UDL in the sense that students would have options for how they shared their ideas so they could find a way that felt comfortable for them (*Representation: multimodal*). To do this, the instructor projected a class Padlet at the front of the room. We found evidence from the student responses that this task was realized as Anna noted:

> It's kind of an equal chance for everybody to share their ideas. Even with people, like me, that don't like talking in front of big groups of people. She kind of just let us post it on there to talk about it.

Additionally, we learned that the anonymous feature of the Padlet also supported students to feel comfortable taking risks in sharing their ideas (*Engagement: supportive classroom environment)*. For instance, Micah explained:

> I like how there's the option to be anonymous on it, and I think that takes away a lot of the fear that because of who you are, you might be perceived, or taken differently in you asking your question, and I think it gets rid of any opportunity for that, because then it's like, 'Oh. astounding chameleon asked a question'.

The students also shared that the Padlet increased peer engagement by providing a space for them to see or respond to each other's contributions (*Engagement: supportive classroom environment*). For instance, Trevor explained:

> I think the Padlets - those were helpful to me because I was kind of able to see like what other people were thinking rather than just my group members... It was helpful to see again other people's like opinions or ideas for a question.

For these reasons, we redesigned this teaching practice by expanding it to three different practices (see Table 2, lines 1-3).

In setting up the course, we decided to *implement standard-based quizzes and portfolios (instead of exams) to allow assessment to be more individualized*. This was aligned with UDL in the sense that it would give students more agency in demonstrating their understanding of what they knew and what they needed to learn (*Strategic action: understanding self as a math learner*). We found evidence that the assessment was more individualized in two different ways. First, similar to what we anticipated, it supported students to focus on their learning on their

timeline rather than memorizing or their grades (*Strategic action: understanding self as a math learner*). As Anna said:

> I'm not stressed out trying to... memorize it. Rather with this way, I feel like I could actually sit down and take my time and actually try to learn it rather than just trying to memorize everything in time for exams.

Second, it also allowed students to share *their* mathematics and what *they* find important (*Strategic action: equitable assessment and feedback*). For instance, Imran explained:

> [the portfolio was] showcasing your skills instead of doing a math test where it doesn't really show *you as a student*... [The portfolio] showed *our* understandings. It showed *our* interpretations of standards themselves. [emphasis added]

Thus, we redesigned this teaching practice by expanding it in two ways (see Table 2, lines 4-5).

Creating UDL-aligned teaching practice. One teaching practice that the instructor regularly uses in her courses was *not assigning groups in order to allow students to work with who they would like*. We were not attentive to this practice during our initial design; but, through our conversations with students, we realized that it was a practice that could align with UDL by supporting relationship building (*Engagement: supportive classroom environment*). Micah elaborated on how choosing the groups and staying with the same group was important to them:

> chosen groups versus assigned groups have it have a huge impact on what that group dynamic looks like ... there is a much, much lower chance of [exclusion] happening in chosen groups, and I think that sort of just adds another level of safety to it.

They continued to explain that staying with their chosen group helped them to "establish a consistent relationship" and that "made it so that it was a space where you guys were working together, not a space where you guys were forced together like you were actually collaborating, not just sitting next to each other doing your work." We also got insight from students about how the group size (partners vs groups of three or more) allowed (or prevented) individuals to contribute and reduced the possibility of exclusion (*Engagement: supportive classroom environment*). Students shared that it's easier to exclude yourself or others in groups of three. Shaan explained:

> in the third unit I didn't participate enough, but there was another new person who was talking to [my partner]. So, I was fine, like, I was not interacting. If ... it was just two of us, I would have like added more like to the conversation.

Trevor also explained that larger groups can lead to exclusion because he tries to find similarities with others to connect over:

> let's say we're in a group of three... And then there's two people who are more similar to each other. I think that those two people are gonna interact with each other more just because they're similar and maybe unintentionally exclude the person that's different from them.

However, when there is paired groupwork, "You gotta find, like the similarities between your partner [and] figure out how you can have... a functional group". Thus, in our redesign, we added two practices (see Table 2, lines 6-7).

Maintaining UDL-aligned teaching practice. Originally, we intended to *regularly share that the expectation is to share rough draft ideas (rather than fully formed polished ones) to normalize mistakes and emphasize growth*. This was aligned with UDL in the sense that such framing supports students to take mathematical risks by creating a safe and welcoming environment. (*Engagement: supportive classroom environment*). The students shared this

practice was realize, for instance, when Nina said, “I never felt like I had to be perfect in my understanding of everything in order to participate.” Similarly, Alice elaborated:

> I can actively give like not a fully correct answer and not feel ashamed of it. I feel like that really helps my learning. And when we worked in our small groups in class... we would all build off of each other, and we'd be... comfortable with each other not having the full answer.

Because of this feedback, we kept this practice in our redesign (See Table 2, line 9).

Discussion

Returning to our first research question, we crafted a set of UDL-aligned teaching practices for IO classrooms (see Table 2). Student feedback suggests these practices can help mitigate inequities documented in prior literature (Brown, 2018; Ellis & Alzaga Elizondo, 2023; Earnest et al., 2019; Johnson et al., 2020; Reinholz et al., 2022). We attribute this, in part, to the theoretical grounding UDL provided for scaling IO instructional materials in ways that attend to student experiences beyond the mathematical trajectory. For example, we reconsidered grouping not only in terms of mathematical productivity but also in relation to students’ comfort with taking risks and sharing emerging ideas. Similarly, UDL encouraged us to broaden what counts as participation. Although IO instruction often privileges verbal contributions, incorporating tools like Padlet helped us recognize non-verbal participation, thereby expanding whose ideas could be acknowledged and built upon. Although our insights arose from materials on sequences and series in Calculus 2, we see potential relevance across a range of IO contexts. We do not claim these practices work universally, but they may provide a starting point.

Importantly, and in response to our second research question, our work illustrates how UDL can serve as a generative framework for designing IO instruction. From the outset, UDL shaped the design of our practices by hypothesizing procedures that could accomplish a task related to UDL’s goals (engagement, representation, and strategic action). Post-implementation, we used UDL to analyze how these practices functioned, and student perspectives were crucial in this reflection. By inviting students into the research centering their perspectives, we were able to identify practices that supported them across the three UDL dimensions, practices that we at times did not even anticipate.

One notable point of divergence between our findings and the prior literature concerns group formation and size. Earlier research in mathematics education often recommends teacher-assigned groups of three or four to mitigate status differences (e.g., Cohen & Lotan, 2014). In contrast, our students emphasized that working in chosen, stable pairs reduced the risk of exclusion and fostered a sense of safety and collaboration. We interpret this difference as reflecting the distinct emphases of UDL. Whereas the groupwork literature often foregrounds managing status dynamics, our UDL framing foregrounded agency and supportive relationships. This suggests that grouping practices may be more context-dependent than the literature sometimes implies. For IO classrooms guided by UDL, chosen groups may offer advantages over assigned groups by fostering learning environments where students feel safe sharing emerging ideas, a key characteristic of IO instruction (Kuster et al., 2018).

This work takes initial steps toward scaling IO instructional materials in ways that extend beyond streamlining meaningful mathematical tasks. Future research could further examine how UDL interacts with specific IO practices across varied institutional settings, offering insight into how these practices might be refined and scaled sustainably.

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