UNDERSTANDING INSTRUCTIONAL CAPACITY FOR HIGH SCHOOL GEOMETRY AS A SYSTEMIC PROBLEM THROUGH STAKEHOLDER INTERVIEWS

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This paper reports an ongoing effort to address the problem of instructional capacity for high school geometry from a systems improvement perspective. In an effort to understand the system that contains the high school geometry instructional capacity problem, we identified key stakeholders and conducted preliminary interviews to learn about the problem from their perspective. We use these interview data to describe the system in more detail and to identify six major factors contributing to the high school geometry instructional capacity problem.

Keywords: Geometry and Geometrical and Spatial Thinking, University Mathematics, Teacher Education - Preservice, Systemic Change

This paper describes emerging efforts to develop a networked improvement community to address the problem of instructional capacity for high school mathematics. The capacity problem as we see it is the following: While scholars' understanding of the knowledge teachers need for teaching has progressed to a point that this knowledge base could be used to inform teacher development efforts (Ball, Lubienski, & Mewborn, 2001), the volume of aspirants to secondary mathematics teacher education has been decreasing to a point that sustaining and improving university programs for initial mathematics teacher preparation can be challenging (Sutcher, Darling-Hammond, & Carver-Thomas, 2016). Traditional efforts at instructional improvement have started from the design of policies or practices (including curriculum implementation) that are believed to have the potential to solve problems, followed by evaluation efforts that seek to achieve main effects. Following such an approach might require action at the college level, seeking both for investments in the recruitment of teachers and implementation of curricular approaches for teacher preparation focused on the knowledge teachers need. Such efforts have been underway (e.g., U-Teach, https://uteach.utexas.edu/uteach-institute-seed-grant; see also Newton et al., 2010) and may help produce some improvement. At the same time, Bryk et al. (2015) have described such approaches as problematic on account of their top-down logic of improvement, relying on developers' own understanding of the problem and conception of the solution, which usually put a premium on implementation fidelity.

Bryk et al. (2015) propose a different approach to improvement that seeks to involve all actors within the system being improved in the process of problem formulation, system mapping, and improvement design aimed at reducing variability in outcomes. This seems particularly useful in a context where improvement design and implementation is likely to cross boundaries across systems (e.g., K-12, higher education) with different existing practices and norms, where the logic that might support improvement in one system (e.g., curriculum implementation at the K-12 level) may or may not be useful in the other (viz., higher education).

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Our paper documents an initial effort to undertake systemic improvement in secondary mathematics teaching knowledge by developing an understanding of the problem of instructional capacity for secondary geometry. While the former seems like a huge problem in general, addressing it systemically seems crucial. By this we mean understanding connections across the systems that participate in the problem, specifically university teacher preparation, K-12 teaching, and the policy level (see Figure 1). Thus, our first approximation looks at a smaller version of the problem of instructional capacity while still addressing it systemically. The choice of geometry is strategic as a way to simplify the more general problem of instructional capacity at the secondary level because geometry is largely contained in a single secondary course and is taken by almost all high school students. Likewise, most teacher preparation programs require their candidates to take a Geometry for Teachers (GeT) course. Furthermore, some progress has been made measuring mathematical knowledge for teaching geometry (Herbst & Kosko, 2014; Ko, 2019). Hence, reducing the investigation of the problem of developing instructional capacity in secondary mathematics to secondary geometry may allow us to maintain attention to systemic issues while not being overwhelmed by the sheer scale of the systems being investigated. In this paper, we outline the development of an understanding of the system that produces the current high school geometry (HSG) instructional capacity problem with the goal of further developing an inter-institutional community of university instructors of Geometry for Teachers courses.

Theoretical Framework: Systems Improvement Approach

Bryk et al. (2015) developed the concept of *networked improvement communities* by adapting an improvement science framework to the context of education research. In the early stages of the formation of a networked improvement community, Bryk et al. (2015) recommend developing a complete understanding of the "the system that produces the current outcomes" (p. 57), followed by systematic experiments in which members of the community implement small changes that have the potential to produce measurable differences in the target outcome. This requires that stakeholders identify a specific problem to be addressed and seek understanding about the larger system by asking "why" questions. Bryk et al. (2015) suggest using some diagrammatic tools to visualize who the stakeholders are and elicit their knowledge about the system to develop an accurate picture. Both a systems diagram (Figure 1), and what Bryk et al. (2015) call a fishbone diagram (Figure 2) for problem formulation are used.

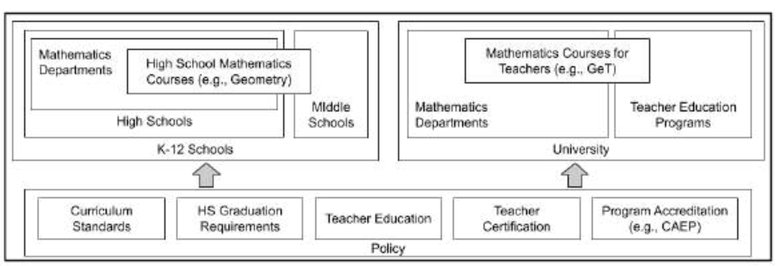

Figure 1. Schematic of the system that contains the HSG instructional capacity problem.

We developed the schematic in Figure 1 to determine who the potential stakeholders are in the problem of HSG instructional capacity. Material connections between stakeholders are indicated by overlapping rectangles. For example, the geometry courses for teachers overlap mathematics departments and teacher education programs because, while those courses are usually offered by mathematics departments, their existence relies on being required by teacher preparation programs. Students and teachers flow through the complex system: For example, high school students take geometry courses in high school; their mathematics experiences in school, for better or worse, prepare them for studying mathematics in college; those who decide to become mathematics teachers take college courses like Geometry for Teachers; if and when they get certified to teach, they are hired in K-12 districts where they might be teaching high school geometry. Likewise, some university students eventually become mathematicians who might be employed in mathematics departments and assigned to teach GeT courses. Mathematics teacher educators might also be observed in the system, inasmuch as they include former teachers and ordinarily participate in policy work such as standards development.

The *systems diagram* (Figure 1) is therefore useful as a way of identifying potential stakeholders in the problem of HSG instructional capacity. The diagram helps identify the institutional roles of people whose perspectives inform the problem. These include HSG teachers, secondary school or district leaders, HSG students, university Geometry for Teachers instructors, university mathematics department chairs, GeT students, faculty and administrators in secondary teacher education programs, recent university graduates, state or national policymakers, teacher assessment developers, and anyone making decisions about teaching certification and evaluation requirements at the state level. We surmise that improving the problem of instructional capacity for teaching high school geometry may require gathering representatives of all these institutions.

A *fishbone diagram* (Figure 2) provides a visual representation of the problem of focus for the networked improvement community (the head of the fish). Typically, these diagrams have five to six major bones, each representing a key factor that contributes to the problem, with more contributors (sub-bones) to each of those factors underneath. As our view of the HSG instructional capacity problem becomes more complex, the fishbone diagram serves as a tool to help us look for connections across stakeholders and determine potential levers for improvement.

One crucial component of a networked improvement community is a "hub" that serves to organize the information and activities of the network, including defining the system and eliciting the formulation of the problem. Our research team fills this role by gathering information from stakeholders in the system, collecting data, and disseminating the results back into the network. Members of our team have experience conducting research and teaching in secondary and higher education settings which supports our efforts to fulfill the role of network hub as well as collect and analyze the data reported in this paper.

Methods

We conducted semi-structured interviews with four sets of stakeholders from across the system in study; GeT instructors (*n = 42*), secondary school leaders (*n = 7*; 2 HS principals, 2 HS mathematics department chairs, 3 state/district instructional leaders), university mathematics department chairs (*n = 3*), and early-career mathematics teachers (*n = 3*). Recruitment and selection of participants varied by stakeholder group. The GeT instructors were already part of our project as members of an inter-institutional network made up of instructors of GeT courses located in mathematics departments at universities with teacher education programs. The secondary school leaders and early career teachers were recruited through a mass email to school leaders in a midwestern state that included an eligibility form to facilitate the screening process. We selected participants to ensure variability in administrative role, school and district size, and years of experience. The university mathematics department chairs were recruited through individual email requests from universities in a midwestern state that have a GeT course.

The interviews were conducted over video conference and recordings were transcribed for analysis. The interview protocol differed by stakeholder, but analysis of all interviews focused on connections between the data and our systems and fishbone diagrams. After the interviews had been conducted and analyzed, we reported our findings back to the network of GeT instructors through interactive online seminars.

Results

Each stakeholder group contributed to our understanding of the "hidden complexities" (Bryk et al., 2015, p. 14) within the complex system that contains the HSG instructional capacity problem. Within each stakeholder group, individual participants were able to offer insight into the particular ways in which those complexities manifested within their context. Participants vary in the number of years they have held a particular position within the system, and many of them also drew on experiences they had moving through the system (e.g., secondary school leaders that are former mathematics teachers who took a GeT course and were once students in HSG). In this section, we identify 6 main factors that contribute to the problem of HSG instructional capacity as indicated from interviews across stakeholder groups.

De-emphasizing the HSG Course

A contributing factor to the HSG instructional capacity problem is that the course has been de-emphasized by several stakeholder groups. Participants mentioned three underlying causes; (1) much of the HSG content is not needed to succeed in AP Calculus and AP Statistics, (2) HSG content is not rigorously assessed on the SAT, and (3) there is a lack of clarity on where and how HSG content should appear within the high school mathematics sequence (e.g., integrated into first- and second-year courses, as a fourth-year standalone course, etc.).

One district/state instructional leader shared that "the districts in [my] county right now are struggling with offering geometry, which is unfortunate, but they don't see an emphasis on the SAT" (CE). In addition, she identified an "importance of all students having success in Algebra 1 before they get to higher-level courses," which affords the Algebra 1 course more importance (and therefore more resources) within the high school mathematics sequence. This provides some evidence that the choice to de-emphasize HSG comes from pressure (or lack of pressure) at the school or district level. Policies at the state level may also be contributing to the deemphasizing of HSG within the system. "Messaging at the [state department of education] is that we don't have a course called geometry. Students have to demonstrate proficiency in the K-12 standards," some of which address geometry content (IF; district/state instructional leader).

There are a number of potential impacts on the HSG instructional capacity problem when schools, districts, and state education departments don't emphasize the HSG course. For example, while professional development specific to Algebra standards is frequently offered to inservice teachers, it is much less common to find Geometry-specific professional development.

HSG is not a Desirable Course to Teach

Teacher preparation programs set out to provide candidates with the knowledge, skills, and beliefs necessary to be successful secondary mathematics teachers, but multiple stakeholders identified disparities between the preparation candidates receive and the preparation they ultimately need. By far, the most common shortcoming in the preparation of HSG teachers is the overwhelming number who arrive on the job market with a lack of desire to teach geometry. Secondary school leaders at each level of administration told us, in one way or another, that "teachers don't like teaching [geometry]" (CK, Principal). One participant went so far as to say that teachers "were fearful of it" (IF, district/state instructional leader). Although there was one district that has had a steady stream of secondary mathematics teachers that view the course favorably, that was an exception to the trend.

While some stakeholders described the general phenomenon of teachers' lack of desire, some went further to identify underlying reasons for the undesirable nature of the HSG course; (1) compared to upper-level courses, HSG is not an ideal teaching assignment, (2) teachers are not comfortable with the HSG content, and (3) teachers hold an opinion that it is more difficult to plan for HSG than other mathematics courses. A district/state instructional leader shared that upper-level courses are more desirable for a number of reasons:

> There seem to be lots of people to volunteer at the upper-level courses to teach and not as many that want to teach Algebra and Geometry...I've been told those kids are easier to teach [in the upper-level courses], they come better prepared...The upper-level courses tend to have more stable classes, less kids that transfer in and transfer out...There seems to be a status thing, too, with teaching the upper-level classes where it's not seen as prestigious to teach Algebra or Geometry or an intervention class as it is to teach the upper-level classes. (ZM)

While some teachers express a desire to teach upper-level courses rather than HSG, others communicate discomfort with the content covered in HSG. A high school mathematics department chair described geometric proof as the most prominent stumbling block for teachers; "[A]s much as we can see what the process should be..., it's more difficult to teach that when it's pretty far from the other standards of math that are 'here's the process. That's it'" (RU). When one principal summarized experiences telling new hires that they would be assigned the HSG course, she said "[T]hey just cringe. They constantly tell me 'this is not my strong point.' And they try to blame it on the kids and say, 'the kids hate it'" (CI, Principal). One early career mathematics teacher even identified it as "kind of a beast to plan for—a lot of diagrams and whatnot and different notations—as far as making materials, it kind of seems overwhelming" (JL). Although none of these explanations for the lack of desire to teach HSG connect directly to university teacher preparation programs, we suggest that the structure of the system connecting universities to high schools, through the preparation and hiring of secondary mathematics teachers, may present levers for improvement.

Structure of University Teacher Preparation Coursework and Clinical Experiences

There are a number of factors that contribute to the HSG instructional capacity problem that are related to the structure of coursework and clinical experiences within university teacher preparation programs. Namely, there is wide variation in student teaching experiences, comparatively fewer opportunities to engage with geometry content, and a mismatch between the knowledge teachers gain and the knowledge they need on the job. Due to the wide variety of school contexts, teaching assignments, curriculum materials, and instructional styles, the student teaching experience often looks "wildly different, building to building, classroom to classroom, district to district" (ZM, state/district instructional leader), even for prospective teachers that come from the same program. On top of that variation in experiences, one principal reflected that "most student teachers do an Algebra [course]," and that if their mentor teacher has some sections of Geometry, "they don't really have them [take over] the geometry course until the end" (CI). If prospective teachers don't gain experience teaching Geometry in their clinical placements, they would need to rely on their university coursework for opportunities to think deeply about geometry content. If the GeT course is not required for certification, they may only have their own HSG experience to rely on. One HS mathematics department chair shared that "the most common response [to being assigned the HSG course] is 'I haven't done geometry since high school. I'm going to need to refresh on this'" (RI).

Even when prospective teachers do take a GeT course during their university coursework, the content is not always aligned to what prospective teachers feel they need when they begin teaching. Thinking back to his own university coursework, one principal shared that "there wasn't a whole lot of focus [in the GeT course I took] on what students would actually be learning in high school. It was more of exploring the higher levels of math. So I felt like there was a gap overall in my undergraduate experience of learning about subject matters that I would be teaching" (CK). One university mathematics department chair voiced support for that version of the GeT course, saying that prospective teachers "should know the subject matter a bit deeper than what their students do or what the textbooks cover" (RA). To him, that means that while HSG geometric proofs tend to be structured in two columns and contain a limited number of statements, "in a college course, they need to go one level deeper" (RA).

In addition to a focus on content that is beyond the high school curriculum, some GeT courses are taught in a style that runs counter to the instructional practices secondary mathematics teachers may be expected to enact when they are hired. An early-career mathematics teacher described the instructional style of his GeT course that was focused on spherical and hyperbolic geometry: "In the class itself, we never worked together. It was very lecture based. You sat there for an hour fifteen, got lectured to and left" (JL). This suggests that GeT courses at some universities are designed to support students' content knowledge but do not attend to their pedagogical content knowledge. However, the secondary school leaders described the ideal qualifications for a HSG teacher in terms that blended content and pedagogical knowledge, indicating that they were not so cleanly distinct in practice. For example, a district/state instructional leader said that "we need someone who kind of has a vision of the content and what they feel is the best way to teach it" (ZM). Another described ideal applicants who are "comfortable enough with their own knowledge to be able to listen to or hear their students when their students are proposing or conjecturing and that they're flexible enough not to shut them off right away and say, no, that'll never work" (CE). The possibility that the GeT course does not prepare students to become the teachers that these leaders identify poses an issue that GeT instructors may have the power to influence. However, GeT instructors have a variety of backgrounds and visions for what the course should be.

Variability in Geometry Preparation Within Teacher Education Programs

Despite some common experiences across participants, there tends to be significant variability among GeT courses, across instructors and institutions. We have heard from many GeT instructors that the course is unique within the mathematics department offerings because of the diverse student population that enrolls. Many courses report a mix of prospective secondary mathematics teachers, mathematics majors, and students from other departments that are taking the course as an elective. The mix of students creates a tension for instructors who are not sure how to balance the rigor required for a mathematics degree with the practical needs of prospective teachers (see Milewski et al., 2019). One GeT instructor went so far as to say that prospective teachers "take the same hard math classes all the other math majors take… [but] they typically don't like those courses. And some of them don't see the value of it for being a teacher" (RU). Depending on the particular context of each institution, the instructor assigned to the GeT course may have a doctorate in mathematics or in mathematics education. One GeT instructor expressed that the course is "mathematically sophisticated enough that mathematicians should be teaching it" (MV), while at some institutions the mathematics department chair defers to the recommendation of a mathematics educator to determine who teaches the course. Moreover, there is not a set criteria for determining the particular instructor. According to the university mathematics department chairs, GeT instructors have been chosen depending on instructor preference (AR) or who taught it most recently (MA). Depending on which instructor is chosen, the course content can vary drastically in terms of the extent to which HSG topics are covered and pedagogical content knowledge gained. Lastly, the GeT course is not highly valued at some institutions "because this course is really not a crucial part of the mission of the math department" (DZ, GeT Instructor). As a result, fewer resources are devoted to the creation of a course syllabus and materials, and stewardship of the course is left to individual instructors. All of these factors contribute to the varied geometry preparation of prospective teachers which, in turn, adds to the HSG instructional capacity problem.

Lack of Communication Across Institutional Stakeholders

Each set of stakeholders holds responsibility for some aspects of the preparation and support of HSG teachers, but there is no single stakeholder that controls the entire system. In addition, the system does not contain structures to support communication and collaboration across groups of stakeholders. A university mathematics department chair reported that there was not direct communication between the mathematics and education departments. At his institution, an informal communication system emerged, but it was not systematic.

> Well, indirectly we get input because [an instructor] also teaches a course in the education department. And so she sort of brings us sometimes, 'no, okay—they are doing this, we might need to modify this course or something. But I don't actively ask them to. (MA)

At a different institution, a GeT instructor mentioned that "the education department and the math department don't collaborate together, as they're in separate departments—we send our students [to the school of education] to do a credential, but we are separate departments in that sense" (KC). Although that instructor seems to trust that their education department counterparts are providing the appropriate instruction in service of their shared goals, a high school principal shared that she was "not very confident with the universities" (CI) in terms of how they supported prospective teachers in gaining content knowledge.

If stakeholders did not have opinions about what could or should be occurring within other parts of the system, it would be reasonable to expect minimal communication across stakeholders. However, our interviews with secondary school leaders indicate that they have clear ideas about how their potential hires should be prepared. Looking across the levels of school or district leadership, we heard the desire for prospective teachers to have "some kind of experience with computer [based] instructional materials" (ZM; e.g., GeoGebra), to have experiences struggling with mathematics content (ZM), to take a curriculum course "where math teachers truly know the [state standards] or the common core [standards]" (CI) and how the standards build across grade levels (CK, IF), to learn strategies for teaching problem solving skills (RU), and to have support determining how geometry is used outside the classroom (CY). Without structures in place to incentivize communication across stakeholders, it is likely that efforts to better prepare HSG teachers will fall short of serving the local community's needs.

HSG Staffing Decisions Made for Subject-Generic Reasons

When hearing from the secondary school leaders, it became clear that these leaders often make staffing decisions based on generic factors rather than subject-specific considerations. For example, one district/state instructional leader shared that the choice of who teaches Geometry "doesn't seem to be about the mathematics at all. It seems to be more about the behavior management of those classes and who's got the right attitude, the growth mindset" (ZM). In addition, staffing decisions at secondary schools tend to be made by taking into consideration the preferences and requests of current mathematics teachers so that when a position opens up "there will be kind of a reshuffling in terms of who is teaching what" (CK, HS principal). Furthermore, several secondary school leaders explained that they fill open positions by posting secondary mathematics positions rather than HSG positions. This may be a result of the current teacher credentialing system: "I think as long as they have secondary mathematics credentials, then they're supposedly able to teach Geometry. So it would just be expected" (CE, district/state instructional leader). These hiring practices may be contributing to the HSG instructional capacity problem as declining instructional quality impacts high school students who then travel through the system before returning to secondary schools as mathematics teachers.

Discussion

By considering the interview data presented here in the context of the systems diagram (Figure 1), we develop a more nuanced view of the system that contains the HSG instructional capacity problem. Schools and districts post openings for secondary mathematics teaching teachers, but tend to place the new hires in Algebra 1 and Geometry courses because the current teachers within the department request to teach other courses. This means that Algebra 1 and Geometry courses tend to be taught by new hires, many of whom are just out of teacher preparation programs. Upon being hired, those new teachers will receive comparatively less geometry-specific professional development and support as a result of school, district, and state educators de-emphasizing the HSG course. In their university teacher preparation programs, these teachers were not guaranteed to have had opportunities to develop geometric pedagogical content knowledge through their coursework or clinical experiences. These connections across major bones in Figure 2 indicate that there is a need for a network that spans stakeholder groups to inform improvement efforts.

As we move forward with this work, we plan to use what we have learned from these interviews to create surveys that can be administered to a national sample within each stakeholder group. A larger sample is a critical way to address limitations to analysis that arise from making claims based on idiosyncratic experiences. We will consider how the preliminary interview data from one stakeholder group can inform efforts to craft survey questions for the other stakeholder groups. For example, secondary school leaders indicated that they sometimes look to see if applicants earned a passing grade in their GeT course, so we might like to ask how often GeT Instructors assign a non-passing grade in those courses. We are also interested in learning more about how preservice teachers' experiences in the GeT course might relate to their desire to teach HSG when they apply for jobs. In our role as the hub of this networked improvement community, we have a unique opportunity to disseminate the knowledge and perspectives of parts of the community across stakeholder groups in an effort to improve the instructional capacity of the high school geometry course.

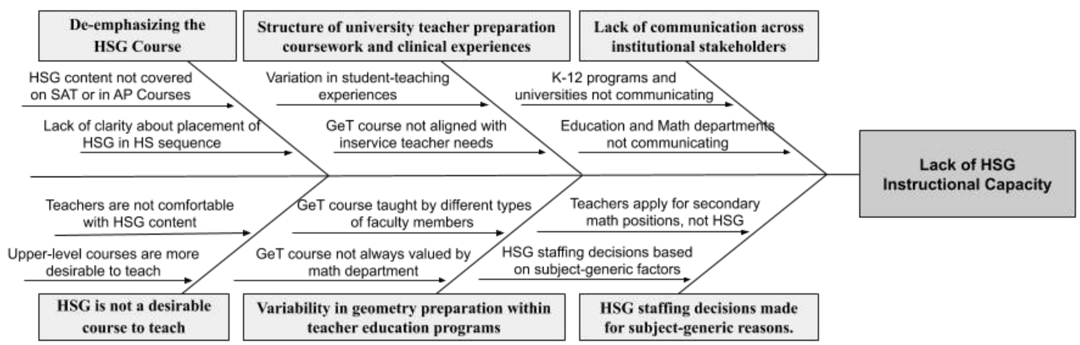

Figure 2. Fishbone diagram representing lack of HSG instructional capacity.

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