Nontraditional Pathways to Teaching Postsecondary Math: A Qualitative Study on Educators Between the Boundaries of High School and College

Charlotte Beckford
University of Tennessee

Nathan Burns
University of Tennessee

Emily K. Campbell
University of Tennessee

Jessica L. Kingsley
University of Tennessee

Anne M. Ho
University of Tennessee

Past research typically assumes that an instructor is a high school or college instructor, but not both. The mechanisms to obtain teaching credentials for each are also traditionally separate, but some instructors teach at both levels simultaneously or transition between them during their careers. To better understand them, we surveyed instructors with experience in both high school and college math teaching. For our qualitative study, we asked questions centered around the Pedagogical Content Knowledge domains within Mathematical Knowledge for Teaching (Ball et al., 2008; Shulman, 1986). In this paper, we discuss the survey, data collection, coding, and findings on teacher perceptions of their jobs that fall across institutional boundaries.

Keywords: Pedagogical Content Knowledge, high school, college, teacher education, professional development

The University of Tennessee's Master of Mathematics program targets current U.S. high school math teachers interested in transitioning to postsecondary teaching. Some are interested in full-time employment as a lecturer/instructor. Others are interested in continuing their full-time high school careers with additional part-time teaching at a postsecondary institution, including dual-enrollment teaching. In both cases, we consider them as part of a pool of prospective VITAL faculty, which is the MAA's acronym for Visitors, Instructors, Teaching assistants, Adjuncts, and Lecturers, a growing teaching force in the US (Blair et al., 2018; Levy, 2019).

These prospective VITAL faculty are taking a nontraditional route to becoming postsecondary educators. Rather than enrolling in courses that form foundational knowledge for research, they enroll in courses emphasizing applications to teaching. Due to their current high school employment, these educators cannot also work as Graduate Teaching Assistants (GTAs) to gain college teaching experience. Even if they had the time, a traditional GTA role often caters to novice instructors (Speer, et al., 2005) and is arguably inappropriate for these educators who have more experience and knowledge of pedagogy. As a group, they are understudied in research. One reason is that many are associated with two-year colleges, and the literature on two-year math instruction is already sparse in comparison to K-12 or university education (Mesa et al., 2014; Mesa, 2017). A second reason is that dual-enrollment literature tends to focus on policy and students rather than on the instructors' practices (An and Taylor, 2019; Barnett and Stamm, 2010; Gonzalez, 2018; Johnson, 2018; Karp et al., 2004; Mokher and McLendon, 2009).

To better understand and eventually support these educators, our research team started by considering the views of similar faculty. In our qualitative study, we surveyed educators with experience in both high school and college math teaching. Because these educators work between institutional boundaries, they have a unique perspective and can directly compare high school versus college teaching in a way that other math educators cannot. For this first phase, we focus on the research question: What are the perceptions of math teaching for educators with experience in both high school and college?

Framework: Pedagogical Content Knowledge

As identified by Shulman (1986), an instructor should be proficient both in the material they teach and in pedagogy. Although he identified these two types of knowledge for teaching in separation, Shulman claimed that instructors employ both types of knowledge in conjunction and that research should reflect this. Furthermore, he proposed the existence of PCK, the idea that instructors must possess knowledge of the subject they are teaching which other experts of that subject do not require. Stemming from interest sparked by Shulman's work, Ball et al. (2008) formalized an empirically supported and practice-based framework of MKT. Two overarching domains compose the framework: Subject Matter Knowledge and PCK, the latter of which we focus on in our work because some subdomains of Subject Matter Knowledge aren't as clearly defined for secondary and post-secondary teaching (Speer et al., 2015). In addition to Shulman's Knowledge of Content and Curriculum (KCC), Ball et al. identified two empirically differentiable subdomains of PCK: Knowledge of Content and Students (KCS) and Knowledge of Content and Teaching (KCT).

In more detail, KCC refers to instructors being familiar with the materials and resources available to them to teach their topic, as well as the contexts when they should be used, such as horizontal/lateral and vertical curriculum knowledge (Shulman, 1986). KCS refers to teachers anticipating students' thoughts and misconceptions (Ball et al., 2008). Lastly, KCT refers to instructors knowing how best to teach their subject with illuminating examples and appropriate scaffolding. We used PCK as our framework to study teachers with experience in both high school and college math teaching; we describe implementation details in the next section.

Methods

Survey and Cognitive Interviews

We developed open-ended survey questions relevant to each subdomain to explore various facets of teaching. We asked two versions of each question: the first being a version about high school math teaching, and the second being about college. We asked participants to describe their teaching practices, a strategy that aligns with Ball et al.'s (2008) practice-based approach.

We first conducted semi-structured cognitive interviews (Karabenick et al., 2007) with five participants using video meetings (Zoom), and we made slight adjustments to our questions for clarity before we collected data from our target population.

As an example of our questions aligning to KCT, we asked instructors how they choose class activities to help their **high school** students learn, and then we followed with a question about how they choose class activities to help their **college** students learn. We developed each question with one specific subdomain of PCK in mind (see Table 1), but during the cognitive interviews, we encountered a type of "boundary problem" like what was originally described by Ball et al. (2008) as some of our interviewees blurred the line between subdomains of PCK. As Ball et al. had originally admitted, "It is not always easy to discern where one of our categories divides from the next, and this affects the precision (or lack thereof) of our definitions" (p. 403). Thus, rather than attempting a perfect one-to-one mapping of our survey questions with subdomains of PCK, we take the stance that this boundary problem is inherent to the subject.

We further recognize that we, ourselves, are components to our instruments in our research (Maxwell, 2012). We acknowledge that our research team consists of individuals who have been in or are currently in a traditional research-focused math graduate program and have thereby not taken the same career path as the individuals in our study. One of our research team members has completed a teacher education program and has taught in a secondary classroom in the UK (instead of in the US). Four of us were GTAs for most of the first phase of this project. Currently, two of us are full-time lecturers at a large, public, and research-focused university.

Table 1. A classification of survey questions according to the subdomains of pedagogical content knowledge.

Question Pairs	Intended PCK Subdomain
Q4/5: Describe how you choose class activities to help your high school/college students learn.	KCT
Q6/7: Describe how you make decisions about which topics to teach in a high school/college class session.	KCC
Q8/9: Do you use technology to support high school/college student understanding of particular topics? If so, how?	KCT
Q10/11: Describe how you scaffold content for a class of high school/college students with a range of backgrounds.	KCS
Q12/13: Describe how you support high school/college students in communicating and justifying their mathematical thinking.	KCS
Q14/15: What do you think is the relationship between high school/college math courses and the rest of a student's education?	KCC

Data Collection

We sent the online qualitative survey instrument via relevant email and professional society message boards. The first question asked participants if they had taught both high school and college math courses in the U.S. Participants in the target population self-reported their experience in further detail with information about the types of institutions they worked at, courses they taught, and years of experience. In this first dataset, we have 26 responses. If we think of the "traditional" pathway to teaching college math as starting from graduate math coursework and ending in a tenured professor role, then our participants presented a range of nontraditional pathways to college teaching. For instance, Participant 5 started as a tutor and adjunct at a community college, moved to a full-time two-year college role, went back to math graduate school, and then ended up teaching at a private high school while continuing to adjunct at a college. Most of the participants started in high school and added on college teaching later, but we also have people like Participant 11 who started college teaching as a GTA in a math graduate program, taught full-time at a college, and then switched to full-time high school teaching. Most of our participants did not disclose their tenure-track or non-tenure-track status, but many discussed experiences in temporary (n = 11) or adjunct (n = 7) college teaching roles, and the average number of years of teaching is 17 (including part-time and full-time teaching).

Coding and Analysis

We analyzed our data with thematic analysis (Braun and Clarke, 2006). Our initial phase was familiarizing ourselves with the data by reviewing it in totality, which included typed responses and transcriptions from audio recordings—our survey was developed on the Phonic platform, which allowed participants to choose between typing written responses and recording audio responses (Phonic). We employed an inductive approach to search for potential patterns and to compile our initial codebook. Next, we organized an updated, condensed codebook with clearer definitions for a total of sixteen codes. We re-coded each question independently with two researchers per question. Finally, we computed percent agreement for interrater reliability, discussed discrepancies, and re-coded one last time.

Our codes emerged from our reading of the data, but we also find clear relationships between our codes and facets of PCK. For instance, we have three codes on the reasons behind an instructor's usage of technology, which relates to both KCS and KCT. Participant answers were typically coded as using Technology for Scaffolding, using Technology for Understanding (including visualization of content), or thinking that Technology is Distracting. We primarily used these codes on our pair of questions about instructor use of technology. Interestingly, we also found that these codes emerged in other pairs of questions. For instance, when we asked participants about choosing class activities, Participant 19 reported that they "try to choose activities that have a strong visual representation and, when possible, a dynamic piece of technology that they can engage with to explore mathematical relationships" (coded as Technology for Understanding). On the other hand, some participants merely listed technologies that they use when we explicitly asked about technology usage. For example, Participant 12 simply said, "Yes. Graphing calculators and Geogebra." Their answer involves technology but does not present any information past that, so we left this response uncoded.

As with the technology codes, we had other codes that we expected to see in certain pairs of questions. In one pair of questions, we asked participants to "describe how you support high school/college students in communicating and justifying their mathematical thinking." Rather than focusing on the frequencies of our Justification code here, we considered the times that it showed up in other questions unprompted. We focus on the details of the unprompted codes in the next section.

Findings

Instructors Have Student-Centered Intentions

Student Interests. One of our most common codes involves descriptions of practices that cater to Student Interests (including career goals, motivating examples, applications, other courses, and explicit mention of student engagement), and we saw this code across all questions in the survey. The Student Interests code emerged most frequently in Q14/15 when we asked, "What do you think is the relationship between high school/college math courses and the rest of a student's education?" Participant 1 indicated that they adapt their college teaching practices based on student career goals. For non-STEM students, they said, "in the end what I want the student to remember 5 years down the road is not the properties of logarithms but rather how I might engage with critical thinking and reasoning to work my way through solving a problem that arises." For STEM students, this instructor said, "I need my STEM students to understand how they are going to be using the math we are currently doing later in their studies and in their possible future careers. They still need those critical thinking and problem-solving skills, BUT they also need to [be] able to think more mathematically and quantitatively." When asked about topics in specific college class sessions, Participant 1 consistently centered on Student Interests as they stated, "I generally pick topics that I know students will need for subsequent courses or that I feel apply the mathematics in creative ways." Many other instructors were also attentive to student interests across questions, and we applied this code seventy-six times across all twelve content questions in our survey, which was one of the most frequent of the codes we used.

Interestingly, when comparing pairs of questions, we saw more mention of Student Interests for high school students than for college students in Q4/5 and Q6/7. Participant 15 is one of the instructors who mentioned student interests in their response about high school but not in their response about college. For high school teaching, they said that they must consider topics on the standardized exam "but that also help students connect math to the real world." This differs from their practice when teaching college-level math, for which they said, "I look for activities that students can start in class but finish at home, since many students work at different speeds and college class time is quite limited. I favor online activities that can be automatically graded." In college, the time pressure to cover content is so great that this instructor changed their teaching practice, and they opted for the ease of automatically graded problem sets.

Social and Emotional Needs. Another relevant code is that of the instructor attention to students' Social and Emotional Needs (including connections to peers, collaborative skills, attitudes, confidence, and comfort). We also saw this code emerge in every pair of questions that we asked, though it showed up more frequently in our questions about student justification and communication (Q12/13). When asked to "describe how you support high school students in communicating and justifying their mathematical thinking," Participant 14 simply described what the peer-to-peer interaction is in their class: "Students explain to each other how they got their answers. Students think about other approaches to a problem and try to explain other's methods." Several other participants also utilized group work and discussion in "think-pair-share activities" (Participant 17) or by having students "explain their work to each other" (Participant 18). For college teaching, multiple instructors said that their classroom choices were the "same" (Participant 17) or "identical to high school" (Participant 24). Furthermore, it was also important to some instructors to "build enough trust and rapport between [the teacher] and among the students to allow students to contribute imprecise or tentative ideas" (Participant 8). Participant 11 also emphasized the creation of a "comfortable" classroom environment. Overall, we found that our survey respondents believed that students' communication and justification skills were inextricably linked to their social and emotional needs.

Instructors are Influenced by Test and Time Pressures

Test Pressures. As expected, we saw our Test Pressures code appear in all questions, although it did not explicitly show up as frequently as other codes. In Q14, many teachers discussed foundational knowledge, but Participant 25 talked about the practical side of college applications by saying, "As long as math ability is tested on [the] SAT and a basis for college acceptances, it is probably the most critical course selection in a high school student's transcript. It can affect science classes and the ability to schedule any other honors level courses." Participant 22 also reported test pressures but in reference to Advanced Placement (AP) tests. In Q6, they reported, "For all but one year teaching high school, the school I taught at followed the AP curriculum (for better or worse). So the topics for the course were fairly well set in advance."

For college teaching, local expectations for exams also influence instructor choices. In the case of Participant 17, test pressure came up in the question about utilizing technology in the classroom, and they said, "I don't use technology as much in my college classes because they won't be allowed to use the technology during the exams, which make up most of their grade." For their high school teaching, this instructor used graphing calculators and Desmos, but they change their teaching practice in college when it didn't align with the expectations for the high-stakes exams. Participant 8 had a similar sentiment and said their department also had a "no-calculator policy"—since they couldn't "assume or guarantee access to graphing technologies," they would "rarely engage students in using technology to explore or understand ideas."

Time Pressure. For college teaching, our participants also felt that the lack of class time (when compared to high school) affected their classroom decisions. Notably, our code of Time came up more frequently in the question about choosing class activities for college classes when compared to the parallel high school question. As we saw earlier, Participant 15 was attuned to Student Interests but was pressured by the lack of time and so they chose online activities with automated grading. Participant 20 also thought college class sessions were too short, and although they reported a mix of lecture and group activities in their high school classes, they said, “Due to the limit of a 55-minute [college] class, it is mostly a lecture style class,” a choice echoed by Participant 18. Additionally, Participant 22 described how they heavily utilized Inquiry-Based Learning (IBL) in their high school teaching and tried to incorporate it in college, but “this did not work out—the students were not used to this type of learning, and because I had to get students ready for the next calculus course, I felt I didn’t have the time to use IBL methods.” Even for instructors who used more active learning methods in their high school teaching, some felt so much time pressure in college teaching that they used lectures more or active learning methods less.

Instructors Provide Commentary on Their Working Environment

Predetermined Content. One of our codes is about Predetermined Content, meaning the content was determined by someone other than the instructor themselves. We expected to see this when asking teachers about high school course content decisions as we assumed that state standards would frequently be discussed. Unexpectedly, we saw that this code came up more in the college teaching answers than for the high school ones—in fact, 64% of the responses for Q7 were coded as Predetermined compared to 30% of the responses for Q6. Perhaps Participant 7 explained this by saying, “My understanding is there is a lot more leeway with the topics that are taught at the college level. However, I believe there should be a bit of a consensus if you are teaching a class that is a prerequisite for another class.” We also expected there to be more flexibility in college courses overall, but our participants reported that they primarily taught introductory non-major courses, and so they were more likely to be working with a course coordinator or a preset list of topics. For Q7, Participant 9 had a representative answer: “The topics to teach are again completely set by the [department] syllabus—I don’t really have a choice on this.” When reflecting on their lack of autonomy, many instructors maintained a matter-of-fact tone without a positive or negative connotation; those like Participant 20 simply stated, “I am told which topics will be covered in the course.” However, in both descriptions of high school and college teaching, some instructors had negative associations with their lack of choice. For example, Participant 21 said, “Unfortunately, the district curriculum prescribes my topics and associated pacing.” When talking about their college teaching, the same instructor said, “Again, topics are already decided. In general, I will avoid teaching content that I know is not on the test. For example, even though I may find some underlying concepts in the complex numbers rather interesting, I avoid teaching them because students generally only need to know the procedure.” Due to predetermined content that was procedurally focused and test-driven, this instructor actively avoided teaching concepts and topics that they find interesting.

Commentary on the System. Another notable code is the one regarding Commentary on the System. This is a code that cuts across and outside multiple dimensions of PCK, but we saw it appear in every question of our survey. In most cases, teachers were providing commentary on barriers. Some of these barriers related to prerequisite student knowledge, such as when Participant 9 talked about how they must “spend a long time ‘undoing’ the unintended consequences of prior instruction. Students have typically automated all kinds of procedures without fully understanding when or why they should be used.” Other instructors, like Participant 4, commented on the lack of technological resources to support student learning: “It was a poor school district. The extent of technology in my classroom was a very old computer, an overhead projector, and 5 TI-85 calculators," a complaint that other instructors, such as Participants 25 and 26, mentioned as well.

Finally, multiple instructors commented on math classes themselves being barriers to students. On Q14, Participant 4 said, "Unfortunately, I think high school math serves as a sort of gatekeeper for college. Students who come to the university with poor math understanding get stuck taking remedial courses - often more than once, which can lead to setting back graduation or even dropping out." Participant 8 described the ideal role of math versus the perceived reality:

> Ideally, high school courses would help students construct foundational knowledge and develop skills in reasoning and problem solving that would support further study. In practice, high school math courses often lead to well-practiced but poorly understood procedures (and sometimes poorly recalled procedures) for technical tasks, and lead students not to trust their own reasoning and not to trust instructors to treat that reasoning as valuable or respected.

For Q15, Participant 26 added that math courses were "just a hoop for [students] to get through." Lastly, Participant 17 warned, "For students who struggle in these gateway courses, it changes the trajectory of their lives."

Conclusion

As far as the research team knows, this dataset and analysis provide the first direct comparison between the teaching practices for high school and college math classes in the US by instructors with personal classroom experience in both. We primarily examined these with a lens focused on subdomains of PCK, and we began to answer the question: What are the perceptions of math teaching for educators with experience in both high school and college?

Currently, we are implementing initial findings into our capstone course for the master's program to provide relevant perspectives from teachers in a more similar career trajectory to those of our prospective VITAL faculty. Additionally, we will next consider the specific views of dual-enrollment instructors, such as full-time high school teachers with an adjunct appointment at a college, full-time college instructors who teach high school students, or other arrangements that complicate the traditional secondary and post-secondary divisions.

Although readers of this article are more likely to be engaged in research and less likely to have taken the same career path as those in our study, we suggest that their responses provide a means of reflection for our own practices and policies as college educators, course coordinators, administrators, and leaders of professional development sessions. These educators who work between institutional boundaries have a unique means of direct comparison for high school and college math teaching. Thus, we end with a series of questions prompted by our engagement with our dataset: When faced with pressures and local policies, why do some instructors change their instructional practices from active learning to lecture while others maintain their course? How can we alleviate those pressures or modify policies to better leverage these instructors' existing PCK? What are the reasons that instructors think their own math courses are merely gatekeepers, and how can we make changes to better align the reality that these instructors describe to the ideals of their student-centered practices?

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