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Teaching and Supporting Authentic Math Experiences in Grades 6-12

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Abstract

This qualitative study was designed to understand the experiences of middle and high school educators in teaching mathematics that is authentic and relevant to students' lives. With many studies in the literature review confirming the importance and effectiveness of authentic opportunities in math learning, the study looked at what holds educators back from these teaching practices. In-depth interviews with five mathematics teachers of various levels of experience offered insights into processes, barriers, and support needed to develop students' classical, critical, and community knowledge in mathematics. The study revealed a theory of the systemic shifts necessary for teaching authentic mathematics in grades 6-12.

Introduction and Problem Statement

According to Erin Turner et. al. (2009), "Students who feel that their out of school experiences are valued and integrated with their formal schooling have greater potential to see school as relevant and are better positioned to see mathematics, in particular, as a powerful tool in their lives" (p. 139). Unfortunately, many math educators, particularly of grades 6-12, have reported challenges in providing engaging experiences for students that are both authentic to students' lived experiences and aligned to academic standards. While there is a breadth of literature around the importance of authentic learning in mathematics (Brown, 1989; Honey et. al., 2014; Leinwand et. al., 2014; Showalter, 2013) and even some examples (Fancher, 2019; Garfunkel et. al., 2016; Gutstein, 2008; Gutstein & Peterson, 2013), there is little research around the processes educators use, the barriers they face, or the support they need to facilitate authentic learning experiences in mathematics (Turner et. al., 2009).

Review of Literature

Defining Authentic Math Learning Experiences

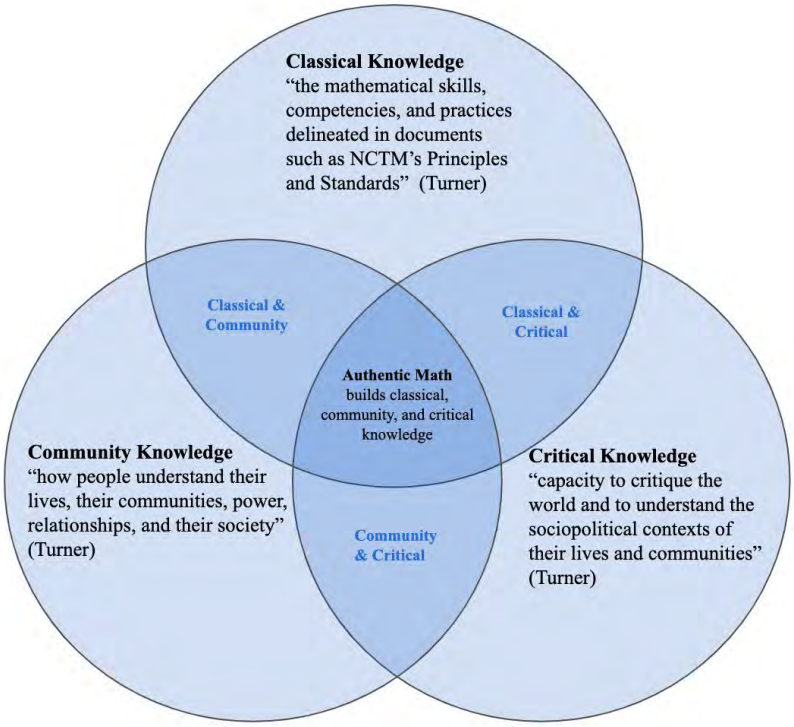
For the sake of coherence, and to align with the literature, we will define authentic learning experiences as those that require students to draw upon and develop multiple knowledge bases; including community, classical, and critical knowledge (Turner et. al., 2009). Note that there have been numerous attempts to define authentic learning experiences, and there have been many examples of learning experiences that align fully or partially to this definition of authentic, but use other terms to describe them like experiential, real-world, culturally relevant, place-based, contextual, or situated; among others (Brown, 1989; Fancher, 2019; Honey et. al., 2014; Showalter, 2013). Additionally, specific tasks in a math course are authentic when the goal or

outcome is defined, but the path to the solution compels student choice (Biccard, 2018; Mazur, 2003).

Turner describes *community knowledge* as understanding one's community, self, relationships, and the role of power in society. *Classical knowledge* includes the skills, practices and competencies you might see described in math texts or academic standards. Finally, *critical knowledge* is one's ability to "critique the world and understand the sociopolitical contexts of their li[fe] and communit[y]" (Turner et. al., p. 140).

Figure 1

Defining authentic mathematics as the overlap of community, classical and critical knowledge



As seen in Figure 1, it is in the overlap of community, classical and critical knowledge, that authentic mathematics experiences exist. Based on this definition, examples of authentic math tasks could be:

- Using functions to model the costs and benefits of buying local food versus buying imported food in our community, or
- "Estimating how much water and food is needed for emergency relief in a devastated city... and how it might be distributed" (Fancher & Norfar, 2019, p. 7).

These tasks incorporate classical knowledge, in that they require students to use and develop mathematical content skills (modeling with functions, estimating, etc.). They engage learners in considering their own community and their involvement in it, thus developing community knowledge. Finally the tasks are likely to engage students in critiquing the world, as they make assumptions about food choices (e.g. Are costs and benefits always financial?), and as they consider distributing resources (e.g. Should certain populations get emergency services first?).

A Call for Authentic Mathematics

At the national level, the Common Core State Standards for Mathematics (CCSSM) and NCTM Math Process Standards call for students to have opportunities to engage in authentic tasks and apply deep, conceptual understanding to meaningful contexts (Honey et al., 2014; Leinwand, S. et al., 2014). Implementing a rigorous curriculum, one of the "Key Shifts in Mathematics" (2020) called for by the CCSSM, requires teachers to "Pursue conceptual understanding, procedural skills and fluency, and application with equal intensity." As such, authentic, applied math learning can be a motivator for gaining procedural and conceptual understanding (Garfunkel, 2016).

Leaders at the state level are also calling for more authenticity in mathematics learning and assessment. In Maine, the Standards Review Steering Committee, recently called for the Standards Writing Committee to review the current state standards "through the lenses of the importance to ALL Maine students for College, Career, and Civic Life." They further called for examples in the standards that "raise the profiles of statistics, modeling, and cross-curricular applications such as: providing examples applying statistics in the context of social studies and sciences, and providing examples using modeling in the context of social studies, the sciences and computer science" (Clifford et. al, 2019). Educational leaders and researchers at the national and local level are calling for mathematics teaching and learning that address the needs of a changing world, while ensuring all learners find relevance and meaning throughout the process.

Having authentic experiences in a child's schooling is an issue of equity. While a purely classical style of learning may engage some learners, it is quite often that not all learners' needs are being met when math is presented in disconnected or contrived topics. There is growing evidence that providing students with authentic and integrated experiences, engages students who were formerly less engaged or lower performing (Lee & Galindo, 2018). In What We Know About Mathematics Teaching and Learning, Mid-Continent Research for Education and Learning (McREL, 2010) discusses the need for equitable teaching practices that engage all students in making deep mathematics connections, saying "When mathematics is taught in rich and realistic contexts, more students are able to build deep understanding. Students who learn mathematics through complex problems and projects outperform other students whose learning is more compartmentalized and abstract" (p. 64). It is critical to think not only of diversity of performance, but also of students of minority groups who have often been marginalized from

learning math in authentic ways. Citing a variety of studies, Turner et. al. (2009) states, "students from historically underrepresented groups demonstrate achievement gains when instruction builds on their cultural and community funds of knowledge" (p. 153).

Authentic Math Teaching Practices

Similar to other shifts in education, there doesn't seem to be a clear path towards authentic math teaching and learning for all. With all of the pressures and accountability systems that educators are facing on an increasing basis, it is unclear what processes effective educators are using to integrate an authentic approach, and what professional learning support all teachers need to do so (Turner et. al., 2009).

There are also different needs at varying levels of mathematics. Showalter (2013) states, "Since teachers more readily find examples of basic mathematics (e.g., arithmetic, proportional reasoning, geometric shapes) in the community, the unsuccessful struggle to find deep and authentic activities is often greatest for teachers of college-bound high school students" (p. 3).

Emerging from this need for more information about the processes behind authentic math teaching, this study focused on understanding teachers' experiences with teaching math authentically.

Research Purpose and Questions

The purpose of this study was to understand educators' experiences and processes in integrating community, classical, and critical learning in mathematics in grades 6-12. With most scholarship in the area of authentic mathematics focused on the effectiveness of specific teaching methods, the findings intend to help to build an understanding of the processes of teaching math

authentically, and inform professional development and pre-service teacher preparation. The study sought to answer the following research questions:

1. What processes are educators using to integrate community, classical and critical knowledge in mathematics teaching?

2. What barriers are educators facing as they strive to provide their students with authentic mathematics learning experiences?

3. What professional learning support do educators identify needing as they integrate authentic teaching practices?

Methods

Since the purpose of this study is to more deeply understand and explain the processes behind authentic math teaching and learning, a grounded theory design was appropriate. Grounded theory design is "a set of procedures used to generate systematically a theory that explains, at a broad conceptual level, a process about a substantive topic" (Creswell, 2019, p. 454). The qualitative study was a systematic approach to uncovering teacher experiences and therefore developing a conceptual model of potential systemic and instructional shifts needed or teaching authentic mathematics.

Procedures

Sampling

The process for selecting individuals for this study included a combination of theory sampling and snowball sampling. Theory sampling is a strategy of purposefully selecting

participants that, due to certain criteria, will help generate a theory (Creswell, 2019). Since the theory developed in this study was around teaching authentic mathematics in Grades 6-12, participants each had some experience with teaching mathematics at that level, and have facilitated or have considered facilitating authentic learning experiences. Participants spanned a great range of experience, which likely contributed to a more comprehensive understanding of processes, barriers and support needed. The five educators that participated in the study had 2, 9, 18, 28, and 31 years of experience teaching mathematics- averaging approximately 17 years. One of the five educators had recently become an administrator, but taught for many years before transitioning to a leadership role. The remaining four participants were, at the time of the study, working as classroom teachers.

Teachers in any geographical location were welcome to participate in an interview, although those who participated each worked in suburban or rural Maine public schools. Snowball sampling, where participants refer others to participate, was used to help build the sample size.

Teachers were recruited through my professional network, and it was a self-selection process for those who decided to participate. As an education specialist at a nonprofit that serves the state of Maine, my network consists mainly of educators who participate in professional development projects focused on STEM teaching. Recruitment methods included discussion of the study at professional development gatherings, inviting teachers within my network via email, and asking interviewees to share the opportunity to participate with others. All potential participants were informed of the purpose of the study. Specifically

they were asked to partake in a 30-45 minute interview regarding their thinking about authentic mathematics teaching and learning.

Data Collection

This study was designed to better understand teacher's experiences with teaching math that is authentic and connected to their communities. To explore these ideas, self-selected teachers participated in in-depth interviews, where they were asked about their experiences around authenticity in mathematics.

Before the interview, all participants were asked to read and sign an informed consent form that indicates what they were going to be asked to do, how long the interview would take, how the data would be kept confidential, and how the data would be analyzed and used. Interviews were recorded and transcribed, leading to a coding and analysis process.

The interview protocol (Appendix 1) was used to ensure continuity across interviews, and was developed based on the literature review and research questions of the study. At the beginning of the interview, all participants were provided with a definition of authentic math learning experiences on which to base their answers. This was done in order to avoid as much subjectivity around the definition as possible. Some of the interview questions were aligned directly to the research questions (e.g. *10. What professional learning support (if any) do you think teachers need in order to teach authentic and relevant mathematics?*), while others were designed to obtain a larger picture of teacher experiences (e.g. *6c. Could you provide some examples of authentic experiences you've facilitated?*).

Question 6 (*Would you say this definition (or components of it) aligns to your current math teaching practice?*) was originally designed as a means to filter participants who did not

have any experience teaching authentic math according to its definition. However, in the first two interviews, participants said that they did not think the definition aligned to their teaching practice, but then proceeded to share examples of authentic math they had facilitated. I then made the decision to ask each of the sub-questions of Question 6 to every participant, regardless of how they perceived their own practice, in order to get comprehensive data from all participants.

Data Analysis

A systematic coding process was used to analyze the interview data and generate a theoretical model. In phase one, open coding was used to form initial themes about the phenomenon. Axial coding, in phase two, narrowed the themes and made connections to other themes. The themes and sub-themes interact to expose the processes, barriers and teacher learning behind authentic mathematics teaching and learning. In phase three, selective coding was used to synthesize the relationships between the themes into a cohesive theory (Creswell, 2019).

Findings

The reflections of the interviewed teachers revealed a number of themes around processes, barriers and support needed for teaching authentic mathematics. As summarized in Table 1, the findings are organized by the themes and subthemes that emerged in the interview data for each of the three research questions.

Table 1

Teaching authentic mathematics

Themes	Sub-Themes

Processes for integrating community, classical and critical knowledge in mathematics teaching	
Examples/NonExamples	Connections to something outside the classroom Collecting, analyzing, and representing real data Using current events or issues Not random word problem that has no meaning to the kid Not covering curriculum for its own sake
Aligning to standards	Flexible curriculum sequence Order of planning
Connecting with community	Teachers making connections Having students make connections Service learning Helped with content unknown to teacher Challenging finding partners with ability to work with youth
Barriers to teaching authentic mathematics	
Standardized testing	Covering enough for students to succeed on test Testing format not aligned to teaching methods Test prep consumes time
Standards	Number of standards - depth or breadth dilemma Assessing standards but keeping it authentic Pacing guides and programs that dictate when standards are covered
The work is onerous	Teacher exhaustion Need more collaboration Not enough resources
Community tradition and trust	Communities not trusting of new ways of teaching Tradition of teaching math in discrete topics/procedures
Student needs	Gaps in foundational skills Different levels of understanding
Professional learning support needed for teaching authentic mathematics	
Models of success	Examples and models of projects and teachers facilitating projects Creating project timelines

Support in connecting with community members	List of community contacts Resource for how CCSS connect to real world careers
Teacher autonomy	Loosely structured exploration Curricular freedom Culture accepting of mistakes as areas for growth
Teacher collaboration	Firm goals but flexible means Involve all colleagues- not just a couple Time during summer, but also embedded throughout the year

Processes for integrating community, classical and critical knowledge in mathematics

When considering the integration of community, classical and critical knowledge in a math curriculum, teachers shared processes for standards alignment and community connections as well as several examples and non-examples of authentic math activities.

Examples and Non-Examples

Interviewees were first asked about how they perceived the importance of authentic learning in mathematics. This spilled into an opportunity to share about examples of their own processes with teaching authentic mathematics. Speaking about the importance of authentic and connected learning experiences in math, one teacher summarized,

> I think math unfortunately becomes... it's so classical knowledge, like that's what's pushed through schools. And it makes it hard for kids to buy in, but also makes them... It makes it hard for kids to like, make the connections to the classroom and things that are going on in society and then that empathy piece of, you know, understanding the world around and like where people of diverse backgrounds come from, or issues that are in our community. I feel like it's really lacking in the math curriculum, and I think it's a really important skill to have for our kids to have empathy and understand relationships and power and inequality and things like that.

Participants were asked to describe what an inauthentic math activity might look like, or one that did not fit the definition of connecting classical, community and critical understanding.

Some non-examples they shared were word problems without meaning or connection to students' lives. One teacher said,

> So not authentic is just me giving a kid a random word problem that has no meaning to the kid. But it's just taken out of a textbook and it's solely there to see if they can do the...they can perform the concept being taught.

Another teacher's perspective considered how word problems might be a gateway to authentic learning, saying, "[Authentic math] is not word problems necessarily. Although, I think word problems do open a window to authentic learning, because it just allows kids to make those connections."

Two teachers described non-authentic math learning as covering curriculum with a focus only on procedural practice. One said, "Off the top of my head, a non authentic math class would be covering curriculum for its own sake. I wouldn't be too enthusiastic about parallel lines, alternate interior angles, that kind of stuff." The other one said,

> I know a lot of math you have to practice to get better and sometimes just practice, practice, practice is a good way to go...But I think making it authentic- the difference would be relating it back to their lives and kind of incorporating the why and the how behind it, whereas the non authentic math is just the what?

When it came to examples of authentic learning, interviewees shared times where they supported students in making authentic connections to current events or issues, and where they were able to connect math learning. One example a teacher was facilitating at the time of the interview:

> We're doing a project on sustainability and resource use, and [students] will be reaching out to people in the community. And they'll be coming up with their own solution and collecting their own data and it's really their choice. And it has, it will have an impact on our school community.

In each case, participants described authentic math teaching examples by the connection they made to a worldly topic, before talking about the math they connected with it. Some of the topics included: climate change and carbon footprints, bias in the news, fish hatcheries, culinary arts, and elections.

Aligning to standards

A recurring theme across interviews was how teachers connect content standards with experiences that build community and critical understanding. Participants were asked explicitly about how they align units and projects to math academic standards, but they also brought the topic up several times while answering other questions. Two main strategies surfaced for standards alignment: maintaining a flexible curriculum sequence and deciding an order in which to plan –whether to plan a project around certain standards or attending to a project idea before connecting to relevant standards.

Having a flexible curriculum sequence, participants said, allows for some spontaneous connections to current events. One said, "I try to hit all the things we're supposed to hit, but sometimes if I see something we're going to cover in two months, but now is a great time to do it, I'll do it." For example, one teacher said they shifted some of the standards they planned to do later in the year to do a project on the electoral college around the time of a presidential election. Another teacher had just moved their circle unit in geometry to fall closer to March 14, to celebrate what's known as Pi Day.

When some interviewees thought back to projects they had done that they considered authentic, they observed that their process for standards alignment most often started with a project idea on a certain event or issue (e.g. presidential election, climate change, etc.),

prompting them to consider which grade-level standards they could cover in an exploration of that issue or event. A participant summarized,

> It wasn't like I looked at standards and said, I want to cover this standard, this standard, and this standard. I looked at the project, then said okay, what standards can I connect to it?...I feel like that's probably the easiest way to go but I also understand that in the end you have some standards that maybe you haven't covered and what do you do there?

Another teacher similarly noted that when they are working across disciplines, a topic idea is usually considered before standards alignment:

> If it's interdisciplinary, it usually starts with the project idea first and then we look at the standards to see how they could fit the project, but sometimes the standards trigger the ideas. Those projects stemmed from the science department, so I would like to start doing more math related interdisciplinary projects.

The one administrator interviewed shared a different perspective, saying that as a teacher they would start with a project idea first before aligning to relevant standards, but now as a leader, they think the process should be reversed. They said,

> And my thinking now as I'm an administrator, my thinking has really changed on this, because now I'm responsible for the learning of all the students in all subject areas... I really feel like the way to do it is to make sure there's some skills based [time] which may not be quite as much fun, but then really take these skills and find ways to creatively incorporate them into something that kids and teachers are excited about.

While there wasn't consensus about the order of planning authentic math experiences. There was commonality in the notion that authentic units or projects should cover multiple standards. One interviewee put it, "...if we're going to invest so much time and energy into one interdisciplinary project, we want it to hit like a few standards, just because of that timeline."

Connecting with community

An essential component of authentic math teaching is connecting students with their community, whether local or global. When asked about their processes for connecting with community members, interviewees shared examples of partners as well as how they utilized the partnership for learning. They also shared the challenges they've faced in making and maintaining those partnerships.

Examples of partnerships included: a partnership between elementary and high school classes dubbed "Math Buddies"; presentations by non-profit organizations like the local watershed coalition and an energy education program; a foundation who provided funding for a student-led project; and parent volunteers and local business leaders sharing their expertise.

Interviewees also shared about the nature of these partnerships. Many were isolated events where an expert would come in and share about how math is connected to their career, while others were connections that were more longstanding. One teacher shared an example where a community member had expertise that they didn't have about renewable energy and helped them get a project "off the ground" and helped them understand what data would need to be collected by students.

Teachers often made the connections to community members by reaching out to people in their own network, or by others reaching out to them. One teacher also shared how they had students do the work of reaching out to partners,

> In terms of the service learning projects, we have a lot of partners that individual groups had, they identified what they wanted to do. And then we found different partners. So for example, one group of students wanted, we had a greenhouse and they wanted to have fans that ran in the greenhouse to keep it cool during the summer. They wanted them all to be run by an energy source that was renewable. So they researched solar panels and figured out the cost solar panels and wrote a grant proposal. They had a fundraiser. So we

> partnered with Maine Community Foundation. I think that was the largest grantor of the funds."

Working with partners beyond the school community did not come without challenges. Interviewees cited challenges with knowing who to reach out, but also in finding time to adequately screen and prepare those who would be working with students. One teacher said,

> If I bring people in and they're not great with middle schoolers, I just don't, you know, I have to have that fine line...I've tried to prep [engineers] before, but it actually made them back off from coming into the middle school. Like I was saying, this math that they're doing is probably over my kids' head. Is there any way you could bring it down so that they can make the connections and it ended up just not working out.

Barriers to teaching authentic mathematics

Standardized testing

Standardized testing was identified as a barrier to teaching math authentically, because it takes time away from connected learning; it isn't always aligned with teaching methods; and it puts pressure on teachers to ensure they cover adequate content before students take the test. Standardized testing consumes time for not only the assessment itself, but also for preparing students for content and test-taking proficiency. When asked about barriers, one participant shared,

> There's so much testing. There's a lot of testing and I understand the importance of it on like, an RTI basis, and I do think that the data is good, but I also think students notice how much testing goes on…I don't think we've had like a solid month of school where we haven't had to do any testing or anything.

Testing places pressure on teachers throughout the school year. Another teacher captured the concatenated pressure, "It becomes tough when standardized testing puts pressure on administration who then put pressure on math teachers."

The standardized assessments that students take are assessing procedural skills more than conceptual or applied math understanding, which forces teachers to focus more heavily on procedural than conceptual or applied which are usually developed through authentic experiences. One participant suggested,

> Or maybe they change how they test instead of doing these standardized tests if there was something more of a project-based opportunity where they could show what they know, as opposed to just a test.

Standards

Similarly, the state standards that inform curricula and are used to measure student achievement were seen as another barrier to the participants interviewed. The number of standards, finding authenticity in the standards, and pacing guides or curriculum programs that dictate when standards are covered, were all cited as challenges inflicted by state standards. Many of those who cited them as a barrier, also saw value in them for theoretically ensuring equity across schools. Summarizing this dilemma, one teacher said,

> And I think it's important to have some standard across states for what should be taught in each grade level. Maybe there's just too much put in each grade level, you know, I think I'm always rushing to get content in. And so I think Common Core standards is a, you know, ideally a great thing so that everyone's on the same playing field in some sense, but I think maybe there's just too many standards to complete in one year. Like if I had less standards to complete, I could spend more time really diving deep into those standards and making more community connections and making it more authentic.

The number of standards expected of students increase dramatically in high school. There are 25 standards in 3rd grade, 28 standards in 8th grade math, and 52 standards in Traditional Track High School Geometry (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). One high school teacher expressed,

> Sometimes you just got to cover stuff and it's really hard to find that engagement part, you know, especially when the curriculum has been, "you have to do this." It's like there's no relevance or connecting to the real world.

There are also barriers in the grading system - how achievement of the standards is documented. As described by some participants, authentic learning involves opportunities for students to guide their own learning path. This often leads to students learning different skills at different times, as needed for different tasks. Negotiating both student choice and a timeline for certain standards has been a culprit for frustration:

> And I need a grade for a standard, which is the most frustrating part, is that instead of just focusing on learning, we also have to worry about grades…in an interdisciplinary project we're doing right now, the kids are getting data in so many different ways, I can align it to the standards, but it's not the same for every kid. So, you know, I have some where their data really is something where we could do, you know, like a two way table and look at the percentages and do that standard. And then I have others where we could do the scatterplot, and all of that kind of stuff. But it's, it hasn't been where like one standard that I can fit every kid under. So that's been our dilemma.

Many schools and districts choose to follow a specific math program usually from a published source. However, teachers noted that the resources provided are often disconnected from community and culture, and are often bestowed by administrators with strict pacing guides, which keeps them from seeking connections outside of the classroom. As one teacher put it, "The more rigid the curriculum, the more you're kind of focusing on classical [learning]."

The work is onerous

Another challenge to teaching mathematics with authentic and relevant connections to the community is that the work is challenging and time consuming. Summarizing the workload of integrating mathematics in a community-based project, a teacher shared,

> And I'll just reiterate that it's a lot of work. And it's a big picture sort of project...So you can't just really do it day to day, you really have to start with the end in mind when you get started. And you have to have a good sense of timing, because it's easy for one of

> these projects to go way over. And I think that being able to figure out a timeline beforehand that's accurate, takes some skills, or some training. I think that if you don't have those skills, you can learn it.

Teachers are exhausted: “At any time, we have this really tightly wound 183 day school year. And people are tired at the end of the day, and they're stressed at the beginning of the day.”

Some interviewed teachers pointed out a more systemic factor in the reason for why this work is so onerous. “I just wish we had more time, and I wish we had more resources,” a participant said. Without comprehensive resources for teaching math authentically, teachers said they are developing curriculum on their own time outside of the school day; and while they see where collaboration could lighten the load, there isn’t enough time dedicated to teacher collaboration either.

Community tradition and trust

Another barrier cited by teachers is tradition and trust. Two of the participants described challenges they’ve had with communities, both in and out of the school, not trusting new ways of teaching. One teacher shared that they have parents and community members who are critical of teachers not teaching “the same way they were taught,” and of when teachers leave school at the end of the day. They concluded, "Teachers have not been given much autonomy...the barriers are enormous in terms of tradition and, and the community trusting the teachers.”

Another participant who shared challenges where administrators were not trusting, noted the impact of traditional teaching on learning: "So right now we have a tendency, or traditionally we've had a tendency to teach everything very separately. And students then aren’t applying the learning, then they don't really fully understand the worth of the learning.”

Student needs

Gaps in foundational skills have also deterred teachers from facilitating authentic math tasks. Some teachers reported not feeling equipped to manage a project-based math experience, where students were all approaching the project from different levels of mathematics understanding. One teacher said,

> I also think something that I find holds me back a little bit is math gaps. So if a kid comes up, and struggles with multiplication and and just basic math, it becomes hard to connect current standards, because they don't have that foundation.

Similarly, another teacher described a situation where they weren't sure how to differentiate the learning that was happening in the context of an interdisciplinary data collection project:

> You know, if a kid was stuck sometimes that can make me just sit there like, I don't know what I'm supposed to do. You know? So I think yeah, that's the biggest barrier that kids are at different levels. You know, I have kids who are struggling just to make the coordinate graph, and then other kids who have the graph and want to go further.

Professional learning support needed for teaching authentic mathematics

When asked about professional learning support, interviewees shared ideas for resources and formats that might support their growth in authentic math teaching practices. Many also shared cautionary tales of times where they felt undervalued in overly structured professional development.

Models of success

All five participants shared a desire for examples and models of authentic math teaching. When asked about professional learning support, one teacher expressed, "I personally would love just more examples of it being done. I always like stealing ideas from math teachers that are doing

things well." Similarly, another teacher wanted the opportunity to read literature that provides examples of authentic learning:

> But also maybe even books that we could read to become more educated on authentic learning. Books with ideas of how to make it more authentic project ideas. Just a compilation of, of things that we can use to get started on a project of some sort or different assignments.

Another teacher expressed that while they have participated in a variety of professional development opportunities, more examples and models may help them to see what they are not yet seeing,

> … just also examples of what other people have done successfully. You know, like, just some models so that you have a jumping off place, like I like to look at what other people do and then take it and make it my own. So I think just examples of what it really means and what it looks like. I feel like I've done a bunch but I'm still not prepared. So I don't know what I'm missing.

Teachers shared that high quality examples could stand as a "guided structure" for creating their own projects, and that learning to use such a framework could be an essential component of professional learning support. One teacher noted,

> And you have to have a good sense of timing, because it's easy for one of these projects to go way over. And I think that being able to figure out a timeline beforehand that's accurate, takes some skills, or some training. I think that if you don't have those skills, you can learn it.

Support in connecting with community members

Another area for potential support that surfaced in numerous interviews was in connecting with community members that could help engage students in building community understanding through mathematics and building mathematics understanding through community connections. One participant said,

> Yeah, I think, a list of just people to reach out to community members...because there are so many people who work in the school and there's so many connections, and we just

> know those connections because we don't think to ask people so if there was maybe like a contact list of people that could help in a certain subject.

In addition to a directory of community members that could assist teachers in building their network of local professionals, another teacher expressed a desire for a list of explicit connections between careers and the state mathematics standards. They added that a list of those connections could support them in seeking authentic community connections.

> And it would be awesome if some place, they had just a list of common core standards that were being taught and like, had these specific parts of that career. Like I know the list like chemistry, you know, chemists use this or, you know, scientific notation if you're doing anything with space, but it'd be really nice to have a list of where these things are actually used...broad ones that you could find people in your community that are using it. Yeah, I don't know, just like a guided structure and examples would be really, really helpful.

Teacher autonomy

Many participants shared that meaningful professional learning needs to embrace teacher autonomy. One teacher bluntly stated, “Educators are fatigued and one day workshops are a slap in the face,” adding that, given time to explore with loose structures and goals in place, “every day you go to work can be a professional development day.”

The one administrator that participated in the study who was a former mathematics teacher, shared what they are doing to allow teachers to collaborate and explore:

> Time for exploration is important, and right now in our district we have half days every single Friday and Friday afternoons are for professional development. And some of that is structured, but there's also some less structured time which allows teachers to collaborate and there needs to be that time to collaborate for a really rich project to happen.

The administrator added that this structure was put in place because of the experiences he had in developing authentic math projects in the past. The ones they considered most successful were

the projects where teachers had dedicated time to explore resources and collaborate with colleagues.

Participants also expressed that their professional growth depends on cultural shifts toward teacher freedom and trust. One teacher said,

> And I think that's the other thing is you have to really give people permission and allow for mistakes because they're going to make mistakes when, when they try something new, so honoring that, recognizing that and celebrating mistakes, because mistakes is how we grow."

Similarly, another teacher said, "Yeah. And letting it be okay, that well, that was a total flop. You know, and how are we going to improve it next year?"

Teacher collaboration

Finally, every teacher interviewed sought collaboration with colleagues in order to teach authentic mathematics. When pressed for specifics, the average amount of time they thought would lead to success was approximately 3-5 hours of collaboration per week in both the planning and implementation phases of a project, in addition to time during the summer. One teacher expressed their frustration with schedules that don't allow for that time:

> So I think that making time dedicating time for professional development and collaboration is the number one thing. If you don't have time within the week, and teachers are teaching 35 hours a week and then spending 15 hours planning just to meet those 35 hours...how do you ever give them the time that they need to go beyond that, and to try some really innovative things?

One interviewee shared that professional learning opportunities need to involve the entire team, so that their whole department can collaborate without leaving anyone isolated. They shared,

> I definitely think there needs to be some PD, perhaps, teacher workshop days or conferences, and I'm always on the hunt for conferences, because I do enjoy them. But maybe one where like, the whole Math Department attends so it's not just one or two colleagues going- it's everyone. And just having you know, that kind of like this discussion about what is authentic learning and how we can do this in a manageable way.

Overlapping with the theme that planning for authentic math learning is onerous, teachers expressed that planning cannot happen on a day-to-day basis, and that collaboration must happen far enough in advance. One teacher shared that time in the summer might be required in order to plan curriculum within current scheduling constraints, saying "I feel like it would take a lot longer to put more things together throughout the year and we can build on stuff but there's really not much time unless we do it over the summer."

Discussion

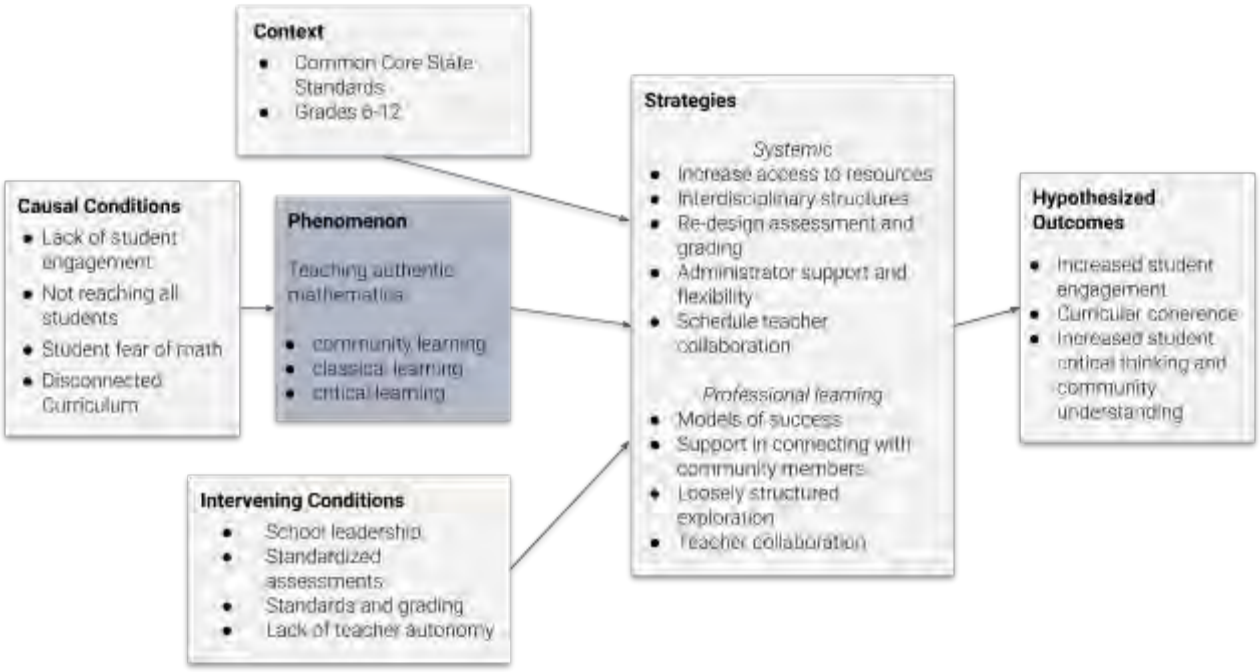
The purpose of this research was to investigate processes for teaching mathematics in grades 6-12 that builds students' classical, community and critical knowledge. A synthesis of the reviewed literature and the data collected in this study suggests a tension –that connected and relevant math experiences are necessary for rigorous learning, while at the same time are challenging for teachers to incorporate given current educational climate and systems.

Extensive interviews with teachers who strive to facilitate such learning were employed to explore some of these challenges as well as some of the processes teachers use to navigate them. The qualitative data collected revealed some of the strategies teachers have used to engage with community partners and align authentic math projects to academic standards. It also uncovered a number of perceived barriers to authentic math teaching, including: elements of standardized testing (frequency, volume, and type of items); restrictions of a standards-based system; substantial work loads; educational traditions in communities; and the varying needs of learners. Finally, interviewed educators suggested areas for additional professional learning that would support them in authentic math teaching.

The data supports an argument that many of the barriers holding teachers back from a fully authentic curriculum are results of systems that, if changed, could result in more authentic math learning. Moreover, other studies have found that these authentic experiences often lead to increased student engagement, curricular coherence, and increased student critical thinking and community understanding (Biccard, 2018; Darling-Hammond et. al, 2002, Turner et. al. 2009). Therefore I hypothesize that strategic systemic changes and teacher support could lead to these improved learning outcomes. Figure 2 illustrates a theoretical relationship between the current conditions and contexts impacting math teaching practices, as well as the proposed strategies for implementing authentic math curricula.

Figure 2

A theory of strategic shifts necessary for authentic math learning



Rationale for adopting authentic math teaching

Not only does the literature call for authentic learning in mathematics (Brown, 1989; Honey et. al., 2014; Leinwand et. al., 2014; Showalter, 2013), but the interviewed teachers also shared reasons they seek to implement authentic math teaching practices. While this data did not specifically address this study's research questions, the answers help us build a more comprehensive theory. Their rationale was founded on their experience with teaching or witnessing less authentic math curricula, and include: lack of student engagement, student fear of math, and disconnected curriculum. With regards to engagement, one interviewee shared that authentic learning would better motivate their students,

> And I also feel like in terms of engagement, that if they know that they're addressing a real critical need, then they're going to be much more engaged in the learning and they say okay, a math skill is something that I need to master to be able to address this critical need. And I'm really going to learn that skill, because there's a reason behind it.

Another teacher said that teaching authentic and connected math could help students who often fear math,

> And I think a lot of students like I've noticed A lot of the students that I've seen, especially last year when I was a new teacher to them, they fear math, like not every kid but like, if a kid's not good, if a kid's gonna be afraid of a subject, it's often math. And I think the reason for that is because it is sometimes seen as right or wrong. And I think making it more authentic, first of all, will help kids become more comfortable with it, because they're getting things that they're actually they know, like, they're being able to use that, such as the community aspect of it, and relating it back to their lives.

Two participants expressed that when they were not focused on making the learning authentic, they felt as though they were not reaching all students, while others cited a disconnected curriculum as a reason to work on creating more authentic learning opportunities for students. As

demonstrated in Figure 2, each of these reasons can be seen as causal conditions for teaching authentic mathematics.

Intervening conditions serve as barriers

The most common barriers that participants shared (standardized testing, standards, the work is onerous, community tradition and trust, student needs) can be traced back to the conditions of the job. Educators brought up school leadership, assessment practices, and lack of autonomy as intervening conditions that influence many of the barriers they face.

Implications for practice

The implications for this study are primarily directed at educational leaders, professional developers, and those who have influence on school-based systems. Structures like the Common Core State Standards expect teachers to make shifts toward teaching authentic mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), but in order to do so, they must have high-quality professional learning and supportive administrative systems in place.

Systemic Shifts

Based on the barriers identified in this study, several systemic changes can be recommended. First, participants cited challenges in accessing curricular and community resources for teaching authentic math. In response, administrators may need to increase access to resources, by seeking out curriculum materials that build community, classical, and critical understanding; or allocating financial resources or personnel to building math curricular connections.

Most of the examples of successful authentic projects shared by teachers were interdisciplinary in nature. This could imply that structural changes (e.g. flexible scheduling, cross-discipline collaboration) need to be made in order to accomodate the nature of projects that support authentic math learning.

Participants repeatedly expressed challenges with the current system of assessment. The frequency and volume of standardized testing as well as the types of items used to assess were perceived as barriers to authentic math learning. In addition, several educators said that grading practices can force topics to be addressed in isolation. Strategically redesigning assessment and grading practices to better suit authentic learning might alleviate some of these barriers.

Once more, teacher collaboration was a theme found across all three research questions. This has systemic implications in that teachers need adequate time for collaboration with one another as well as with community members.

Professional Learning Supports

The data from this study could be referenced in conjunction with the literature on high-quality professional learning in order to design supports for teachers adopting authentic math teaching practices. When asked what would support their professional growth, teachers expressed a desire for models of success, support in connecting with community members, time for loosely structured exploration, and goal-oriented collaboration. There are implications that each of these should be considered in order to support teachers.

It could be important to consider professional learning support that does not depend on the systemic shifts suggested by this study. For example, there may not be a forthcoming overhaul to the assessment system or standards, however this does not imply that authentic math

teaching practices must be avoided. Instead, professional learning could focus on helping teachers embrace some of the coherence in the Common Core State Standards as an opportunity to group standards together within a project, in order to navigate the challenge of having "too many standards" and avoid teaching concepts in isolation.

The data suggests that examples of authentic math lessons and units should be sought out or created. Where this is not yet possible, teachers could be supported in using curriculum materials they have as a starting point to making learning authentic. For instance, as one teacher put it, word problems might be labeled as application exercises by publishers, and while they often do not fit the full definition of authenticity, they could possibly be used as inspiration for connecting community-based problems with specific math concepts.

When teachers shared that they wanted examples of authentic math projects, they said they wanted models to serve as a framework for creating their own. In reflecting on those assertions, it could be considered compelling that they didn't say they wanted their whole curriculum written out for them. It is unknown whether they said this because they work in a culture where teachers are expected to write their own curricula, or if they do really desire to create their own.

In addition to providing teachers with such models, another implication for professional learning could be in helping teachers make authentic interdisciplinary connections. Most of the examples of interdisciplinary projects shared in interviews integrated data and statistics in science-focused projects. Professional development could focus on helping teachers move beyond solely connections with data, and towards other mathematical skills and practices. These

could include using mathematical modeling, event simulation, or decision optimization to explore interdisciplinary concepts (Oliver, 2020).

Participants suggested support in the area of connecting their classes with the community. This could take a variety of forms: additional personnel focused on community outreach or partnerships; training for teachers in communicating with local experts; or as suggested by one interviewee, a directory of people interested in working with students. A school-based research study could investigate which particular support would be most effective in building community relationships for math learning.

Finally, a major theme across interviews was a desire for more teacher autonomy and collaboration in professional development. This implies that those who support the learning of educators need to establish norms that allow teachers to have voice and choice in their own learning, as well as opportunities to learn with and from each other.

Implications for future research

Based on the outcomes of this study, there are many paths future research could take. In addition to a replication of this study with a larger sample size, future research could examine how teachers' own community, classical and critical knowledge impact student learning outcomes. Another important research effort would be to further examine how these systemic shifts influence teachers' ability to teach authentic mathematics.

Similarly, data from this study suggests that there could be a link between teachers feeling autonomous in their learning and decision-making and students getting authentic learning opportunities in mathematics. This hypothesis could be confirmed through additional research, in addition to measuring the effectiveness of specific professional learning supports sought by

participants of this study.

Limitations

The small number of participants allowed for an in depth analysis of teacher perceptions, however such a sample size is certainly limiting in getting a full representation of the field. Additionally, the sampling procedures were based on invitations and self-selection which may have been similarly limiting. Three of the five interviewees had a prior professional relationship with me which may have led them to adjust their answers based on what they thought was expected of them.

The decision to share a definition of authentic math learning with each participant at the beginning of the interview was made to provide a common premise for answers. Nonetheless, participants could have understood the provided definition differently than anticipated based on prior experience with the term.

Finally, I recognize my own bias towards professional development and systems thinking as effective means for educational reform. This bias could have influenced the coding process and overall focus of the study.

Conclusion

Earlier studies have questioned how teachers negotiate the tension between teaching meaningful learning and increasing systemic barriers (Turner et. al., 2009). It was the intent of this study to explore the processes and barriers for teaching authentic mathematics and consider how those challenges may be overcome. Strategies for teaching and managing authentic math experiences were uncovered, as participants shared examples of projects they had facilitated and community partners they had engaged. A number of barriers were cited by those who

participated in interviews, including challenges in standards and assessment, workloads, community trust and tradition, and in meeting students' needs. Finally, ideas for professional growth and support were elicited, and common responses included support in connecting with community members, models of success, teacher autonomy, and teacher collaboration. As mathematics educators build authentic learning experiences that incorporate classical, critical and community understanding; leaders can expect to support them through systemic change and opportunities for autonomous professional learning.

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APPENDIX A: INTERVIEW PROTOCOL

Practices for Teaching Authentic Mathematics in Grades 6-12

1. What grade level(s) do you teach?
2. What math courses do you teach?
3. How many years have you been a mathematics teacher?
4. To how many students do you teach mathematics in an average year?

For the sake of this interview, we will define an authentic learning experience as one that integrates community, classic and critical knowledge.

- *Community knowledge* involves understanding one's community, self, relationships, and the role of power in society
- *Classic knowledge* is the skills, practices and competencies you might see described in the math standards
- *Critical knowledge* is one's ability to critique the world and understand the context of their lives and communities

This Venn diagram shows the relationship between each area.[Show venn diagram]

5. On a scale of 1-5, with 5 being very important and 1 being not important at all. How important would you say it is for students to have authentic learning experiences in math that build community, classic and critical knowledge?
    a. Please explain your rating.
6. Would you say this definition (or components of it) aligns to your current math teaching practice?

    [If they say NO, skip to question # 7]

    [If the say YES or PARTIALLY, ask the following:]

    a. What do you do to make math learning authentic?
    b. What supports your use of authentic math instruction?
    c. Could you provide some examples of authentic experiences you've facilitated? Please provide as many details as possible (task/project, duration, final

product/audience, math standards, community connections, student collaboration, outcomes, etc.)

d. What is your process for ensuring tasks and experiences are aligned to academic standards?

e. Have you ever engaged with a community member to enhance student learning?

i. If yes, can you tell me about that process? How did you connect with them? How did the partnership enhance student learning?

7. What would you say is the difference between an authentic math task and a non-authentic one? Could you give examples?

8. What barriers (if any) do you think hold teachers back from teaching math that is authentic? If you think there are no barriers, please explain why you think so.

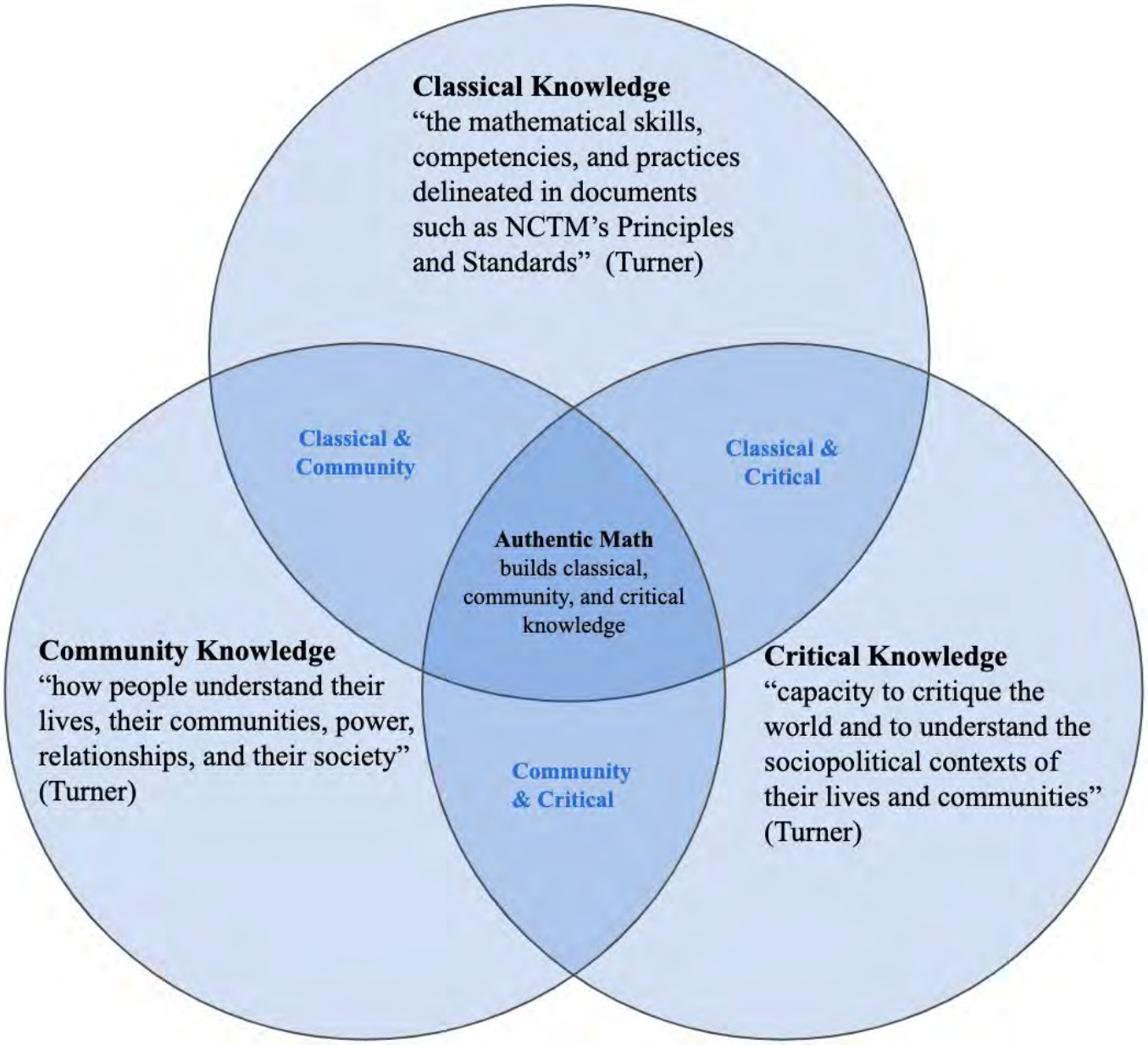
9. What systemic changes (if any) need to be made for teachers to successfully teach authentic and relevant mathematics?

10. What professional learning support (if any) do you think teachers need in order to teach authentic and relevant mathematics?

11. Do you currently have access to curriculum materials that you consider relevant to your students? [Yes/No]

a. If yes, where do you go to access relevant curriculum materials?

12. Is there anything else you'd like to add on the topic of authentic mathematics instruction?



Text from: Turner, E. E., Gutiérrez, M. V., Simic-Muller, K., & Díez-Palomar, J. (2009). "Everything is Math in the Whole World": Integrating Critical and Community Knowledge in Authentic Mathematical Investigations with Elementary Latina/o Students. *Mathematical Thinking and Learning*, *11*(3), 136–157. doi: 10.1080/10986060903013382

APPENDIX B
ADULT INFORMED CONSENT FORM

You are invited to participate in a research project being conducted by Hannah Lakin, a student at the University of Maine at Farmington. The purpose of the research is to understand educators' experiences in facilitating relevant and authentic mathematics learning in grades 6-12. For participating, you will have the opportunity to enter a drawing for a $20 gift card.

What Will You Be Asked to Do?
If you decide to participate, you will be asked to partake in a 30-45 minute interview regarding your experiences with mathematics teaching. This interview may take place in person or over video conference. This interview, with your consent, will be recorded. You may skip questions, you do not wish to answer, and you may stop the interview at any time.

Risks
Potential risks include the time and inconvenience of completing the interview. You will also be asked specific questions about your teaching practice, which may make some people feel uncomfortable.

Benefits
Potential benefits include the opportunity to reflect on teaching practices. This study may potentially add to growing research around math teaching practices and could be used to inform teacher support and professional development opportunities.

Confidentiality
Your identity will be kept completely confidential. No dissemination of results will include your name or place of work. Results may be shared at conferences or through publications. If this occurs, this data will continue to be kept confidential as discussed above. Some data may be shared with Education Specialists at the Maine Mathematics and Science Alliance. If this occurs, the identity of any participants will not be linked with the interview data shared, nor will any information that could potentially identify you as a research participant; for example, your name, the school where you teach, or involvement in certain programs. All data collected including interview transcripts, recordings, and notes, will all be kept on a password protected computer or in a locked file cabinet. This data will be kept indefinitely in these places.

Voluntary
Participation is voluntary. If you choose to take part in this study, you may stop at any time. You may skip any questions you do not wish to answer. There are no repercussions for joining or not joining.

I, _____, fully understand the purpose of this research and the procedures to be followed. I understand that my records will be kept confidential, my participation is voluntary, and that I may withdraw at any time without penalty. I also recognize that I may skip any questions I don't wish to respond to. Results of this research will be shared in the form of one or more publications and verbal presentations. If you have any questions about this study, please contact me, Hannah Lakin at hannah.lakin@maine.edu or 207-423-7806. You may also reach the faculty advisor on this study, Brian Cavanaugh at brian.cavanaugh@maine.edu or 207-778-7099. You may also contact the Chair of the IRB Karol Maybury at karol.maybury@maine.edu. By signing below, I assert that I fully understand the above and give my consent to serve as a subject in this research. (If you would like a summary of the results, please make the request of the researcher at the contact given above).

Please indicate whether you:

__ Agree to participate **and** agree to have the interview recorded

__ Agree to participate but **do not** agree to have the interview recorded

_____ _____
(Date) (Signature)