DHSP Summer Recruiting Talking Points

- DHSP is a program created by the LSA Dean's office. It's only for freshmen who are interested in majoring in math and science, and who are going to take two semesters of calculus in their first year—that's calc 1 in the fall and calc 2 in the winter. DHSP is an extra class that you take alongside the regular calculus classes. The regular calculus classes are Math 115 and 116, and DHSP is Math 145 and 146.
- Math 145 is a workshop class. It meets for 4 hours a week, and you get two credits for it. But there's no exams and no homework and no grades. Grading is credit/no credit: to get credit you have to show up and you have to participate. So there's no mystery about how much time it takes—it takes 4 hours a week.
- What we do in the workshop is hard calculus problems, in groups, at the board. So at the beginning of a typical class we'll split into groups by some pseudo-random method—3 or 4 people in a group, different groups every day. We'll have a room with lots of blackboard, and every group will get a section of the board, and some chalk. Then I'll give everyone a set of hard problems, and we'll work like that, in our groups at the board, for about an hour and a half. That leaves us half an hour at the end of class to come together as a big group, present our results to each other, and try to reach a consensus on the answers. So I give questions, but not answers. If you want answers, you have to find them yourself. *(That usually gets a smile if they're following.)*
- The problems are all hard. They are a little bit harder than what you will see in the regular calulus class. The idea is to take the tools of calculus that we learn in the regular class, and do something interesting with them.
  - So some problems will be applications of calculus to other sciences, like biology or chemistry,
  - some of will be foundational, for instance where we try to explain why some formula we've been using is true,
  - some will be very beautiful (those are my favorites),
  - and some will be very practical—they will be old exam problems.
- We get especially practical right before the Math 115 exams: We'll take a day to do a practice exam and a day to go over it. Then the day before the exam we'll have a review session. One of the nice things about being sponsored by the Dean's Office is that they pay for pizza for our review sessions. (That always gets a smile.)
- So our goals are:
  - See some interesting stuff that you wouldn't get to see in the regular calculus classes. The regular classes are packed pretty tight with stuff that's going to be on the exam, and whenever I teach one of those classes it's very frustrating,

because there are all these interesting things we could do with the tools we've developed, but there's just not enough time. So that's what we get to do in the workshop.

  - Of course we want everyone to do well in the regular calculus classes, and
  - Our third goal is to form a community around doing math. It will be a small class, 18 people max per section, versus about 1900 in Math 115. Since we do all our work in groups, we will all get to know each other very well.

- So, what do you think? (This is their escape hatch. If they seem to have made up their mind at this point that they won't do it, let them go. Otherwise, continue.)

- Would you like to do a math problem? (If this makes them anxious, reassure them that it is not a test, it's just an interesting problem.)

- (Then I refer them to the online whiteboard. I make one of the cities the place where the student is from, and name the others appropriately. For anything in SE Michigan, Kalamazoo and Flint are good choices. Insert the appropriate cities and states in the text below.)

- "Your mission, should you choose to accept it, is to imagine that it's a long time ago, and these are the only 3 cities in Michigan. Right now they are isolated from each otherr—there is no way to get between them. But people in Kalamazoo want to go to Flint, and people in Flint want to go to Detroit, and so forth, so the mayors of the cities have hired you to build a network of roads connecting them. And the only spec they give you is that when you're done building it should be possible to get from any city to any other city.

- "They're going to pay you a flat rate, like 5 million dollars. But out of that you have to pay all your costs, like labor and materials. You want to keep your costs low, and that means making the total length of all the roads as short as possible. So what would you do?" (Then wait for them to try it. Don't give in too soon, but don't torture them. They need to learn that you can't be passive in DHSP, you have to participate.)

- (If they draw the triangle) "Nice job. You have met the specs of the job—you can get from any city to any other city. Now, can you make it shorter? Here's a hint: if you're in Kalamazoo and you want to go to Detroit, you actually have two choices: you can go directly there, or you can go through Flint. So there's some redundancy in the system." (They usually realize at that point that they can erase one of the lines. If they still don't see after a few seconds, I go ahead and explain, and erase it for them. Then I ask if they can do any better, but if they don't have an idea, move on.)

- (If they have a node in the middle) "Nice job. It looks like you've built a roundabout here" (draw a little circle where the roads intersect) "and connected it to all three cities. I like that idea a lot. Of course you could put the roundabout anywhere—you could put it here, or here, or here." (Choose three random points.) "So I'll change the question on you, and ask where's the best place to put the roundabout. What do you think?" (Let them think for a bit. If you they have a new suggestion, have them draw the new netork in a different color. Then refer to the networks by color as you say something like:)

- "Let's think about what happens when you move from the red network to the blue one. It looks like the road to Flint gets shorter, but the other two get a little longer. Which means it's not obvious whether the total length is getting longer or shorter, because there's this tradeoff going on: you're taking away from some roads and adding to others. Which is why this is an interesting question."
- "This turns out to be a really interesting question, not at all obvious, and certainly not something I expect you to have seen before. So it's not a test—it's just an interesting problem. But you might guess that it's a calculus problem, since we're trying to minimize something, and finding mins and maxes of functions is one of the great applications of calc 1. But on the other hand, there are no numbers here and no formulas, so it's really not obvious how to start applying calculus to the problem. It doesn't look like a textbook problem."
- "It turns out, you can solve this problem with the methods of calc 1, but it takes a few days of work. So there's just not enough time to do it in the regular calculus class. But we will do it in the workshop."
- "And we'll also do it with soap. Have you ever watched someone blow a really big soap bubble?" (Most have.) (Show picture of giant bubble.) "The intersting thing about the big bubbles is that they're not round at first—they're some weird funky shape like the picture. But if you were to wait a few seconds, that thing would wobble and bounce, and become a sphere. (or it would pop.) With little bubbles it happens so fast that you don't notice—they're just spheres as soon as you perceive them."
- "Why do you think they become spheres?"
- (They give various explanations, some physical.) "That's good. There are several good answers to this question, and you get a different answer depending on whom you ask. If you ask a physicist, they'll talk to you about equalizing pressure; if you ask a chemist they'll talk about surface tension. I'm a mathematician, so I'm going to give you the mathematician's answer."
- "Soap is kind of stretchy, like a rubber band. If you stretch it out, it wants to shrink back to a point. When you stretch it over a volume of air, it *wants* to shrink back to a point, but it can't because the air's trapped inside. But imagine all the little molecules of soap with little rubber bands between them. They're all pulling on each other and trying to get close to each other. The best they can do, the closest they can get, is when the surface area of the bubble is as small as possible. And the sphere is the figure with a given volume that has the smallest surface area. Think of old barrels: they were basically spheres with a flat top and bottom. That's because the barrel-maker was trying to use as little material as possible to enclose some fixed volume. Sound reasonable?" (They agree.)

- "All right! Using that idea, that soap wants to be small, we can solve the cities problem with soap."
- (Now switch to the other camera, pointed down onto the desk.) "I have here two pieces of plexiglass, with three bolts representing your three cities." (Point to the bolts and give them the same names as the cities on the whiteboard.) "And if I dip it in soap" (do this while talking), "the soap will form a network connecting the cities." (Drain off excess liquid with Flint at the bottom, so that the soap makes the two-segment network. Then put the toy down on the tray.) "Now you see it's found the network which goes Kalamazoo to Flint and Flint to Detroit. It's stuck there, because this post" (point to Flint) "is kind of thick. But if I blow on it, I can make it find a shorter network."
- (Blow until a Steiner network appears. Most are impressed—they have never seen soap do that. Hold it up to the camera and rotate until the soap films are visible. Give them a few seconds to stare at it.) "You can see that the soap has put the roundabout over here, near Flint, and I can tell you that it always picks that same point. If I blow on it, I can deform it," (do so) "but it will go back there, because that's the point that minimizes length."
- "But that's not an answer we should be satisfied with! It's a proof that there is an answer: there is one point that's better than all the rest. But it doesn't tell you how to find it without soap. And

  - What if we had three different cities?
  - What if we had 4 cities?
  - What if we had cities in three dimensions?

  It just opens up a lot of questions, which is what the best problems do. As a mathematician you want to get to the heart of the matter, and figure out what's really special about that point."
- (Switch back to the regular camera.)
- "That's the kind of stuff we do. We don't always have toys to play with, but we always try to take a natural question from the real world, and apply calculus to it. In this case our goal will be to solve this problem with calculus, and check our answer with the soap. We'll see if we are smarter than soap."
- "So, what do you think?" (Another escape hatch. Let them go if not interested.)
- "Let me tell you catch again. DHSP is a year-long commitment: Calc 1 in the fall, and Calc 2 in the winter. The bargain you're making when you join is:

  - You agree to stick it out for a full year, and
  - The University, in return, agrees to support you for the full year, through me. I spend a lot of time outside of class working with people on the regular calculus classes, doing homework and getting ready for exams.

So if you join, I'll ask you to sign a piece of paper promising to stick it out for a whole year.

- "If you decide to do it, I'll make sure you have an override so you can sign up for Math 145, which is the DHSP workshop. Of course not you'll sign up for Math 115 as well."
- "Any questions?"
- Tell them it was a pleasure to meet, and send them on their way.

Some optional points:

- Because there are no grades, it's a very relaxed and low-pressure environment. It's a place where it's OK not to get the right answer on the first try. But it's not OK to give up.
- Occasionally we will break from our routine and do something else for a while. For example, last year we heard from a number of DHSP alumni, who came to class to tell us about science majors and careers they are pursuing.
- 2022–2023 will be the 17th year of the program. I have taught the class for the past 15 years, and I'll teach it again this year. It has been a lot of fun, and the students usually end up liking it quite a bit.
- The students will come from all different sections of 115. So if you didn't understand the way your instructor explained a particular topic, for instance, you'll have a chance to hear how someone else explained it, and maybe that will work better for you.
- The idea is to make the whole experience of calculus a little more intriguing, and also a little more social and fun.
- Sometimes they ask if this will improve their grade in Math 115. I say that that is one of our goals, though it's not our only goal. We can document that DHSP students do better at 115 and 116 than students who were invited to join the program but didn't. For instance, in 2009–2010 76% of DHSP students earned an A or B in Math 115, versus 52% for the control group. (Need more current numbers.) I never bring up this topic unless they do. If they're just in it for a grade bump, they won't appreciate the exploratory nature of the class.