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Teachers' Use of Resources for Equitable Integration of Computation in Science Classrooms

David Stroupe, Ph.D., Julie Christensen, Marcos D. Caballero, Ph.D., dstroupe@msu.edu, jacris@msu.edu, caball14@msu.edu, Michigan State University
Sunghwan Byun, Ph.D., North Carolina State University, sbyun2@ncsu.edu
Julia Willson, University of Central Florida, willis51@msu.edu
Daniel L. Reinholz, Ph.D., San Diego State University, daniel.reinholz@sdsu.edu

Abstract: While computation is a crucial aspect of modern science, students rarely have opportunities to engage in such work. In this study, we designed a series of professional learning opportunities for 12 physics teachers to support their enactment of equitable computational pedagogies. We asked how and why teachers utilized two primary resources of the PLS when making decisions about computational pedagogies. We analyzed multiple data sources using lenses from a situative learning perspective to examine teachers' critical pedagogical discourses. We discuss how teachers' critical discourses shaped the way the resources were utilized when designing computational learning opportunities for their students and the implications for future equity-oriented computational professional learning opportunities for teachers.

Purpose of the Study

Modern science increasingly rely on computation to explore and to understand the natural world; however, computation is largely absent in many high school science courses. Science teachers, then, must plan, enact, and reflect on opportunities for students to engage in computational practices. However, two challenges arise when considering how to support science teachers in designing opportunities for computational practices. First, current high school science teachers have likely not engaged in computational practices, nor have they considered how to plan, enact, and reflect on students' participation in computation. Second, merely providing students with opportunities to engage in computational practices does not necessarily result in equitable participation (Ensmenger, 2012).

Both challenges demonstrate that science teachers need support to provide equitable computational opportunities for students. In this study, we report on a series of professional learning opportunities for 5 secondary physics teachers. In this professional learning series, we provided teachers with a suite of resources to support their enactment of equitable computational pedagogies. By resources, we mean physical and intellectual commodities that teachers use to solve problems of practice (Stroupe, 2016). For this study, we asked:

1. *How did teachers attend to equity when planning, enacting, and reflecting on computation practices?*
2. *What resources were useful in supporting teachers' planning, enacting, and reflecting on equitable computation practices?*

Theoretical Framing

The above research questions are informed by sociocultural theories of teacher learning. When using resources, teachers engage in complex forms of intellectual activity that might otherwise be too difficult without some form of assistance. Note that teachers do not use resources absent of a context. As teachers use resources in their school, the community reciprocally reshapes the resources and their function to better serve valued goals (Cole & Engeström, 1993). While most science teachers use students' ideas, and other resources, to shape instruction, how and why they use the resources could vary. Therefore, we wanted to understand how teachers recognized and used resources to make decisions in concert with multiple voices from various instructional settings.

To unpack how and why teachers recognized and used resources, we examined their *critical pedagogical discourses* (hereafter, critical discourses). Critical discourses describe an individual's developing personal theories about what counts as productive teaching and learning (Flores, 2006; Rex & Nelson, 2004; Thompson et al., 2013). What makes these internal discourses critical is that they are consequential to an individual's actions and learning. Such discourses mediate learning and can influence how teachers think about practice and resource use across contexts (Sfard & Prusak, 2005). For this study, we used critical discourses to understand teachers' resource recognition and use, and we argue that teachers' instructional decisions using resources depends on what they see as problems or opportunities in

practice. The explanatory power of critical discourses can broaden when the field understands why science teachers select particular resources to reason with and about, how their personal theory of teaching and learning shapes their resource use, and why their personal theory of teaching and learning helps them mediate contextual pressure to teach in specific ways.

Methods

The Professional Learning Sessions and Participants

With the goal of equitable integration of computation in secondary science classrooms, our professional learning sessions (PLS) had three major components: (1) a week-long workshop held in the summer, (2) workdays that occurred every two months during the school year after the initial workshop, and (3) informal communication between teachers and different workshop facilitators. The participating teachers were White with roughly even gender distribution. Over the course of the PLS, we introduced multiple resources to support teachers' implementation of equitable computational pedagogies. In this study, we focus on two primary resources (Table 1) from the PLS, minimally working code (MWC) and Equity QUantified In Participation (EQUIP, Reinholz & Shah, 2018). From the start of the week-long workshop, we introduced computation using MWC to make computational tasks accessible to both the teachers and students with minimal background in coding (Caballero, Kohlmyer, & Schatz, 2012). Together with teachers, we used EQUIP (Reinholz & Shah, 2018), a participation tracking tool, to analyze video recordings of students' small group collaboration on computational tasks. During workdays, each teacher debriefed the EQUIP analytic with a teacher educator.

Data and Analysis

To examine how the teachers took up these resources, we drew from two data sources. First, we interviewed six teachers who consistently participated in the PLS for two years. The semi-structured interview focused on the use of resources shared/promoted during the PLS, intended to provide insight into resource use (e.g., which were framed as useful/not useful, what resources were used by most teachers). Second, we analyzed recordings of debrief sessions. These recordings allowed us to see how resources were used with students (teachers talked about their resource use throughout the debrief session), particularly in terms of resources related to equity.

Based on thematic analysis, we identified how and why the two primary resources were used by teachers and each teacher's critical discourses. We triangulated our findings by drawing on both interviews and debrief data. Similarly, we identified each teacher's critical discourse that is consistent across their interviews and debriefs. These themes were specific to particular teachers, although there were some similarities across some of the teachers. In findings, we focus on two primary resources (MWC and EQUIP) and present teachers' critical discourses.

Findings

Our analysis showed that depending on teachers' critical discourses, they took up MWC and EQUIP differently. We compare and contrast how pairs of teachers applied these resources.

Responding to Students' Frustration with MWC

When the teachers talked about using MWC for their lessons, one salient theme was managing students' frustration because of students' unfamiliarity with computational tasks. More detailed analysis showed that the teachers managed this issue differently by either prioritizing *comfort* or *perseverance*.

> I don't mind that the students get frustrated. But I don't want them to spend the hour on that same frustration. Because they don't. They give up. They turn to another group or something like that. (Ms. Miller, interview)

> It feels good. And I think that's a really valuable thing to expose students to. Remember the last time you were frustrated at the beginning, and you just kept at it, and you kept working, kept working, let's try that again. Let's see if you can't do it again. (Mr. Ross, interview)

Although both Ms. Miller and Mr. Ross attended to students' level of frustration, the teachers interpreted the high level of frustration differently. Ms. Miller, based on her critical discourse of comfort, talked against the prolonged frustration that students might experience. On the other hand, Mr. Ross, based on the critical discourse of perseverance, spoke positively about students experiencing challenging computational tasks.

Their contrasting critical discourses also shaped different instructional decisions. Ms. Miller used the comment features (texts followed by # in VPython, computation-related pedagogical technique) to guide students during the task.

> It was too big of a jump for them. They needed, I have already gone in and done a bunch of commenting because there was no commenting in there. (Ms. Miller, interview)

Mr. Ross on the other hand allowed students to struggle for a longer period of time and presented his solution toward the end of the lesson when his students ran out of time to complete the task.

> I'd love to be able to spend time with this, but we've got to move on. And let me just show you a couple of – I'll show you the approach that I used. And so, I'll take a minute and do that. (Mr. Ross, interview)

Interpreting Inequitable Participation Using EQUIP

Teachers' critical discourse shaped how they interpreted disproportionate participation patterns shown in EQUIP analytics. We found two broad critical discourses of *individual mindset* and *systemic influence*.

When the facilitator asked Mr. Taylor about the marginalized pattern of participation for Manny, a male Latinx student, Mr. Taylor shared his explanation about the perceived fixed mindset that Manny held.

> Facilitator: So there are times when Manny is brought in there, but maybe it's just a sampling that happens to be [showing] this extreme pattern...or do you think that's more normal?
> Mr. Taylor: I've been fixated on growth versus fixed mindsets lately...encouraging students, kids to adopt a growth mindset because it's true. The idea that we can continue to grow throughout our life is true. ... So I am very much focused on the fixed mindset that Manny has, that all of us can adopt at a moment's notice. ... So it's not surprising to me that he gets into that fixed mindset quite often, and he isn't trying to grow, and become better, and accept the challenge, and work through the difficulties, and come out the other side being better because of the struggle that he goes through. So it's not surprising to me at all. (Mr. Taylor, debrief)

Mr. Taylor consistently portrayed Manny as not trying to grow and challenge himself, rather than considering how his race (i.e., a systemic influence) may be affecting Manny's opportunities to participate in small group learning settings.

Ms. Collins below shared an alternative critical discourse of systemic influence. When the facilitator asked Ms. Collins about equity-related patterns before reviewing the EQUIP report together, Ms. Collins offered her gendered experiences as a woman being positioned as the secretary in a small group setting, and she applied her critical discourse of systemic influence to interpret why she might see disproportionate participation by her marginalized students.

> I guess I expect that my minority students, whether that's in their academic level or their ethnicity or things, I'm sort of expecting to see that those are the students that are gonna end up asking questions more than they're gonna be doing explanations and answers. ... I'm expecting a lot of the time that those are the students who are gonna get put in the, "Here, just calculate this for us, run the calculator." … And not the ones who are reasoning. Mostly because I'm thinking about my time, when I was in college, as one of the few girls in the group, do I get relegated to the secretary position all the time? So I'm wondering if it's a similar thing in terms of my students of color and my lower academic-achieving students. Is that the same thing happening to them? (Ms. Collins, debrief)

Her critical discourse also shaped what she attended to in EQUIP analytics, such as who is asking questions or explaining and answering questions.

Contributions of the Study

Our analysis showed how the teachers took up two primary resources (MWC and EQUIP) differently based on their critical discourses. This leads to three main contributions of the study. First, the range of how the teachers managed students' frustration with computational tasks highlights the importance of supporting teachers to meaningfully navigate the tension. Offering too much scaffolding nor leaving students in a helpless position would not be ideal. Explicit discussions on what and how much teacher support would encourage students to engage in disciplinary practices is a critical component of integrating computation in science.

Second, the contrasting interpretation of disproportionate participation by minoritized students showed that offering an equity-oriented tool is not enough. In particular, Mr. Taylor's interpretation of Manny's disproportionate participation concerns us because he attributed the issue to the perceived deficit of the marginalized student. His critical discourse also showed that the common frame of reference (e.g., growth mindset) could be twisted to place the blame on the marginalized students.

Lastly, the study largely highlighted the crucial role of teachers' critical discourses in the process of professional learning. Teachers' personal theories of teaching and learning represented in their critical discourses shaped the way they used two primary resources offered in PLS. We found that equity-oriented tools, such as EQUIP, may even be counterproductive when teachers' critical discourses reinforce deficit views on marginalized students. This warrants further research on how the computation- and equity-oriented professional learning contexts can be modified to explicate and reshape teachers' critical discourses.

Table 1: Two Primary Resources

Resources	Descriptions
Minimally Working Code (MWC)	Pre-made VPython codes that model particular science phenomena. The codes are working; meaning, they execute without an error. However, the codes need modifications to accurately represent the desired phenomena.
EQUIP Web App (EQUIP)	Classroom observation tool that generates quantitative analytics on student participation patterns based on students' social markers, such as gender and race (Reinholz & Shah, 2018; https://www.equip.ninja).

References

Caballero, M. D., Kohlmyer, M. A., & Schatz, M. F. (2012). Implementing and assessing computational modeling in introductory mechanics. *Physical Review Special Topics - Physics Education Research, 8*(2):020106.

Cole, M., & Engeström, Y. (1993). A cultural historical approach to distributed cognition. In G. Salomon (Ed.) *Distributed Cognitions* (pp. 1-46). Cambridge, UK: Cambridge University Press.

Ensmenger, N. L. (2012). The computer boys take over: Computers, programmers, and the politics of technical expertise. MIT Press.

Flores, M.A. (2006). Being a novice teacher in two different settings: Struggles, continuities, and discontinuities. *Teachers College Record, 108*(10), 2021-2052.

Reinholz, D. L., & Shah, N. (2018). Equity analytics: A methodological approach for quantifying participation patterns in mathematics classroom discourse. *Journal for Research in Mathematics Education*, *49*(2), 140–177.

Rex, L.A., & Nelson M. (2004). How teachers' professional identities position high-stakes test preparation in their classrooms, *Teachers College Record, 106*(6), 1288–1331.

Sfard, A., & Prusak, A. (2005). Telling identities—In search of an analytical tool for investigating learning as a culturally shaped activity. *Educational Researcher, 34,* 14-22.

Stroupe, D. (2016). Beginning teachers' use of resources to enact and learn from ambitious instruction. *Cognition and Instruction, 34*(1), 51-77.

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious early-career teacher practice. *American Educational Research Journal, 50*(3), 574-615.