Designing self-diagnostic tools for students in large introductory classes

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Dr. Broccio discussed the self-diagnostic tools he designed and implemented in his large introductory physics class in the fall of 2014. The impetus for designing these tools was in large part due to the following observations he has made while teaching:

- Students expect to receive knowledge, not construct it: 76% of students agree with the statement that they cannot learn unless the professor explains things well in class.
- Students often approach problem solving by trying to find an equation which uses the variables given in the problem (82% agree) – which means they do not see the need to understand the concepts relevant for solving the problem.
- Students are also reluctant to admit that they do not understand something
    - For example, in office hours, students are often afraid to ask questions and say that they understand something the instructor just explained, but later probing reveals that they really do not.

In addition, the following issues are important, especially in large classes:

- Difficult to provide individualized feedback
- Audience if very heterogeneous
    - Varied student motivation
    - Varied student prior knowledge
    - Varied student goals for taking the course
    - Etc.
- Students have different “zones of proximal development” (Vygotsky) – difficult to target instruction in an effective manner
    - You can aim for an “average” student
        - Not very effective for tails – high tail – bored; low tail – confused
- Manifestation of expert blindspot
    - After many years of teaching it can be very difficult for an instructor to know students’ difficulties and where they are coming from
    - It is important to understand these difficulties in order to target feedback at the appropriate level – stay within the zone of proximal development

Self-diagnosis is important because:

- Students realize what they do not understand and work towards understanding on their own – less reliance on instructor.

- Students are not judged by others.
- No danger of targeting instruction outside the ZPD of students' since they can get motivated to fix their misunderstanding on their own and work at their own pace.

Dr. Broccio thinks of instruction in terms learning objectives centered around specific competencies:

- Mathematical proficiency – we often think of it as a prerequisite, but it is important to keep in mind that students don't always have it.
- Translation between different representations.
- Etc.

Dr. Broccio often uses diagnostics at the beginning of a term to identify what students know and what they do not:

- At the beginning of physics 2, he gives a diagnostic of basic ideas covered in physics 1, and often finds lower than expected performance.
- At the beginning of physics 1, he gives Lawson's test of scientific reasoning, and here too, he often finds lower than expected performance.

In order to help students develop the skills and competencies required to reach the learning objectives, instruction focuses on providing opportunities to practice individual skills and learn how to put them together to solve problems which require multiple skills.

- An analogy useful in understanding this – soccer
- Many different individual skills required: dribbling, passing, shooting, sprinting, conditioning etc.
- If a player lacks one of those skills, it makes sense that he/she will first practice that skill individually (e.g., dribbling around obstacles) before trying to integrate it with other skills (e.g., in practicing playing a game).

When we give students homework we are essentially asking them to practice multiple skills at once, individually, before they have gotten the chance to develop some of the individual skills needed. In addition, there is little feedback given (e.g., online homework which provides only correct/incorrect feedback).

The idea is to identify the competencies students need, and provide opportunities to practice them individually and with peers while providing feedback (e.g., peer instruction) before asking students to combine them.

This is where self-diagnosis tools come in:

- Instructor designs self-diagnostic tools centered around specific competencies to help students
    1. Recognize to what extent they have developed individual skills
    2. Practice individual skills

- The self-diagnostic is given before lecture – students practice individually, and are given correct/incorrect feedback
- During lecture, students practice the same skills again but working with peers and get feedback both on correctness and reasoning
- In recitation, students practice integrating different skills together to solve more complex problems (e.g., context-rich problems which are based on real-life situations), and get feedback from recitation instructor.

The challenge of the task is to design multiple-choice diagnostics assessments which incorporate common incorrect reasoning patterns of students. In the pilot, students only got correct/incorrect feedback from the self-diagnostic, but the feedback could be more personalized.

- One idea discussed is to include redundancy, i.e., several different questions probing the same competency to make sure that students use a certain type of (incorrect) reasoning consistently
    - This can give you a "profile" of each student, and feedback given in the self-diagnostic can be more individualized (e.g., if you've answered A, D, C, think about [x concept], you are missing […], or you are neglecting […]. This kind of feedback can be given before or instead of providing the correct reasoning.)
    - More individualized feedback can help students learn better, but in order to give this kind of feedback, the instructor must be knowledgeable of the common incorrect reasoning patterns.

Dr. Broccio gave an example of a specific self-diagnostic he used. He is aware that students have certain misconceptions about free-body diagrams and designed answer choices to fit with those misconceptions (the codes he uses correspond to these, for example, "NF=W" is related to the student misconception that weight and normal force are always equal and opposite). He then gave a transfer problem in the midterm exam which included the same misconceptions. The problem was quantitative and different incorrect answers corresponded to different incorrect reasoning students could use.

- Calculated conditional probabilities (i.e., if a student has misconception [x] on the self-diagnostic, what is the probability that he/she will have the same misconception on the midterm problem?"
- For certain misconceptions, he found high probabilities that students will answer with the same misconceptions.
    - Implication: perhaps individualized feedback on the self-diagnostic can help students repair their knowledge and shed the misconception in favor of correct reasoning.

Another idea discussed was that the particular codes identifying the misconceptions could be given to students at the end of the self-assessment and they could be asked to match the codes with their answers, in essence, answering the question – what are you consistently getting wrong and what is the underlying reason (misconception). This can help students identify their misconceptions on their own (without explicitly being told) and result in increased learning.

Matteo plans to use some of the ideas discussed to improve upon the design of self-diagnostics and implement the changes in the fall of 2015.