

[SQUEAKING]

[RUSTLING]

[CLICKING]

**NELSON
REPENNING:** What do you think you get out of this if you do it well? So if we have good model that gets published in a good place, what can we reasonably expect that a system dynamics model could produce? What would be the upshot of this type of analysis? Yeah, go ahead.

STUDENT: Like you were saying, you can discover good policy that could help fix any problems you're encountering. But also, at least I find in the process of actually writing the entire model out, you usually uncover parts of the problem that aren't immediately visible. So I guess that goes back to policy. Like, you actually start to robustly understand the entire issue rather than just the very small, like, first-order ideal kind of things.

**NELSON
REPENNING:** OK.

STUDENT: I would say also testing mental models. So some of the mental models are actually [INAUDIBLE].

**NELSON
REPENNING:** Good. [INAUDIBLE]

STUDENT: I don't know. This one really bothers me. My first-order answer is you can learn about the consequences of how things are organized if you're asking the organizational question. That's it.

**NELSON
REPENNING:** OK.

STUDENT: You understand much better what is kind of the nature of what's driving the system. You feel you understand better what's happening. It's really helpful for me, I think.

**NELSON
REPENNING:** OK.

STUDENT: I think you can understand the feedback loops that in-- that are driving the behavior of the system, and also the leverage points where you can apply the policy, more strict policies, in order to change the behavior of the system in the way you want.

**NELSON
REPENNING:** OK.

STUDENT: Yeah, I think sometimes, it can have a--

NELSON

You're going to have to speak up.

REPENNING:

STUDENT:

Sometimes, it can have an organizing and a calming effect on the conversation with the people whose problem it is. And so I think when you're talking with people about, oh, these things are horrible, what's happening, and this, and that, and the other thing, and it's everything, and it's totally unsolvable. And then what you get out of distilling it into a model is, like, you get to validate what they're talking about to them. And it kind of is-- it makes sense. Their own problem makes sense in a different way to them. And then they can kind of come up with different things and stop getting stuck in the same thought patterns.

NELSON

REPENNING:

Yeah, so I think you're all on the right track. For my tastes, and again, I think my view of this probably differs slightly from Hasier and John, is in the end, all we're testing is the sort of logical consequences and consistency of the theory that's embodied in the model. It's not a statement about the real world. It's a statement about the internal logic of the assumptions that you have made. If you then, which I know Hasier has a lot of expertise, sort of validate it, and estimate it, and compare it, then you are, to some degree, establishing some connection to the sort of external phenomenon that you're trying to model.

But always keep in mind, right, these are not randomized experiments. So the fact that your model fits the data does not necessarily make it true. But the thing that I want to highlight, and what really came out for me from reading the overviews of the problem you have is, at the end of the day, I would say that we either are looking for policies, as many of you mentioned, right? We need to figure out where to sort of intervene.

Or I think for those of you that aspire to be academics, the kind of ivory-tower framing of that is, we're looking to explain puzzles. So why is it that the conventional theory would predict x, but in fact, we get y, or we get not x, or something like that? And that's really a sort of, at least originally, a theoretical question of, OK, if the conventional theory says x and we're seeing y, we need a set of assumptions that seem reasonable that then add up to y, then there's the sort of testing validation question that I think comes second in terms of, OK, now we have an internally consistent theory of why we're getting y. Do we think this is sort of remotely in the ballpark of a reasonable thing to do?

And so I think-- I understand that these are just assignments, but for my taste, many of your overviews are a little muddled in terms of what you wanted to get out of your exercise. And I don't want to pick on one. I don't even remember who it was, but someone said, I want to study the effects of x on this system.

And I don't think that's a great framing because it doesn't give you a kind of yardstick to decide what's going in your model and what's outside the model. So I would very much urge you to be much more precise about, there's either a specific phenomenon I want to understand that I don't understand, or there's a phenomenon out there that maybe we don't like, and we want to do something about it, right?

So Jake, if I looked at yours, and we'll come back to that, because I think it's a very interesting topic about how the sort of-- if I understood it correctly, the epicenter of the movie business is now no longer in sort of Hollywood, California. But I think you have both a dynamic hypothesis kind of as to why, which is it's now cheaper, and there's tax incentives, and other cities have figured out this is a good thing. That doesn't seem that complicated a problem.

But then I think there's a much more interesting question of, if you're the Chamber of Commerce of Hollywood, what do you want to do about it? Or if you're an investor, where should I put my chips? But I think in a lot of cases, in some of your other ones, it was just a little unclear sort of to what end you're directed.

So I would really urge you, and we can go through these as we go through them to be super clear on either there's a puzzle I'm trying to solve, so if I go back to my work a million years ago, everybody knows product development should be done one way, and everybody does it some different way. That just doesn't kind of make sense to first order, right? It seems a very dysfunctional sort of way of behaving.

Or I have a system where maybe we have some understanding of why it works, but people aren't doing the things that we think that they should do. So now, we have to figure out how to put our scarce resources in. So another way of putting that is, if your problem statement or model motivation is, I want to understand the x system, I think you're already headed down a troubled road.

Now John and I have had this debate for more years than probably some of you have been alive. When I started in the field, we used to always say, we model problems, not systems. But I will say that I think some of my colleagues, their work often lapses pretty close to modeling systems, and they sort of throw in everything. I'm not sure there's a resolution to that question. So I just want you to kind of be aware of the different philosophies that are out there in terms of thinking about it.

But I think it does often lead to a model that's very hard to sell, at least from a scholarly point of view, is, I have built a model of the x system, and it fits the data from the x system very well. Full stop. Right?

And I think the journals tend to be like, OK. What do I do with that? Is there implications for this for policy? Or have we learned something new from a theory? Or does it challenge our understanding of this?

And I think it's very easy, and the field is very sloppy in general on this, which is you go to the conference, half the papers are system dynamics model of x. And I would urge you to be very wary of that because you're going to have a very hard time writing kind of the discussion and conclusion section of your paper because, OK, so now I have a model that replicates the behavior of x. What are the implications? Should I either think about this social phenomenon different? Should we intervene in this differently? Should we allocate our resources differently, or whatever?

So that was kind of the big thing I got from just kind of browsing the problem statements is I think it's-- and you're not alone in this. I think everybody lapses into this if you're not careful. But then it makes it very hard to finish your project because you sort of have no idea what you're going to work on. So does that make sense? Or do you have questions or comments about that?

I mean, again, it's a little bit philosophical, but I think it's quite important. And I've certainly watched enough students kind of wander off into enormous models, and then they're not really quite sure what they have when they're done. And there can be a lot of rework to kind of circle back to have some finding that would be a job market paper, or a consulting project, or whatever it might be. Yeah. Go ahead, Jason.

STUDENT:

I think this is hard because you have to decide early and shut off other potentially interesting avenues that you might want to hang on to. Of course, there's a trade off in hanging on to those things and you might end up nowhere.

NELSON Yep.

REPENNING:

STUDENT: So how do you deal with that foreclosure and willingness to commit?

NELSON So I think this is a really good question. I thought the other thing that, as I read through the overviews, that I thought, I don't know if I'd say it was missing, but could have used, is I think you all have instincts for your projects why this is a good dynamic problem to look at. And so that's why I asked you, what do you think these models are good for?

So I don't know if we still use this language in class, but we used to talk a lot about the dynamic hypothesis. And there's this endless and never-to-be-resolved debate in the field about whether you start with causal loop diagrams, or stock-and-flow diagrams, or whatever, which I think is an enormous waste of time.

But I think there is a kernel of wisdom in there, which is if you think this is a good area for dynamic modeling, or a good puzzle or problem, chances are you have some instinct about why. You have a dynamic hypothesis underlying that. And I think in many cases for your proposals, I think it would have been helpful just to be more explicit, right? I think there's a reinforcing feedback-- I'm going to pick on you, Jake, because I happen to remember yours. Sorry.

I think there's a reinforcing feedback loop that's driving the epicenter of movie making to Vancouver or Atlanta or whatever it is. Right? And that was kind of implicit in what you had. But I think it's much better, and actually better science, to state, this is my hypothesis about what's out there, rather than a kind of much more amorphous, I'm going to build a model about the x system.

So I think, Jason, to answer your question, the first answer is, I think you just have to be kind of honest with yourself about your priors. And whether it's a causal loop diagram or stocks and flows, I don't actually really care about it. But you have some instinct that this is a good thing to work on.

And then I think, as you all know, but it can't be reinforced, it pays to proceed incrementally. So you build a little model, you test it, and understand it, you add, so you want to be agile or whatever flavor. And so yeah, you have to make trade offs about what is the next most interesting feedback, or structure, or disaggregation to do.

And that's always a judgment call in terms kind of model complexity. I always tease John, he's the patron saint of the broad model boundary. He never met a feedback loop he didn't want to add to a model. I tend to be kind of the opposite. I'd much prefer the sort of much smaller, more aggregate representation. I don't think there's a right or wrong sort of answer there. But you do have to make choices about what's the next thing to go at, or the next disaggregation to work on. And it's just-- yep.

STUDENT: [INAUDIBLE]

NELSON There's no algorithm that says, this is the next feedback loop. And that's kind of where the art of this. And I'm not sure even AI is ever going to solve that particular problem.

STUDENT: Thank you.

NELSON So other thoughts or comments? I actually think this is a really important point. So I want to kind of make sure it's seared in your heads before we jump into equations and details. Yeah.

STUDENT: Yeah, I think I have a problem definition that I thought was pretty like-- I don't know. It was pretty, like, well designed in my mind when I wrote it down. And then I found myself more so than with the problem definitions that we've got in the past from faculty, where it's very obvious what the structures should be. I found myself with the blank-page syndrome, with my own problem definition.

And but I couldn't identify what was wrong with it that was making it so-- I don't know if it's the case that it's because I made it that I'm kind of getting stuck versus when I see one that someone else made, it's easier to look at it a little differently or what. But I don't know. I had a lot of trouble kind of deciding what structures should go in the model that I proposed.

**NELSON
REPENNING:** OK, so let's start with yours. So you're going to regret probably speaking in class. But so tell us about your problem. What's the area?

STUDENT: OK, so it's kind of the puzzle idea. The puzzle is that book sales have really increased a lot after many kind of years of decline. They increased a lot starting around 2019, 2020. However, reading rates, like the number of adults who have read a book in the last year, and the number of books that adults are reading have both stayed on decline. And one of the hypotheses that I had was--

**NELSON
REPENNING:** Time out. So just before we get to the explanation, so just in one sentence, the puzzle that you're trying to resolve is?

STUDENT: Book sales up, reading down.

**NELSON
REPENNING:** OK, and the kind of casual intuition would be that the more books we would sell, right? So we wouldn't expect those two graphs to go in the opposite direction. OK? This is a little bit of a tangent, but it would be relevant if you wanted to turn this into a paper. I mean, is that a puzzle that other literature acknowledges as such? Or is this something that you've come across? Or--

STUDENT: It's something that I came across. I think it's relatively new phenomenon. Like, from 2020, 2021. And no, I haven't seen it in other literature. I've seen people, I mean, people are talking a lot. I think where I kind of found it, or came up with it, is people are talking a lot about the crisis of literacy, and how people are not reading. And then I had remembered reading headlines about, oh, Barnes and Noble, like, was going to shut down, but suddenly they've had a resurgence, and they're opening new stores, and things are looking up.

And then. I thought, like, oh, that's interesting. It's not clear why Barnes and Noble is suddenly doing so great in the last few years, and literacy rates among adults are plummeting.

**NELSON
REPENNING:** OK.

STUDENT: Yeah.

**NELSON
REPENNING:** All right. Did those two things move together at some point in earlier history?

STUDENT: Yeah, they've moved together until, like, the last four or five years.

NELSON OK, so over what time horizon? I mean, roughly. Is it the last 50 years or the last hundred years? Or--

REPENNING:

STUDENT: No, nothing like that. I think 30. I think the data that I have on reading goes back to the '80s, but it's pretty sparse, like every few years. And then the book sales data is annual, but not as far back. I think I have 20 years of--

NELSON OK, I mean, I think that's a perfectly fine problem statement, right? We have two things that used to go together, **REPENNING:** that one of which seems quite important towards polite and civic society. And now, they've diverged for reasons that aren't entirely clear. OK, I mean, I think that's a great setup. I mean, there's a separate question we can talk about offline about if you wanted to publish this in a journal, making links to broader phenomena, things like that, and connecting to the value of literacy, and so on, and so forth. But I think for a kind of initial modeling project, that seems fine.

STUDENT: And you say, connecting to what?

NELSON I mean, I think-- you might want to move down. I mean, I think if you want to publish it, you might need to **REPENNING:** connect it to sort of bigger questions that the journal of choice cared about. And in that case, I think there's probably a variety of different directions you could go. We could spend a few minutes talking about that as well. I mean, it doesn't obviously scream to me at least that there's one literature in which that would go in. But literacy is something that's probably important to a variety of constituencies.

Or you could-- I'm making this up now as I go along. I mean, it could be a strategy paper. If I thought that we normally believe that as more people use a product, demand for that product goes up, but in fact, that's not the case, but yet it seems to be good for business. This would be an important thing for people to know on the strategy side. Or it could be more publicly focused.

STUDENT: There's a story related to one of my hypotheses around, like, exaptation, like the purpose of buying and consuming goods has changed. I think my first brush with, oh, why is this happening? I was thinking about how social media has kind of blown up a lot of books online, and people flock towards single titles by them and then talk about them online.

[INAUDIBLE] that don't-- so then sales are inflated, and things look good for bookstores, but people aren't really reading a variety or widely vary in the books that they're talking about. It's more so like a social signaling thing. But that was what I was like, oh, I don't know about all of that. But--

NELSON Well, so without worrying about how to formulate it, right, you had the seeds of a dynamic hypothesis there. So **REPENNING:** just take it three more sentences in terms of, what's the story? I mean, you had all the pieces. So just link them together a little bit.

STUDENT: Yeah, so I think the story is that you get two kinds of capital, maybe, from buying a book, right? You get the human capital from reading the book, just the entertainment, knowledge, and et cetera that you have. And then you have the social capital that you get from signaling, I'm reading this, this says something about me that I'm reading this, and I'm going to show everybody, oh, I care about this topic, or and am knowledgeable in this area.

So my hypothesis is that, on balance, the social capital has outweighed the human capital. And so it's more valuable than it used to be, relatively, to own and signal the book than it is to have read the book because you can get the CliffsNotes version pretty easily, and from a wide variety of mostly social media sources to kind of don't need to read it to get the big picture.

Of course, you would need to read it to get the little details, but those don't really matter and aren't really valued in the same way. And so yeah, the decoupling happens when the sales are driven by people who want to have the social signaling and not the context.

**NELSON
REPENNING:** OK, that sounds great.

STUDENT: So then an alternative hypothesis is that there's a heterogeneity. So that people have kind of diverged into the readers and the super readers. The super readers are really, really high volume now more than they used to be. And so there are people who are reading, like, a hundred or 150 books a year. Largely, they're reading ebooks and audiobooks just because it's cheaper and easier to do it that way.

So the people who are super readers are classified as such, are tipping the scales of sales. But then the kind of middle is being hollowed out. And a lot more people are on readers or light readers as well.

**NELSON
REPENNING:** OK, great.

STUDENT: Yeah.

**NELSON
REPENNING:** Please, go ahead.

STUDENT: What I don't understand, and this is a model about signaling, is why do you really have to buy the book if you don't really need to read it? You don't really need to buy the book for the signaling. You can just participate and you don't need to buy.

STUDENT: Yeah, I think-- that's a good point. On the one hand, you can just totally put a picture of the book and say, oh my gosh, I really like this. On the other hand, I see a lot of content where the person's like, listening.

STUDENT: OK, OK.

STUDENT: So they have to-- but yeah. I think that's a fair point and leans more into the heterogeneity diverging populations theory rather than the kind of social signaling theory.

**NELSON
REPENNING:** OK, and so then, where did you get stuck?

STUDENT: I think kind of, how do I model these, like, sources of capital? Social capital and human capital, how they change over time, whether people, I don't know. How are people perceiving that? And how are they making a decision really based on what they're going to get out of the book and these components? And yeah, I just, I got a little stuck on that thought,

**NELSON
REPENNING:** OK. So I think here's the trick, and I'm going to ask everyone to help you in a second, is like, we could probably cover the board with different causal diagrams. So kind of a little bit of the art of this is to consolidate this down to the most bare-bones formulation to kind of get started. And then you can add the complexity as you go.

And so I think often, you see this-- it's rare that I give positive feedback to economists. But economists are very good at this part actually because they rely on sort of closed-form models, which is they'll strip a situation down to its absolute essence. But then I think, you can get a really complete analysis of that.

So if you were going to, please help Cathy out. If we're going to strip this down to its really essential elements to get sort of a first formulation, I think you've actually given us most of the breadcrumbs that we need. But well, I'll ask you first, but others can chime in. Where would you start?

STUDENT: Well, I think I was starting with, what are the stocks? The stocks are different kinds of populations of readers. So I was just dividing like non-readers, regular readers, and super readers. And then laying down how many books each of those populations buy, how many books each of those populations read, and then kind of the-- I don't know, the marginal value. I guess I haven't thought about it-- of reading versus buying, and then kind of divergent-- the divergent ability of this.

**NELSON
REPENNING:** Yeah, OK. I would say as a piece of advice, and I noticed in yours too, Jake, actually, is that when you are thinking of a model that you might index, we're going to have multiple types. So I think in yours, you had multiple cities that might become the epicenter of Los Angeles, and Vancouver, and Atlanta, I often would recommend at the beginning, just go with two. Just build the model with two types, and don't use the indexing function in Vensim because I think it's easy to get lost in what's sort of happening behind the screen.

And once you've worked out with two, so in your case, you could be like, we have LA and the rest of the world, and you're lumping all these cities, which of course, has some nuance, and you're aggregating. But that way, I think you can kind of fully understand the dynamics with the simpler formulation, and then going back and indexing to multiple would be much, much easier.

So in your case, Cathy, I think if you're going to go with types, just two. But actually, I'm not sure I would start with the stocks. I mean, you would need to get there quickly. But do others have thoughts on how do we strip this down to the essential formulation? Because I think there is a standard formulation that jumps out of this, or at least part of one, that could help you get started. But I don't know if others-- were you going to jump in, Jason?

STUDENT: It was more of a question, how committed are you to the role of social capital versus human capital?

STUDENT: I just think that that's all, my hypothesis. But--

STUDENT: I don't think [INAUDIBLE].

**NELSON
REPENNING:** So I think the place that I would be very tempted to start is just try to formulate sort of the demand for books with the sort of-- because what jumps out to me is that the attractiveness, or the market share of reading, or the appeal of a particular book, is changing because in some previous epoch prior to social media, you don't really need to model this. You would just have some baseline demand that any given book would have a certain appeal to me.

But then you've added this sort of second element to the attractiveness function of, oh, this is what my friends are reading, or this is-- and then you could formulate, I think, your kind of first reinforcing feedback loop that would be of the flavor. And there's a sort of tricky aggregation thing here that I have to think about a little bit in terms of you're obviously not going to model the whole universe of books. I have to think a little bit about how to handle that.

All right, because what you're saying is that some books are-- well, actually, I guess you don't have to. You can just model the aggregate demand for books. So you don't have to worry about--

STUDENT: Good. Yeah. I was thinking in my original problem definition I had, and I think this exists in the social media hypothesis, there is a demand for a certain type of book, a very important [? wave ?] type of book. And I think that authors can produce to that demand. And I think self-publishing has boomed, like alternative, outside of traditional publishing avenues and offer this, just like online, [INAUDIBLE] stuff, and then also, self-publishing, and selling directly through Amazon, or something like that.

And so the quality and variety of what's produced is changing, as well. But I think [INAUDIBLE] probably too much to start with the first thing.

**NELSON
REPENNING:** Well-- sorry. Go ahead.

STUDENT: [INAUDIBLE]

STUDENT: I'm just thinking also because if the Super users are really powerful there, it's quite quick to calculate their effect. So what market share do the super users actually buy? So you can see, if they've been growing, and if you only look at the super users and the market for the past 10 years, you can see if that line is kind of growing faster than the-- So and because yeah. And see if that is really, like, is it a big part of the market share or is not.

**NELSON
REPENNING:** Yeah, so I think-- I mean, if you have-- and again, I can already see you sort of wandering into other hypotheses. So you're going to have to be very disciplined. But I think you have two that I think sound pretty interesting, and good places to start. One is essentially just a technology shift that's made it easier to consume books. So now, I listen to a book when I drive into work in the morning or whatever. And I think that would be relatively easy to model. That part's not a particularly dynamic problem, right, which is just the cost of consumption has gone down. And so demand is going to go up.

But there probably is some pretty simple dynamics as Audible has been introduced, or as there's online books, or different sort of transcription technologies, that should cause demand to go up. And then I think you have a little bit more feedback-rich version, which is basically the kind of positive feedback around Instagram, and social users, and stuff like that. I think each of those could be modeled in a really spare, stylized way.

And you might well find, this is the kind of places where I think system dynamics is good, is if we were to go with the first hypothesis, which is just technology, right, you probably have to make some very extreme assumptions about the demand curve, that the marginal benefit of being able to listen over read has got to probably have gone up quite dramatically in order to account for the increase in demand, whereas the reinforcing feedback loop might offer more pieces. But I would focus on just those two. Do we have a model from you? You? No? Nothing? OK. So you're still in the--

STUDENT: I have instructure-- instructed--

NELSON OK.

REPENNING:

STUDENT: OK.

NELSON So I think the advice I would give for you is stick with just those two hypotheses, which is basically one feedback loop apiece, plus or minus. Aggregate all books together for now. I know there's these different modalities of self published and stuff like that. And I'm happy to share with all of you, for someone who's recently written a book, all the details of the publishing industry. But that's for another time.

And then I think in this case-- and so this is an interesting thing, which I don't think is, again, a theorem or an algorithm. But this is a case where I think the feedback processes jump out to me more than the stock flow structure. There are some cases where I think the stock flow structure is really clear. We have patients, and then they become whatever, right? In this case, we have readers and non-readers. But I think the kernel of the dynamic hypothesis you have is more feedback rich than it is stock and flow rich.

And that's why I think this debate about should you start with stocks and flows or feedback loops is just utterly stupid because it doesn't matter where you start. Hopefully, you're going to end up with a model when you're done. And so you should pick the doorway that is kind of the easiest to get going. I think in your case, the feedback loops probably jump out a little bit more than the underlying sort of stock flow structure because, yeah, you're probably going to have a flow of kids that learn how to read, and then they either become regular readers, or non-readers.

And then the regular readers are going to have some certain number of books that they consume per year or something like that. So that's probably relatively straightforward. So--

STUDENT: OK. That's helpful.

NELSON OK. That's good. Does that help?

REPENNING:

STUDENT: Yeah, it's succinct.

NELSON I think it's a good problem. And I think there's a corollary, which this is just an editorializing that I have long been interested in, which is if you look at the sort of different forms of media we consume, so say, just books, movies, and music, to me, it's always looked like the movie industry is the most top heavy. If you were to plot demand, there's a few movies that get zillions of views and then it falls off very rapidly. And my impression is that books are much more egalitarian. I mean, you still have bestsellers, and it's probably a power law.

But I've never seen a good story as to why what sort of determines that distribution. And why is it that maybe there's 10,000 book titles that are viable, and there's only a thousand movie titles that are viable, or something like that? And then but then there's been a huge change in technology, Netflix, and streaming, and ebooks, and stuff like that. And so has that sort of changed that kind of power-law-esque distribution of the winner sort of take all pieces.

And what's happened in the music industry, where now no one seems to make any money except for Taylor Swift or whatever? But it does seem like there's a huge diversity of titles that are out there available. And you could probably think of it. I'm not proposing that you do that. But I think if you get this sorted, it could lead to all sorts of really interesting kind of industry dynamics kind of questions.

STUDENT: There's the book by Anita Elberse at Harvard called *Blockbuster* that looks specifically at that question, like why, in [? US ?] entertainment, are there some, usually popular ones, a lot. That's [? important. ?]

**NELSON
REPENNING:** And I assume it's a sort of positive-feedback-ish argument. Is there a form of modeling in there? Or--

STUDENT: I don't think there's any formal modeling. No. But I mean, it's basically the idea of if you have a huge success, it's initially, it's because of word of mouth and people telling their friends like, oh, this really is good. And once you've had one huge success, you're already in the blockbuster category. [INAUDIBLE]. So you're able to go around and get deals, the best marketing in the world, basically. And everyone already knows, oh yeah. I heard of that movie. And [INAUDIBLE] hits.

**NELSON
REPENNING:** Right. But I do wonder, and we'll get to the next one, this is an empirical question. Is the top heaviness in the movie industry and the book industry of the same degree? And it might be as simple as movies are just way more expensive to create than books. Video games, probably the same thing. But it's an interesting question of what kind of allows-- and who's working on the luxury goods?

STUDENT: I am.

**NELSON
REPENNING:** Yeah. So you have a really interesting flavor of this because--

STUDENT: [INAUDIBLE] There's two of us here.

**NELSON
REPENNING:** Oh, OK.

STUDENT: Which one?

**NELSON
REPENNING:** Oh, OK. Is someone else working on this?

STUDENT: [INAUDIBLE].

**NELSON
REPENNING:** Oh, OK. So I think this is also a fascinating problem. Maybe we'll come to yours next because there's a simple version of increasing returns, which is the more people that read this book or watch this movie, then that just leads to more demand. But then there's the flavor that I think you're thinking about, which is that's true up to a degree. And then suddenly, I don't want to listen to that band anymore because you all listen to it, and so it's no longer cool, which adds, I think this really interesting kind of balancing feedback loop.

And I don't know if anyone maybe there's someone's worked out that if I want to be in that niche market, how do you sort of manage the scarcity, and the hype, and sort of all that stuff so that you don't-- because I was just listening to some podcast about how for many years, there were the same luxury hotels. There was like The Four Seasons, and The Ritz, and then suddenly, there's been a whole new group that has come in on top that charges even more than The Four Seasons.

And like, it just seems like there's this dynamic where every so often, another brand will show up that is even more premium and more scarce than what we thought was the logical conclusion. And I don't know if anyone's sort of worked out the dynamics of it. Seems like a really interesting question. Yeah.

STUDENT: There's so many ideas that I could share. But one thing that, before I forget, since in your model, one thing I'm realizing that might be helpful to think about separately is kind of the weight that readers might put on, like, the intrinsic value of the media produce versus the weight they would put on what it does for them socially.

So I wouldn't-- if this book was just here, I wouldn't read it. But because other people are reading it, I'm interested. So there's a weighting function, and then there's also the actual quality of what gets produced. They're different.

STUDENT: And the quality of what is produced is what was suggested that I got as dynamic. Yeah.

STUDENT: So hold that constant?

STUDENT: Yeah, just not worry first about the supply side.

**NELSON
REPENNING:** Well, so again, I mean, I agree with that. But I want you to know why you're doing that, which is you have a dynamic hypothesis about what's important here. It could be right, it could be wrong. And I have no particular view of that. But I think, don't let any of yourselves kind of get wrapped around the axle. Well, geez, I know all six of these things are important, so I'm going to put them all in at once. Then you're just creating a big mess that's going to be very hard to sort out.

So it kind of goes back to Jason, where it's hard to make those decisions, particularly when you have a lot of instincts about what's going on. But that typically is trouble to try to get too far away from a model that you can simulate and that you can understand and analyze.

STUDENT: Yeah, but what I don't really understand is if Cathy, and I agree with her, thinks that's an important contributor, how do you-- and that's where you want to land. It seems to me, irreducible, and you cannot leave it out.

**NELSON
REPENNING:** In the long run. The key is you don't want to get too far away from a model that you understand why it does what it does. So here's another, like, editorial comment. Like, this is one of the many reasons that I don't go to the conferences often anymore. This is my least-favorite presentation, which is I built this big model, I threw in every feedback loop I could possibly think of, and a few I got from my mom, and my dog, and so on, and so forth. And look, the behavior is really complicated.

[LAUGHTER]

NELSON It just sends me over the edge because-- or nowadays, because the computational is so cheap, and look, it fits the data really well. OK, great. What have I learned from this? Right? Again, it goes back to, has it either helped me out the puzzle that we were targeting? Or have I identified some policy where I could intervene if I was going to give advice to the next high-end handbag maker that's going to come over, Birkins or whatever? Do I have some policy conclusions?

And in some cases, they have policy conclusions that have been computationally derived. But I don't have any faith. I don't know why they work. And frankly, if you were going to build a model where you're not going to worry about the why it works and you're just going to take the model on faith, you might as well just use the AI models because they're bigger and they're more accurate, right?

STUDENT: Yeah, they fit data better.

NELSON Yeah, they fit data better. And so if you're going to give up on understanding the underlying structure of why, **REPENNING:** then you might as well go with the more powerful sort of technology. So yeah, I think it's proceeded incrementally. And again, I will place this as John and I have had big fights about this over the years, right? I think he's more comfortable putting a lot of stuff in, and often because well, because we know it has to be there. And I think, again, you're just creating risk for yourself in terms of your ability to understand what's going on.

STUDENT: As a practical matter, like when you're planning ahead, OK, here's my vision. So I want to build this structure so that it can accommodate a changing quality of content. What I'm hearing from you is, kind of build it in airtight kind of compartments, not necessarily planning ahead. I don't know.

NELSON I'm not so worried about the planning ahead part. I mean, I think that's fine. I think another way of saying what **REPENNING:** my advice is I think the model size, and your understanding of it, should go together.

STUDENT: I see.

NELSON Right? Rather than, I think there's an instinct of, I'm going to put in everything that I think I need to put in, **REPENNING:** formulate it properly, use all standard formulations, and so on, and so forth. And then when it's done, then I'm going to analyze it. And I think that, for all the reasons you cited, because it's dynamic, and non-linear, and so on, and so forth, it's going to be very hard to derive any meaningful insight from that that you actually understand. There may be insights embodied in it, but they're very hard to find.

And I promise if you go that route, you will end up simplifying it after the fact to try to test your instincts about what's going on. And then this is a little bit more for just people who have sort of academic ambitions. At least in the organizations strategy world, right, model size is, at least in my experience, not dictated by the complexity of the phenomenon. It is dictated by the complexity of the existing theories in the literature.

And what I mean by that is if a theory in the strategy world has sort of implicitly three feedback loops, and you bring in a model that has 50 of them, your paper is going to get rejected as, like, I don't understand this. This is way too complicated. And I think this is an era that system dynamics has made for decades.

Now if it's a policy model, that's a different question. But if it's something you're going to publish, you can't get too far ahead of the sort of state of the art because referees are going to have no idea how to kind of process that or make sense of it. So the doctoral students already hold this. So many of the things I publish are these very simple models. And many cases, one of them in particular, really started out as a joke. Like, let's see what is the simplest thing that I could send to the journal. And it turned out it did very well, and it was a popular paper. It was the disaster dynamics model.

But that was just because in that particular thread of the literature, there were no models at all. So one stock was actually an advance over the discussion that had happened before. Different facets of the literature are in different places. OK, who'd like to go next?

STUDENT: I can do--

STUDENT: [INAUDIBLE]

STUDENT: I can do mine.

**NELSON
REPENNING:** OK. Do I have yours in my--

STUDENT: Yeah, but my diagram, it's not readable because I started doing it, and then I kind of like lost sight of what the boundary was. It should be under Sampson [INAUDIBLE].

**NELSON
REPENNING:** OK. Yeah.

STUDENT: And so it doesn't make any sense.

**NELSON
REPENNING:** Oh, shit. I did it wrong again. Sorry. So tell us about the problem you're solving, or the puzzle, and then we'll come back to the model because I opened up in the wrong thing.

STUDENT: Yeah, so what he was saying, one of the main ideas I was trying to look at was how you maintain the coolness of a brand when people from the out-group start buying more of it. Which was the problem started kind of because I initially had been thinking a lot about how resellers impact the amount of profit that the actual brand can get. But then I started looking at the in-group, out-group dynamic. And I thought that was more interesting so that I didn't have-- I don't have any of really the reseller or profit dynamic in here at all. That might need to get put in later.

**NELSON
REPENNING:** OK, so let's back up. What is the puzzle you want to answer or the policy--

STUDENT: So the puzzle is like you imagine--

**NELSON
REPENNING:** You want to figure it--

STUDENT: --the brand, Supreme. I kind of already said this in a prior class, but they became really popular because it was like, cool, all the skaters were wearing it like any other street brand. Then people from the out-group who aren't skaters start buying it because you want to buy into this culture of being cool streetwear, or skater person.

But then people from the in-group as the out-group starts to claim a bigger share of the people who are wearing it. It's no longer cool to wear it, and they go to alternatives, or they stop buying it altogether.

And additionally, the more out-group people come in, particularly in streetwear culture, and this would be different depending on what brand you were looking at, the price starts to get jacked up, which makes it cooler for the out-group, but makes it even less cool for the in-group. And they're usually more price sensitive, or care less about that because they're the ones making the culture. And so they leave. And then with some delay, eventually, out-group people realize that this brand is no longer cool. And then their demand also ends.

**NELSON
REPENNING:**

And then the brand dies.

STUDENT:

And then the brand dies, depending on the brand. There could be an argument that maybe eventually, the in-group comes back once prices have cooled, like depending on [INAUDIBLE] how good the alternatives are.

I was thinking, it would be cool, like this would be an extreme generalization of it, but it could also maybe eventually pertain to language as well. Like, there's specific ways that for example, like, gay people talk or frat people talk that signal through their voice, like, I'm part of this in-group and you're not part of that in-group. But then once mainstream hits it, and everyone starts using that, that's no longer signaling that you're part of the in-group. So that in-group itself has to invent new ways of language to show each other that you're within that in-group.

And so that's an extreme generalization of this. But it's kind of why I started thinking the in-group, out-group dynamic was more interesting than like reseller profit dynamics.

**NELSON
REPENNING:**

Yeah, I think this is fascinating. And I have children that are probably close to your age. And they get so mad at me when I try to appropriate their language. They're like, Dad, you're not using it right, or whatever. So--

STUDENT:

What are you trying to say?

**NELSON
REPENNING:**

Yeah, exactly. [LAUGHS]

OK, so I get the phenomenon. But again, what's the question you're trying to answer here? And this is a hard question actually.

STUDENT:

Yeah, so initially, the idea was looking at it from brand manager perspective, how do you maintain your brand image? How do you make sure only the in-group or more in-group is getting your products, rather than allowing out-group people to get it? So there's one idea, which is just make sure out-group people never know that this brand exists. Like, that's true of a lot of super high luxury brands, like Brunello Cucinelli or Hermes before the whole Birkin thing blew up. They did not want average people to know that they existed, and that's how they maintained their in-group.

But then with brands like Supreme, which like part of the allure is also that it's very scarce. And it's not just on price it's scarce, it's just that no one buys it because they make such huge quantities. Like, is it even possible to balance that hype with maintaining a few?

NELSON OK, so let me just repeat back to you what I thought you said, which is that one question to which modeling could be directed is, I am the brand manager, or the CEO, of a small company. Like, how do I manage this? If I'm in a market that might have these dynamics, how do I manage it sustainably so that I don't get this crazy overshoot and collapse?

STUDENT: Yeah.

NELSON OK, I think that's a great question. And it requires a diagnosis, which is you need a theory, which it sounds like you already have, of this kind of life cycle of these hype brands where cool kids do it, and then the nerds start doing it, and then it ruins it for the cool kids, and so on, and so forth. But then I think there's a really clear question at the end, which is if I'm in that space, what combo of pricing, exclusivity, and stuff like that? I think that's great.

And by the way, this is an age-old problem. When I was of sort of where you all are sitting, one of the companies that we worked with here was Harley-Davidson, the big motorcycle manufacturer. And through the 1970s, they had had a core user base that was largely blue-collar, relatively middle-income people. And during that time period, the quality of their motorcycles had been crap. And but their kind of core, sort of blue-collar user base had stuck with them, and the company had survived largely on them.

And then in the '80s and sort of early '90s, suddenly, Harleys became the hot thing to have if you were like a dentist or a plastic surgeon in Southern California or whatever. And so they became super hot. So their demand just goes through the roof. But to their credit, Harley was really worried that they were basically pricing their original user base out of the market.

And at some point, the plastic surgeons were going to switch to Ducatis, or sports cars, or whatever. And they were worried there was going to be no kind of core left. And so that actually was a super hard problem to manage. So that sounds great. So are there comments for-- is it Oriana?

STUDENT: Yeah.

NELSON Yeah, about the problem formulation and the setup before we go look at the-- sorry, my computer keeps turning off. Or suggestions for what she just said?

STUDENT: The how question might be very hard. It might be a later-stage thing. I think it is impossible to not collapse. Like, is it possible to have a takeoff without a collapse at some point?

STUDENT: Yeah.

STUDENT: That's--

STUDENT: Yeah, because I guess Harley-Davidson still exists. I think Gucci managed--

NELSON They're a fraction of what they were. Yeah.
REPENNING:

STUDENT: Gucci managed to still survive after-- they had their own hype cycle, I don't know, six to eight years ago. They still exist. I guess I should look at what fraction they're at now compared to [INAUDIBLE] maybe cycle of this to see if it is possible to--

STUDENT: There might be something structural with this thing that you actually cannot become super popular--

STUDENT: Yeah, but the in-group will never fully return once it's lost.

STUDENT: So that's just one version of the question.

STUDENT: I don't know if there's something because they have a lot of back and forth between going public, and being private, and should be the shareholders or what. And I wonder if-- I mean, it's not a feedback story really, but I wonder if the ability to be disciplined on how much I'm buying into the hype that exists, how much I'm capitalizing on the hype that exists is a major factor in whether these companies are able to sustain their core base versus kind of being forced by market demands to alienate their base.

STUDENT: Yeah. Yeah, there's a lot of interesting strategies that I think brands have developed to try and get as much profit out of people without alienating their base. I think Dior and some other brands have interesting dynamics, which is the really rich people who are the in-group that people are fantasizing that they are buying ready-to-wear and couture. And then if you can't afford that, you can buy their canvas tote bags. And if you can't afford that, you buy their fragrance line. And if you can't afford that, you buy their blushes [INAUDIBLE].

So like, I feel like that's kind of a good way that they like segment everyone and they still manage to keep the allure of being very classy, very well up brand, while if you can only afford to save up \$50 for their blush, then you can still imagine that you're part of their consumer base if you can imagine that you're one of those people sitting in New York Fashion Week, even though you never will be.

STUDENT: So diffusion length are a good story there. Like--

STUDENT: Yeah. But I think that would almost be an entirely different--

STUDENT: Well, that's a product category, but these brands also create diffusion lines like Marc by Marc Jacobs is everywhere. Like, yeah, those are, yeah, targeted at people who want the feeling but don't have the money.

STUDENT: Yeah. So it's kind of--

STUDENT: And then [INAUDIBLE] people who are purchasing the kind of top thing. It's like, oh, that's the diffusion line.

STUDENT: It doesn't affect the--

STUDENT: Yeah, it's just--

STUDENT: The caliber of the top ones.

STUDENT: Yeah, so I guess then, that's the way that the managers are reacting to pressure like such--

STUDENT: Market pressures.

STUDENT: Market pressures to sell without hopefully, like, destroying their core base.

STUDENT: [INAUDIBLE]

NELSON Yeah, and I mean, don't take this as contrary to my earlier advice. I think there's a bunch of other feedbacks you could conceivably add. I think this is a place where investors, and particularly Wall Street, can be a huge enemy to doing it correctly, because you often see these dramatic growth patterns.

So I think we talk about this in the core class. But think about Peloton. So it's growing quickly, and then we have a pandemic, and it was like the go-to Christmas gift for every wealthy family in America, which then, just their share price has gone through the roof. But it was the classic boom and bust from John and Mark [INAUDIBLE] work from long ago. There just was no way that you could sustain that level of growth. But somehow, their expectations don't sort of account for that.

So you can imagine owners or investors, like, see that sort of short-term payoff, which just makes all these dynamics worth. So I think this is great. So tell us a little bit about your model structure that we have here.

STUDENT: There's no model structure. So the attempt was to, here are our out-group people, which these are like anyone who's in the out-group is these people. These are people who are interested. And the way I-- my variables are kind of vague, so it's not good. But interested kind of started doubling for people who would be willing to purchase, which gets complicated because there's two purchasing levels, which is retail purchase price and resale purchase price, which you may or may not be able to access depending on how in demand it is. So that was kind of its own issue.

And then hypebeasts are here, which I don't know if I really need. But these are people who are just do not care about price, and will buy at any level, and are the reason that resellers can start jacking up prices to 10x retail.

NELSON I think that's the best variable name ever. But-- [LAUGHS]
REPENNING:

STUDENT: Well, yeah. That's [INAUDIBLE]. And these are--

STUDENT: It's really called hypebeasts?

STUDENT: Yeah, they're called hypebeasts. Like, people who buy brands just to be cool, but don't get it. They're called this. And then these are our in-group people, which is anyone who's in that in-group. So for Supreme, you could imagine skaters. And then these are people who are willing to purchase at whatever retail prices.

And so they lose interest depending on how many alternatives are there. Are there other brands that can signal that you're a skater pretty easily? Or is Supreme the only one? And then also, perceived coolness.

So for in-group, I think the perceived coolness drops really quickly the second a lot of these people start entering. And it's gained, like, dramatically slow. While on the other hand, perceived coolness by the out-group is immediately really high because it's at first essentially only in-group people, and then it cools down, or it loses coolness very, very, very slowly because they actually don't understand these people at all.

And then this part was kind of attempting to start to understand how this demand and sellout happens. So this is, like, total interest. Oh. Then there's the exogenous quantity that the brand is willing to produce. Like, Supreme could start making a million shirts, but they choose to keep very limited drops.

And so then surplus demand means that the resale price can get jacked up. And then as that gap increases, my thought process was, less and less in-group people are going to be able to buy it because they're either more price sensitive or they just have other things they'd rather be buying. And so that fuels a loop through perceived coolness eventually.

And then I had, down in this corner, if you scroll, there's the case study kind of of my hypothesis of how-- [INAUDIBLE] Oh, why does it look like that? Well, it used to look better, but this is kind of like my hypothesis of how the Supreme case should go.

**NELSON
REPENNING:** Do you have data from Supreme?

STUDENT: No.

**NELSON
REPENNING:** OK.

STUDENT: But so I need to get that. But this is the general idea. I think maybe a way I was thinking about modeling interest maybe could be just like, how often does like the name, "Supreme" come up on TikTok reels, articles, might be a good place to start.

**NELSON
REPENNING:** Yeah.

STUDENT: But that's the general idea.

**NELSON
REPENNING:** All right. Suggestions? Comments?

STUDENT: Yeah, I don't really know what my stock and flow should be. Or the whole pricing thing is a bit confusing.

STUDENT: So in-group relevance, or getting cooler for the in-group, and sort of in-group relevance, which is a--

STUDENT: In-group relevance is essentially just like, out of everyone who owns the brand, what percentage of them are part of it? If it's like 100%, then it's super cool. If it's 50%, it's in the not-cool [INAUDIBLE].

**NELSON
REPENNING:** So this is for all of you. What do you think is the biggest sort of crossroads here in terms of modeling assumptions when getting started with this formulation?

STUDENT: [INAUDIBLE]

**NELSON
REPENNING:** What?

STUDENT: I can't tell if this is [INAUDIBLE]. It's a huge product.

STUDENT: Yeah.

STUDENT: Wait, am I not-- there's no formulas. So I don't know [INAUDIBLE].

STUDENT: Yeah, but just your stock and flow. Like, you're interested in your buyers' potential buyers, seem separate from hypebeasts.

STUDENT: Yeah.

STUDENT: Hypebeasts are [INAUDIBLE].

STUDENT: These are entirely out-group.

STUDENT: They're out-group?

STUDENT: Yeah.

STUDENT: So I don't understand.

STUDENT: Hypebeasts are just people who are super obsessed with the brand kind of just to buy the brand because they can buy the brand and it's cool. And they, like, will spend any amount of money. These are the people who spend, I don't know, \$1,000 for a crowbar with the word, "Supreme", on it. Those are hypebeasts.

STUDENT: OK.

STUDENT: I have a question. So this is about Supreme, and then the in-group is defined by participating in like skater culture. So their ability to pay the higher resale prices is limited. And so it's driven by coolness. They don't want to buy the thing because it's uncool. But also, they can't buy the thing if it's too expensive, and it sells out, and they can get it-- the next price later.

But for luxury brands, if we're talking about buzz, the in-group is everybody who's kind in a social group with a ton of money anyway. So they're not going to get priced out of the market. It's only going to be the coolest anyway.

STUDENT: The price there is-- yeah, I was thinking about that, which is it's probably more easy alternatives. And how much is it signaling that you're part of the in-group? I do think depending on if this model was made correctly, I do think changing price sensitivity for both should like change. Like for example, for Birkins, it's just also a \$10,000, \$50,000, \$100,000 bag. You just have less people who could even buy that. And so then the boom-and-bust cycle has to be less because rather than a, I don't know, \$70 t-shirt that a lot of people could reasonably save up to buy, you're not saving up for a \$100,000 bag.

And so I think that would-- the difference would just be if the price sensitivity for both was pretty much 0, like they'll pay whatever, then I think in a good model, that cycle should just be temporary there.

STUDENT: I agree. I think in the spirit of minimum, maybe what about taking out the price dynamic and just thinking about in-group, out-group coolness? Rather than these kind of slow-to-learn out-group people can keep afloat an artificial sales cycle long after the in-group has [INAUDIBLE].

STUDENT: I did not make sense.

STUDENT: And then maybe the price comes back in--

STUDENT: After this is worked out. Yeah.

NELSON So one thing to be very careful of, and this is an easy mistake to make that people make over and over again, is
REPENNING: if in that stock flow chain of the out-group interested in hypebeasts, if they're in the same stock flow chain, you have to assume that they all have the same average attributes. So you can't mix people that have more or less price sensitivity in there. And this is a mistake people make all the time, and they try to work their way around it with co-flows. But it never works.

STUDENT: [INAUDIBLE] It's like average out-group people, wealthy people.

NELSON Well, so where I was going with, I think the biggest assumption you've made, which I'm fine with, it's just I want
REPENNING: you to be clear what you're doing, is you have now, to me, the first kind of analytic divide is you have now differentiated between sort of cool kids and out-group, right? And that's fine. But I actually think there's a way to build this model where you have just one chain, and the in-group out-group actually emerges endogenously. That may or may not be a good thing to do, but I just, again, I want you to be clear.

So for now, I think it's not a bad assumption to say, look, simplest formulation. We're going to start with two kinds of people. We've got cool kids and we've got everybody else. And then I think in terms of standard formulations, what you need to then sort of formulate for these two different groups, and it kind of goes back to where I was headed with Cathy's idea is, you've got to sort of formulate a model of their demand for these items. Goddamn this. I got to turn this thing off. Sorry.

And the reason you're distinguishing between these two groups is you have a hypothesis that they have very different demand sort of functions in terms of what they want. Basically, the nerds, or the hypebeasts are looking at what the cool kids are doing. And the cool kids are, to some degree, looking at what the nerds are not doing in some sense.

So I think, again, back to what they were doing before, what we were talking with her, like you need to figure out in a very simple way, what is the attractiveness or the appeal of this particular-- I assume this is a generic product from Supreme or whatever it is. And I think you could get, using standard formulations, a very sort of stripped-down model. The other thing is a kind of standard formulation is I do imagine you need some kind of diffusion style introduction.

So when they offer a t-shirt or whatever it is, it's going to go through some Bass style kind of diffusion process. But then I think this is really interesting because there's sort of two diffusions going on. And you have to think about how they interact with each other, which would actually be an interesting little problem I have to think about.

But I think where I would start is I think the stock flow chains are pretty-- I don't even know if you need three stocks for the-- you could probably start with, I just have two types of people, and they're either buyers, they're either owners, or not owners. So just two on both sides. And then I think the tricky part is to formulate-- the interesting part is to formulate the two demand functions for the two groups. And that's really where the two groups will differ in this context because your cool kids will basically be looking at some attribute and making sure that the non-cool kids don't have it. And then the non-cool kids will sort of be doing the opposite.

And I think from there, you can get sort of the core dynamic. And then you can start to layer in some of these other feedbacks. But again, kind of on what is becoming the theme for the day, I would do incrementally, sort of feedback loop by feedback loop.

STUDENT: So look for stocks just like [INAUDIBLE]?

NELSON
REPENNING: I think that's the sparest sort of formulation you could come up with. Again, I have to think about it. I don't know if anybody's in instincts. There is a sort of diffusion process that's going, where both of these groups are learning about it. And you have to think a little bit about who's looking at whom in terms of this. The cool kids are probably-- if you think of the standard Bass diffusion model or simple epidemic model, first, I have to learn of it. OK, Supreme's got a new t-shirt or something like that. And then I have to form, what's the appeal to me?

And so I guess for the cool kids, well, you tell me. But I imagine that they look at the other cool kids. And the more the cool kids have it, that increases their demand. But then when I see middle-aged people like me walking down the street with that t-shirt, that's probably a negative. So you'll have to think carefully about how to formulate the relative attractiveness of it because I think that's going to be where the action is for this.

I think it's a great problem actually. And I think this is a case where actually, to the extent that you can start with a fairly specific example, so I think it's good you picked one brand, and even with one product in the brand. And you may want to make this a more generic treatment at some point, but I think it will be easier to sort of kind of model formulations if you're focused on, OK, I want to look at t-shirts from this brand or whatever.

And back to Cathy, I think you're smart to focus on just books rather than-- you may extend it someday to music, and movies, or whatever. But I think for now, it's actually having a specific case will be more helpful rather than trying to kind of build the grand, perfect sort of universal model. Other suggestions for this? I think this is a great choice.

And you haven't written any equations yet, right? So it's just a stock flow structure. Yeah, and I would say too, I think the resale market is also super interesting. Again, as a matter of strategy, I would get sort of the core dynamic with just these two groups and sort of the life cycle first, and then probably add that resale sort of feedback or stock flow structure in later. I mean, doesn't this happen in sneakers all the time, that there's this sort of secondary market for hundreds of dollars, and multiple markups, and stuff like that? I think it's a fascinating area.

STUDENT: Would you be able to have a simple structure that can showcase both behaviors of, [INAUDIBLE] screen thrasher? Like thrasher feels like it hasn't really hit people as much. It's still sort of [INAUDIBLE] constant demand on group, whereas Supreme does hit out-group, and then suddenly, it's [INAUDIBLE]. And then, you can just showcase it. What happens to have it be sustainable? And what happens to have it definitely crash? And then all the management group goes away. Then it's already pretty cool on [INAUDIBLE].

NELSON
REPENNING: Yeah, and I think there's some really interesting policy questions, which is if, under a certain set of conditions, if basically the brand is going to kill itself because it's going to become too popular, and then the cool kids don't want it, OK, so I need to restrict it. Well, pricing will have some desirable properties and probably some negative properties basically depending on the in-group versus the out-groups.

I mean, you could end up with a really interesting story. If the in-group are also the wealthy people, like Kardashians or something like that, that probably leads to a very specific set of strategies that goes with the Birkin thing. Basically, we're just going to price everybody else out of the market, and we have this super luxury brand. And then maybe, you have the kind of multi-level thing where we then create other versions. But if the cool kids are actually on the lower income side, then it probably becomes a much thornier sort of problem. So then how do you restrict demand in other ways besides pricing is--

STUDENT: I know Supreme kind of-- what-- kind of failed by just trying to make itself like an extreme luxury brand. It [INAUDIBLE] like \$10,000 bags or whatnot. So I don't think we're [INAUDIBLE].

**NELSON
REPENNING:** Well, and I imagine, and you could even sort of show this in your analysis. It's got to be enormously seductive to do the wrong thing. So if I start this low-end brand, suddenly, all of Hollywood is wearing my sneakers or they're in the Academy Awards, like swag bag or whatever, there is an enormous payday that you could probably capitalize on. But then you could probably also kill the goose that laying the golden egg pretty quickly.

It's ancient at this point, but if you read the original version of Malcolm Gladwell's *Tipping Point*, the book is probably older than you are, there's a whole chapter on hush puppies, which were these dorky shoes that suddenly became cool again. And like, so there's a nice little case study that you could sort of grab there about-- and the same thing happened with Vans. Vans sneakers were, like, orthopedic sneakers and then became popular with skaters. And I don't know. They seem to still survive. So they may have figured out a way to do it.

But I would focus on your Supreme case now. But once you've kind of got your story, then if you were going to kind of continue with this, you could then use your model with different parameters to explain, this is what happened to Vans, this is what happened with this and that. And it could be a really interesting piece. OK, should we take a break? Do you guys normally take a break for this class? OK, what's the normal--

STUDENT: 10 minutes.

**NELSON
REPENNING:** 10 minutes? OK.

STUDENT: 40 maybe

**NELSON
REPENNING:** Yeah, 10:40 and then plus the usual MIT discount. So we're probably not to get to everyone, given that not everyone posted their model. I'm guessing that's not going to be a heartbreaker for everyone. But if you want to think about whether you want to get in the queue before we get to 12 o'clock. But I would like to talk about yours.

STUDENT: Yeah, yeah.

**NELSON
REPENNING:** I think it's interesting too.

STUDENT: I need help.

**NELSON
REPENNING:** OK. OK, well, why don't we get going? Hopefully Oriana will-- is she the only one that's missing? I guess. OK. Yeah, so we don't need to worry about the model for a second. What's the problem or puzzle you're trying to sort here?

STUDENT: So in the current state, the problem is with one of these, what are the consequences of having a structure that looks like this? What are the consequences? So the idea is building a simple model of how a flight books from the day it's born to the day it takes off with realistic kind of booking behavior on both ends. So customers show up, they're willing to pay if the price is low enough. But when booking, they might wait.

And then on the other side, there's a revenue manager kind of adjusting prices based on where they are relative to that point. The thought was, can we build first just one flight on one departure day, kind of booking until it takes off, and then layer in a competitor? OK, why bother with any of this?

The hypothesis kind of idea is that because demand is not fully observable, meaning if you're priced too high, you cut off some demand at certain times, and then you can lower it later, get some of that. There's a bit of a challenge in attributing the perspective of the airline, like whether your forecast was off, if the competitor priced too aggressively. And if you play this game over and over again, you can wind up perhaps learning the wrong lesson and getting stuck in these very sort of misaligned beliefs about what the demand environment actually is. So I didn't really give you a problem statement.

**NELSON
REPENNING:** Good. You didn't. Who can help Jason? Or what question are we about to ask next, which you kind of already are on the--

STUDENT: What exactly is the problem?

**NELSON
REPENNING:** Yeah, exactly.

STUDENT: Yeah, what's the problem we're trying--

**NELSON
REPENNING:** Or why should we care? So I mean, I know you know this, but you're getting the cart and the horse a little bit in the wrong order here. You have a sort of structural, I want to model this, the story of what happens. But to what end? What are we going to get out of this?

STUDENT: I need help with that.

**NELSON
REPENNING:** OK.

STUDENT: It's accurately finding demand from the sale percent [INAUDIBLE].

It's not-- it's--

STUDENT: I mean, one question you could ask is like, is it important to have an accurate forecast of remaining demand? Or when is it important? It's one question, but it's not really--

STUDENT: Let me look at my problems.

**NELSON
REPENNING:** So you need a puzzle or a policy question. Yeah.

STUDENT: I need a puzzle.

NELSON I mean, I think the one that we were talking about in the hallway, which is how is this industry that seems to be very lucrative, in fact, has cumulatively lost money over its entire existence? It's a very interesting question. That may not be the one that you're interested in. But just so, free associate a little bit. I mean, why is this interesting to you? I know you're from the industry, but I'll pin you down on a problem statement later, but just what grabs you about this? Why is it appealing to you?

STUDENT: Because it doesn't seem like it should work. So OK.

NELSON What doesn't seem like it should work?
REPENNING:

STUDENT: The claim is that the revenue manager, so the person who's managing the flight and deciding what the fare should be at any point in time, has some expectation about what kind of booking will materialize and when. And they wind up kind of claiming-- the whole system is set up to match the right passenger with the right seat at the right time. So that's the claim.

But in reality, there's a lots of places where it breaks down. And I don't know. I just want to know how it works. I want to see what the consequences are. Why is it interesting? Here's why it's interesting. It's incredibly complex. The true dynamics are incredibly complex. And you have to design kind of roles in the running of the organization that are reducibly kind of simple.

So a lot of that complexity has to be like confined to the background. And my confusion, or my kind of instinct is that too much is shifted to the background, and forgotten about, and then the actual simplicity of kind of the roles that get enacted don't account or appreciate for what's actually going on. And that lack of accounting and lack of appreciation gets embedded into the system and feeds back in horrible ways that can lead to divergences.

NELSON Give me an example of a horrible way.
REPENNING:

STUDENT: OK. It's been a while since I've thought through this. One example is, like, a, self-fulfilling prophecy sort of story, where-- I know that Easter is a week earlier this year. So the demand for my flight is going to be a lot higher than it was last year. So I set the fare level 10% higher across the whole curve.

And then that demand, suppose it does not materialize. Your new booking history is going to be lower than what it would have been if you had priced more accurately. So now, you have a biased forecast for next time. And no one's accounting for that unconstraining process of-- I mean, there is nominal ways they account for it, but--

NELSON OK, so let me repeat back to what I think I'm hearing, is you have an instinct that this process doesn't work as well as it could have, it could. And so there is a pathology, or a problem here, in the sense that this is somehow suboptimized. OK, so let me give you the alternative.

So I know nothing about this industry, right? When I was a student, this kind of dynamic pricing was a very hot topic. And so my naive take on this would have been, actually, it works pretty well because there's a feedback loop where they essentially auction off each seat in the airplane. And every time I fly, it seems like the seats are pretty full.

STUDENT: Yes.

**NELSON
REPENNING:** So I don't know. It seems like it works pretty well. But it sounds like your instinct is, there's something in there that doesn't work well, or there's a potential pathology that can recur or something like that?

STUDENT: I think there's a lack of accounting for the feedback effects in the forecasting process, proper accounting. And I'm curious to note that is consequential. I'm not sure, but I have a feeling it is.

**NELSON
REPENNING:** OK, so I think this is an interesting challenge, right? Because you have an instinct that maybe there's something going wrong. But unless-- God damn this thing. Unless I am misinterpreting you, you don't have a lot of evidence that this thing is going wrong at this point. It's more just--

STUDENT: I have no evidence.

**NELSON
REPENNING:** Yeah, no evidence. So I would suggest you go in two directions at once, which is it'd be interesting to look at the data and see if there's a kind of thought experiment that you could run that would give you a better sense that the fact there is something going wrong. I mean, I would imagine, for example, there's an upper bound of I have x number of flights, I have y number of seats. That should add up to this much money. And what they get is somehow less than that.

I mean, my casual empiricism is it doesn't seem like there's a lot of empty seats on these flights. But maybe they're not filling them in some optimal way. But that casual empiricism could also just be wrong.

STUDENT: Yeah, I mean, there's a trade off between load and yield. You can sell out a plane. I saw a plane tomorrow if I make all the tickets \$50.

**NELSON
REPENNING:** Right.

STUDENT: So the kind of challenge of the revenue manager is to decide kind of what kind of demand is remaining, and what value is of-- I think-- like, I could articulate a much clearer feedback story. But then, I'm committing myself to a story for which I don't really have evidence.

**NELSON
REPENNING:** Right. But I don't think you have a choice there because so here's-- I think one path is to see is, can I go collect some data or talk to people, and kind of give more detail to this what now sounds like a fairly vague instinct that there's something wrong and then there hills there that something's going wrong.

And then I think, you can try to model it, right? Because you have the nuggets of a dynamic hypothesis that somehow the different kind of expectations processes in the players are not adding up to the right answer.

STUDENT: Right. Here's what I'd do from my experience. There's a demand forecast that gets used as a tool every day as a revenue manager is managing. That forecast is produced as a result of an automated process. The revenue manager uses that forecast as an input in their decision on how to adjust fares. And as a consequence of the forecasts and the decision they make, it's going to feed back and create future forecasts. What's left out?

There's no evaluation of the forecast accuracy. Zero. So this is a recipe for having very divergent bad forecasts, and no one trusts the forecast. So--

NELSON
REPENNING: OK, so this is getting more interesting. I like that no one trusts the forecasts. That gets my spider senses tingling a little bit. I think the way to go after it is without worrying about Vensim equations yet is to really-- again, you have kind of a loose dynamic hypothesis about something going wrong. And I think the question here is, does it matter? Because this is a system that has quite a bit of negative feedback to it, which is, again, if I understand revenue management, if we have a hundred seats left on this flight with a week to go, we're going to start lowering the price until-- now whether that's optimal or not.

But so I think you need to kind of think really carefully at a conceptual level of, and you are committing yourself to a story, which I think is the thing I'm getting the sense is making you uncomfortable. But you don't have a choice, right? Again, if you don't, you're going to end up modeling the system. You're going to just throw in every detail that you can possibly think of and you're going to end up with a Jackson Pollock painting of a model that's probably not going to be super helpful.

So I think you need to think hard about what your story is and commit to it. And when I say you have to have a puzzle or policy, I think the real world is a little more iterative than I'm characterizing it, because I think, often, you will start building your model. And then you realize that the question that you were interested in is actually not the most interesting one. And then you come back, and that's totally fine. I have no problem with that.

What I don't want you to do is kind of go down the kitchen sink strategy of, I think there's a problem somewhere in the city. And so I'm going to start drawing a comprehensive map of all of Boston to see if I luck into finding it. That I think is going to be a little bit of a fool's errand.

STUDENT: Right.

NELSON
REPENNING: And again, I think the question, though, is if you identify a pathology around forecasts, and this is a question a dynamic model could answer, is, does it matter? Because there might be enough self-correcting negative feedback there that it really doesn't. Or it might matter a lot, in which case, you would have discovered sort of something new. But I think it's your intuition needs to be made quite a bit more kind of concrete about where you think something's going sideways.

STUDENT: Got it. So [INAUDIBLE]. My sense is, and I can make it more concrete, just a little bit thinking, but my sense is there is a hidden kind of reinforcing factor that's not really the problem.

NELSON
REPENNING: Now we're getting closer.

STUDENT: And it won't be too much effort for me to identify because that will give rise to some path dependency. And then the question is, are the balancing feedbacks that exists, that are built into the system and behavioral feedbacks enough to correct for that?

NELSON
REPENNING: Yeah.

STUDENT: Yeah.

NELSON
REPENNING: And enough on a time scale that matters.

STUDENT: Yeah.

**NELSON
REPENNING:** Right? And so and it is fairly complicated, right? Well, there's at least another layer of complexity, right, which is what little I know of the industry is, yes, I'm auctioning off seats on this flight. And I presume that if I sell out the flight months in advance at a high price, then oh, maybe we should add a couple more flights on that route. So then there's and the time delays between changing pricing and changing capacity probably are very different.

STUDENT: Yeah, I'm not mentioning that yet.

**NELSON
REPENNING:** But I think you have an instinct that there is a kind of, I think path dependence is the right answer here, is that forecast kind of anchors us in a certain--

STUDENT: Realm.

**NELSON
REPENNING:** Quasi equilibrium that then, we don't search outside of it, that we may be missing opportunities, or it allows competitors to come in, or something like that.

STUDENT: Yeah, so clarifying really, so what I need to do is kind of really articulate the dynamic hypothesis. And then why do I need a model? I need a model to test it.

**NELSON
REPENNING:** Yeah. Right. And I think, again, it goes back to what I was asking you, just to get clear on what dynamic models are good for. That balancing loop of I auction off seats, and that I see that this flight is full, and so I add new routes, that operates at a certain speed. And that may or may not be fast enough to offset the errors that you're identifying. That's going to be a very hard question to answer just through kind of casual thought, right? And so I think a dynamic model would be very helpful to figure out sort of which of those feedbacks is sort of dominant in that context.

STUDENT: I think I'm also running into a trap, proximity to the thing. So I have this thinking complexity that I want to capture. And--

**NELSON
REPENNING:** See, the problem is, is you know too much about how it actually works, right? So you want to leverage all that.

STUDENT: It's not useful. I mean, so I had actually started with more at the level you were talking about, where there was multiple time horizons. And I was encouraged to scale it down to the most atomistic level, one flight on one departure day. Kind of how does that work? But I actually think there's some middle ground because where I started off is too vague, and that's probably where it [INAUDIBLE].

**NELSON
REPENNING:** Well, but also, it doesn't sound like the one flight on one day captures your dynamic hypothesis. The thing that I've heard from you is that you think that somehow, a particular forecast gets kind of embedded in the system, and either limits search or is self-reinforcing in some way. One flight in one day is not--

STUDENT: Going to do that.

**NELSON
REPENNING:** That aggregation choice won't help you with a dynamic hypothesis. See, this is why that dynamic hypothesis is pretty--

STUDENT: Important.

NELSON That's it.

REPENNING:

STUDENT: All right. [INAUDIBLE]

NELSON OK.

REPENNING:

STUDENT: I'll go back to the dynamic hypothesis, rework the model. I had a question.

NELSON Yeah.

REPENNING:

STUDENT: It might have gone away, but you can check it real fast.

NELSON Yeah, go ahead.

REPENNING:

STUDENT: So if you-- well, it might be answered with your statement earlier that you had the stock flow chain, the average has to be the same for everyone in that chain. So if you want to model the distribution, you have to just have separate stocks for each [? individual distribution. ?]

NELSON Yeah, so the technical assumption is perfect mixing, right? Which means that if we just take seats remaining--

REPENNING:

STUDENT: Well--

NELSON I mean, it's maybe not a good example.

REPENNING:

STUDENT: Yeah, yeah, yeah. Yeah, scroll down a little bit. So this average reference price, people wouldn't book. It's the same for everyone. But really, that average represents kind of, it's a summary of some distribution. And the shape of that distribution could change. It's actually what we care about, not just the average. We care about the shape.

NELSON Yeah.

REPENNING:

STUDENT: And to capture that, I need multiple stocks. I can't [INAUDIBLE]. And I was trying to get the shape through a parameter, but the parameter is fixed. So I'm just basically giving it the same shape every time.

NELSON Yeah, I mean, I've often wondered if you think about how the co-flow works, you're basically just capturing the first moment of a distribution. So you're just capturing the average attribute. And the perfect mixing assumption means that anyone that comes out of that box, it's just a random draw and they have the same average propensity. So you can't take out of a stock the high-propensity demand, the tail.

And I don't know enough probability to work this out. But if you had a co-flow that had higher moments, so if we had variance, and-- could you get around this? I don't know the answer to that. And again, I don't know enough probability to work on that.

STUDENT: It's worthwhile.

**NELSON
REPENNING:** Yeah, but I think you could have two types. So you can have n types or, right? I mean, you could get a distribution. You can get around it by having-- we could have business customers and leisure travel customers. And then we could get two different propensities for--

You see this error all the time. People try to work their way around that perfect mixing assumption, and it always gets them in trouble because you're just violating. There's a whole kind of distributional assumptions underlying all of this that--

STUDENT: Yeah, I think the reason it's tempting to want to work your way around that is because if I introduce more-- more and more I disaggregate intuitively, the closer I am to something that's--

**NELSON
REPENNING:** To God.

STUDENT: Continues. Not to God. The more and more I disaggregate, like, OK, I could have a hundred different buckets and I still wouldn't cover the full demand curve distribution. Over 1,000 buckets still doesn't cover it. So I'm picturing a continuous thing, and then it's tempting for me to want to represent that with one stock. But I think that doesn't work.

**NELSON
REPENNING:** Yeah, and I don't-- Tom Friedman gave a paper at the last conference I went to, where the model would sort of rewrite stocks sort of as needed. I mean, I think there probably are other mathematical formulations that someone could invent to solve that problem, but I haven't seen one that-- PJ, I know, worked on this a little bit. But yeah, the moment you say, well, I'm going to take out the one tail of the distribution first--

STUDENT: You need to put it in [INAUDIBLE].

**NELSON
REPENNING:** Exactly right.

STUDENT: OK. This helps. I might not even need to deal with this part. OK.

**NELSON
REPENNING:** OK? All right. Awesome. All right, who's next?

STUDENT: [INAUDIBLE]

**NELSON
REPENNING:** Yeah, I'm sorry.

STUDENT: No, you should go.

**NELSON
REPENNING:** All right, so how many people do we have left? I'll actually be a little more disciplined than I normally am. So we have an hour left. And how many want to go? So we have four of you?

STUDENT: I could have on little [INAUDIBLE].

**NELSON
REPENNING:** OK, so we'll probably do about 10 minutes. So I'm going to have to actually not be myself and be more efficient. OK, so who wants to go first? Jake, do you want to go?

STUDENT: OK.

**NELSON
REPENNING:** OK. So again, it's the same-- which one was yours? The runaway production?

STUDENT: Yeah.

**NELSON
REPENNING:** So tell us your story, or what--

STUDENT: It didn't upload.

**NELSON
REPENNING:** Yeah, here, I got it. No, I think I have it.

STUDENT: So the story is Los Angeles has basically always been where basically all film and TV production has happened, at least for major English-language blockbusters. And recently, it's been sort of a saving to other locations at an increasing rate.

And there's a bunch of explanations for that that come from various, like, spokepeople in the industry, whether it's studio heads, whether it's other types of advocates, that boil down to labor cost is too much now because of all the strikes and the agreements that they came to, tax incentives elsewhere are just really way too enticing for us to ever do anything here, to maybe there is just some aspect of nowhere else had the ability to produce things before, and now they do, and it's a reinforcing feedback loop that makes it possible [INAUDIBLE].

So the problem question to me is like, if the story is a tax incentive thing, or can you work within the system to place a tax incentive as the city of Los Angeles to bring back a lot of this production, or at least stop it from leaving? Because right now, there's a lot of debate on what should that incentive level kind be? So that's sort of why.

**NELSON
REPENNING:** So it's a policy question. You want a policy answer to what suite of interventions, taxes, or otherwise, that would keep the business in Los Angeles. OK, great. Love that.

STUDENT: So then here, in [INAUDIBLE]-- so I originally set it up exactly the way you're talking about it. Like it's LA, and it's rest of the world. Yeah, I did subscript everything, but it's just two locations I have [INAUDIBLE] the rest of the world at the moment. I originally was like, LA attractiveness, through [INAUDIBLE]. But it felt like everything would need like, you would need the LA town experience and [INAUDIBLE]. So I was like, it might just make more sense to [INAUDIBLE].

**NELSON
REPENNING:** So I think in the long run, subscribing is fine. And this may just be my own foibles, but I find it just is much easier for me to visualize what's going on when I do the model of two and I have the same stock and flow for LA and rest of the world. Your brain's maybe bigger than mine, and you can sort of keep that. But I just think, I find it much easier to work out the details where I can see all the structure first before going to the subscribing that.

STUDENT: If I was going to explain it to somebody who's setting policy, I would need [INAUDIBLE].

NELSON Before we jump into this, so why do you think this is a dynamic problem? So an economist would walk in here and

REPENNING: say, yeah, you just need to calculate the optimal tax incentive so that the price of doing business is Los Angeles is cheaper than Vancouver. We don't need dynamics for that. We can just sort of estimate the relative demand curve. So again, it kind comes back to the question I've been asking everyone. My guess is you have some instinct that there are some interesting dynamics here.

STUDENT: Yeah, I do. So I mean, I think that it is definitely like there's a sort of agglomeration dynamic piece of it for sure that I think this, if you have a really successful movie that's produced in the UK, suddenly you've proven that you can make a really successful movie in the UK. And people are more willing to sort of go and do that.

NELSON OK.

REPENNING:

STUDENT: And I think even within the tax credit sort of system, there's obviously going to be some sort of response from the sort of rest of the world to the decisions that you're making.

But really, I think it's the reason I find it dynamic is because there's a level at which if enough production goes away, suddenly, LA is no longer the spot that has the advantage of being the better spot because there's just been too much experience gained by local talent elsewhere. There's been too much local infrastructure investment that's happened elsewhere. So it's like, it's never coming back. So I thought that was maybe more feeds into itself.

NELSON So I heard two dynamics. One is kind of like a proof dynamic, which is like, OK, I had a blockbuster that was

REPENNING: made in Akron, Ohio. So now we can prove we can do it. That dynamic sounds relatively speedy. But then it sounds like you're also talking about a much more infrastructure-based story of, I assume there's skilled trades, and infrastructure, and people, and stuff you need in a location.

STUDENT: [INAUDIBLE]

NELSON Yeah, exactly. OK. OK, good. So you have a pretty clear dynamic hypothesis. And actually, what I think is kind of

REPENNING: interesting about your dynamic hypothesis is, if I hear what you're saying correctly, is you're worried about a cliff.

STUDENT: Yeah.

NELSON Which is like, OK, it's fine. Production is going to these other places. But there is the fear of a reinforcing

REPENNING: feedback that if it gets going too strongly in the wrong direction, LA could be kind of screwed. And then--

STUDENT: Yeah.

NELSON Yeah.

REPENNING:

STUDENT: Film production in LA is like water, in [INAUDIBLE].

NELSON OK, that sounds great. So tell us a little bit about that model so far.

REPENNING:

STUDENT: So this is like the sort of most basic version I could make of where it has sort of a tax credit that starts somewhere else that starts to pull production away. In general, like, if you were to run it with no tax credit for elsewhere, then LA just builds up all of the local talent experience because they start with a little bit more of the experience, and infrastructure, and production scaling. So they're just going to continuously become stronger and stronger as a reason to go there.

And then I made a switch so that you could set it so that, OK, now there is a 30% tax credit in Georgia, we start seeing some productions away, and over time, that sort of share of productions grows, and grows, and grows because there's a tax credit. And we like local infrastructure and talent that it sort of built up that pull everything away.

And then I don't yet have things that feel important to me in this of, I think there's sort of a cost and a benefit piece of talent, for instance, whereas I only have sort of a benefit piece of that right now [INAUDIBLE]. I think there's a cost and a benefit to a lot of different pieces. Like, I might be more willing to shoot in an expensive location if I know that I can make a better movie, for instance. But if it's going to be cheap enough, I might be willing to do it in a worse-off place.

So I don't have that baked in yet. But right now, I have sort of feedback loops for infrastructures or [INAUDIBLE] talents and [INAUDIBLE]. And then there's sort of a tax-credit piece of it too that goes into locations of active attractiveness.

**NELSON
REPENNING:** So have you have evidence, casual, anecdote, or otherwise, that the positive feedbacks have been working in these other locations in the sense that Georgia is starting to develop soundstages or I don't know what skilled trades you need for a movie, but electricians, or photographers, or something like that.

STUDENT: Yeah.

**NELSON
REPENNING:** Yeah. OK.

STUDENT: Canada and the UK both, like if you look at the UK's level of soundstages, they now have as many as Los Angeles does and sort of put a lot of investment in specifically making that infrastructure become available. And as they've done so, there's been more and more [? adherence ?] from the UK. There's smaller pieces of anecdotal evidence. Like right now, so *The Lord of the Rings* time, like they did a lot of the special effects and museum [INAUDIBLE] be easier.

And as a result, the museum now has the most state-of-the-art visual effects in the entire world. So now, movies like *The Avengers* will even go to New Zealand to have them do the visual effects.

**NELSON
REPENNING:** Interesting. OK. Well, in the interest of getting to everyone, let me give you a couple thoughts. So I think the aggregation level looks pretty good for now. I mean, I can imagine a world in which you start to disaggregate between soundstages, and visual effects, and stuff like that. But I think basically, now, if I understand this correctly, you've kind of just disaggregated between kind of hardware and software, right? So we have people and stuff. I think that's fine.

I think you'd be smart to have, even in just in your documentation, some examples of each of those because a lot of this is going to turn on relative delays. How long does it take to develop a soundstage or whatever. So I think you want examples in there just to help you think about. I have no idea how long it takes to build a soundstage, but that will matter.

In this local attractiveness thing, this is probably the only detailed formulation feedback I will give, but I looked at this earlier. Almost certainly, you're going to want to use the-- and this goes generally for these attractiveness formulations, the multinomial logit formulation. It's discussed in John's book. You can find it on the web.

It's just the version of this formulation that has the kind of most robust story underlying it because I think you had like just a fractional, like a convex combination, of the two things. So when doing these attractiveness, that should probably, in most cases, be the default option.

And what I would suggest you do actually as a kind of analytical strategy is the equilibrium of this model, I think, I would suggest you start with most of the production is in LA, and then your intervention is the most of world gives this tax incentive. And then some small number of movies will go, but then you can see how these other feedbacks start to then grow stronger and maybe start driving some sort of more balance. And again, I'd do the two pieces.

But I think this is a great question. And you may end up disaggregating across soundstages, visual effects, and stuff like that. But I would stick with kind of the hardware and the software for now, and sort of get this working so that you understand it. And it could lead to some really interesting policy conclusions, right?

I mean, LA may have to work hard to keep-- because I don't know if they have cost disadvantage. I mean, it's probably more expensive to be in Southern California. Just so this may be a hard thing to do in order to-- it's a great question, though. So I mean, if you had a client for this, would it be the movie studios, or the Los Angeles Chamber of Commerce? Or--

STUDENT: Yeah, exactly. MPA, which is the [? parent ?] of all studios. And then I think, [INAUDIBLE].

**NELSON
REPENNING:** They're going to think you're a Dr. Doom when you walk in and be, like, we're going to lose the whole thing if we don't change the--

STUDENT: Well, as you say, it's easy to sort of share the story, and like if other places have these tax incentives, and then what will be happening there is all these feedback loops, here's what necessarily will happen in terms of [INAUDIBLE].

**NELSON
REPENNING:** *Right.* And tax incentives is only one lever. And I know we need to move forward. But you could imagine infrastructure investments. You could subsidize computing clusters for visual effects, which would require, I think, a pretty careful theory of what is the future of movie making going to look like, and what are going to be the scarce, hardest-to-replicate resources? Is it going to be soundstages? Is it going to be computing power? Is it going to be engineers?

And also, I think there's some interesting questions about, as technology requires fewer and fewer physical assets, the terms of competition could change in some interesting ways as well. I think this is cool. OK, who's next?

STUDENT: [INAUDIBLE]

**NELSON
REPENNING:** Yeah, did you-- I think I have yours, right? So is this one right here?

STUDENT: [INAUDIBLE]. Yeah.

**NELSON
REPENNING:** OK. All right. Tell us about your problem.

STUDENT: So it's about heat principles and the effects on health.

**NELSON
REPENNING:** Yeah.

STUDENT: I'm starting with mortality. And basically, it should be a policy problem because we know that originally, the puzzle that I looked at was that basically, despite some measures we're taking, like early warning systems and awareness campaigns, if you look at the hot and hottest days, which are controlled in Celsius or [INAUDIBLE] Fahrenheit, there was still an increase in mortality.

But I think the puzzle is not why because we know why. And we know that we have more hot days, and they're hotter. And we know that the population is getting older, and the housing is not made for this weather. So I think it's a [INAUDIBLE] question, and kind of seeing which policies could help to reduce this trend.

And I think I probably have to take a step back and simplify this. But I think the question in my head was, what would this structure look like? Because I basically have the population separated in three cohorts. So because the most vulnerable are the young and the old, so I now have the population separated as young up to 15, and then adult from 15 to 65, and then 65 plus.

And then I wanted to separate at least high and low income because that's another vulnerability factor. And then I wanted to separate-- [INAUDIBLE]. Oh yeah, the housing. So [INAUDIBLE]. And yeah, I put some numbers, but they're just, like, fake numbers to see if this thing works. Yeah, this is just the very beginning of the population structure.

**NELSON
REPENNING:** OK, so the question you want to answer is, given finite government resources to manage-- or what's the best way to manage this problem, to minimize sort of climate change, heat-related mortality? OK, that sounds great. That seems pretty clear. OK, so what do y'all think about this structure?

So you have four stocks, right? So there's population, and you have a low-income population, and adequate housing, low-income. So we have low-income people on adequate and inadequate housing, and they have different mortality rates presumably from the heat increase. And then the same thing for high income. And then you have this kind of maximally connected so that people are able to move between all the different states.

STUDENT: This looks nice expected for the age cohorts. So first, I made this with 12 stocks. So each separate cohort with the-- just to understand, what do I have here [INAUDIBLE]. And then I simplified this way. In between this, I was thinking that maybe, I should have just one stock of population, and everything substituted. But then I couldn't really get my head around it, so I didn't say.

NELSON OK, what do y'all think? Suggestions or critiques?

REPENNING:

STUDENT: I would stay away from the heat stratification for [INAUDIBLE]. I think if there was dynamics [INAUDIBLE].

STUDENT: Say again. Sorry.

STUDENT: I would go smaller in terms of stratification. Instead of 12, I would stick with these four for now.

STUDENT: Without that age?

STUDENT: Yeah. For now. You can add more complexity. It's a lot of [? problem. ?]

NELSON Yeah.

REPENNING:

STUDENT: Are there other feedbacks very important or linked to the flows between these stocks? Or are the dynamics driven by people transitioning from one state to another? Or just the dynamics are different for each group?

STUDENT: I don't know exactly. It's a good question. I wouldn't imagine that they're driven by the transition, but I think the mechanisms are different. So that's why I wanted to separate them. But I'm not sure. I might have to change it.

NELSON So what's your guesstimate over the appropriate time horizon for this analysis? Right? So how long are we going
REPENNING: to have to look into the future to really think properly about this? So I'm imagining that it's not going to be like-- in one year, not much is going to change. And so this is a-- I think it's--

STUDENT: [INAUDIBLE]

NELSON Yeah, I would guess probably longer. But so it's measured in decades. For sure. OK.

REPENNING:

STUDENT: Especially if you want to see that, because the population is aging, so if we want to capture that, since we expect more people to go to the elderly category. So more people will become older.

NELSON Yeah, OK. So that makes a lot of sense to me. Yeah, so other thoughts?

REPENNING:

STUDENT: Yeah, I think I would probably separate it by age and then housing and that because income level and adequacy of housing are so [INAUDIBLE] here. But I think you could take out income level and just focus on housing and age because those are the things, like if you're an older vulnerable person, and inadequate housing-- that's the highest risk-- going to be. And the income's kind of in the background of that.

STUDENT: I think you have a good point, especially because I noticed, actually, the income doesn't matter because you could be high income, but still the housing may be so old that it doesn't have any insulation. And it's kind of air con is not very present in Switzerland. Like, only the very modern buildings have it. So I think you're right.

STUDENT: The money in your bank account doesn't save you from this. It's like, it's housing risk factor.

STUDENT: I think that's a good point.

STUDENT: But people tend to-- I mean, all the people live with children, obviously.

STUDENT: Sorry?

STUDENT: Muslim house. I mean, if you have 15-year-old, I mean, they of course live with the older people.

STUDENT: Yeah.

STUDENT: Like, in the other. So I'd rather aggregate it in two. I mean, the old and the-- because you have the children living with the, I don't know, 50 minors.

STUDENT: I mean, if you have it by age, then there might be a person in the young person stock and a person from the old person stock who are both living--

STUDENT: In the same house.

STUDENT: [INAUDIBLE]

STUDENT: Yeah, I think the income kind of makes sense to me because if you're designing a policy and you want to see how it changes, moving somebody from low income to high income feels like less important than a government's perspective than moving them from the ability to being in adequate housing to [INAUDIBLE]. So it feels like it distracts you from the focus of the [INAUDIBLE].

STUDENT: So you're also going to get rid of the income?

STUDENT: Just in terms of modeling actual sort of [INAUDIBLE]. I think it's harder to make that sort of leap from a policy perspective [INAUDIBLE].

**NELSON
REPENNING:** So do you think you'll have wealthy people who might still be in inadequate housing? You do?

STUDENT: Yeah.

STUDENT: It's illegal to have air conditioning, at least in Geneva, in your house. I mean, it's not legal. So even if you're rich, I mean, it's not enough.

STUDENT: Yeah.

STUDENT: So but the policy question is, should you allow for air conditioning?

STUDENT: In houses.

[INTERPOSING VOICES]

STUDENT: I mean, you sleep in the basement. That's what-- yeah-- if you have a basement.

[LAUGHTER]

STUDENT: I do hope [INAUDIBLE].

STUDENT: At least in Geneva. It's not a lot.

STUDENT: Is it for all buildings?

STUDENT: It's at least for where you live. It's allowed for offices. And if you use-- yeah.

STUDENT: But does it depend on the age of the house? Maybe some of the very new buildings, they have it already? But if it's like an old property, you're not allowed to make--

STUDENT: Well, you have to check. I lived there, and there was no aircon in the houses. And you're not allowed to install the aircon. But it's different with office buildings and maybe if it's a certain size or certain efficiency. And they have a system coming from the lake of Geneva. So if you use that, so you get the [INAUDIBLE]. So it's also a regulatory thing that you're [INAUDIBLE].

**NELSON
REPENNING:** So what's your dynamic hypothesis, right? This is a guess, right? It might make you uncomfortable the way it made Jason uncomfortable. But what do you think is the most important dynamic that's going to drive this? Or do you have a guess at which policy you think has the most leverage here?

STUDENT: I think it would be some update of the building's insulation, some type of passive cooling, and probably more like green areas on the streets and so on. [INAUDIBLE]

**NELSON
REPENNING:** So what I would suggest here is I think a lot of people are kind of saying in different ways, I think your stock flow structure is probably too complicated for now. For example, right now, you allow people to move from low income to high income and back again. I'm sure that there is some transition between those states, but you would have to work pretty hard to convince me that's going to be relevant for the problem that you're trying to solve because I'm guessing that's a fairly tiny-- relative to the dynamics you're talking about, that's a relatively small fraction.

So you could imagine just a stock flow chain, right? I think one dynamic that you said that to me sounds important is just the demographics, which is that the balance of the age cohorts is going to skew older. So which could make this problem worse because old people are more susceptible. And I'm perfectly comfortable for now with your kind of, we have zero to 15, 15 to 65, and 65 plus. That seems totally fine. And you could make that down to one-year age increments at some point, if you wanted to be really precise. But I don't think you need that as a first step.

So I would maybe start with just that aging chain of 15, 15 to 65, and 65 plus. And then presumably, those data are available. So you could get that to match the existing demographics roughly. And there's probably good forecasts out there because these are the kinds of things that are-- I don't know how the retirement funding system works here. But if it was the US, our Social Security Administration is forecasting this stuff all the time in terms of what happens.

And you could do that either for low income only, or for low income and high income. I'm kind of agnostic about that. Given that you think that this may well be a problem for high-income people, I might just do one aging chain for now.

And then I think the other thing I would do would be, and this is kind of a system dynamics classic that would make John Sterman very, very happy is to then have a similar aging chain for the housing stock because presumably, the newer buildings are, even if they don't have air conditioning, or ventilated better, or have other cooling mechanisms, or whatever, I don't really have a good instinct off the top of my head about how many stocks you would want in that chain. You might have to do a little research in terms of the innovations, but you might do it in 20-year age cohorts or something like that.

And then I think if you know the rough demographics and you have some sense of the age of the housing stock, then you can use the perfect mixing assumption to kind of calculate just some averages of, given the number of people and the number of houses, assuming some kind of perfect mixing, we are going to have x number of vulnerable people living in outdated housing. And then from there, you could sort of forecast the mortality rates that go with that. And I don't know what kind of data are out there.

So I would say if you could get that to work, and to kind of at least roughly match the data that you have. And the reason I'm chuckling about this is if you really want to go deep tracks, this was essentially the question that John Sterman answered in his general exam, which was kind of, how quickly would the housing stocks energy consumption change based on new housing, and retrofits, and stuff like that?

So I remember he handed this to me when I was a PhD student. So documentation of this must exist. It was in Dynamo, right? It was in before Stella, or Vensim, or whatever.

But then I think it would allow you, even that would allow, some interesting kind of policy explorations basically, which would boil down to, given your hypothesis is, should we focus on new houses? Or should we focus on retrofits? And I don't know anything about this world. So I don't even know if retrofitting is even remotely possible.

But there might also be a little bit of a shock-and-awe thing, right? If you take the kind of increase in mortality from temperature and mesh that with the changing demographics, I could imagine that 20 years from now, the mortality rates, the raw numbers could look much higher because of the confluence of those two things. And who knows whether that's showing up in anyone else's forecast?

But I think that would be a simpler formulation than what you have because right now, you have, essentially, a lot of transition probabilities from one state to the next that I think, to first order, you can assume are not relevant to this problem. I mean, I suppose you could imagine another policy, which would be rather than building houses, we could just give people more money.

So we could move more people from low income to high income. But it didn't sound like you thought that the income demographic was going to-- or the income stratification was going to make a big difference in terms of mortality. So you're going to have to make some bets on what you think are the higher leverage policies. But--

STUDENT:

And just to make sure I understand correctly, so you're saying half the stock and flow aging structure just for the age, just for the-- so half is subscripted by cohort, by age cohort, remove from the people stock and flow the housing and the socioeconomic status?

**NELSON
REPENNING:** So I'm not sure I would even subscript it, because again, I tend to get confused with the subscripts until I really understand what the model does. But that's sort of neither here nor there. I think I would start with just a exactly as you delineated a three stock chain, 0 to 15, 15 to 65, 65 plus, you probably want third-order delays in between those.

And again, you could go more detailed if you want, but I would only do that if you had some data suggesting that the mortality rates, you would have to have pretty granular data. If I asked you, what's the mortality rate for 50-year-olds versus 55-year-olds? I'm guessing that you don't have that level of precision of--

STUDENT: I [INAUDIBLE].

**NELSON
REPENNING:** Yeah, so you could go look for that. But I would do that, and then you have mortality rates out of that. And then I think, as a general rule, or guideline, you want the stocks in your model to match the physical stocks in the system. And if you think about what you're doing, you have a stock of people, and the housing is a very physical stock. And so I think I would capture the housing. And I think the reason capturing The stock flow chain of the housing might be helpful is then, it would give you a very clear way of thinking about, do we build new houses? Do we retrofit old ones? Do we destroy old ones?

Because now, the policy choices are going to be basically represented by the flows in that. And then I think, to calculate the mortality, which is the thing that you're after, now you can do some sort of simple algebra of, we have this many housing units in these states. We could then calculate kind of on average, how many people in the 0 to 15 cohort are in inadequate housing, for example?

And then you could enrich that a million different ways. But I would get that kind of, again, sort of bare bones formulation sort of working. And I think in this case, again, you could probably have it loosely fit the available data. I mean, with that simple model, you're probably not going to get super high fidelity, but at least you can get the order of magnitudes kind of in the right ballpark, which I think would also be a good start. Does that make sense?

STUDENT: Yes.

**NELSON
REPENNING:** OK, that's it. Another good one. OK, so who do we have left?

STUDENT: I can also go next.

**NELSON
REPENNING:** OK, great. Do I have yours in my--

STUDENT: Yes.

**NELSON
REPENNING:** Yeah, OK. Which one? This one? OK.

STUDENT: So first of all, the model is halfway there. It's a combination of a stock management problem for clinical resources problem and the self-governance mechanisms we have in econ division.

And they're [INAUDIBLE] 1980s and 1990s. They did a bunch of experiments showing that actually, communities can self-sustain their resources. And they introduced a controlling mechanism, like a punishment mechanism, so that if I see that Jason is using that resource more than he should have used, so I'm going to impose a punishment like this controlling mechanism to control his vehicle, break his speed.

And I have shown that this have worked for a lot of situations. But there have been a grey area in the empirical data that is still some of the comments, despite these mechanisms, have failed. And during my PhD, I realized that one of the things that we haven't recognized is that all this decision making and capital investment, and resource regeneration, all involve delays.

And we actually replicated that if the delay is short in this context, so these punishment mechanisms of governance mechanism will go. But if the delay is longer because the self stock management problem becomes harder, then those self-governance mechanism to actually make the situation even worse because people start blaming each other, that in that case, for example, Jason has corrected himself, his behavior. But because I'm not seeing the immediate outcome of his corrective actions, so I keep blaming him and I feel that-- sorry, that's [INAUDIBLE].

STUDENT: No, it's OK. I think this is awesome.

STUDENT: That is the general thing that I wanted. So we have done experiments, actually, on this. It was a open model, not a closed feedback one. So right now, I'm trying to close all the feedback loops so that I can run experiments.

**NELSON
REPENNING:** So you probably know this, but there's a fairly substantial literature in system dynamics on this and the famous fish banks game, and stuff like that. And actually, I don't know how much experimental evidence is out there. But so given that this is a place where there's existing work, what's the puzzle kind of in the existing literature that you're trying to sort? I just want to make sure I'm clear on--

STUDENT: You're absolutely right. The puzzle is that, first of all, these self-governance mechanisms haven't really been captured thoroughly, at least, and understand. But the puzzle is, why is this contradictory outcomes or observations that some studies suggest that these mechanisms are working, but on the other hand, the data shows that in some situations, which is a little bit also unclear in the literature, that they're failing as well?

**NELSON
REPENNING:** OK, so at a very 50,000 feet, the empirical puzzle is, in some cases, they work, in some cases-- and just I'm not super familiar with this literature. What's an example of a self-governance?

STUDENT: So in the case of fisheries, people sit together and they created an NGO. And each of us have a license. So if somebody deviates from agreed-upon behavior, their license is being revoked, they're not going to have access to that system.

**NELSON
REPENNING:** OK. And there's some empirical evidence that sometimes, this works, and sometimes, it doesn't. OK, great. And so I think I heard you say this, but your dynamic hypothesis as to the source of this puzzle is what?

STUDENT: So what we found so far is that if the delay of capital growth and resource regeneration, or maybe just let's focus on capital growth is shorter, usually managing even absent all these mechanisms, managing the resources easier. But these mechanisms actually help for managing these resources to be improved that are having better management. But if the delay is longer, not only the management of the resource becomes challenging, more challenging, but if you add these self-governance mechanisms, they actually make the situation worse.

NELSON OK. So let me just repeat back to you what I thought I heard, which is your hypothesis is that these governance mechanisms work well as long as the delays are short enough, basically, and that there is some threshold beyond which the delays are so long, not only does it not help, but maybe even makes it worse. OK, so that sounds great. I mean, and that hasn't been, as far as you know, studied, or experimented upon in the literature?

STUDENT: People are starting experimenting or exploring the impact of delay, but different parts of it, like the whole thing. Some people will say that especially economists. So they say, OK, let's do the impact of delay on the punishment [INAUDIBLE]. I imposed this sanction mechanism, but it will be in place with some sort of delay.

NELSON OK, so you may or may not be aware of this. Not exactly in this context, but the sort of generation of John's PhD students that were before me, almost all of them did sort of experimental studies in different systems that showed basically what you're after, is that as the delay went up, performance went down. So Mark did it in the boom-and-bust context, Christian Kampman was on markets and so on. So there's a long, pretty old literature, at this point.

OK, so if you haven't, I would just double check to make sure that no one's run exactly this experiment before if that's where you're going. But it sounds like a great problem. And I'm imagining where we're getting to is that the hard modeling problem is to model the self-governance, the kind of behavioral mechanics of how that works. OK. All right. So why don't you show us what we've got?

STUDENT: So I think that stock management problem, I really don't have any issues, as you pointed out. It's a classical stock and flow. But if you scroll up a little bit, so this is just for an example of a CPR resource problem. The shared resources here is water. And these are, you can imagine, a bunch of farmers that have some land, and they all rely on that water.

NELSON Yeah.

STUDENT: So as the water becomes scarce, it is also the case for other resources, and the costs of obtaining that resource goes higher. And that actually contributes to lower profits. So that is how the whole thing is being regulated.

What I haven't added yet is the punishment mechanism so that when people see-- first of all, one of the things that I need feedback is usually these people need a signal to impose that action. In the experiments that we did, we relied on the spark of-- they're capitalists. For example, again, an example, I see that Jason has a larger fleet. So I would relay him that, you're catching the most fishes. So you are [INAUDIBLE]. So that is one of the things that I'm right now sorting at the time.

NELSON It's a great problem. So I think this is hard, right? But I think you're thinking about it in the right way, which is I think this is a case where when we don't have a standard kind of stylized, canonical formulation, it really pays to think through the micro mechanics. And so it sounds like what you're-- and I know this is sort of where you were headed in your problem, but so what's the cover story? The water is the--

STUDENT: Yeah, the water. Yeah. So a bunch of farmers, and they rely on irrigating their lands based on the water. But then water becomes a sparse, so their profits start to decline. But then they would look to who has the most land. [INAUDIBLE] So that's the person who's [INAUDIBLE].

NELSON OK, so how do they know that water is becoming more scarce? The price goes up from the utility or just less

REPENNING: comes out--

STUDENT: [INAUDIBLE]

NELSON OK. So I think the first thing is to model the kind of perceptual-- you have a flow basically. It's water. And it's

REPENNING: going down. And then there's some perceptual dynamic. It's got to get to a certain threshold before I can notice it. So is it the actual flow of water that I see, or the pricing from the utility?

STUDENT: I think you actually see the stock of water. And you also see that it also [INAUDIBLE].

NELSON OK, so you're going to need some simple underlying model of essentially the aquifer, which could just be a stock

REPENNING: and people taking out of it. OK, so then I notice that there's a problem. And then the next step is now, there has to be some attribution of blame.

STUDENT: Right.

NELSON Right? And so what's-- so how do you think that works? This is a great--

REPENNING:

STUDENT: [LAUGHTER]

NELSON This is hard. I mean, this is not-- maybe someone's figured this out. But I don't know of a solid formulation for

REPENNING: this.

STUDENT: So can I also share this? In the experiments, we provided all this information and I never thought that how if I wanted to do a feedback-rich model, how should I do this? That part is actually a little bit unclear. But what I'm hypothesizing is that probably, people would see the level of water like aquifer compared to the thresholds is that those thresholds would start letting others see that you have to stay in the rules, you don't have to grow your orchards or lands. [INAUDIBLE]

NELSON Yeah, so I think what you're going to have to sort out is there's going to be different cases that are going to sort

REPENNING: of turn on the observability of the usage. So I mean, so you've, I think, advanced a couple of times a sort of hypothesis that I'm just going to yell at the person with the biggest orchard, because they're the one that's probably taking-- so that's one rule.

We think about the fish, I don't know. In these fisheries, are there records of-- I mean, do I have to log in the number of fish? Or do I have the number of fleet or whatever? So these settings are going to differ in terms of kind of how observable it is. Like, if I just look at your orchard and it looks greener than mine, maybe that I-- so you could have an underlying model of how much each person is taking. I mean, you might, again, to keep it simple, just start with two.

I could look at the productivity, but I think the interesting part is there's both delays and uncertainty in that. And then so you'll probably have a stock that's going to be kind of my mental estimate of how much water you're using, which is going to be updated through these processes. And then if that exceeds my expectations, then there's going to be some-- I read Hasier's comments, and he was talking about how this is a sort of game theoretic thing. So I mean, you could solve for some kind of equilibrium, but it's the inputs that go into it that are interesting.

But I guess I would urge you, and I know we're running low on time, is, this is a case where I think having a more specific setting you're modeling, fish, water, I don't care, will really be helpful because I think that will help you kind of sort the actual kind of micromechanics of I see that I'm running out of water, I see that your field is greener, or you're getting more apples out of the orchard or whatever, we have our monthly meeting, I come in and I negotiate, and maybe you have some simple Nash bargaining solution or something like that that would be a real simple model of those negotiations.

And then you could kind of see, there'd be some feedback adjustment. And then I think, kind of having had hypotheses and all those delays, you could see whether essentially, that response is fast enough to, I could imagine either it could die, or you could get some kind of cyclicity to that. Yeah, that's good. I don't know if this is helpful, but I think it's a good problem.

And it's funny. John has a paper too on, I think it was called *Behavioral Game Theory* or something like that, which you've seen it?

STUDENT: Yeah.

**NELSON
REPENNING:** So yeah. OK, so I know he's worked on this a little bit. But this is an interesting kind of convergence of sort of an SD classic with some econ that I'm not-- I don't always know the literature, every paper. But I'm not sure I've seen those two put together. So it's kind of cool. So--

STUDENT: The nice thing about it was through the experience, he actually could replicate findings in the econ literature. So it's [INAUDIBLE] short. Actually, the situation is going to be better for everyone.

**NELSON
REPENNING:** Yeah.

STUDENT: But the other end of the spectrum, delay is longer. No one has looked at it. And we actually showed that the situation is going to get worse and worse.

**NELSON
REPENNING:** In the experiment. OK, so now, you're kind of building a theory of why that happens in some sense. Yeah, OK. Awesome. That's great. All right. Who's left? We we have two more? Yep. OK.

STUDENT: So I could. Yeah.

**NELSON
REPENNING:** OK.

STUDENT: I have [INAUDIBLE] something, but I'm not very happy with it.

NELSON OK.
REPENNING:

STUDENT: So I'd rather maybe just get sort of a feedback on how it should go.

NELSON OK.
REPENNING:

STUDENT: My research is on the lung cancer screening.

NELSON OK.
REPENNING:

STUDENT: The problem there is we're getting better at identifying the population we need to target this group. [INAUDIBLE] not sure. We're getting somewhere around 15% of the [INAUDIBLE] screening. There's always this hypothesis that, especially for lung cancer, these are people who smoke, who [INAUDIBLE].

So they may not be very caring about their health care. That's why they're not sure. The very same studies show that the same people who are eligible for lung cancer screening, 15% of them show up for lung cancer screening. If they're eligible for, let's say, breast cancer screening, colorectal, 65%.

STUDENT: Show up to this--

There's a 50% gap between showing up for lung cancer screening and with the cancer-- the same group of people. So it's not an attribute of the people. The test, it's just a simple [? step. ?] It's not very expensive. Insurance covers it because they're eligible. It's not intrusive, less intrusive than the other tests. So there's this puzzle, why they're not showing up to the screen. [INAUDIBLE]

I have this hypothesis that there's sort of a cost-benefit analysis for people. And there's lots of false positives in the first layer of screening. And if there's something seen there called for for a second follow up among those who get any positive tests in the first screening, around 40% of them show up for follow up, which is still very low.

NELSON So even if you have a positive on round one, 60%--
REPENNING:

STUDENT: Absolutely positive. So there are different layers. So if it's something very bad in there, so they go to treatment. But if something [INAUDIBLE]. It's usually-- the decision is, you're OK. There's something there. Come back in six months, and we'll see again. And then that come back doesn't happen all the time. So you only have 40%, 50%. So there is something there, and I'm trying to--

NELSON OK, so it's a great puzzle. Why do you think a dynamic model is the way to answer that puzzle?
REPENNING:

STUDENT: I have a sense that there's this dread of the worst-case scenario and a blame game that gets this reinforcing dynamics, which is if I'm a smoker and I've done this to myself, I don't want to know. There's somewhat of a willful ignorance. And as time goes on, my situation is getting worse. So I don't want to know more. So I feel like there's some dynamics that-- I'm not sure. I don't think anyone that-- has any idea of why.

**NELSON
REPENNING:** It's a fascinating, and super interesting, and important problem. It doesn't immediately scream to me that a kind of feedback-rich model is the way to go after it. I mean, so I think there's another story you could tell that there's some kind of biased risk calculus that's going on in people's head of, or some dread, or something like that. That's a very different class.

So where I thought you were going is that the treatment had developed a bad reputation, basically, because of the false positives. And so that was driving people away, or something like that.

STUDENT: There is dynamics there for sure too, that because of false positives, people don't think that there's much benefit to this screening. As a slower dynamics in testing, I'm not sure. But there is some data. I still don't know what to go after.

So what I've done so far, and I think I got my first round of the [INAUDIBLE] was to focus on building the structure, this actual structure. And I did go through that, lots of stocks, and lots of ideas for subscription. But then I felt like whatever I'm doing there, I already have as math models coming from ACI. All the parameters are calibrated by ACI [INAUDIBLE]. I can recreate. I think I managed to do that. But I don't think it got me any closer to the dynamic that I would want to.

**NELSON
REPENNING:** Yeah, so it sounds to me like what you're missing here, and this is kind of a fundamentally creative act, is the sort of core dynamic hypothesis. And I'm certainly willing to accept that there might be some dynamics there. But there may not be, right? I mean, it may just be a kind set of perceptual biases. I mean, it's a fascinating--

Why people would sign up for this less than a colonoscopy, which is invasive and enormously disruptive, is really an interesting paradox that makes no sense.

But I mean, the only place where I can see that system dynamics would really bear on this, if there is a kind of social learning set of dynamics that goes along, that somehow, by reading the paper, and talking to their friends, people have learned that the colonoscopies are helpful, and they catch this early, and you can live a long, happy life, where somehow, they have informed the same perception of the lung cancer screening. So it's a case where it seems like the learning mechanism has really gone sideways in some weird--

STUDENT: Like [INAUDIBLE].

**NELSON
REPENNING:** Yeah, exactly. So I actually think this is a case where you might want to read the literature. If there's first-person accounts of, have they interviewed people that don't show up or whatever? And start scribbling causal loop diagrams, actually, I think, because I'm not sure you have anything to model formally yet. I mean, you could model kind of how people move through the aging chain. But like you said, that's been done, and that alone hasn't solved the problem. I think you need a hypothesis basically. But it's a great-- I don't know. I have trouble wrapping my head around that one.

STUDENT: Thank you.

**NELSON
REPENNING:** OK. Do you want to--

STUDENT: Yeah, just discuss it a little bit because I haven't done much modeling around this, but I'm interviewing businesses in a ecosystem, and trying to find the circular economy KPIs, so Key Performance Indicators, for where they actually are [INAUDIBLE] where you can see the advantages of collaboration. So if they are sharing resources, or it's a gov-- so to try to have a governance system for the whole ecosystem system to show the benefits.

And I have done some interviews, four or five interviews, and I see that there are a lot of shared needs that they are satisfying within that ecosystem. And they all share those needs, and this is not really captured by the ecosystem itself because it's more like a legitimacy or reputation. It's a motivation of the employees. It's very important for the ecosystem, but it's not being captured in any performance.

**NELSON
REPENNING:** So this feels a little bit like a solution chasing a problem. I mean, so if you're able to solve this problem, what will get better? What's the thing that you care about at the end of the day?

STUDENT: Yeah, it's really helpful for the ecosystem to organize itself. I mean, to capture the benefits of what they're doing. So today, they are, for example, they are doing some stuff, but they don't really know the benefits from it. But they believe they're doing the right things.

**NELSON
REPENNING:** Because I'm missing a piece of context. I mean, doing what? Trying to--

STUDENT: So the ecosystem is kind of helping-- there is one party within that system that is supporting them. So they do events, they invite people to come over, and visit. And there's-- so they organize events. They also organize the travel and visit other potential customers. And they also advise on, or giving market advice, negotiating advice. So there's a lot of support for that system.

**NELSON
REPENNING:** But to what end? Another way of saying this, if you build a model, what's the performance metric that you're going to look at?

STUDENT: I'm trying to capture the KPIs that they could kind of measure their performance. So by looking at that-- I'm not explaining this--

**NELSON
REPENNING:** Well, I know we're rushing you, which is not very helpful. But I mean, and I'm happy to talk to you about it.

STUDENT: It's like you are a party, you are developing a product. And within the ecosystem, you find somebody within the ecosystem who actually is using that product. So you can work together and you develop the product together. So you have the benefits of having access to a product development partner, which is also benefiting from you because you provide the service. And then they develop the product together, and they get the benefits because they are both in the ecosystem.

**NELSON
REPENNING:** OK, so you have a hypothesis that if people collaborate more, something will get better.

STUDENT: Yes. And it's in the concept of circular economy because circular economy, you need to collaborate more in order to, I mean [INAUDIBLE].

NELSON Right. But again, if your hypothesis is true, what's the thing that will get better? Is it GDP is going to go up, or
REPENNING: environmental impact is going to go down? Or what's the final performance metric? Or is that the thing you're trying to figure out?

STUDENT: Yes. I mean, is it happening? So that was kind of, is it really happening within that system? Which I have found out in the interview. But it's actually happening. And then also, what is going up or down, and how-- so--

NELSON Yeah, so I don't think that's a system dynamics problem per se. I mean, there might be some modeling to be
REPENNING: done. I mean, I think that's much more of a kind of, not to quote my own papers, but you have to kind of figure out what problem you want to try to solve in this context. And again, I'm totally fine with reverse engineering in the following sense, which is, again, I think you have a hypothesis that collaboration is good and more of it would help. But you have to sort of reverse engineer to what end would that be directed?

Will we have a more sustainable economy? Or we will have a more circular economy, or something like that? Because you need that final performance measure, because otherwise, you're going to build your model. You're going to have no yardstick to tell you what to put in, and what to put out. So you're going to have to-- this is what was making Jason uncomfortable earlier, right, which is you're going to have to make some choices about what to really focus on. And that's ultimately a value judgment, right? It's about what are the things that you really care about and that.

STUDENT: Yes, because it really helps to do a causal loop diagram. I mean, and maybe that's enough because I mean, that really helps, and just count the loops in a way. I mean, I could see that the people who are benefiting the most from the ecosystem have the most loops because that makes the most contacts. But I don't really know if--

NELSON OK. Well, so I think they're waiting outside. But I'm happy to chat with you. And I apologize that we ran out of
REPENNING: time a little bit. But we did it. All right. Thanks, everyone. Thanks for your patience. This was maybe a little bit disorganized, but hopefully, there was some useful nuggets along the way. So--

STUDENT: Thank you.

NELSON OK.
REPENNING: