USING THRESHOLD CONCEPTS TO GUIDE CHANGES IN THE (BIOCHEMISTRY) CLASSROOM

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With a little help from my friends…

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Goals

- Learn about threshold concepts (TCs)
- Consider how TCs could be relevant for your teaching

Threshold concepts

"a portal opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding… something without which the learner cannot progress."

Meyer JHF, Land R (2003). Threshold concepts and troublesome knowledge. In: Improving Student Learning—Ten Years On, ed. C Rust, Oxford, UK: Oxford Centre for Staff and Learning Development, 412–424.

Threshold concepts

- ***Transformative:*** Once a threshold concepts is understood learners may begin to see themselves as chemists/ biochemists
- ***Irreversible:*** Once a threshold concept is understood it is unlikely for the learner to return to old ways of thinking
- ***Integrative:*** Mastery allows the learner to make previously invisible connections
- ***Troublesome:*** Threshold concepts are often difficult for students

Troublesome knowledge

- ***Tacit knowledge***: understanding implicit and therefore often overlooked
- ***Ritual knowledge***: routine and therefore meaningless
- ***Troublesome language***: discipline-specific usage of terms
- ***Conceptually difficult knowledge***: complex and/or different from personal experience of the world

TCs and teaching

- Understanding TCs within a discipline provides teachers a way to target instruction to those areas that are most difficult and most important for students to learn
  - Jewels in the curriculum
  - Learning is recursive

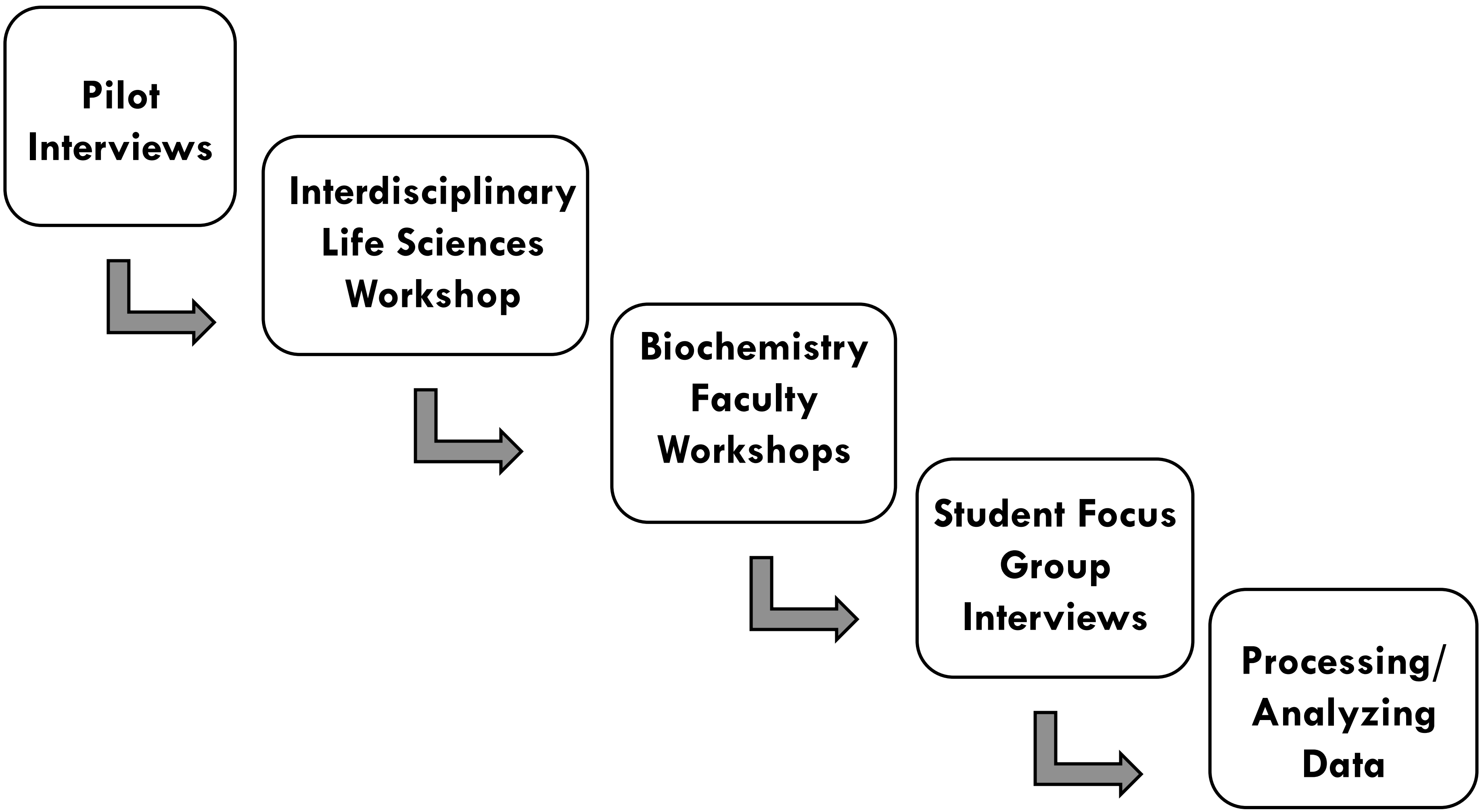
TCs and teaching

- Considering TCs can help us become better, more reflective teachers
  - Listening for understanding
  - Creating an environment that tolerates confusion

NSF Project goals

- We will work with a community of biochemists, biologists and chemists nationwide to:
  - Identify threshold concepts for biochemistry
  - Design classroom activities and assessment tools targeting these concepts
  - Disseminate classroom activities and assessment tools
  - Measure changes in student understanding

Process for identifying TCs



Loertscher *et al.*, CBE-Life Sciences Education, 2014, 13, pp. 516-528

Thanks to our community…

- Five concepts were selected for further examination:
  - The physical basis of interactions
  - Steady state
  - Biochemical pathway dynamics and regulation
  - Thermodynamics of macromolecular structure formation
  - Free energy

For each TC we created

- **Knowledge statement(s)**
- **What is unlocked once concept is understood**
- **What connections were invisible prior to deep understanding of the concept**

Physical Basis of Interactions

- **Knowledge statement—**
  - Interactions occur because of the electrostatic properties of molecules. These properties can involve full, partial, and/or momentary charges.

Physical Basis of Interactions

- **Biochemical ideas that are unlocked once this concept is understood---**
  - Once this concept is understood, similarities between different types of interactions become clear. Although interactions are given different names, they are all based on the same electrostatic principles.

Physical Basis of Interactions

- **Connections that were invisible prior to deep understanding of the concept**
  - A core biochemical principle is that structure governs function. Correct understanding of non-covalent interactions is essential in integrating structure and function.

TCs and your teaching

- Join with three or so people around you
- Discuss what your take home message is or should be for the Physical Basis of Interactions (10 minutes)
- Choose one idea to report out to the large group

Physical basis of interactions

Physical basis of interactions

- ***Student G16-A:*** *I'd just say like in my classes - I don't know about what you all had - but we never really talked that much about van der Waals interactions. Other than the fact that they said, you know, everybody has them and they keep it from floating away.*
- ***Student G16-B:*** *Yeah, I think I heard at one point in time that it just adds to stabilization, to, well, especially to protein structure. Yeah, it's not really touched on.*

Physical basis of interactions

- ***Student G14-A:*** *Those are the ones that come in close contact with each other. They don't necessarily bond in a sense. They interact closely. I can show you a picture of that too.*
- ***Interviewer:*** *What is the basis of their interaction, why are they interacting?*
- ***Student G14-A:*** *Close proximity.*
- ***Interviewer:*** *Close proximity?*
- ***Student G14-B:*** *But what attracts them?*
- ***Student G14-C:*** *I think it's electronegativity. I don't want to--, I think I might be wrong.*

Steady state-Knowledge Statement

- Living organisms constitute open systems, which constantly exchange matter and energy with their surroundings, yet net concentrations remain relatively constant over time. This dynamic, yet outwardly stable condition is referred to as a steady state.
- “Steady” is not synonymous with chemically “stable”. Concentrations are determined by kinetic, rather than thermodynamic factors. Hence, biological systems do not exist in a state of chemical equilibrium.
- If an organism reaches chemical equilibrium, its life ceases. Consequently, organisms have evolved extensive regulatory systems for maintaining steady state conditions.

Steady state-what is unlocked

- Steady state is an emergent process that results from regulation of numerous biological reactions.
- Steady state is a metastable condition that can be maintained only because of constant input of energy from the environment.
- Steady state defines the conditions of life under which chemical reactions take place in cells and organisms. Therefore an understanding of steady state is necessary in order to correctly contextualize all of biochemistry.

Steady state-Connections that were invisible

- Once the condition of steady state is recognized, the purpose of complex regulatory systems in maintaining steady state and their connections to each other become apparent.
- Once the metastable nature of steady state is recognized, the importance of multi-tiered energy storage systems (starch, glycogen, triglycerides, etc) becomes apparent.

Steady state

- Join with three or so people around you
- Discuss what your take home message is or should be for the Steady State/Equilibrium (5 minutes)
- Choose one idea to report out to the large group

Steady state

Steady state

- ***Interviewer:*** *Are reactions in the body at equilibrium?*
- ***Student G13-A:*** *I think it has to be at equilibrium. Like she said, if there's too much of something, it's gonna throw, you know, one of the systems off.*

Steady state

- ***[Student G31-A]:*** *"I think like it's not hard to understand equilibrium, but there's a key difference when you're looking at, like when you're studying equilibrium in gen chem or analytical chem versus in biochem."*

Thermodynamics of structure formation

Thermodynamics of structure formation

- ***[Student G20-A]*** *"So in gen chem it is just thinking about molecules separately, not the overall picture of like if we kept folding this in on itself again and again."*

Thermodynamics of structure formation

- ***[Student G20-B]*** *"So polar things want to interact with polar things and the non-polar things don't want to interact with the polar so they are going to hide somewhere else."*

Biochemical pathways

Biochemical pathways

- ***[Student G21-A]*** *"I think it's hard to grasp the concept of something that can be in equilibrium going back and forth, but also having to favor one side. Like, equilibrium, it has the word equal in it, so in my mind, they should be the same. So it's hard to have dynamic flow of something to favor something when they're in equilibrium. So it's just a difficult concept to grasp."*

Teaching of TCs is recursive

- We will need to cover TCs in more than one context
  - Prerequisite courses
  - Biochemistry and Molecular Biology Courses
- We need to emphasize the fundamental understanding
- As experts we need to help students move from more novice to more expert—an appreciation of TCs and their implications can help us.

Thanks!

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- Faculty participants: Kevin Ahern, Karen Anderson, Rodney Austin, Adam Cassano, Hannah Chapin, Colleen Conway, Carol Dieckman, Shari Dunham, Steve Dunham, Martina Ederer, Matthew Fisher, Katherine Frato, Thomas Freeman, Laura Furge, January Haile, Bruce Heyen, Brian Hogan, Nicole Iranon, Brett Kaiser, Margaret Kanipes, Jennifer Knight, Lisa Kroutil, Anne Kruchten, Paula Lemons, Kimberly Linenberger, Kent Littleton, Sunil Malapati, Jenny McFarland, Tracey Murray, Wally Novak, Philip Ortiz, Jeffrey Owens, Kalyn Owens, David Parkin, Mandy Schivell, Janet Schottel, Duane Sears, Tricia Shepherd, Daniel Smith, Kimberly Tanner, Ann Taylor, Heather Tienson, Sachel Villafañe, Linette Watkins, Mark Werth, Adele Wolfson, Xiaoying Xu, and several participants who wished to remain anonymous
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