Incorporating Cultural Assets in Yucatec Maya Mathematics Classrooms: Opportunities Missed?

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Abstract

In Yucatec Maya middle schools in the Yucatán, mathematics scores are low and high school dropout rates are high. While addressing larger social and economic causes is crucial, improving mathematics instruction is a feasible approach. This paper draws from a six-month ethnographic, mixed-method study documenting two cultural approaches to problem solving. It explores the extent to which middle school mathematics instruction capitalizes upon these cultural assets and pilots two real-life mathematics tasks that incorporate them. Findings add details to the school/community culture gap around mathematics knowledge and have implications for mathematics education for marginalized students in México and the US.

Keywords: Mathematics Education, Poverty, Yucatec Maya, Cultural Assets, Real-Life Mathematics

Introduction

Two Yucatec Maya boys, aged five and nine, want to fly a kite, but they have no money. Consequently, they engineer a kite using hand-torn, black plastic garbage bags, salvaged fragments of wood, and mixed remnants of red, blue, and yellow cotton twine and fishing line. For an hour, they pilot their construction at the ocean's edge, without adult supervision. They experiment with launches: tossing the kite up against the wind, with the wind, from the top of a stone wall, and from inside an abandoned boat. They innovate and improvise. They lengthen the kite line by adding salvaged beach string. They add weight to the tail and adjust how the kite line is attached to the cross spar. Three times, they extricate the kite from the branches of an Uva del Mar tree. When these boys arrive in the local middle school classroom, to what extent will mathematics teachers capitalize upon this wealth of practical problem-solving expertise?

This scenario is from a 2014 study in a rural, Yucatec Maya community in the Yucatán. It is one of many examples that illuminates the practical mathematical expertise local students possess that are not fully capitalized upon in the local mathematics classroom. This paper draws from a larger study that (1) identified a disconnect between school and community mathematics knowledge and (2) documented two community approaches to problem solving (Darling, in prep). This paper addresses two research questions: To what extent does mathematics instruction in the local middle school incorporate these community assets into mathematics instruction? And what does it look like to deliver mathematics tasks that incorporate these cultural assets? This paper explores the disconnect between community and school mathematics knowledge and identifies missed opportunities for teachers to capitalize upon student autonomy and improvisational mindset in the mathematics classroom. Also, this paper pilots two mathematics tasks that incorporate students' funds of knowledge around autonomy and improvisational mindset into mathematics instruction. Exploring the cultural incongruence between community and school mathematics is important for improving mathematics engagement and achievement and ultimately improving high school retention rates among indigenous communities in the Yucatán. In addition, from this single case of a Yucatec Maya village, we may glean insight into how we can improve mathematics instruction for other historically marginalized students in México and the US.

Conceptual Framework

The Case of the Yucatec Maya

This village is a single case of a community with few socioeconomic resources, but with exceptional funds of mathematics knowledge. It is representative of other indigenous communities in the Yucatán in terms of its low mathematics scores and high poverty and high school attrition rates. Therefore, results may be generalizable to and inform mathematics instruction and teacher education in other Yucatec Maya schools in the Yucatán. In addition, examining this special case may offer insight for improving mathematics instruction and teacher education in schools in the US and México, where there are high proportions of socioeconomically disadvantaged students.

According to El Instituto para el Desarrollo de la Cultura Maya del Estado de Yucatán (INDEMAYA, 2011), there are 15.7 million indigenous people living in México. This study concentrates on the Yucatán peninsula, where one-third of the indigenous population in México resides, and focuses on a small village near Mérida, which has demographics similar to other municipalities in the Yucatán. In this region, more than 91% of the population is Yucatec Maya, the poverty rate is 70%, average years of education is seven, and the high school dropout rate is over 50% (INEGI, 2005). While high school dropout rates among indigenous in the Yucatán are related to a confluence of factors including poverty, social exclusion, school violence, high rates of interstate migration, unwanted pregnancies, and alcohol and tobacco addictions (Aguiar Andrade & Acle-Tomasini, 2012; Herrera & Elena, 2004), one study links it to students' lack of belonging in school (Reyes, 2009). This is important because a greater sense of school belonging is correlated with stronger cultural identity among Yucatec Maya students (Casanova, 2011).

Conversely, Yucatec Maya students who are more acculturated to the dominant Mexican culture have lower GPAs (Casanova, 2011), and students who have more formal schooling are less knowledgeable about local, indigenous ecology (Fernandez, 2012). While it is true that larger social and economic factors mentioned above contribute to extremely high rates of poverty and high school attrition in this region, we can look toward the classroom for more immediate and feasible solutions to addressing the problem. After all, research on cultural congruence suggests that if formal schooling could reinforce cultural identities and foster a sense of belonging, then Yucatec Maya students might simultaneously maintain their ties to their cultural identities while exceling academically (Dee & Penner, 2017; Yeager & Walton, 2011). This current paper responds to this issue by: (1) exploring the incongruence between students' funds of mathematics knowledge and what is considered legitimate mathematics knowledge in school; (2) examining the extent to which mathematics instruction in a Yucatec Maya middle school incorporates two community assets; and (3) seeking to redress this cultural incongruence by piloting two mathematics tasks.

Exploring Cultural Incongruence: An Asset-based Approach

Bourdieu states that students arrive to school with a "habitus," a well-established set of dispositions and knowledge inherited from their families and communities (1986). This habitus may or may not be congruent with or valued by the school culture. Several studies build upon Bourdieu's theory to suggest that redressing this incongruence improves academic outcomes for ethnic/racial minority students, both in literacy (Au and Mason, 1981; Lee, 1995) and mathematics (Aguirre & Zavala, 2013; Ezeife, 2002; Jorgensen et al., 2011; Lipka et al., 2005; Turner, McDuffie, Aguirre, Bartell, & Foote, 2012). Recent research in the US also demonstrates that the socioeconomic achievement gap is as salient as the ethnic/racial achievement gap

(Carnoy & Rothstein, 2013; Reardon, 2011). This finding is particularly relevant today, because the majority of students in public schools in both México and the U.S are low-income (INEGI, 2005; Suitts, 2015). This current study explores the tension between school and community mathematics knowledge of a specific group of low socioeconomically-disadvantaged students, namely rural Yucatec Maya students. Whereas many studies emphasize deficits of low-income students such as high rates of absenteeism or low rates of word recognition, Lareau pioneers an asset-based approach (Lareau, 2011). She finds that US students from working-class families are afforded certain qualities that are not readily available to their more affluent peers. Still these would-be assets of lower-income students are at odds with navigating the school culture. Like Lareau, this current study showcases asset-based research of a subgroup of socioeconomically disadvantaged students. Unlike Lareau, this research emphasizes cultural assets that are relevant specifically to problem solving in the mathematics classroom. Furthermore, this study examines a case where mathematics teachers miss opportunities to incorporate two community approaches to problem solving into mathematics instruction. In addition, it pilots two mathematics tasks that build on these two approaches involving *autonomy* and *improvisational mindset* (Darling, in prep), discussed in more detail in the next section. Several ethnographic studies illustrate tensions between formal schooling and problem-solving approaches in mathematics of socioeconomically disadvantaged or indigenous youth (Aguirre, J., & Zavala, 2013; Chavajay & Rogoff, 2002; Ezeife, 2002; Furuto, 2014; Jorgensen et al., 2012; Nunes, Schliemann, Carraher, 1993; Saxe, 1988). In addition, researchers of *culturally relevant pedagogy* and *culturally sustaining pedagogy* advocate that teachers value and incorporate cultural assets into instruction to improve outcomes for marginalized students (Ladson-Billings, 2014; Paris & Alim, 2017). This paper examines cultural incongruence between community and school mathematics knowledge and explores two culturally relevant mathematics tasks. Results have implications for improving mathematics education for a broader population of historically under-served students in México and the US.

Community Approaches to Problem Solving: Autonomy and Improvisational Mindset

There is a disconnect between school and community mathematics in this Yucatec Maya village (Darling, in prep). The majority of community members define "mathematics" as arithmetic, mathematics they learn in school. When asked how they use mathematics in everyday life, 90% of the villagers' responses were related to arithmetic: "counting squats and lunges," "dividing while cooking," and "paying bills" (Darling, in prep, p.13). Community members equate "mathematics" with school mathematics. Furthermore, they do not recognize their own practical problem-solving expertise as "legitimate" mathematics knowledge, because they did not learn it in school (Darling, in prep). Regardless, community members possess two *community approaches to problem solving*, which is defined as a "constellation of inherited mindsets, reasoning, skillsets, and strategies used to solve everyday problems involving navigation, practical engineering, logic, and arithmetic" (Darling, in prep, p. 3). The two documented approaches to problem solving are *autonomy* and *improvisational mindset*. They are subsets of a community member's habitus around problem solving. Autonomy is reminiscent of the concept studied by Rogoff (2003) and Lareau (2011). *Autonomy* in this paper is defined as an independence, a self-directedness, that is likely fostered by exposure to consistent opportunities to engage in independent play and novel problem solving without adult supervision (Darling, in prep). Like Yackel and Cobb, this paper defines autonomy with respect to students' participation in practices in specific contexts of the community and not as a "context-free characteristic of the individual." (1996, p. 473). Thus, autonomy is an approach and not an intrinsic characteristic.

The second approach, i*mprovisational mindset*, is not an intrinsic characteristic either. It also results from participation in practices in the specific contexts of the community. *Improvisational mindset* is conceptualized as "a culturally imparted cultural asset that emerges organically from solving a variety of novel problems generated by real-life, local contexts" (Darling, in prep, p. 23). The study does not emphasize the extemporaneous aspect of "improvise," where it means to "create and perform (music, drama, or verse) spontaneously or without preparation." ("Improvise", Definition 1, 2016). Instead it focuses on the idea of fabricating something from objects that are found, objects that may not necessarily be of high inherent value. In this case "improvise" means to "produce or make (something) from whatever is available: *I improvised a costume for myself out of an old blue dress."* ("Improvise", Definition 1.1, 2016). *Due to limited financial resources, community members develop* innovative approaches to solving everyday mathematics problems like in the example of the kite (Darling, in prep). In another example, *mototaxis* (motorcycle taxis) in the village have no gas gauges, odometers, or speedometers, yet motorcycle taxi drivers derive original and diverse methods to calculate *kilometrage* (similar to mileage). They use time, money, centimeters, and trips as proxies for kilometers in their "calculations." *Autonomy* and *improvisational mindset* are inextricably entwined. Similar to the way Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo describe how autonomy informs a collaborative approach to problem solving among indigenous heritage Mexican children (2003), in this village *autonomy* fuels an improvisational approach to problem solving. This is illustrated in the kite example above where two young, unsupervised children act independently to innovate and improvise.

Current US reform mathematics initiatives seek to teach students to solve multi-method, multi-solution problems using inquiry-based approaches rather than teaching students to solve single-solution problems using preset algorithms. This shifts the learning focus from algorithmic, procedural knowledge toward deeper conceptual understanding. In addition, the labor market in the US and other parts of the world emphasize building 21st century skills like creativity and innovation. To accomplish this shift, education scholars advocate teaching students adaptive expertise (Hatano, 2003; Torbeyns, Verschaffel, & Ghesquière, 2006). Adaptive expertise is similar to improvisational mindset in that it is a skillset or mindset used for solving novel problems in innovative ways. However, adaptive expertise is a cultivated skillset that is learned from exposure to a variety of teacher-generated problems, which have imposed, fabricated constraints. On the other hand, improvisational mindset is a cultural asset that evolves organically from solving a variety of novel problems in real-life, local contexts. These novel problems emerge from real-life constraints. These Yucatec Maya students arrive in the mathematics classroom with a habitus around problem solving that includes autonomy and improvisational mindset. Results of this current study suggest that mathematics teachers could draw from these students' problem-solving habitus to teach adaptive expertise in mathematics classrooms, rather than overlooking and overwriting students' wealth of community approaches to problem solving.

This paper discusses results related to six months of data collection and analysis conducted in three Yucatec Maya, middle school mathematics classrooms. It builds on the previously reported findings that: (1) there is a cultural incongruence between school and community mathematics knowledge; and (2) community members approach problem solving in everyday life using autonomy and an improvisational mindset (Darling, in prep). This article adds details to the complex portrait of the incongruence between community and school mathematics knowledge. Also, it describes missed opportunities for local middle school teachers to build on student autonomy and improvisational expertise when teaching mathematics. Finally, it describes two piloted tasks that explore incorporating these assets into mathematics instruction. These findings are not only relevant to improving indigenous mathematics education in the Yucatán, but also to informing mathematics education for other marginalized students in México and in the US.

Methods

Participants and Setting

This is a Yucatec Maya village where community members possess practical problem-solving expertise, but low mathematics scores. It is representative of other indigenous communities in the Yucatán, because high school dropout rates are above 50% and national mathematics scores are low (INEGI, 2005). All participants in this study are Yucatec Maya, and live in Tunkuruchu a rural town of 4000 located outside of Mérida in the Yucatán peninsula in México. (All names of people and places in this study are pseudonyms). La Escuela Secundaria Pública Jacinto Canek includes grades seven through nine and has 280 students. Maestro Olegario, Maestro Noé, and Maestra Judít, are Yucatec Maya. However, they possess varying levels of teaching experience and education. Maestro Noé graduated three years ago with his bachelor's degree in teaching, but has less than three years of teaching experience. Maestra Judít graduated ten years ago with her bachelor's degree in teaching, and has ten years of teaching experience. The senior teacher, Maestro Olegario has been teaching for twenty-eight years and received no formal training whatsoever. He inherited his position from a relative, which had been a customary practice in the past.

Data-collection and Analysis

Cultural insiders

Being a cultural outsider, the Principal investigator (PI) drew from the insights of six cultural insiders to complete the study. When conducting outsider research, careful selection of cultural insiders and strategic incorporation of insider feedback through an iterative process is crucial for producing novel results informed by local perspectives (Darling, 2016). The initial cultural insider, Nina, is twenty-two years old. She introduced the PI to the most senior mathematics teacher and the principal at the school and helped to recruit other cultural insiders, who formed the community advisory group (CAG). The CAG helped to: educate the PI about local culture and customs, refine and adapt protocols to make them more culturally sensitive, and verify potential findings. Two teachers, two local college students, and three local middle school students participated in the CAG. Nina recruited the teachers and college students. To ensure that students other than those with high grades from wealthier families were included, only one of the three teacher-referred students participated in the CAG. By talking with students in the school yard and at local businesses, the PI recruited two students from lower-resourced households who had lower mathematics grades. This was done to in order to diversify the perspectives. CAG members provided insider perspectives throughout all phases of the study. Data table is in Appendix A.

Classroom and campus observations and field notes

The PI observed classroom and campus activities for six months. Classroom instruction was observed fifteen times and videotaped. The PI wrote field notes when observing students at break or moving between classes; when chatting with teachers at 7:00am in the circle of red plastic chairs outside the office; and after school at community events and cultural celebrations. All field notes were written by hand.

To analyze the field notes, qualitative analytic coding as described by Emerson, Fretz and Shaw (2011) was used. First, the data was read through line-by-line as a single corpus and continuous open coding was used for finding patterns, themes, ideas, and issues, until no new themes emerge. The PI wrote initial analytic memos daily deciding which codes were the most relevant, and afterwards separating the data according to code categories. Then, the PI used more fine-grained, focused coding to code the entire corpus of data—breaking these codes down further. Finally, the PI wrote integrative memos where analytic codes were linked together, seeking relationships between coded field notes. Data collection and analysis was a simultaneous process. Emerging themes determined where to focus in subsequent classroom observations. For example, when the theme of "off-taskedness" emerged, CAG cultural insiders were consulted, and the next day the PI counted how many students were not following the teacher at regular intervals. Codes included student opportunities to: collaborate, act autonomously, improvise, and solve open-ended problems. Teacher codes included: asking open-ended questions, using supplementary materials, and class management moves.

Teacher interviews

All three teachers were interviewed informally between five and ten times. Drawing from Taachi, the PI used an in-depth, unstructured interview protocol that allowed for the exploration of complex topics in indirect ways (Taachi, 2003). This involved a list of themes with potential sub-questions to guide the open conversations. Themes included classroom practices, mathematics curriculum, student discipline, and teacher backgrounds. More than fifty-five hours were spent talking with Olegario, the senior teacher. His role at school was supervisory, so he was in the courtyard every day. In addition to the informal, unstructured interviews, each teacher was interviewed once using a semi-structured protocol. These interviews were videotaped and transcribed.

Student tasks

Nina and the PI developed two real-life tasks that were open-ended, had multiple solutions, and invited multiple approaches. Students collaborated already in class sometimes to solve problems, but they focused on getting the "one correct answer" and doing it "the right way." We developed tasks that would give students opportunities to work in groups to solve low-floor, high-ceiling tasks with multiple entry points and multiple solutions. This approach seemed more aligned with students' cultural approaches to problem solving, because it invited students to use autonomy and improvisation. Also, the tasks were culturally-aligned in the sense that they were based on real-life problems from the village. The tasks were given to the sixty-six, ninth grade students, and they were video recorded. The purpose of the tasks was: (1) to illuminate details about the gaps between community and school approaches to problem solving, and (2) to explore elements of mathematics problems that could potentially tap into students' cultural approaches of autonomy and improvisational mindset. The attitudinal questions at the end of each task were validated with members of the CAG to make sure questions were understandable, relevant to students, and yielded the intended data. They were statistically considered. Write-in responses were open coded and refined. Interrater agreement was negotiated and interrater reliability was calculated at 94%. Student tasks are in Appendix B and Appendix C.

Student surveys

All 280 students in grades seven through nine were given a survey to explore their mindsets. The first eight questions of the survey consisted of the well-established, six-point, Likert-type growth mindset survey (Dweck, 2011). They were scored and interpreted according to the established scoring protocol. The questions ascertain if a student possesses a growth or fixed mindset. An individual with a growth mindset believes: (1) intelligence is malleable and not fixed; (2) effort is more important than natural ability; (3) mistakes are sources of learning and do not confirm a lack of ability; and (4) correct answers are not as important as the process (Dweck, 2007; Anderson, Boaler, & Dieckmann, 2018). The last three questions were asked to explore students' attitudes specifically about mathematics. They were validated by consulting with a mathematics education/growth mindset researcher and discussions with CAG members. Questions eight and nine were six-point, agree-disagree, Likert-type statements: "There is only one correct method to solve each mathematics problem." and "There is only one correct solution for each mathematics problem." These were statistically analyzed using descriptive statistics. Question eleven was a free-response question designed to examine attitudes specifically about mathematics ability, "Do you know someone who is good at mathematics? Name three characteristics that demonstrate that they are good in mathematics." This was added to see if students identified fixed mindset attributes like "always being correct" or more growth mindset attributes like, "they work hard. It was open coded, codes were refined, and then interrater agreement was established and interrater reliability was calculated at 91%.

Results

The Disconnect Between Community and School Mathematics Knowledge

This paper further illuminates the incongruence between community and school mathematics knowledge found in the larger study (Darling, in prep). Dweck states that students who possess growth mindsets believe: intelligence is malleable; making mistakes and taking risks are key to learning; effort versus innate talent improves ability; and process is more important than performance (2007). On the other hand, students with fixed mindsets believe that some people are just born with ability and when people make mistakes or expend great effort while learning, then they are not good in that specific domain. According to the mindset survey, 75% of the local middle school students possessed a growth mindset. This makes sense, because these students are enculturated in a community that values autonomy and improvisation (Darling, in prep). It is reasonable to surmise that independently solving a variety of novel problems on a daily basis nurtures the idea that making mistakes and taking false paths are essential parts of problem solving, and that problem-solving ability improves with experience and effort. Despite the evidence that the vast majority of students possess a growth mindset in general, the last three survey questions suggest that a majority of the students possess attitudes associated with having a fixed mindset. For example, question eleven on the survey asked students to identify a person who is good at mathematics and "describe three characteristics that demonstrate that he or she is good at mathematics." Only 28% of the responses were characteristics associated with having a growth mindset. These responses included "students who are good at mathematics": (1) "expend a lot of effort," (2) "work hard on the problems or assignments," and (3) "learn from their mistakes in mathematics." Similarly, twice as many (56%) of the responses suggest fixed mindset attitudes about what it means to be "good" at mathematics. These responses include "students who are good at mathematics": (1) "are just good at mathematics," (2) "never make mistakes," (3) "are fast at answering mathematics questions," (4) "are fast at doing mathematics problems," and (5) "mathematics is easy for them." This discrepancy makes sense, because community members improvise, experiment, and persist in solving a multitude of novel problems with multiple solutions and methods in everyday life (Darling, in prep).

The other two questions indicate that the majority of students believe that mathematics problems have one correct solution and approach. This supports the idea of a disconnect between school and home mathematics, which was documented in the larger study (Darling, in prep). Unlike in school, in the community, students solve novel mathematics problems every day, and these problems have more than one correct solution and approach. Therefore, it makes sense that students would have a growth mindset in general. However, the three survey questions, teacher interviews, and classroom observations triangulate to indicate that in the mathematics classroom, students focus on solving mathematics problems with only one correct solution and one correct method and may have some fixed mindset beliefs specifically around mathematics learning.

In sum, findings suggest that students who approach problem solving in everyday life with autonomy and improvisational mindset may possess growth mindset beliefs in one domain, but not necessarily when it comes to solving mathematics problems in school.

Cultural Assets Valued

Autonomy and improvisational mindset are conceptualized the same across independent domains. Results indicate that they are valued in one domain at school; namely navigating classroom structures and tasks. Analysis of classroom observations and field notes indicates that these local teachers value these two student approaches and also incorporate them into their classroom management practices in order to teach students to be responsible. Teachers invite students to make independent decisions to solve problems in their own unique ways when completing classroom tasks. For example, upon entering the classroom, students arrange their desks in elective configurations and sit in self-selected groups of three to five. When the teachers address the class, some students continue talking about non-mathematics subjects. At ten-minute intervals during class about 1/3 of the students are "off task." In a randomly selected five-minute block, there is wide diversity of what students are doing to complete tasks. In one moment, eleven students are looking at the teacher and taking notes, five students are looking at the teacher and not taking notes, twelve students are not looking at the teacher and continue to talk about non-mathematics-related topics and do not take notes, and five are asking their classmates questions about the mathematics content. In another five-minute block of time, different permutations of students are electing to pay attention, take notes, or collaborate in their own unique ways. Students complete classroom tasks at the pace and order in which they elect. To an outsider it may appear, that local teachers do not have strong classroom management skills. However, there is evidence to the contrary. For example, when any adult steps into the classroom, students spring up and chime in unison, “Buenas tardes Maestro(a) _______.” Also, students respond without hesitation to small, non-verbal cues such as Maestro Olegario’s half-eyebrow lift about the left pant cuff of a student being rolled up three inches. This scenario is similar to a finding by Boaler (2002) where minority students’ mathematics achievement improved in inquiry-based mathematics classes where students were afforded opportunities to complete tasks at their own pace and in their own ways. Students are not castigated for navigating the classroom structure by using autonomy and improvisation. On the contrary, teachers encourage and cultivate student autonomy and improvisational mindset to teach responsibility.

Olegario says, “Teachers provide ‘libertad’ (freedom to act), “ then students act independently to finish tasks at their own pace and in the order that they see fit.” Through this process, students learn “responsibilidad (responsibility).” Olegario says, “When students work in groups, some of them just talk and do not work on mathematics. …Eventually the natural consequences of their actions teach them to be more responsible.” This is an important finding since Lareau found that working-class students suffer when their cultural asset of autonomy is not valued in schools (2011). While students are encouraged to complete tasks in their unique ways in order to learn responsibility, they are not encouraged to approach mathematics problem solving in original and innovative ways. Mathematics instruction in these indigenous schools misses opportunities to incorporate students' cultural approaches to solving problems. It relies heavily on the national curriculum, which does not have problems related to real-life in the Yucatec Maya village.

Missed Opportunities in Mathematics

Although teachers capitalize upon autonomy and improvisational mindset in terms of task completion, they miss opportunities to incorporate these cultural assets into mathematics instruction. Yackel and Cobb (1996) describe intellectual autonomy in mathematics class as when students draw from their own intellectual capabilities rather than relying on external authorities like the teacher. While local students did exercise autonomy in terms of completing tasks in the classroom, they relied primarily on the external authority of the teachers when learning mathematics. For the much of the instructional time, teachers' strict adherence to the national mathematics curriculum limited student opportunities to act autonomously or improvise while solving mathematics problems. While tapping into student autonomy in mathematics class may be relevant for all students, at least one study showed that it is crucial for students from lower-resourced or marginalized communities (Boaler, 2002). In the case of these Yucatec Maya students, it is a part of their everyday culture.

Maestro Olegario's class offered the fewest opportunities for students to be autonomous, to interact with each other about mathematics, and to improvise while solving mathematics problems. Students completed 40 problems in their workbooks independently while sitting in rows. Afterwards, they lined up single-file with their completed workbooks in hand, waiting for the teacher to pronounce their solutions correct. Maestro Noé did some group work and some student presentations at the board. However, the group work was leveraged only minimally to deepen conceptual knowledge—and he relied solely on problems in the text. For example, he wrote five problems from the text on the board. Then, he selected one member of the five-student group in the center of the classroom to write the answer on the board. With each new problem a person from the middle group rotated out with one of the members of the other four groups on the periphery of classroom. His method improved student participation, but did not emphasize unique approaches to problem solving. Instead it reinforced that getting correct answers was a higher priority that using an original approach. While the majority of time, Maestra Judít relied on problems from the text. Sometimes she, "went on the internet to find supplementary materials." One day she veered from the text to have students measure their height and weight to do statistical calculations around measures of central tendency. However, still students deferred on her external authority to pronounce methods and solutions correct. The 280 surveys confirmed that students perceived school mathematics problems as having only one solution and one acceptable method of solving.

Students Prefer "Common Sense" and "Improvisation" versus "Equations"

The PI gave two, fifty-five-minute mathematics tasks to sixty-six, ninth grade students in order to give students opportunities to solve real-life mathematics problems using cultural approaches of autonomy and improvisation. Survey results indicated that the majority of students possess beliefs associated with a fixed mindset with respect to mathematics and that they believe that mathematics problems have only one correct solution and approach. The two real-life tasks had multiple solutions and multiple entry points. This was radically different than the one-solution, one-method approach that they were used to working with in mathematics class. These tasks were low-floor, high-ceiling tasks, which means that students could build on their prior knowledge and begin to solve the problem from their unique starting points. Students worked in self-selected groups of four to complete the tasks. Follow-up interviews were conducted with three CAG students.

Nina, the primary cultural insider, and the PI developed Task 1 and Task 2 to be culturally relevant in two ways. First, the tasks are related to the lived experiences of the students in that they include everyday problems from the community. Second, they build on students' cultural approaches to problem solving, because they are open-ended tasks that invite students to use autonomy and improvisation. Task 1 asked about social issues in the community. To make Task 2 more culturally relevant, it was based on the documented approaches to problem solving of local mototaxi drivers (Darling, in prep).

In order to mask the mathematics aspect of Task 1, Maestro Olegario and the PI led this task in his ethics class. Upon Maestra Judít's recommendation, the PI focused on the Pythagorean theorem, because students were still struggling to master the topic. Task 1 began by asking students to identify three community problems and then to address them by designing a community center with a right-triangle-shaped eco space in the center and three other community areas of their choice enclosing it. Students engaged in rich, small-group and whole-class discussions about social problems such as lack of access to education, lack of communication, alcoholism, inadequate economic resources, and road condition issues. They proposed community areas such as a sports stadium, Internet café, ecological park, gymnasium, art museum, and a children's park. While all groups participated in the whole group discussion in Part 1, the level of engagement flagged a bit when students encountered the specific geometric constraints related to the Pythagorean theorem in the second part. Still, four of the seven groups persisted to calculate the areas of the rectangles that circumscribed the inner right triangle, and thus discovered the Pythagorean theorem. This is important, because the Judít identified this as a topic with which students were still struggling. Follow-up interviews with three CAG students confirmed observations that classmates enjoyed the improvisational part where they got to select three community problems, generate solutions, and improvise a design but struggled with the "mathematics" part. Erik said, "I like communicating with my friends about solutions to community problems," but found "difficult", "the parts that had to do with mathematics." Yamilet "liked being given the opportunity to create a community center… to help people." However, she did not like, "that I could not make any triangle I wanted, because there were [constraints]." This preference for lack of constraints and freedom to improvise makes sense given that students are afforded a lot of autonomy in the non-mathematics domain of task completion in class. Results indicate that when given an open-ended problem with multiple solutions, some students persisted in completing the task to learn the intended mathematics concept, and that students enjoyed the opportunity to act autonomously and to improvise.

In Task 2, Nina and the PI developed another real-life community mathematics problem, but did not choose a specific mathematics topic from the curriculum on which to focus. This mototaxi problem was derived from the fifty community interviews in the larger study, thus making it an authentic, culturally relevant task. The PI wanted to see what students would do when there were even fewer constraints. The task, again, encouraged multiple entry points and solutions, making it unusual for a mathematics problem in their school. Maestro Judít and the PI led Task 2 in her mathematics class. Students were asked to solve a problem involving a member of their family who was a mototaxi driver. They were told the capacity of his gas tank and the fact that mototaxis in town have no gas gauges, odometers, or speedometers. They were given real-life, tabulated data gathered from mototaxi drivers. The twenty-five rows contained data for the driver's trips beginning at 5:30 a.m. and continuing until 1:00 p.m., when the driver ran out of gas. The columns were labeled, "time," "destination," "distance traveled," and "fares collected". Unlike Task 1, Task 2 ostensibly had a lot of mathematics in it at the onset. Students were expected to work in groups to devise and write a plan to ensure that the mototaxi driver does not run out of gas.

For the first twenty to thirty minutes of the Task 2, students in all seven groups took out calculators and attempted to make sense of the table, thinking it was like any other mathematics problem that they encountered at school. Erik said, "at first my group took a lot of time to understand the problem… because we had not seen a problem like this in mathematics class." Follow-up interviews with three students revealed that at first students thought the problem was hard, because they thought they had to use mathematics in a very specific way. However, they enjoyed the task when they realized that they could draw on their own cultural resources and improvise. Yamilet said that in her group, initially, "We talked about using equations… then, Jorge suggested, 'Maybe we could just use common sense.' " Yamilet said, that in the end, "the problem was easier than the usual mathematics problems, because we did not need an equation." Erik echoed this idea of common sense, "The problem was easy when we realized we only had to use "sentido común (common sense)." Results suggest that students enjoy drawing from the intellectual resources that they bring to class, "sentido común," rather than using the specific algorithm provided, "equations." Task 2 solutions were diverse, and the majority of students relied on mathematics to solve the problem. For example, one group suggested using "a ruler to measure the gas" and calculate "kilometraje" (similar to mileage). Another group recommended using, "the amount of fares collected the day before to predict when he will run out of gas." Another suggested using time as a proxy, "before 1:30 p.m., he has to refuel."

The piloted attitudinal questions at the end of Task 2 suggest that students enjoyed some aspects of this new type of mathematics problem. There were almost three times as many positive as negative responses to the task: 148 versus 56. Many of them liked: “working in teams” (85%) and “working on a real-life problem” (38%). While a large majority of students persisted in completing both tasks, some contradictory findings suggest that the novelty of the task was problematic. First, 14% of the students like that “the problem had many correct solutions” while at the same time, 8% dislike this. Second, of the 33% of students who wrote-in free responses, the top two positive responses indicate students think the task is, “fun or enjoyable” and they had to “think hard.” At the same time, the top negative free response was that “the problem is hard or complicated.”

In sum, findings from piloting the two tasks suggest that Yucatec Maya students may benefit if mathematics teachers facilitate real-life tasks that tap into community approaches to problem solving involving autonomy and improvisational mindset. Task 1 and Task 2 afforded students the opportunity to engage in real-life mathematics tasks that are radically different than the single-solution, textbook problems that they encounter. Students overwhelmingly enjoyed the tasks, and the majority of students overcame the novelty of the tasks and persisted in solving them. Results indicated that many students actually prefer improvising and drawing from their own expertise (using common sense) to using “equations” or “mathematics” to solve mathematics problems. The task results suggest that more consistent exposure to open-ended problems that connect with their cultural assets may help students become more engaged in mathematics learning. Mathematics reform in the US seeks to shift the focus away from correct answers and single-solution problems toward the Common Core approach where students explore solutions and approaches and discuss their reasoning. While text-driven and lecture-driven mathematics instruction is not optimal for any learner, studies show that it is particularly detrimental for low-income students of color (Boaler, 2002). My study findings indicate that the lecture-driven approach is particularly misaligned with the cultural assets of the Yucatec Maya students, and they may benefit from instruction that affords them more autonomy and freedom to innovate.

Results Summary

There are four major findings discussed in this paper. First, survey results further illuminate the cultural incongruence between school and home mathematics knowledge that was documented in the larger study. While the majority of students possess a growth mindset in general, three survey questions suggest that the majority of students entertain some fixed mindset ideas about mathematics, specifically. The second finding is that these three Yucatec Maya teachers value and incorporate autonomy and improvisational mindset in one non-mathematics domain in the classroom, namely classroom management. They capitalize upon students' cultural approaches of autonomy and improvisation to facilitate the learning of responsibility. However, the third major finding is that teachers miss opportunities to incorporate cultural approaches of autonomy and improvisation when teaching students to solve mathematical problems. Instead, teachers rely largely on single-solution, single-method mathematics problems to teach an algorithmic approach to mathematics problem solving. The final result is that students are engaged when solving culturally relevant mathematics tasks. They prefer drawing from their own knowledge and expertise, "sentido común" (common sense), when solving problems rather than using "equations" and "mathematics." At the same time, they persist in solving multiple-solution, real-life tasks, that are radically different than the single-answer, single-method mathematics problems to which they are accustomed. These four findings suggest that developing real-life mathematics tasks that build on students' cultural problem-solving expertise may improve engagement and ultimately achievement for Yucatec Maya students.

Discussion

There are three implications of this study. First, study results are important for redressing the mathematics achievement gap involving Yucatec Maya students as well as other historically marginalized students outside of the Yucatán. The village in this study is representative of indigenous communities in other parts of the Yucatán. Therefore, results may be generalizable and may be used to improve the mathematics education of other Yucatec Maya mathematics students. Perhaps, valuing and building on the wealth of cultural assets of the Yucatec Maya to teach mathematics could foster cultural identity and a sense of school belonging. Ultimately, this could improve academic achievement.

In addition to benefitting Yucatec Maya students, insight gleaned from this special case of cultural incongruence may inform mathematics instruction for other socioeconomically disadvantaged students. It is likely that other historically marginalized populations possess similarly overlooked cultural resources that are underutilized in the mathematics classroom. Furthermore, it is reasonable to speculate that students from other low-income, cultural groups in México and the US approach problem solving with autonomy and an improvisational mindset (Darling, in prep; Saxe, 1998). More research should be conducted to explore exactly how autonomy and improvisational mindset may be articulated in other low-resourced communities. These are timely speculations, since the majority of students in public schools in both the US and México are low income. Mathematics educators may want to build on these two cultural assets in order to improve mathematics education for other under-served, socioeconomically disadvantaged students.

The second implication of the study is that it may hold clues for how to teach adaptive expertise and other 21st century skills like innovation and creativity. Current US mathematics curriculum emphasizes teaching students in groups to solve multi-method, multi-solution problems using inquiry-based approaches rather than teaching students to solve single-solution problems using predetermined algorithms. Because many historically under-represented students may come to class with a well-established habitus around problem solving that includes autonomy and improvisation, educators should draw from these deep wells rather than overwrite these two cultural approaches. Rather than viewing Yucatec Maya students as lacking mathematics expertise, we could glean clues from the Yucatec Maya about how to teach autonomy and improvisational skills to other more affluent students who do not possess these cultural assets due to the virtue of their upbringing (Darling, in prep).

The final implication of the study is that it holds clues for how educators can: recognize and value students' cultural approaches; identify opportunities to incorporate them into mathematics instruction; and to teach culturally relevant tasks. This is especially relevant for those teaching in public schools where there is cultural incongruence between students' home and school mathematics knowledge. Study results demonstrate that we cannot presuppose that even insider teachers, like the ones in this study, will incorporate students' cultural knowledge and approaches into mathematics instruction. While these three indigenous teachers recognized and capitalized upon cultural assets in the classroom to a limited extent, they did not fully incorporate cultural approaches into mathematics instruction. Partly, no doubt because they were bound by a national curriculum. One can imagine the importance of explicitly teaching these culturally responsive teaching skills to educators in urban schools where cultural incongruence is most pronounced. In the US, 83% of teachers are white, female, and middle class, while the majority of public-school students are low-income and students of color.

It is clear that new models of mathematics instruction and teacher professional development are necessary to bridge the gap between home and school mathematics knowledge, and ultimately improve mathematics achievement for historically under-served students. I propose a three-tiered teacher-education model that makes cultural assets count. This model teaches educators to:

1. lean in and recognize students' cultural approaches and identify opportunities to incorporate these cultural approaches into mathematics instruction
2. develop real-life mathematics problems that deepen conceptual knowledge
3. teach an inherently egalitarian instructional model, like complex instruction (Cohen et al., 1999) or Boaler's Mathematics Mindset" (2016), which includes inquiry-based, group learning; eliciting the unique approaches of all students: facilitating constructive conversations, growth mindset strategies; and consensus-driven norm-setting.

Conclusion

There are limitations in this study. This school is representative of other Yucatec Maya schools in the Yucatán in terms of socioeconomic and ethnic demographics, mathematics curriculum, and national mathematics scores. However, this is still just a single case. Yucatec Maya community members are not culturally homogeneous and there are variations among mathematicsematical teaching practices between the mathematics teachers at this school and in other villages. Finally, although multiple data sources were analyzed and cultural insiders guided all phases of the study, still only two tasks were given to students at this one school. More iterations of the piloted task should be done to develop mathematics tasks that both deepen conceptual knowledge and build on students' lived experiences and culture.

As mathematics educators, we may not always recognize or value the cultural assets that our students bring to class. This study signals steps mathematics teachers can take to recognize, value, and incorporate into instruction the cultural assets of their students. First, teachers can examine their own assumptions and biases in terms of the mathematics achievement of marginalized groups. In this study, students who historically had high dropout rates and low mathematics scores possessed deep wells of cultural mathematics knowledge that were largely being untapped in mathematics class.

Second teachers can recognize that incorporating cultural assets does not simply mean incorporating references to Yucatec Maya food or vocabulary into word problems. It means teaching in ways that both tap into students' lived experiences and value students' cultural approaches to problem solving. This is challenging, because cultural approaches to problem solving may vary from group to group and even within a group. Teachers may have to take on the role of ethnographer. They may have to ask more questions; be more curious; and read about the histories and backgrounds of different cultural groups. Also, to learn more about students' cultures, teachers could ask students to create and solve open-ended word problems related to their own identities and cultural heritage. Third, teachers can adopt an egalitarian instructional approach like Boaler's Mathematical Mindsets (2016) or complex instruction (Cohen et al., 1999) that involves inquiry-based, group learning. These approaches make students' unique perspectives and approaches to problem solving explicit through discussions. Ultimately, inquiry-based, group instruction provides teachers with opportunities to lean in, notice how students approach problem solving, and build on these assets during instruction.

One final note is that is important for teachers to avoid the tendency to essentialize a group when delivering culturally sustaining instruction. It is difficult to claim with certainty that an attribute is a cultural feature for every person in a group. For example, upper middle-class Yucatec Maya students in the US may have different cultural assets than the students in this study. In fact, study data suggests that autonomy and improvisation may be more related to socioeconomics than indigeneity. However, it is possible that exactly how these two approaches are articulated in problem solving may be related to ethnic heritage.

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Appendix A

Table A2: Data Analysis

Question	Data Source	Data Analysis
1. What is considered "legitimate" mathematics knowledge and what traits make someone "good" at mathematics according to community members, students, and teachers?	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.
	280 Student surveys	Descriptive statistics, correlation analysis, subgroup analysis.
2. To what extent does mathematics instruction in the local middle school incorporate community assets into mathematics instruction?	Series of 5-10, informal interviews with each of 3 teachers.	Open code. Write initial memos, then focused coding and integrative memos.
	Field notes from observations of 5 lessons from each of 3 teachers.	Open code. Write initial memos, then focused coding and integrative memos.
	280 student surveys with mathematics mindset questions.	Qualitative and quantitative analysis.
	Observations of 2, 55-minute student tasks with 66, 9th	Videotape. Transcribe. Open code. Write initial memos,

	grade students that draw upon student approaches involving autonomy and improvisational mindset—with follow up interviews with 3 students.	then focused coding and integrative memos. Attitudinal question on tasks are a priori coded. Descriptive statistics on some items

Appendix B

Task 1

Let students move into groups of any size they want. Give a lot of wait time for them to move into groups of their choice at their own rate. Have them discuss question #1 in groups and then have them share with the whole class. Give plenty of wait time and look for clues that they are ready. Repeat process for question 2.

Currently, the Tunkurunchu community is experiencing some social problems. It's the same in many communities around the world.

1. Do you think there are social problems in the community?

   What do you think are some of these problems?

   (possible answers: poor diet, youth addictions, obesity, poverty…)

2. Have you thought about ways to alleviate these problems?

What are your ideas?

INTRODUCTION TO TASK

(Have a student read)

Today your group will have the opportunity to design a community center in the community of Tunkurunchu. Your group is free to choose three activities to include in the design of this center. Your design needs to include a triangular shaped ecological area in the center of this community center.

Part 1: *(Have a student read)*

Work with your group to decide which three activities you should include in your design of this community center. Describe them here.

1.

2. ____

____

3. ____

____

Part 2: *(Have a student read)*

Draw a sketch (specifying dimensions) and divisions of each of the three areas of activity. Each of the three activity areas should have a square shape. Also, the spaces for these three activities should abut a green (ecological area). This green area is a triangle-shaped area (a right triangle) that is enclosed by the three square or rectangular spaces. **The total area of the three activity spaces in the community center is less than 8,000 m^2.** This 8,000 m^2 does not include the triangular ecological area. You should design your three activity areas so that you **maximize the size of the triangular ecological area** in the center of the community center. Please, show all work.

Final Question: Did you enjoy working on this task? Why or why not?

____

____

____

Part 3: *(Have a student read)*

Use the following information to estimate the cost of bricks, cement, carpets, grass that are needed to construct the floors of this community center. Choose the most appropriate material for all three activities.

- Natural Grass = 600 pesos per m^2
- Synthetic Grass = 500 pesos per m^2
- Hardwood = 400 pesos per m^2
- Tiles = 200 pesos per m^2
- Cement = 150 pesos per m^2
- Plants for Green Area = 400 pesos per m^2

How much is the total cost of materials for all of the floors in the community center, including the three activity areas and the ecological area? (*Show work*)

1. ____

Final Question: Did you enjoy working on this task? Why or why not?

____

____

____

Appendix C

Task 2

Name:_________________________ Team:__________________

Date:___________________

Taxi-driver Problem

Directions: A family member in Tunkurunchu has a new business as a motor cycle taxi driver. However, he/she has a big problem. On Monday, he/she ran out of gas at 1pm, because she did not know how to estimate how far he/she could travel on one tank of gas (2 liter tank). The same thing happened on Tuesday. Please work in teams to develop a plan to make sure that he/she knows when to fill up her tank before she runs out of gas on Wednesday. He/she gets 20 pesos to drive someone the distance from Tunkurunchu to Tulum Pueblo and 5 pesos for any trip within the town of Tunkurunchu or Tulum. On Monday, he/she drove 41 kilometers and had collected 220 pesos, and she/she ran out of gasolina at 1pm.

1. Describe your plan for how he/she can fill up his/her tank before he/she runs out of gas on Wednesday. Explain why your plan will be successful. Base your responses on the information on the following page.

____

____

____

____

____

____

Saludos, ___________________

TRIPS AND FARES ON MONDAY

Time	Destination	Distance traveled	Money Collected
5:30 a.m.	Tulum Pueblo	4 km	20 pesos
6:00 a.m.	Tunkurunchu Pueblo	4 km	20 pesos
6:30 a.m.	Primary school	.7 km	5 pesos
6:45 a.m.	Primary school	1.2 km	5 pesos
7:00 a.m.	Primary school	.7 km	5 pesos
7:10 a.m.	Primary school	1.2 km	5 pesos
7:15 a.m.	Primary school	.8 km	5 pesos
7:20 a.m.	Primary school	1.2 km	5 pesos
7:25 a.m.	Primary school	.5 km	5 pesos
7:30 a.m.	Primary school	1.5 km	5 pesos
8:00 a.m.	Primary school	.9 km	5 pesos
9:00 a.m.	Combi in Tunkurunchu	.9 km	5 pesos
9:15 a.m.	Tulum Pueblo	4 km	20 pesos
10:00 a.m.	Combi in Tulum	1.1km	5 pesos
10:15 a.m.	Primary School	1.1km	5 pesos
10:30 a.m.	Tunkurunchu Pueblo	4 km	20 pesos
10:45 a.m.	Tulum Pueblo, then store	5 km	25 pesos
11:20 a.m.	Tunkurunchu Pueblo	4 km	20 pesos

11:50 a.m.	Secondary School	.5 km	5 pesos
12:00 p.m.	Secondary School	1.5 km	5 pesos
12:10 p.m.	Secondary School	.9 km	5 pesos
12:20 p.m.	Secondary School	.9 km	5 pesos
12:30 p.m.	Secondary School	1.1 km	5 pesos
12:45 p.m.	Secondary School	1.1 km	5 pesos
1:00 p.m.	Ran out of Gasoline	43 km	215 pesos
On Tuesday, he/she drove 44 kilometers and had collected 230 pesos, and she/she ran out of gasolina at 1 p.m., as well.			

The group who has the ***most reliable and creative solution with the most convincing reasoning*** *will receive 500 pesos. The group that has the second best answer will receive 300 pesos. The group that has the third best answer will receive 100 pesos. The money you receive must be used to purchase something for the school. You can combine your prizes and buy something that is 1000 pesos (for example) or each winning group can decide how they want to spend the money separately.*

Final Questions:

1. Which of the following do you like most about this activity? (*check all that apply*).

    (1) I can earn money for my school

    (2) I work in teams

    (3) This is a real-life problem

    (4) I compete against classmates

    (5) It involves a family member

(6) There are many correct solutions

(7) I write a lot

(8) Other (write in response)_________________________

2. Which of the following do you like least about this activity? (*check all that apply*)

(1) I work in teams

(2) This is a real-life problem

(3) I compete against classmates

(4) It is difficult

(5) It involves a family member

(6) There are many correct solutions

(7) I write a lot

(8) Other (write in answer)____________________________