Metacognition and Disciplinary Thinking

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I remember the first time I heard about metacognition and its importance in learning; I was attending Project Kaleidoscope's Summer Institute in 2002 and one of the keynote talks focused on providing an overview of the recently published National Research Council Report *How People Learn*. That seminal report focused on three key findings, one of them being that a "metacognitive" approach to teaching and learning could help students take control of their own learning. The finding made sense to me in the abstract, but I would have been the first to admit that I really didn't have a clear sense of what that meant in terms of classroom practices that could engage my students. The other two key findings--focused on the importance of engaging student initial understanding of a subject and the different dimensions required to develop competence in an area of inquiry--were much easier points for me to begin reflecting on in my own practice as a teacher and what I might improve.

If I fast forward a decade to the present, there have been some significant changes. Metacognition has become an important part of the current discussion of teaching and learning, and there are a lot more high quality examples of how faculty can incorporate a metacognitive dimension in class. To mention just a few examples, there is Kimberly Tanner's article "Promoting Student Metacognition" published in CBE-Life Science Education in 2012, the recent book by Ambrose *et al*. titled *How Learning Works: 7 Research Based Principles for Smart Teaching*, and *Using Reflection and Metacognition to Improve Student Learning* edited by Kaplan *et al*.

Wrappers

Tanner gives a thorough list of self-questions that students can use for planning, monitoring, and evaluating their learning in several different contexts (classroom, assignment, quiz or exam). She also provides several practical suggestions for how faculty can explicitly teach students to be metacognitive learners and create a classroom culture grounded in metacognition. The volume by

Ambrose *et al.* has a separate chapter on how students become self-directed learners, which requires development of metacognitive abilities. While the chapter includes a number of specific suggestions, one that I have used myself is the "exam wrapper", a short handout given to students when an exam is returned that guides them through an analysis of their performance and relating that to aspects of how they studied for the exam. The exam wrappers I have used in general chemistry usually follow the format of:

- asking how long the student prepared for the exam
- asking what specific things the student did to prepare for the exam and roughly what percentage of the time spent studying was spent doing each thing
- asking which specific topics on the exam were ones where the student lost points
- asking what the student will continue doing in terms of preparing for an exam as well as what the student might do differently.

The book by Kaplan *et al.* contains contributions from a number of faculty who have focused their attention on metacognitive strategies in their own classes, including a chapter by Marsha Lovrett (one of the co-authors of *How Learning Works*) that presents the exam wrapper concept in greater detail.

Discipline Differences

Over the same ten year period, there has also been significant attention given to the unique characteristics of different disciplines and how that understanding can be used to create more effective learning environments. Two such approaches highlighted in recent issues of *NTLF* include the "Decoding the Disciplines" framework developed by history faculty at Indiana University (Diaz *et al*. *NTLF*, V16N2, Feb. 2007) and the idea of threshold concepts initially developed by Jan Meyers and Ray Land in the UK (NTLF, V22N4, May 2013). The Decoding the Disciplines approach focuses on bottlenecks that students encounter in the "epistemology" of a course and how experts in that discipline get around these same bottlenecks. Threshold concepts are those concepts in a discipline that, when mastered, fundamentally transform how a person understands that discipline. A third way to describe the unique characteristics of learning a discipline can be found in the concept of signature pedagogies, which are often described as pedagogies that most fully immerse students in how experts in a particular discipline think, know, and do.

These two different perspectives – metacognition and the unique characteristics of learning core concepts and skills of a particular discipline – didn't come together in my own mind until I was working on my presentation for this year's annual conference of the International Society for the Scholarship of Teaching and Learning. For the past 18 months, I have been working on a project tentatively named "How Chemists Think" that seeks to develop a descriptive model of the disciplinary habits of mind that characterize how chemists think, know, and do. A central part of the project is my doing think-alouds with a range of chemists – B.S. through Ph.D. – that utilize scenarios both close to the individual's self-identified area of specialization as well as significantly removed from that area. In that work, I was beginning to notice that two perspectives dominated – the molecular (the level of atomic structure) and the symbolic (equations and other representations different than structure). In contrast, the macroscopic perspective (what we observe directly with our eyes, such as the appearance of a solution) was hard to notice. There was a constant movement back and forth between molecular and symbolic. And when one of the chemists was faced with an unfamiliar situation, then the molecular perspective REALLY dominated.

See/Think/Predict

As I worked on my presentation, I realized that this discipline-specific dimension (the importance of the molecular perspective) was missing from the prompts in the exam wrappers I was using. The prompts found in the exam wrapper were general, and while certainly useful could just as easily be used in other disciplines as in chemistry. At the same time I remembered that I had, for the past few years, been using an approach in the first semester organic chemistry course that could also easily serve as a framework for metacognition. The framework was one that I had heard Stephen Graham (St. John's University) talk about several years before in a session on teaching organic chemistry at an American Chemical Society meeting. Graham had built the idea of ***knowledge transformations***, first described in an article by Robert Grossman as "a process that alters a concept or principle from the form in which it was specifically presented to any other form." What Graham had done was to highlight expert practices in the course by making the knowledge transformations transparent; he called his specific approach "See/Think/Predict."

I realized that I needed to add some prompts to my exam wrappers in organic chemistry that reflected the discipline specific factors Graham had described. The wrapper for the first exam had been identical to what I used in general chemistry the previous semester and was focused entirely on general metacognitive strategies that were still important. But for the second exam wrapper, I decided to add questions focused on redrawing and selected procedural elements; the emphasis in this wrapper would be on *SEE*. For the third exam, the wrapper would add questions focused on mechanism arrows and property labels.

While all three elements would be included in the wrapper, the emphasis would be on *SEE* and *THINK*. The fourth exam wrapper would repeat the questions from the third exam wrapper, with perhaps more emphasis on *PREDICT*. My hope was that these revised exam wrappers would prompt students both in terms of general metacognitive strategies as well as ones that were clearly specific to the discipline of chemistry.

That experiment is ongoing as I write. But the importance of engaging students in both dimensions of metacognition (general and discipline-specific) was brought home to me as I listened to several other sessions at ISSOTL – Leah Savion and Carol Hostetter (both of Indiana University) talking about general metacognitive skills in the context of critical transitions in learning, Stephen Bloch-Schulman and Ann J. Cahill (both of Elon University) talking about what they had learned from think alouds regarding how students and philosophers approach reading a text in very different ways. Particularly in the presentation by Bloch-Shulman and Cahill, I found myself thinking that the discipline specific metacognitive prompts appropriate for their philosophy courses would be very different from the "See/Think/Predict" based prompts that I described earlier. I came home from the ISSOTL conference with this realization - the more that we can incorporate both discipline specific and general metacognitive strategies, the better positioned our students will be to understand how each discipline is structured and how each discipline contributes to human knowledge and to addressing significant "real world" challenges.

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