Faculty naming TCs - examples

Roger Freedman, Physics

1. There is a plethora of threshold concepts (TCs) in physics, including the difference between velocity and acceleration, the significance of the phase of a wave, and the meaning of the wave function in quantum mechanics. But one overarching TC that I encountered as a physics undergraduate is one that applies to all of the mathematical sciences: *The mathematical answer to a problem means something, and the problem isn't solved until you figure out what that is.*

So often students think that the point of a homework problem is to "get a number" or "get an equation." The TC is the realization that the number or equation contains information, and it is the problem-solver's job to extract that information. ("This answer says that the air drag on a cyclist is proportional to the square of her speed. So to go twice as fast, she has to contend with $2^2 = 4$ times as much drag. And that means...")

This TC is *troublesome* (it's much harder to *think* about the answer to a problem than simply to *obtain* it), *transformative and irreversible* (you never again look at equations in the same way), *integrative* (you realize that math and science are really not separate ways of thinking), *bounded* (you realize that problems that can't be described mathematically are fundamentally different), and *liminal* (even when this TC is learned, students feel anxious and unsure about doing the kind of exploration that's needed).

2. In my response last week I stated that *"In my junior year as an undergraduate I began to have major 'ah-HA!' moments when solving physics problems."* On reflection this suggests that I had crossed a threshold and absorbed the TC mentioned above. The challenge is to get our students to do the same much earlier in their undergraduate careers. (That's one reason why the worked examples in my textbooks include a final part called "Evaluate" or "Reflect" that explores the meaning of the answer - and why the worksheets that our students use in Physics 1 and 2 discussion sections at UCSB require them to do this.)

Vanessa Woods, Psychological and Brain Science

I think that my experience of a Threshold concept occurs often when I am teaching and a student asks a question that makes me think (not say outloud) “Wow-- if you don’t understand ____ then we need to go back 3 concepts ago”. In my experiences teaching I believe a threshold concept in Biopsychology is that there are interrelated phenomena, and when the students “memorize” facts the miss their interrelatedness of the systems (biological, physiological, electrochemical etc.). I also personally am struck by how many times the students essentially make more work for themselves by trying to “memorize” a bunch of seemingly unrelated facts instead of learning the material as as system with variants (i.e. once a person understands how a neurotransmitters is made and what enzymes do then the rest is just

knowing names like learning the names of people in your class). One idea I had in thinking about how to improve my Psy 106 course is to be more explicit in the system with variants approach. I plan on providing a structure in the first couple of slides in the lecture to be this systems idea to try to help them see the structure before they get caught up in the details of the phenomena. My personal realization of this particular threshold concept of interrelatedness happened when I was a student studying, and I had this aha moment that this was all very similar and that if I just mapped out a general idea and then added the details it made much more sense to me. I am also reminded of something that is peripherally related to this idea of a threshold concept. There is some interesting work in cognitive psychology looking at how experts approach problem solving compared to novices. One interesting thing to note is that experts categorize the problems differently than novices, specifically by separating them based on conceptual knowledge needed to solve the problem rather than surface features of the problem. So part of realizing or understanding a threshold concept is the reorganization of the knowledge within new conceptual structures. This suggests to me that an essential role in figuring out the threshold concepts for my area is to figure out the basic conceptual structures that are common in my discipline.

2. In my response from week 1 I pointed out two times I felt in defending my discipline (large level or sub level) that I was forced to define it, and by defending it had to decide what made it different from other related disciplines. I think it is interesting that my process in deciding what was essential about Neuroscience was based primarily on what it wasn't (which one of the readings mentioned defining through negating). I was relating my responses to what I wrote in response to question 1 about categorization and conceptual bases for a discipline as a key to threshold concepts and I noticed that this re organization is important. A better way to approach defining my discipline is to define the threshold concepts as concepts along which to organize knowledge. I feel like the realization of my discipline specific threshold concepts is process I am still going through, but when I am best at doing this iis when I am realizing what students need to realize to get to a particular point of understanding.

Kathy Foltz, Biology

1. Similar to what I posted on forum 1, I recall several moments when I realized that science was not a list of facts, but a way of trying to learn more about and to try and understand the world that was based on evidence. It is a *process*. You will notice I used the word "try" here - because part of this realization was that science would not and could not provide *the* answer. As evidence emerged, conclusions would evolve with that evidence. I was extremely uncomfortable with this at first, but gradually came to embrace this concept of science as a process. A specific example occurred in graduate school, when it became clear that a "fact" that was taught in all biology courses and in all of the text books was not correct. I'll spare you the details, but it basically has to do with whether or

not cells can go "backward in time and space" in terms of their identities - for example, could a "heart cell" revert to a more plastic type of cell and then become a "gut cell" or a "retinal cell?" I recall having a discussion about this with my PhD advisor, who was delighted with my admission that perhaps everything I thought that I knew or understood could be totally wrong. The TC that science is a process, not a list of facts to be memorized, can be challenging to convey to students.

2. Looking back to my responses to the forum 1 prompts, I would define my a-ha moment as one where I realized that curiosity and a passion for trying to understand was a driving force in my life and informed my decision to pursue a career in research - a moment of realization of what it meant to "think like a scientist." This is of course is connected to what I wrote above as a crucial TC - science is way of thinking and investigating, a process. I suppose this is the underlying reason I preface most of my classroom discussions with "this is what we think is happening and here is why we think it happens like this in 2016" and why I focus more on what we don't know...? Interestingly, this is not a conscious decision I made for my teaching - it just happened.