IS THIS MATH? COMMUNITY APPROACHES TO PROBLEM SOLVING IN YUCATEC MAYA MATH CLASSROOMS

Felicia Darling
Stanford University
fdarling@alumni.stanford.edu

In Yucatec Maya middle schools in the Yucatán, math scores are low and drop out rates are high. Although addressing larger social and economic causes may ameliorate these issues, improving math instruction may be a more immediate, feasible approach. This ethnographic, mixed-methods study explores community approaches to problem-solving relevant to middle school math classrooms. Findings indicate: (1) community members possess specialized, practical mathematical expertise that is overlooked in the research around rural, impoverished students, and (2) formal math instruction misses opportunities to capitalize upon cultural approaches involving autonomy and improvisational expertise. Results are relevant for curriculum reform in the US, México, and beyond.

Keywords: Equity and Diversity, Advanced Mathematical Thinking, Middle School Education, Problem Solving

A Yucatec Maya carpenter remodels a kitchen using no tape measure, yet armed with specialized knowledge of the 3-4-5 right triangle, a length of string, and a makeshift level crafted from plastic pipe and water. Despite this engineering expertise, he does not consider his mathematical knowledge to be legitimate, because it is not a product of formal schooling.

Introduction

This carpenter lives in a typical village in the Yucatán with low national math scores and high drop out and poverty rates. His story illustrates the tension between formal and informal schooling in rural, high-poverty communities in many countries. Today, in México and the U.S., academic achievement of socioeconomically disadvantaged students is a pressing issue, because the majority of students enrolled in public schools in México (INEGI, 2005), and the U.S., are low-income (Suitts, 2015). My study departs from the typical deficit framework as it documents, often unrecognized, expertise of socioeconomically disadvantaged students. Results inform mathematics instruction, because they illuminate undocumented cultural assets that can be capitalized upon in math instruction to teach 21st century skills like innovation and creativity.

Bourdieu states that students arrive to school with a "habitus," a well-established set of dispositions and knowledge imparted by families and communities that may be incongruent with school culture (1986). Several studies build upon Bourdieu's theory to illustrate that redressing tensions between home and school cultures of ethnic/racial minority students improves academic outcomes (Au and Mason, 1981; Lee, 1995; Lipka, 2005). Given that recent research in the U.S. demonstrates that the socioeconomic achievement gap is as salient as the ethnic/racial achievement gap (Carnoy & Rothstein, 2014; Reardon, 2011; Suitts, 2015), my study focuses on impoverished students. While the majority of studies emphasize deficits of low-income students such as high absenteeism and low rates of word recognition, one researcher, Laureau, takes an asset-based approach. She finds that working-class students in the U.S., because of their upbringing, are afforded certain qualities like autonomy that are not readily available to their more affluent peers (2003). Because schools, ultimately determine what constitutes legitimate knowledge and learning (McDermott, 2006; Saxe, 1985), these "assets" are not valued when navigating the U.S. school culture, which is constructed to advantage more affluent students. Like Lareau, I am pioneering asset-based research of economically disadvantaged students. I explore a specific case where two community assets in one Yucatec Maya Village are relevant to math instruction. Several landmark

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ethnographic studies demonstrate antagonism between formal schooling and problem-solving approaches of impoverished or indigenous youth (Chavahay & Rogoff, 2002, Nunes, Schliemann, Carraher, 1993; Saxe, 1988). However, my study explores tensions that are especially pertinent to current educational initiatives in both México and the US to teach 21st century skills like innovation and creativity.

Results are relevant to math curriculum in México, because stronger Yucatec Maya ethnic identity and sense of school belonging are linked to positive academic outcomes for indigenous students (Casanova, 2011; Reyes, 2009). If formal schooling could reinforce cultural identities and foster a sense of belonging, then students might simultaneously maintain ties to their cultural heritage while exceling academically. Perhaps, capitalizing upon cultural approaches to problem solving like student autonomy and improvisational expertise could ultimately improve outcomes in the math classroom. Results are also relevant to math instruction in the US and elsewhere because 21st century skills require students to learn innovative and creative problem solving. In math classrooms, this means emphasizes solving open-ended, inquiry-based, and real-life math problems that have multiple entry points, requiring skills of adaptive expertise. This learning approach is linked to improved academic achievement and engagement for minorities (Boaler, 2002), and requires that students exercise autonomy and improvisational expertise rather than simply relying on pre-determined algorithms to solve single-solution problems.

My study is an ethnographic, mixed-methods study documenting how one rural, indigenous community in the Yucatán employs autonomy and an improvisational expertise to solve problems in everyday life. Furthermore, it explores the degree to which local middle school teachers capitalize upon these assets in the math classroom. Through grounded research, my study seeks to contribute to the discussion about: (1) math education of socioeconomically disadvantaged students using an asset-based framework; and (2) how to conceptualize autonomy and improvisational expertise in a manner relevant to implementing the national math curriculum promoting 21st century skills in both the US and México.

Methods

This village is a specific case of a rural, indigenous community that possesses a wealth of community problem-solving expertise, but low math scores. The three middle-school teachers are from the local community, but possess different experience and training. Research questions are:

1. How do community members use math in everyday life?
2. What is considered "legitimate" math knowledge and what traits make someone "good" at math according to community members, students, and teachers?
3. To what extent does math instruction capitalize upon community approaches to problem-solving?

Math In The Community And The Classroom

I define "community approaches to problem solving" as a constellation of culturally imparted mindsets, reasoning, skillsets, or strategies used to solve everyday problems that involve logic, spatial reasoning, navigation, or practical engineering. To explore how community members approach problem solving in everyday life, I conducted over 500 hours of participant observations in the village over a five-month period. In addition, I conducted 14 interviews with community members--including a focal family. I focused on businesses, transportation, community events, and central activities like farming. In addition, I conducted 15 interviews with six insiders to verify findings and adapt methodology. See Table 1 for the complete list of data sources and analyses. To explore the extent to which math instruction incorporated two community approaches to problem solving, I spent over five months at the local middle school. I conducted: 15 classroom observations;

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5-10 informal interviews and one video stimulated recall interview with each of two teachers; six student interviews; observations of two student tasks with 62 students with follow-up interviews with 3 focal students; and 280 student math mindset surveys.

Table 1: Matrix of Research Questions, Data Sources, and Analyses Methods

Question	Data Source	Data Analysis
1.) *How do community members use math in everyday life?*	Field notes from observing 500 hours of community activities over 5 months.	Open code. Write initial memos, then focused coding and integrative memos.
	14 interviews from a range of community members. Snowball sampling used.	Audiotape & transcribe. Open-code, a priori code, or statistically consider items.
	15 hours of Community Advisory interviews with 6 people to verify findings with school and community members.	Audiotape. Transcribe. Open code. Write initial memos, then focused coding and integrative memos.
2.) *What is considered "legitimate" math knowledge and what traits make someone "good" at math according to community members, students, and teachers?*	14 interviews with community members, 5-10 formal and informal interviews with each of 3 teachers, 6 student interviews, 15 classroom observations.	Audiotape and Transcribe (some). Open code. Write initial memos, then focused coding and integrative memos. Some items statistically analyzed (IRA & IRR)
	Audiotape and Transcribe. Open code. Write initial memos, then focused coding and integrative memos.	15 hours of Community Advisory interviews with 6 people to verify findings with school and community members. Some items statistically analyzed (IRA & IRR)
	280 Student surveys (questions 10 and 11)	Descriptive statistics, correlation analysis, subgroup analysis.
3.) *To what extent does math instruction capitalize upon student approaches to problem-solving?*	Series of 5-10, informal interviews with each of 3 teachers.	Open code. Write initial memos, then focused coding and integrative memos.
	One, 1-hour,VSR interview with two of 3 teachers on selected clips from one lesson.	Audiotape, transcribe, open-code for beliefs & reported practices.
	Field notes from observations of 5 lessons from each of 3 teachers.	Open code. Write initial memos, then focused coding and integrative memos.
	1 Videotaped lesson of two teachers.	Transcribe, open-code for observed teacher practices.
	280 student surveys with math mindset questions.	Qualitative and quantitative analysis (IRA & IRR).
	Observations of 2, one-hour student tasks with 62, 9th grade students that draw upon student approaches involving autonomy and improvisational expertise—with follow up interviews with 3 students.	Videotape. Transcribe. Open code. Write initial memos, then focused coding and integrative memos. Attitudinal question on tasks are a priori coded. Descriptive statistics on some items. (IRA & IRR)

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Results

The Disconnect

There is a disconnect between school and community math (Darling, 2016a). In this study, I defined math as any activity done outside of school that involves reasoning, justification, logic, arithmetic, or spatial orientating to solve problems. However, community members considered math as arithmetic one learns in school: counting, adding, dividing, paying. I asked a motorcycle-taxi driver, José, how he used math in everyday life. He responded, "I do not use math in everyday life, because I stopped going to school in the fourth grade." Interviews, student surveys and classroom observations indicated that community members thought someone who was "good" at math was someone who was "rapido" (fast) at doing arithmetic or solving school math problems.

Two Approaches: Autonomy And Improvisational Expertise

I documented two approaches to problem-solving in everyday life in the community; autonomy and improvisational expertise (Darling, 2016a). In essence, they are part of a student's habitus that specifically relates to problem solving. Similar to Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo (2003), I define autonomy as an independence, a self-directedness that is likely fostered by repeated opportunities to engage in independent play and problem solving without adult supervision. Like Yackel and Cobb, I reject "the conception of autonomy as a context free characteristic of the individual" (1996, p. 473). Instead I define autonomy with respect to students' participation in practices in specific contexts within the community. Lareau describes autonomy as independence among working class U.S. students that is at odds with navigating the school culture (2011). I define autonomy as an independence in terms of problem solving and how it may be at odds with math instruction. Also, I describe how it fuels improvisational expertise. I define improvisational expertise as a culturally imparted skillset or mindset used for solving real-life problems in innovative ways. For example, the mototaxista, José, tells me how he does not use math. However, when I ask him how he improvises in everyday life, without hesitation, he says, "yo calculo la kilometraje" (I calculate my mileage). Using no gas gauges or odometers, he calculates his mileage using an elaborate system based on collected fares, estimated distances between landmarks, and gas tank capacity. I documented six distinct methods used by mototaxistas. This is consistent with Saxe's finding that there is wider diversity of problem-solving methods in communities where there is limited access to schooling, as people tend to derive math meaning from solving real-life problems (1988). Findings indicate that autonomy fuels the improvisational expertise much in the same way that Rogoff, et all found that autonomy informs collaboration among indigenous heritage Mexican children (2003). In my study two children aged 5 and 9, with no money to purchase a kite, engineered one from garbage bags, salvaged sticks and string remnants. Unaccompanied by adults, they flight-tested their kites for an hour at the ocean's edge. They launched it with the wind, against the wind, and from the edge of a rock wall. They scavenged beach materials to add weight to the tail, lengthen the string, or adjust the kite's cross spar. They approached problem solving with autonomy and improvisational expertise, but will math teachers capitalize upon this practical, problem solving expertise when they go to middle school?

Opportunities Untapped In The Classroom?

School math instruction incorporated student autonomy and improvisational expertise in terms of completing tasks, but not in terms of solving math problems (Darling, 2016b). Many students chatted while the teacher was speaking. At 10-minute intervals during class at least 1/3 of the students were "off task". Students completed classroom tasks at the pace and order in the order they chose. Were they disrespectful? No. When an adult entered the room, students rose in unison and chimed, "Buenas tardes Maestro Olegario. " Teachers in this pueblo school accommodated students'

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autonomy and improvisational expertise in the math classroom in one non-math domain. This was similar to Boaler's 2002 study that demonstrated that minority students' math achievement improved in inquiry-based math classes where students were afforded the opportunity to complete tasks at their own pace and in their own ways. Olegario, the oldest teacher in my study said: Teachers provide "libertad" (freedom to act); students improvise while learning and completing tasks; consequently, students learn to act responsibly. In essence, teachers granted student autonomy, and students chose how and when to be "on task." Their autonomy informed their improvisational expertise, and students learned how to act responsibly. Although students were encouraged to be autonomous and improvise in terms of how they completed their tasks, teachers' strict adherence to the national math curriculum limited student opportunities to improvise while solving math problems. This is not surprising, because almost all opportunities to learn math involved single-solution, single-method problem solving.

I observed 62 students doing two math tasks based on real-life problems that invited improvisation. I gave attitudinal questions and did follow-up interviews. These triangulated to indicate that students welcomed opportunities to improvise, but did not like the "math part." The first task was presented in an ethics class to mask the math aspect. It required students to identify social problems in the community and then to address them by designing a community center according to explicit geometric specifications leading to the discovery of the Pythagorean theorem. Interviews indicated that students liked the improvisation, but not the math. The second task was completed in math class and yielded similar results. Students were asked to develop a plan to insure that a motorcycle taxi driver does not run out of gas. They were provided with real-life data in the form of a table. Three students interviewed said that at first they thought the problem was hard because they had to use math, then they said, It was easy when they realized they only had to use "sentido común"(common sense). In conclusion, teachers capitalized upon the cultural approaches of autonomy and improvisational expertise in terms of the completion of classroom tasks, but did not capitalize upon either in terms of solving math problems. Students enjoyed solving open-ended, multiple solution problems that were radically different than the typical math problems completed in class (Darling, 2016b).

Implications

Study results are relevant for alleviating academic achievement gaps in math in México. Incorporating previously overlooked cultural assets of student autonomy and improvisational expertise into the curriculum may improve math outcomes for Yucatec Maya youth, because ethnic identity and school belonging may be nurtured. Also, it is likely that these assets are not unique to this one Yucatec Maya community in México. Findings may be relevant to other impoverished, rural, or indigenous heritage immigrant communities in the U.S. Finally, the constructs of autonomy and improvisational expertise are relevant to math instruction that focuses on 21st century skills like innovation and creativity. Adaptive expertise is emphasized in reform mathematics classrooms, because it shifts the learning focus from algorithmic, procedural knowledge to deep conceptual understanding (Torbeyns, Verschaffel, & Ghesquière, 2006). Rather than teach students adaptive expertise from scratch, perhaps scholars could study how to capitalize upon already existing cultural assets to teach reform mathematics to historically marginalized students. Finally, perhaps we can learn from this Yucatec Maya community to teach other students to approach problem solving with autonomy and improvisational expertise to promote 21st century skills.

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