“Making it Culturally Relevant”: A Visual Learning Analytics System Supporting Teachers to Reflect on Classroom Equity

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Abstract: Experience is an important dimension of learning (Roth & Jornet, 2014). Research has drawn attention to the importance of equitable learning environments where all students experience opportunities to contribute to knowledge-building activities. Working in partnership with five middle school science teachers and two instructional coaches, we have developed a visual learning analytics system that aims to support teachers in reflecting on variability in students’ classroom experiences linked to race and gender. This system, the Student Electronic Exit Ticket (SEET), captures and visualizes student experience data related to three constructs that prior research indicates are reflective of equitable classroom experiences: coherence, relevance, and contribution. We share findings from a qualitative study of how the SEET system visualizations supported teachers and coaches to recognize and respond to classroom inequities. Further, we discuss our design process with teachers and how this partnership influenced the visual feedback display.

Introduction

It is critical to make science meaningful to students from a wide variety of backgrounds, identities, languages, and cultures. Equitable practices in science classrooms are supported when we are able to make science culturally relevant to all students. Students can have inequitable learning experiences when teaching and subsequent actions are idealized in potential harmful ways based on learner attributes, such as geography, zip code, language, religion, gender, race, ethnicity, or socio-economic status (Brown, 2019). For instance, a student’s way of speaking or their choice of clothes can deem them as not intelligent to the teacher, and these perspectives on ability can be rooted in biases around culture and race. This has been called the “Black Tax” in science classrooms, which refers to the “additional hurdle or cost faced by many students of color” (Brown). This black tax narrative is not only restricted to Black communities, instead it frames the narrative of many non-white populations who experience challenges (Brown, p.13).

In order to disrupt this narrative and create equitable learning environments, teachers need ways to more deeply recognize, understand, and engage with their students’ experiences of the classroom. Attending to students’ experiences involves integrating the practical, intellectual, and affective dimensions of classroom life (Roth & Jornet, 2014). Understanding students’ experience in the classroom can help science teachers alter their instruction in ways that make it more culturally sustainable for a diverse student body, across gender and race (Paris & Alim, 2017). Penuel and Shepard (2016) note that helping teachers to understand the socio-cognitive dimensions of classroom experience (attending to the social nature of cognition) and the socio-cultural dimensions (attending to the value of participation in disciplinary ways of knowing and doing) of their students’ experiences can support efforts to promote equity in classrooms.

Taking a student-centered approach and gathering reliable information about students’ experiences in the classroom sheds light on the learning community and processes from students’ perspective (Penuel & Watkins, 2019). Drawing on recent efforts to produce ‘Equity Analytics’ as a quantitative approach to view patterns of equity and inequity in classroom participation across gender and race (Reinholz & Shah, 2018), we have developed an innovative system of surveys and visualizations that captures and visualizes student experience data revolving around three constructs: coherence, relevance, and contribution. The Student Electronic Exit Ticket (SEET) system includes three major components: multiple versions of a student survey that can be administered anonymously in classrooms, a data management component, and a corresponding analytical system for teachers that visualizes these survey responses and disaggregates them by gender and race. In this study, we examine how different visualizations of student experience data during design process of the tool can support teachers to understand and reflect on the experiences of diverse students in their classrooms. We also report on how adopting a user-centered design process helped in selecting and adapting the user interface of the SEET system.

In our research, we worked closely with five middle school science teachers and two instructional coaches to design the visualizations and understand affordances offered by different representations for
identifying patterns of equity and inequity of experience in science classrooms. Our ultimate goal is to develop analytic and instructional routines that help teachers to interpret these data and use them to reflect on their classroom instruction. The following research questions guided this paper: 1. How do different data visualizations create different opportunities for teacher’s sense-making? 2. In what ways does visualizing students’ experience data promote teachers’ reflections on equitably supporting students’ needs?

Conceptual framework
We argue that supporting equity involves understanding learners’ experiences based on three constructs: coherence, relevance, and contribution (Reiser et al., 2017, NASEM, 2018, Miller et al., 2018). To this end, we have created an experience based formative assessment premised on these constructs called the Student Electronic Exit (SEET). SEET data provide targeted information about learners’ experiences within a particular academic unit and classroom. Each construct comprises a unique set of questions. SEET questions related to coherence ask students whether they understand how current classroom activities contribute to the purpose of the larger investigations in which they are engaged. Coherent learning experiences appear connected from the students’ perspective, where the progression of learning experiences is driven by student questions, ideas, and investigations (Reiser et al., 2017). Questions related to relevance ask students to consider the degree to which lessons matter to the students themselves, to the class, and to the larger community (Penuel et al., 2018; NASEM, 2018). For contribution, SEET questions ask students whether they shared their ideas in a group discussion, heard ideas shared by others, and whether others’ ideas impacted their thinking. The aim of using the SEET assessment in the classroom is not to judge teachers or identify students’ understanding of disciplinary content. Rather, the SEET assessment is intended to help create an environment for improving teacher instruction and diminishing classroom inequity.

Overview of the SEET system
The SEET system uses experience sampling to gather information about students’ classroom experiences. Experience sampling is a technique for gathering data about how people feel and think during random intervals in their lives (Larson & Csikszentmihalyi, 2014). In our context, the teacher decides when to sample students’ classroom experiences. The SEET system uses a thirteen-item survey to gather information from students on their perceptions of coherence, relevance, and contribution for that day’s classroom experiences. This survey is designed to take only a few minutes for students to complete at the end of a class session. It is important to note that the SEET system does not collect names of students, provide individual-level feedback to teachers, nor does it display disaggregated data across gender and race if there are fewer than three students belonging to a particular gender or race to protect the anonymity of the students. Key steps in the workflow for teachers and students are: (1) The teacher administers a survey that asks students to reflect on today’s classroom experiences, (2) Each student in the class receives the survey and reports on their experience, (3) Student responses from the entire class are combined and displayed to the teacher through a visual analytics dashboard based on the three focal constructs, (4) Teachers reflect on the student experiences’ with visualizations.

Data and study methods
We recruited five middle school science educators (two identified as female and three as male) and two science instructional coaches (one female and one male) from a large, urban school district in the Midwest to participate. The materials for this study included 30 different visualizations across three constructs. Round one included visualizations from a made-up dataset created by the first author that had significant differences in student experience across gender and race. For round two, we drafted visualizations using actual classroom data collected from a middle school science teacher’s classroom in the same school district. This teacher was not a study participant.

In Round One, three science teachers (one female and two male) and two science instructional coaches (male and female) were asked individually and in pairs to reflect on selected visualizations from a pool of 14 different visualizations. Each session took 30-35 minutes. Teachers were shown a visualization and asked to think aloud as they tried to interpret its meaning and its implications for teaching. Think aloud protocols are a technique for understanding the cognitive processes of the participant when a stimulus is introduced during decision making (Ericsson & Simon, 1993). After each think-aloud, teachers completed a short interview about each visualization. During the interviews, we probed teachers about their thinking, asking them “What are you wondering about, assuming this is a real classroom? What is the need in your classroom that this visualization points to, if this were your classroom’s data?”. After seeing all the visualizations, we asked teachers to tell us which ones they believed to be most useful for helping them monitor their students’ classroom experiences.
For Round Two, the same investigative process was followed with two science teachers (one female, one male) and the number of visualizations was increased to 30 (the 14 from Round One and 16 additional visualizations). New visualizations were created to address teacher feedback from Round One.

To gain deeper insights into how specific visualizations supported teachers’ reflection processes, we analyzed our qualitative data with an inductive lens using a grounded theory approach to identify themes (Charmaz, 2014). The first author went through all the transcripts line by line to develop a preliminary code book. This preliminary codebook was developed into a mutually exhaustive and exclusive code book as shown in Table 1, after two authors met multiple times to reach consensus. The high-level codes included “Data reflection”, “Interpretability and Recommendations”. Within each high-level code there are multiple sub-codes. The two coders established high levels of interrater agreement calculated using Cohen’s Kappa; κ= 0.88 for Data Reflections and κ= 0.89 for Interpretability and Recommendations.

Table 1: Coding teachers’ responses to the data visualizations

<table>
<thead>
<tr>
<th>High level Codes</th>
<th>Sub-codes</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Data Reflection</td>
<td>● None: Teacher finds nothing</td>
<td>● Find: “If you answered questions last, did you share any ideas out loud today. That is really striking to me.”</td>
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<td>● Find: teacher finds a particular data pattern.</td>
<td>● Inquire: “I am curious about these don't know categories, what commonalities are there between those statements?”</td>
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<td>● Inquire: Teachers reflect on student experience data possible relationships between constructs and findings.</td>
<td>● Instructional need or aim: “So, I would think that's like something on me to make sure I'm tying it back to like our bigger picture.”</td>
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<td>● Instructional need or aim: Teacher thinks on what can be the next steps.</td>
<td>● Pointing towards equity: “Did anyone else share? 85% say others shared? To me, this kind of points to a sense of inequity.”</td>
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<td></td>
<td>● Pointing towards equity: Teacher talks about students from non-dominant groups and BIPOC, and/or when teacher talks about “equity” or “inequity” across gender or race.</td>
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<tr>
<td>Interpretability and recommendations</td>
<td>● None: Teacher doesn’t interpret and provide recommendations</td>
<td>● Hard Identification: I'm wondering about if I think the volume bubbles are kind of a neat idea for an easy glance piece. But I'm also maybe struggling to find how helpful they are.</td>
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<td></td>
<td>● Hard Identification: Hard to interpret the visualization</td>
<td>● Easy Identification: &quot;One of the things just like overall style, I like looking at the colors, color gradation a lot better.”</td>
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<tr>
<td></td>
<td>● Easy Identification: Easy to interpret the visualization</td>
<td>● Attraction or compelling point: “It's a lot better, a lot easier to figure out what's being visualized. Than the size” or “I like this, I think the most because it gives me data per population”</td>
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<td></td>
<td>● Attraction or compelling point: Teacher reasoning about the compelling and attractiveness in visualization</td>
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<td></td>
<td>● Anytime Principle: Teacher has some anytime principle in mind on how to read visualization. Sense-making process tied up with the anytime principle. (Russel, Stefk, Pirolli, &amp; Card, 1993)</td>
<td>● Anytime Principle: “But it took like, my eyes kept fluttering back and forth, and back and forth, and back and forth. And then I was just jotting. We've got tables, bar graphs, what do I need to look at first? So finally, I just started looking at this table.”</td>
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<td></td>
<td>● Design Suggestion: Teacher provide design suggestion for interpretation of the visualization</td>
<td>● Design Suggestion: “I would like them portioned out per population. so, you could quickly see the smallest population or the largest percentage”</td>
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<td></td>
<td>● Construct Suggestion: Teacher provide suggestion related to constructs of the survey item SEET</td>
<td>● Construct Suggestion: “Knowing my students, that's the comfort area. If I don't understand that question, or I don't know it, I'm gonna choose.”</td>
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Results and discussion
During round I, the first three teachers selected visualizations: Horizontal Stacked Bar Chart, Line Chart, as these supported them in the sense-making of data. Both coaches selected: Choropleth Heat map, Bubble chart, and Line chart, provided the most appropriate sense-making to them. From round II with two science teachers they selected visualizations: Horizontal Bar Chart, Choropleth Heat map, Line Chart. We finalized the ‘Horizontal bar chart with ‘%yes’ only’, ‘Choropleth Heat map with disaggregation of gender and race’ and ‘line chart’ into the visual feedback displays of SEET shown below created from a made-up dataset.

We found that the side-by-side bar charts facilitate easy comparisons, when they show a simple percentage of “yeses”. We implemented small multiples of bar charts (figure 1), adjacent to each other as suggested in prior work by Heer, Bostock & Ogievetsky (2010). The choropleth heat map in figure 2 displays data disaggregated by gender and race, the first three rows at the top display different genders, and then there is intentional space to start with different race categories. These categories are based on the U.S. census. Each column at the top belongs to lesson or measures (coherence, relevance, and contribution) related questions. Color facilitates thinking about the dimensions of experience that are being measured. Although the color is less precise as compared to position based visual representations such as scatterplots, bar graphs, and line graphs, they provide a significant ‘big picture’ information to the users (Albers et al., 2014). The line chart in figure 3 is one type of implementation of its three variants: i) line chart visualized by correct average of SEET measures over time (see Figure 3) ii) line chart visualized by gender and race data over time for a single classroom period iii) line chart visualized by each question over time for a single classroom period. All these visualizations and variants are implemented in the SEET system.

Now we present data from teachers and instructional coaches for both rounds on how their interaction with different visualizations supported several reflections on equity and instruction prompted different reflections on student experience and how it helped in shaping the design of the user interface of the SEET system.

Data reflection
Analysis of our qualitative data suggests that these selected visualizations in figure 1, 2, 3 can be effective in supporting teachers to reflect on their students’ classroom experiences. We now present a few cases where teachers expressed their perceptions related to student experience.
Mr. Alan (Science Teacher), all names are pseudonyms, when asked on what they see looking at data patterns in the horizontal disaggregated bar chart visualization (Figure 3), he responded:

So, within the kind of the first boxes up here, there is a group of students who seem to be making more sense of the driving question and how it ties into less, and then other students. And it’s looking like it’s just the white students better following along better with the driving question board and how it ties into what they did in class and the unit, things like that. But then when we transition down to the other questions, matters to the people in the community and things like that. I’m not really seeing much there in terms of some overall takeaways, except for maybe the Black students. I don’t know how many are in there, though. Like, is that 18%? That one kid or total of five? Okay, there? Yes, I see it now. Total five kids. Okay. So, one of those five kids found that it tied back to their community and things like that, but the four of the five basically didn’t notice that. (Mr. Alan, round II)

Mr. Alan in his reflection on what is the instructional need based on this classroom, responded:

The instructional need would probably be making this culturally relevant to all students in the classroom, making sure that all students do find a connection to it, whatever they’re learning, because it’s clear that all students aren’t finding that connection from the lesson to what’s important to them or their community, only some students are, and it’s solely dependent on cultural background or ethnicity. (Mr. Alan, round II)

Mr. Alan showed concern about the Black students who didn’t have the same percentage of “yeses” as the other students in the classroom. He tied the classroom experience to the classroom environment: saying it was not conducive to all the students from different backgrounds and cultures. In most parts of the interview Mr. Alan was concerned about the instructional connection to minoritized students such as Asian students and how to make it a more positive environment by making lessons coherent and equitable.

Similarly, when Mr. Meer and Mr. Tim (Science Teachers) are asked what they notice from the data visualization showing change over time, how they might use this data formatively for thinking or reflecting on things in classrooms, Meer responded:

It’s interesting that overall, we see it trending upwards. Like, obviously, I feel like that’s each piece of the lesson building on itself, but super big drop off for lesson 3D for males and yeah, a big spike there for females so again, there had to be some kind of a gender disconnect when we get to lesson 3D. Yeah, lesson 3D obviously was off. So, it’d be a good starting point to look there. How can we make lesson 3D more equitable? I think it would definitely give me some empathy; especially like you said for here in coherence for females. (Meer, Round I)

While Mr. Meer pointing towards disaggregated bar chart question on coherence, he reflected:

I would definitely drive my instruction to help to target this group, clearly. This was my classes with my data, I did not do my job enriching these female students. So, that would really cause me to go back and reflect and hopefully make some changes. This piece of data allows me to just directly ask them, what did you need that I didn’t give you? (Mr. Meer, Round I)

Tim and Meer, both noticed the experience of the female students as not to the level of male students in the classroom. Meer was concerned about what he didn’t do to make the classroom experience better for the female students and how he would inquire with students to make a better classroom connection across the parts of the unit to make an equitable environment for them. Mr. Tim and Mr. Meer both agreed that over time data can be helpful for them in identifying connections across the units and also disaggregated bar charts would help them target more specifically each classroom for coherence, relevance and contribution.

Mr. John and Ms. Becky (Instructional coaches), when asked about what’s the instructional need based on the bubble chart representation, Mr. John pointed to inequity of experience related to the relevance for the students.

Deeper piece and harder the relevance question six, there's an imbalance for who this seems to apply to. There’s definitely a certain level of students who aren't feeling like this, this describes
them. So that's like a larger piece. Like, which curriculum are we using? How do we want to make adaptations larger across our district. And then thinking about the training for those pieces. If we had the time to do professional learning. What implementations will we do? (Mr. John, Round I)

Mr. John’s explanation pointed to the need for more relevant instruction for improving student experience on this construct. He indicated that few groups of students are not finding relevance with the lesson and how he can scaffold their experience with more relevant curricula that connects with their classroom experiences. He also wondered how professional learning and their implementations might help teachers for enhancing experience related to relevance. Listening to Mr. John’s conversation, Ms. Becky, talked about the result of those interventions and how it can impact the classroom.

Absolutely. And I think just techniques to incorporate some of these other pieces to help teachers make sure that all students are participating in, are able to connect to whatever it is that's going on. And also making it relevant too like, are we talking about an issue that the students can connect to that has a part of their normal life? (Ms. Becky, Round I)

Ms. Becky stressed on the importance of making sure that students contribute and make lessons relevant to their lives, and how instructional coaches can help teachers in facilitating these roles. Ms. Becky also narrated how student experience can be an opportunity for teachers to learn more and improve classroom environment while interacting with the Choropleth Heat map visualization.

I think this is a really cool opportunity for teachers to gauge their classroom and their students. Like you can see there’s a relatively high participation going on in the class verbally, but then there might be some understanding issues that are happening in kid’s heads. So, the teachers. But I think this is a really informative opportunity for teachers to say, okay, we might need to work on this a bit more. Or how do I encourage my kids to speak up. I think it’s informative for the teachers themselves. (Ms. Becky, Round I)

Ms. Becky pointed out how this representation is providing an opportunity for teachers to hear and know students’ inner voices that can totally be different from their behavior in the classroom and be useful to teachers. As interviewer asked Ms. Becky and Mr. John on what instructional need this points to as your role as district leaders and instructional coaches, Becky responded:

A lot of teaching strategies, you know, you could do a professional learning experience based on each one of these questions. And focus just on pulling that out for the teachers. Have you really included this method of instruction? Or this piece of instruction? (Ms. Beck, Round I)

Ms. Becky and Mr. John both directed on understanding student experience data with different representations as opportunities for teachers to connect with their students. And how they can use targeted strategies with the teachers to meet the instructional needs of diverse and multicultural students. They noted that the engagement level of students tied with the success of students.

In summary, teachers we worked with cared about student experience related to coherence, relevance and contribution as much as they do about the content knowledge. Teachers know experience to be an integral part of academic success for students. Visualizations that disaggregated data by gender and race help them identify issues of equity in all instances, at least this was the case in our study. We found that these visualizations supported teachers to inquire about the experience of students and consider implications for instruction. They showed care for the experience of racially minoritized students and the experience of girls, and they valued student experience data that made this visible. However, how teachers can make use of this experience data related to coherence, relevance and contribution to enrich classrooms and student lives remains an underexplored and rich phenomenon. Visual learning analytic tools can be leveraged for the sake of supporting teachers’ engagement with students’ experience in the service of creating equitable and just learning environments.

Interpretability and recommendations

Teachers’ reflection on the interpretability of visualizations showed us where their interests lie and informs user-centered design of the SEET system. Below we discuss two examples of teacher noticing and suggestions that helped in developing the user interface of the system.
Example No 1: Horizontally categorizing bar chart by gender and Race

When the interviewer posted a data display containing disaggregated vertical and horizontal stacked bar charts to Ms. Yarosh (Science Teacher) to elicit her thinking and understanding would she prefer a horizontal or vertical bar chart, she responded:

And I’m wondering if they’re bars stacked on top of each other. So that takes a bit of thinking to unpack what's happening there? Um in question three. Well, I would say that these could all be bars but proportioned out between lesson three A. So, a bar that is proportionally representative of 20%, and then one that would show stacks on stacks on top of each other, not on top of each other like this but next to each other. So, you get that quick visual like, 63%. A quick visual for each lesson, right? So, I think either way, I would like them portioned out per population. So, you could quickly see the smallest population or the largest percentage.

(Ms. Yarosh, Round I)

Ms. Yarosh initially expressed her thoughts that vertically stacked bars categorized by each lesson are hard for her to interpret the differences across race levels. She suggested that rather than stacking race categories on top of each other vertically on a bar, she would place them next to each other for a quick comparison across student populations to quickly compare. This conversation and suggestion of the teacher led to the design of a horizontal disaggregated bar chart based on categories for gender and race, see figure 1.

Example No 2: Showing only “yeses” or correct responses facilitates comparisons.

A constructive suggestion by Ms. Yarosh shaped the design of visualization, as students were answering multiple choice questions that had three response options (‘Yes’, ‘I don’t know’, and ‘No’). During the first round, we displayed all three responses, conjecturing that it would help teachers identify patterns across the response types (Figure 4(A)). The yellow color represents the percentage of the class who said ‘Yes’. Cyan represents ‘I don’t know’, and Blue represents ‘No’, to a survey question based on a particular construct. Contrary to our expectations, teachers preferred visualizing only the ‘yes’ responses.

So, I guess for me, this neutral choice doesn’t necessarily give me the information I'm seeking. I would prefer it matters or it doesn't. (Ms. Yarosh, Round I)

Analyses of additional qualitative data suggested that displaying only the “yes” responses helped teachers to compare patterns across the three constructs; many instances teachers also showed that approach helped spark discussions about the low percentage of “yeses” answers from the students, as they perceived it a simpler solution for cross comparison across questions. This also facilitated cross comparison between constructs; coherence, relevance and contribution by pointing teachers’ attention only to one value. The resulting visualization based on teacher feedback was a horizontal bar chart displaying only the ‘yes’ percentage only (Figure 4(B)).

Discussion and conclusion

The main objective of this study was to provide insights from the design process of the Student Electronic Exit Ticket (SEET) system and teachers’ thought process. We presented key teacher and instructional coaches’ experiences that played a pivotal role in finalizing the visual feedback displays. A rich understanding of student experience should support teachers to modify their instructional or curricular agenda to better promote equity in the classroom. Along with the help of teacher partners, our team has designed and developed an exemplar application supporting ‘Equity Analytics’. Shah and Reinholdz (2018) called for researchers to build tools and extend ‘Equity Analytics’ work with its applications to support equity across different disciplines. With the wide adoption of such tools, teachers can understand student experiences at scale to make classrooms equitable.
Our focus in this paper has been on analyzing how teachers perceive equity in the classroom when aided with visual learning analytics. We learned that it is imperative for researchers and system designers to have an open perspective when designing feedback dashboards and to deeply attend to teachers’ perspectives and guidance in order to ultimately bring equity to the classroom in meaningful and relevant ways. The teachers’ part of the study were from same school district and subject area (middle school science), a broader and more diverse group of teachers would be needed to further validate our findings.

Understanding student experiences can help teachers to shape classrooms to be more equitable by making them culturally relevant and sustainable (Paris & Alim, 2017; Brown, 2019), enabling all students to contribute and build on each other’s knowledge. It is critical to quantify differences in students’ classroom experiences in order to remove inequities based on characteristics such as gender and ethnicity. Ahn and colleagues (2019) discussed the value of using human-centered-design methods with teachers when designing instructor dashboards providing data on student learning. The aim of our design process was to apply such methods to explore how learning analytics tools can be adapted rather than adopted by teachers and to understand how the design process itself can foster new innovations in designing dashboards. Adapting these design methods influenced the design of the tool and helped with improvement efforts of supporting mathematics teachers. The dashboard helped to visualize patterns easily in data on experience for groups of individuals, such as individuals who are in the same classrooms in the context of their teacher-researcher partnership. Co-designing visual analytics with teachers can play an important role, providing help with interpretable data that enables them to make informed judgments about students’ experiences and to modify their instructional practices accordingly. At the same time, preparing teachers to make sense of these data is not sufficient to promote equity, without consideration for systemic factors such as segregation, racism, and gender inequality in society--that help explain patterns of inequity in student experience data.

References