

Collapsing Spaces, Colliding Places: Leveraging Constructs from Humanistic Geography to Explore Mathematics Classes

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Cover Page Footnote

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Abstract

Humanistic geographers distinguish between space and place: “What begins as undifferentiated space becomes place as we get to know it better and endow it with value” [19, page 6]. In this essay, we seek to demonstrate how mathematics education researchers and mathematics instructors may find space and place illuminating for understanding important aspects of students’ learning experiences during the coronavirus pandemic — and possibly beyond. Specifically, after introducing the terms and relating them to the context of a university mathematics class, we exemplify how home and class places collided for three undergraduate mathematics students forced to deal with the abrupt transition to online education. We conclude by discussing implications of attending to space and place for designers and researchers of (pandemic) online instruction and make connections to how the pandemic and attending to space and place can serve as a catalyst for reshaping undergraduate mathematics education.

Keywords: coronavirus pandemic, COVID-19 pandemic, humanistic geography, online classes, place, space, undergraduate mathematics.

If you were asked to describe a particular university mathematics classroom from your undergraduate days, how would you respond? Would you describe the physical features of the classroom; for example, a large room with six chalkboards at the front of the room, movable chairs, and posters of famous mathematicians on the wall? Or would you focus on your experiences within that classroom, like silently copying what your professor was writing on the board at breakneck speed or being told the answer to your question was trivial and wanting nothing more than for the ground to swallow you up? There might even be a temporal component to your answer: Maybe the mathematics class you are recalling was an early morning class to which you always arrived tired.

What we hint at is the different ways in which a place — like a university mathematics classroom — can be understood: A place need not only be defined by an arrangement of physical objects (i.e., a space), but may equally well include the time, experiences, and activities associated with that space. In short, drawing on the works of geographers (e.g., [2, 5, 14, 19]), we view place as a space-time configuration alongside associated experiences and activities.

The goals of this essay are threefold. First, we seek to familiarize readers with the notions of space and place and apply these notions to the context of a university mathematics class. Second, we aim to make the case that space and place have the potential to be useful tools for mathematics education researcher. We endeavor to make this point by using space and place to frame three undergraduate mathematics students' experiences during the pandemic. We end the essay by thinking about the constructs' implications for mathematics instructors.

1. Conceptualizing Space and Place

The idea of contrasting “space” and “place” is not new, and geographers and philosophers have repeatedly argued for distinguishing space and place while simultaneously acknowledging their connectedness (e.g., [3, 5, 10, 11, 19]). As already suggested by our use of these terms above, space and place have traditionally been linked by their reference to physical objects and differentiated by their reference to experience: Whereas an arrangement of physical objects defines space, a place marries space with human experience [5, 10, 19]. The experiences and activities one associates with a place are typical or defining ones. They can be the result of typically or regularly occurring events that become normed — perhaps even expected — via repetition (e.g., the instructor asking students to get into groups). Alternatively, they can be formed through defining or impactful one-time events (e.g., receiving the instructor's praise for an elegant proof).

Our definition of place also draws on what Agnew [2] termed the humanist or agency-based approach which Sack [14] epitomized as follows: “From the perspective of experience, place differs from space in terms of familiarity and time. A place requires human agency, is something that may take time to know...” (page 16). Hence, on top of experiences, we see the acts of human agents (i.e., activities) in a space and their inherent temporality as co-constituting a place.

We also understand that different components of our definition of place may take precedence in different contexts. As in the example of the university mathematics classroom, for some the spatial component (e.g., the large room with its off-white walls and six chalkboards at the front of the room) may be foregrounded, whereas others may highlight time, experiences, and activities (e.g., silently copying notes). In other words, the degree to which time, experiences, and activities combine with a space to become a place is variable.

Finally, we want to stress that there is not yet a consensus among geographers on how space and place are to be related and that the humanist perspective we espouse is but one of several attempts at resolution [2]. We also want to acknowledge that the terminology of “space” and “place” may be confusing for the reader, particularly since “space” is often used in ways similar to “place” — both colloquially and academically. For example, when Collins [4] wrote about “safe spaces” of U.S. Black women, she was less concerned with the arrangement of physical objects in particular locations than with the experiences of the women in these spaces. Thus, to help the reader with our interpretations of “space” and “place,” we will — where potentially confusing — refer to “space” as “physical space.”

1.1. Class: A Cluster of Places

We have touched upon classrooms, but what about classes? Given the number of distinct physical spaces a university class inhabits, we would argue that a class is a cluster of places with a student’s experience of a class distributed over many physical spaces: the classroom(s), the workspaces in which students study and do homework (e.g., the library, cafeterias, one’s dorm room), and the spaces in which students can go to receive help (e.g., the instructor’s office, the tutoring center). Moreover, each of these physical spaces is associated with certain times: Class takes place in the classroom during a scheduled time, workspaces are used during specific times (e.g., the library from 8am-10pm, the cafeteria during dining hours, the dorm room maybe only in the evenings), and help spaces are only available during specific hours (e.g., the instructor’s office during office hours, the tutoring center during open hours).

Students associate — not necessarily consciously — typical or defining experiences with these space-time configurations. Examples of associated experiences and activities include habitually sitting in the same seat in a classroom, being too shy to ask questions during class but asking the instructor after class, going to a help room to see a specific teaching assistant who welcomes your questions, or being praised in office hours by the instructor for asking a great question. Thus, we posit that for each student, being part of a class becomes being part of a particular cluster of places.

1.2. The Pandemic Class: A Collapse of Class Spaces

In response to the coronavirus pandemic, many university students and instructors around the world were forced to continue their classes online.

For many of them, the cluster of physical spaces that had previously constituted undergraduate mathematics classes (e.g., the classroom, the instructor’s office, the help room, the library, the favorite caf’e in which to work) collapsed into the single physical space where they were living (e.g., a childhood bedroom in the family home). From the purely spatial perspective devoid of human experience, this collapse hardly poses a problem. Why should it matter if class activities happen in one physical space or the other? It is only when we take note of human experiences and activities within a space-time configuration, that is, attend to places, that we can pick up on the severe impact that a collapse of physical spaces entails.

But how do students experience “class” during a pandemic? We argue that although the cluster of spaces associated with a class collapsed into one physical space, various class places remained: students were in Zoom classes, attended office hours via Teams, met with study groups via Skype, or navigated online help forums. In short, many different class places existed (e.g., the online classroom, the online office hours, and the help forum) linked to a single physical space — often home. As we share below, for some students the collapse of class spaces to their family home led to two worlds colliding.

2. Space, Place, and Research: Framing Students’ Experience

To illustrate the utility of the ideas of place and physical space for research, we will use this lens to frame three undergraduate students’ experiences taking mathematics classes during the coronavirus pandemic. Our goal herein is not to present empirical “results” but, rather, to paint three similar stories in broad strokes using select quotes to provide a taste of the potential of researchers attending to space and place.

2.1. Student Voices & Local Context

The quotes and stories we share stem from interviews with undergraduate students majoring or minoring in mathematics at a large public university in the U.S. state of Michigan. These interviews occurred a couple of months after instruction had abruptly moved online in the middle of the semester, a stay-at-home order was issued in Michigan, and most students had returned to their family homes. Given the substantial impact we expected the pandemic to have on these students, we asked questions about the shift to online instruction and the resulting challenges to learn about students’ experiences in their mathematics courses before and after the shift.

Below, we share the perspectives from the three students who alerted us to issues of place. Specifically, the conversations with Emily, Galen, and Kaleb¹ — all of whom returned to their (family) homes — serve to illustrate how the lens of place can elucidate the collapse of class spaces and the interaction between home and class places as well as shine light on concomitant challenges.²

2.2. *The Collision of Home and Class Places*

To begin to understand these students' experience, consider the following quote by Kaleb:

I heard a thing about: “Chew mint gum when you study, and then chew the same gum, when you take the test. And all those things will come back.” ... It's like that but in reverse for me. ... When I'm sitting [at home] at my desk with my computer, I'm in lay-back-have-fun-play-a-video-game mode, not sit-forward-and-take-notes-for-a-college-math-class. ... As opposed to pre-COVID: My dorm is a working space or, and so is the cafeteria. I've got spots and layouts that, like the only thing I ever knew in my dorm was working. So that was naturally a workspace.

Kaleb's analogy points to the collision of home and class places: As physical class spaces and home as a physical space become one during the pandemic, class places and home as a place are interacting and becoming more similar, with their respective associated experiences and activities blending together for students. As Kaleb sits at his home desk while “being” in class, he finds himself wanting to behave in ways consistent with being at home, not with being in class.

To better understand the collision of home and class places, we begin by drawing on Emily, Galen, and Kaleb's accounts of what being home meant.

¹ All names are pseudonyms.

² To learn more about Emily, Galen, and Kaleb and our interactions with them, please see Appendix A.

2.2.1. Home

As Emily shared: “When I’m home, I feel like I should be on break, but that’s not the case anymore.” The sentiment that home is a place of break was echoed by Galen and Kaleb, both of whom also traveled home and quarantined with their families. In fact, Galen specifically mentioned feeling like he was on a vacation, “One of the main challenges honestly was actually . . . the moment [the quarantine] happened it was like oh, it’s not school anymore, it’s summer vacation with homework.” Besides relaxing, being home also triggered Kaleb’s memories of his time before university. On top of the temporal dimension of (summer) vacation and childhood, all three also associated certain experiences and activities with being home such as sleeping in, relaxing, and having fun (e.g., by watching TV, playing computer games, or being on the phone).

2.2.2. On-Campus Class Places

So, what experiences and activities might students associate with on-campus class places? Let us consider Galen’s breakdown of pre-coronavirus class places:

Going to an actual lecture, it gives me a feeling, “Oh wait, I am in class. This is a class. This is a classroom. I am in class. This is a lecture, put my phone away, get on my notes, do my notes, done.” Or, “Okay, this is the library. This library is where I am going to do my work.” So then you can separate them. Then my dorm room is where I would play on my computer, but the library would be where I go to study, so I can separate them and that’s where I would do it.

One can see how different spaces of an on-campus class can help construct different places. For Galen, being in a classroom or the library cued a certain behavior; in other words, the spatial component was highly relevant to the construction of places for Galen. With all class spaces being home during the pandemic, the separation of places became less clear-cut. Thus, we see that distinct spaces can help students distinguish and create places whereas the coinciding of spaces may obscure places.

Apart from on-campus class spaces serving as a way to index experiences and activities, on-campus class places provided structure and routine for our three

participants. As Emily elaborated: “[Having to be at a place at a certain time] adds a lot more structure to help me learn, and, in my head, even I can say, ‘Alright, at this time I’m thinking about this’.” And, as Kaleb added, the feeling of the in-person classroom and face-to-face dynamic with the instructor affect the experiences and activities associated with a classroom place: “When I’m sitting in class it’s a big pressure, at least for me, to pay attention because it feels more official and also just the teacher is there and I feel like I need to pay attention and respect them when I’m in class.”

The various on-campus class spaces allowed Emily, Galen, and Kaleb to distinguish and specialize different aspects of their lives, a compartmentalization which becomes much more challenging when one is confined to a single space. For these students, the on-campus classroom place bore concentration-conducive characteristics that may be difficult for online classrooms to emulate.

2.2.3. Forging New Hybrid Home and Class Places

Having gained an overview of what home and on-campus class places meant to Emily, Galen, and Kaleb, we now consider how these places interacted with each other for them. It appears that being home had an overpowering effect on class places. For instance, technologies like computers and phones seemed to pose significant challenges. At home, computers and phones were generally reserved for entertainment purposes: to play games, watch videos, listen to music, and check social media. Therefore, as Galen (and Kaleb) remarked, it was difficult to focus when technology normally reserved for gaming became part of a class place: “I’ll be on my computer and think, ‘Oh wait, I’ve got a lecture,’ switch. But I’ll still be in the game mindset, the relaxing mindset. And it’ll take me a while to get into [the lecture].” Further, with no one around to enforce a no-phone policy in their homes, these students found it difficult to stay away from their phones during class. On top of struggling to get into a class mindset, they also wrestled with getting up for class, mainly because there was little motivation to set an alarm — an unusual thing to do in a place of relaxation. In short, motivating themselves to show up and concentrate in class became immensely difficult for our participants while at home.

Interestingly, Emily, Galen, and Kaleb appeared to be trying to resist the temptations offered by being home and were engineering their environments to resemble some aspects of on-campus life and on-campus class places.

Specifically, they shared three strategies they employed to make their homes more class-like. The first strategy was to set an alarm, which served to provide their day with temporal structure and triggered some motivation to get things done. Second, to counteract the distraction posed by the phone and be more focused, Emily reported being deliberate about placing her phone out of reach. Third, realizing he felt very little motivation to watch recordings of live classes, Kaleb tried to make sure to show up for his synchronous online class. Thus, the home-class interaction was not a one-way street: Class places also affected home as our participants tried to ensure some semblance of learning and success in online classes.

2.3. Looking Back and Ahead

Drawing on the similar experiences of Emily, Galen, and Kaleb, we were able to illustrate how these three mathematics students viewed home (i.e., as a place of relaxation) and on-campus class (i.e., as distributed over several workspaces), as well as how home and the new online class place cluster collided. Specifically, we saw that being in class and home simultaneously caused problems of motivation and concentration. At the same time, aware of the effects of home and somewhat willing to fight them, our participants came up with ways to import experiences from on-campus class places into their homes. We hope to have thereby demonstrated that space and place can provide a useful framing for better understanding aspects of students' learning experiences during the coronavirus pandemic. Further, we believe that this lens could equally well be applied to instructors' experiences, is neither limited to the university setting nor mathematics education, and seems relevant even beyond the pandemic — particularly with regards to online instruction.

Some other ways in which we can envision space and place being generative for research include spotlighting spatial inequities — examples of which we discuss in the section below — and offering an opportunity to reflect on taken-for-granted audiovisual assumptions and norms. For instance, the marked difference in audiovisual assumptions between in-person and online classrooms (e.g., whether students can choose to be seen, whether the teacher can see all groups with a quick glance) may illuminate how heavily teachers are engaged in surveillance when in a shared physical space with their students — almost reminiscent of inspectors at the center of the Panopticon [6].

3. Space, Place, and Teaching: Reimagining Undergraduate Mathematics

We believe that attending to space and place can also inform the design of pandemic and online mathematics instruction. To illustrate this point, we now reflect on lectures, assessment, and equity in the context of online instruction.

3.1. *Decreased Motivation and Concentration: A Call to Move Away from Lectures*

As illustrated in the previous section, attending to space and place can shed light on students' experiences and issues relevant for designing pandemic instruction, such as decreased motivation and concentration. This particular observation suggests that mere online replications of lectures — the still dominant mode of instruction in undergraduate mathematics classrooms — is problematic. Some may argue that lectures, or the replication of on-campus classes online, can be salvaged through asynchronous instruction. By choosing the time, students can “attend” class when they are motivated and ready to concentrate. This argument, however, appeared questionable when it came in contact with our participants' realities. Kaleb, who had a choice between synchronous and asynchronous instruction, chose the synchronous option after realizing he could not actually work up the motivation to watch recorded lectures. Emily, who only had access to an asynchronous option, reported that “it’s a lot easier to get distracted and off-course because I can just pause anytime and that’s too much freedom honestly.” In sharing Kaleb’s and Emily’s perspectives, we do not mean to advocate against asynchronous instruction — in fact, we currently espouse a mixed synchronous and asynchronous model — but merely point out that issues of motivation and concentration are seemingly not counteracted by asynchronous lectures. Combining the problems of motivation and concentration with the fact that lecture is an ineffective mode of instruction even when delivered by an outstanding instructor [9], we see the coronavirus pandemic as an opportunity to rethink undergraduate mathematics education and shift to more active types of learning that have repeatedly been called for (e.g., [1, 7, 12]).

3.2. *Rethinking Assessment*

Another aspect of mathematics classes that will need to be rethought is assessment. Consider Kaleb’s following remark:

In general, motivation is down. I was pushing off homework or not caring as much. So, I would start googling questions and just get it done quick by looking stuff up.

A lack of motivation is making Kaleb choose the easy way out and looking up answers: A practice enabled by the types of questions posed. (Kaleb’s pandemic behavior contrasts with his restrained use of the internet and opposition to “cheating” on homework in pre-pandemic semesters.) In addition to revisiting the type of homework questions asked, a reconsideration of exam content and format is needed. Since traditional mathematics exams are unworkable during the pandemic, their inherent limitations (such as their strong reliance on memory, time constraints, and a no-collaboration rule) have become abundantly clear. Instead of having students “solve these N problems in this fixed amount of time,” we might instead pose “reflective questions that attempt to explicitly assess the development of virtues, like . . . persistence, curiosity, imagination, a disposition toward beauty, creativity, strategization, and thinking for oneself” [16].

3.3. Access and Equity in Online Class Places

Finally, we note that instructors can gain valuable insights about access and equity in their online class places by asking questions about space and place.³ To illustrate this point, we pose and seek to answer three such questions in the context of online instruction.

3.3.1. Who Has What Access to Synchronous Online Class Places?

Although Zoom — a popular software for synchronous online classes — can technically be accessed with a phone call, genuine access to online class places requires a reliable internet connection and a laptop. Tablets, faster internet connections, and faster laptops further increase opportunities for engagement with the class and its content. They allow one to hear and see one’s instructor and classmates (with little or no interruption), be seen and heard by one’s instructor and classmates (with little or no interruption), and be more active and engaged in the class (e.g., by writing with one’s tablet on a digital whiteboard). In short, more sophisticated technologies allow one to be a more

³ For another recent *Journal of Humanistic Mathematics* article presenting instructor reflections about the pandemic along similar lines, see [13].

“present” class participant, that is, access to online class places boils down to a pay-to-play regime benefiting students with greater financial resources. One implication we see of this is that instructors may wish to rethink whether, and if so how, they assign participation credit (e.g., whether they really need students to turn on their cameras for participation credit). Further, instructors may want to think carefully about whether their activities have technological entry points for all students (e.g., can the group work activity be reasonably done without access to a tablet?).

3.3.2. What Other Places Are Students in While in Online Class During the Pandemic?

During the pandemic, many students had to return from their campus homes to their family homes, from where they joined online classes. Our three participants’ stories of home as a place of relaxation are, however, fraught with privilege. For many students, home may not have been a place of relaxation. Although the reasons for this may not be related to socioeconomic status (e.g., antagonistic relations with family members), greater financial resources can afford privileges such as having one’s own room and having fewer responsibilities to shoulder. Thus, greater financial resources may yet again facilitate access to and engagement with online class places during a pandemic. Instructors can therefore not expect that all students have unfettered and uninterrupted access to the online class.

3.3.3. What Places Are Students in While Taking Monitored Online Exams?

Under the guise of fair examinations, many students are being closely monitored by instructors and software inside their homes. In addition to home (and the concomitant experiences) possibly not being conducive to exam-writing, surveilled examinations are also problematic due to their intrusiveness into people’s personal spaces. Further, monitoring software appears to suffer from the same bias as facial recognition algorithms [15]: Black students have reported that test monitoring software did not recognize their faces unless they shone a bright light into their faces [8, 17]. Thus, the spatial conditions in which students may find themselves in during high stakes assessment can be fundamentally different. For us, the implication here seems to be to move away from monitoring online exams and instead rethink the need or format of the exams.

3.4. *Looking Back*

Asking questions about the spaces and places students are in while they are members of a class (i.e., questions about the students' physical surroundings and the experiences and activities tied to them) can help sensitize instructors to problems with the class. Student experiences like decreased motivation and concentration lay bare the problems of replicating lectures online and traditional forms of assessment. Further, space-place questions can raise issues of access and equity.

4. Conclusion

We hope to have demonstrated that attending to space and place can be useful for mathematics education researchers and mathematics instructors. For mathematics education researchers, space and place may offer a fruitful way of framing students' and instructors' experiences — at any educational level — in the context of pandemic and online instruction. For mathematics instructors, who are moving away from the initial triage of spring 2020, attending to space and place can be valuable as we reimagine classes and move from teaching for survival to good online teaching. The pandemic is an opportunity for re-envisioning classes, and we side with Tanton [18], who stated that with the pandemic throwing a wrench in the gears of our “normal” educational system, educators are set free “to engage student[s] in mathematics conversation[s]: no more, no less” and to redefine mathematical success as asking questions, taking a step towards solving a problem, and engaging in mathematical discourse.

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References

- [1] Abell, M. L., Braddy, L., Ensley, D., Ludwig, L., & Soto, H., editors, *MAA Instructional Practices Guide*, The Mathematical Association of America, 2018.

- [2] Agnew, J. A., "Space and place," pages 316–330 in *The SAGE Handbook of Geographical Knowledge*, edited by J. A. Agnew & D. N. Livingstone (SAGE Publications Ltd., 2011).
- [3] Casey, E., "Smooth spaces and rough-edged places: The hidden history of place," *Review of Metaphysics*, Volume **51** (1997), pages 267–296.
- [4] Collins, P. H., *Black Feminist Thought: Knowledge, Consciousness, and the Politics of Empowerment*, second edition, Routledge, 2002.
- [5] Entrikin, J. N., *The Betweenness of Place: Towards a Geography of Modernity*, Macmillan Education, 1991.
- [6] Foucault, M., *Discipline and Punish: The Birth of the Prison*, second edition, translated by A. Sheridan, Vintage Books, 1995.
- [7] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P., "Active learning increases student performance in science, engineering, and mathematics," *Proceedings of the National Academy of Sciences*, Volume **111** (2014), pages 8410–8415. doi:[10.1073/pnas.1319030111](https://doi.org/10.1073/pnas.1319030111)
- [8] Johnson, K., "ExamSoft's remote bar exam sparks privacy and facial recognition concerns," *VentureBeat*, September 29, 2020. Available at <https://venturebeat.com/2020/09/29/examsofts-remote-bar-exam-sparks-privacy-and-facial-recognition-concerns/>.
- [9] Lew, K., Fukawa-Connelly, T. P., Mejía-Ramos, J. P., & Weber, K., "Lectures in advanced mathematics: Why students might not understand what the mathematics professor is trying to convey," *Journal for Research in Mathematics Education*, Volume **47** (2016), pages 162–198. doi:[10.5951/jresmetheduc.47.2.0162](https://doi.org/10.5951/jresmetheduc.47.2.0162)
- [10] Malpas, J. E., *Place and Experience: A Philosophical Topography*, Cambridge University Press, 1999.
- [11] Massey, D., "Politics of space/time," pages 141–142 in *Place and the Politics of Identity*, edited by M. Keith, & S. Pile (Routledge, 1993).
- [12] National Research Council, *The Mathematical Sciences in 2025*, National Academy Press, 2013.

- [13] Zareen G. Rahman, Rani Satyam & Younggon Bae, “Navigating Mathematics Teacher Preparation During A Time of Crisis,” *Journal of Humanistic Mathematics*, Volume **12** Issue 2 (July 2022), pages 346–356. doi:10.5642/jhummath.GQZE5973
- [14] Sack, R. D., *Homo Geographicus*, The Johns Hopkins University Press, 1997.
- [15] Singer, N., & Metz, C., “Many facial-recognition systems are biased, says U.S. study,” *The New York Times*, December 19, 2019. Available at <https://www.nytimes.com/2019/12/19/technology/facial-recognition-bias.html>
- [16] Su, F., “7 exam questions for a pandemic (or any other time),” blog post dated April 28, 2020. Available at <https://www.francissu.com/post/7-exam-questions-for-a-pandemic-or-any-other-time>
- [17] Swauger, S., “Opinion: Software that monitors students during tests perpetuates inequality and violates their privacy,” *MIT Technology Review*, August 7, 2020. Available at <https://www.technologyreview.com/2020/08/07/1006132/software-algorithms-proctoring-online-tests-ai-ethics/>
- [18] Tanton, J. (2020, April 18). “COVID-19 exposes mathematics education inadequacies: A modicum of (secret) relief for educators,” *Medium*, April 18, 2020. Available at <https://medium.com/@jamestanton/covid-19-exposes-mathematics-education-inadequacies-a-modicum-of-secret-relief-for-educators-48490c44d649>
- [19] Tuan, Y.-F., *Space and Place: The Perspective of Experience*, University of Minnesota Press, 1977.

A. Setting, Participants, and Data Sources

Emily, Galen, and Kaleb (all pseudonyms) were three participants in the “Tracking the Longitudinal Development of STEM Majors’ Autonomy and Agency in Mathematical Proof and Proving” project.⁴ For the purposes of this project, we recruited twenty-nine students (across two semesters) while they were taking the Introduction to Proof (ITP) course at a large public university in Michigan, USA. During the recruitment process, we took

⁴ NSF Grant Number 1835946.

into consideration students' major, gender, race, and nationality in order to gather a pool of participants with a wide range of experiences. To learn about these students' experiences in their ITP course, we observed their sections, asked the students to write a homework reflection log, and conducted two sixty-minute semi-structured interviews (one a few weeks into the semester, one at the end). The purpose of the first interview was to get to know the students (e.g., their educational history, their [academic] plans for the future, their initial impressions of proving and the ITP course). The purpose of the second interview was to learn more about their agency and autonomy by, for instance, presenting them with mathematical problems and asking them questions about their struggles in the course, ways of overcoming them, and their resource use (e.g., internet use, use of the mathematics learning center).

Of the twenty-nine students we recruited, sixteen students continued to work with our project in subsequent semesters when they were taking further proof-based mathematics courses (e.g., abstract algebra, linear algebra, real analysis). Assuming a participant was taking a proof-based mathematics course in a given semester, we conducted a ninety-minute-long semi-structured interview with them during said semester. The interviews were similar to the second interview we had conducted during their first semester of project participation, that is, we sought to continue learning about our participants' experience with proving, responses to challenges, and resource use. In all interviews we conducted, we asked students to graph their confidence on a timeline (i.e., time on the x-axis, confidence on the y-axis) and mark pivotal events that affected their confidence.

In March 2020, a stay-at-home order was issued in Michigan; most students had to return to their family homes, and instruction moved online. The pandemic and online instruction led to a whole new set of challenges for our participants (and possibilities of overcoming them), and our interviews grew to encompass questions about the challenges posed by the pandemic and online instruction (e.g., What has been the biggest change in the move to online instruction? What has been a big challenge for you? [Are there other challenges?] Has anything become easier?). By the time the pandemic began, thirteen students remained part of our project. After reflecting on their thirteen interviews as a team, particularly three participants' stories — those of Emily, Galen, and Kaleb (White U.S. mathematics majors [female, male, and male, respectively]) — prompted us to think about space and place as well as to write this essay.