

Using Option Probability Curves

With distractor-driven multiple-choice assessment items, the correct answer targets the correct science idea being assessed and many of the distractors target student misconceptions. Therefore, we can use these types of assessments to not only learn which science ideas students know and do not know but also what alternative ideas they may have related to the science ideas. Option probability curves make available a more detailed picture of the results of distractor-driven assessments by providing information about how students thinking changes as they gain a better understanding of the concept being assessed. The curves are generated by plotting the proportion of students who selected each answer choice as a function of their overall level of understanding of the targeted science topic (scale score or student measure). The shape of the curve provides information about what types of students are more likely to select the answer choice, how persistent the misconception represented by the answer choice is, and how the popularity of the answer choice compares to the other answer choices. This information may uncover hierarchies of misconceptions that can be used to inform curriculum development and instruction.

When analyzing the option probability curves there are certain characteristics we look for including where the probability of selecting the answer choice peaks on the knowledge spectrum, the width of the peak, the shape of the peak, and the height of the peak compared to other answer choices.

The first thing we look for is whether or not the answer choices have distinct peaks along the ability spectrum or if there are areas on the spectrum where certain peaks overlap others or are subsumed by others. For example, the option probability curves shown in Figure 1 illustrate answer choices that have distinct peaks. In this case, the probability of selecting answer choice B is highest for students at the very low end of the scale. The probability of selecting answer choice D is also highest for students at the low end. The probability of selecting answer choice C is highest for students in the middle and the probability of selecting answer choice A (the correct answer) is highest for students at the high end. From the shapes of these curves, we can conclude that students at the very low end of the spectrum (i.e. students with little to no understanding of the science topic) hold the misconception targeted by answer choice A but students tend to let go of this misconception once they gain understanding of the topic (moving to a higher position on the scale). However, the curves suggest that students let go of the misconception in B in favor for the misconception targeted by answer choice D not the correct answer (because answer choice D is the next curve to peak after B). The pattern then continues that as their understanding increases students move from misconception D to misconception C. Eventually, the students reach a level of understanding where they let go of misconceptions and begin to select the correct science idea represented by answer choice A. Commonly, instead of having three distinct peaks, two curves will overlap or share the same shape (see Figure 2). This indicates that these misconceptions are popular with students of a similar level of understanding or it may indicate that the two misconceptions are consistent with similar incorrect mental models.

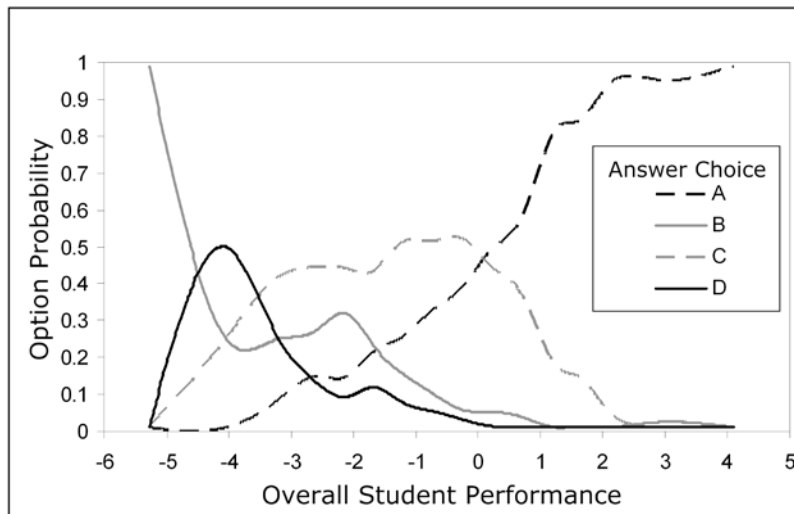


Figure 1: Option probability curves that show a hierarchy of misconceptions

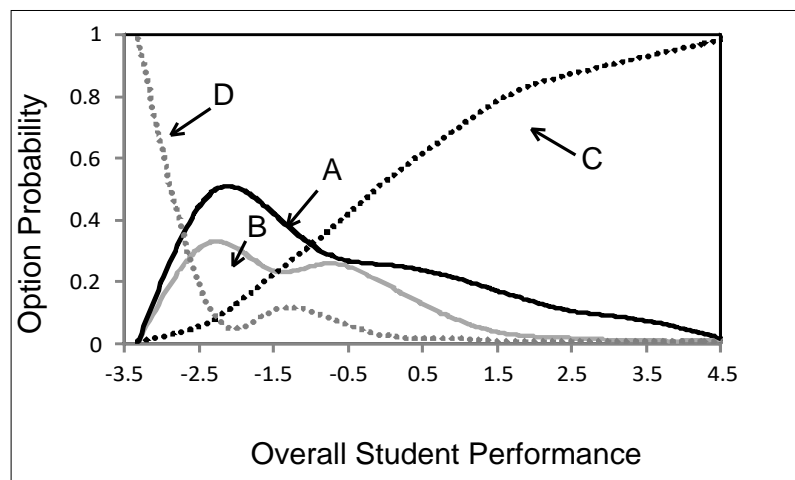


Figure 2: Option probability curves that show two overlapping curves (A & B)

Curves that indicate a hierarchy of misconceptions can be informative for classroom teachers. If teachers know what level of understanding their students have, they can use the information provided by the curves to predict which misconceptions their students may or may not have. Then they can use the misconception information to select and sequence appropriate instructional activities (particularly ones involving phenomena that contradict the misconceptions the students are likely to have and support the correct science idea).

Figure 3 shows example option probability curves from an item where there is no clear hierarchy of misconceptions. In this example, students with a mid-level understanding are equally likely to select any answer choice. This suggests that students either have no strong conceptions or mental models about this concept or are guessing. If students are guessing, it may indicate that they have not yet learned about this idea. It could also indicate that the students' misconception is not represented by one of the answer choices. Results like these may indicate that further assessment is required to understand what students know and think about the targeted science idea.

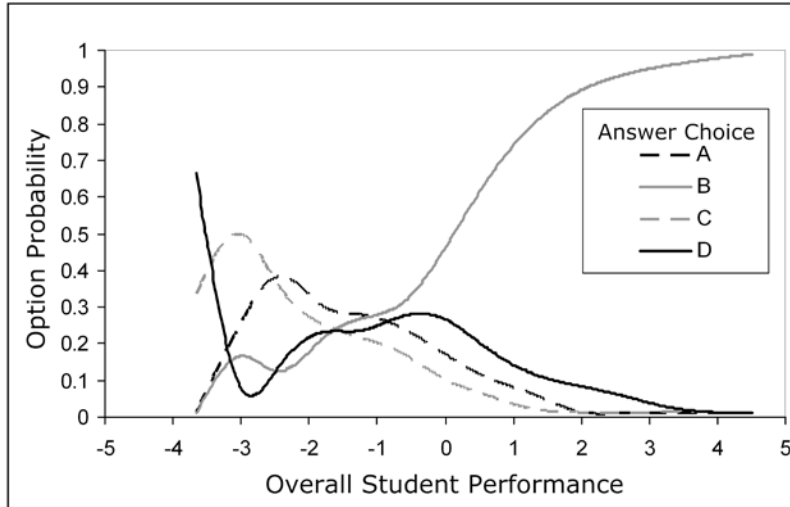


Figure 3: Option probability curves illustrating answer choices that are equally likely to be chosen by students with a mid-level understanding

Next, we look at the shapes of individual curves. As mentioned above, the position of the peak of an answer choice on the student measure scale indicates what level of understanding students who select it commonly have. In addition to the position of the peak, the width of the peak is also important to investigate. Narrow peaks indicate that there is a small range of students who hold the misconception. Wide peaks indicate that there is a wide range of students who hold the misconception. Figure 4 shows an example of these types of peaks. In this example, answer choice A is the most likely answer choice selection for students with little to no understanding of the topic, whereas the probability of selecting answer choice C is high for students with a wide range of scale scores. These curves indicate that students of a wide range of understanding are likely to hold the misconception targeted by answer choice C and students of a smaller range of understanding are likely to hold the misconception targeted by answer choice A. These curves suggest that misconception C is more persistent than misconception A.

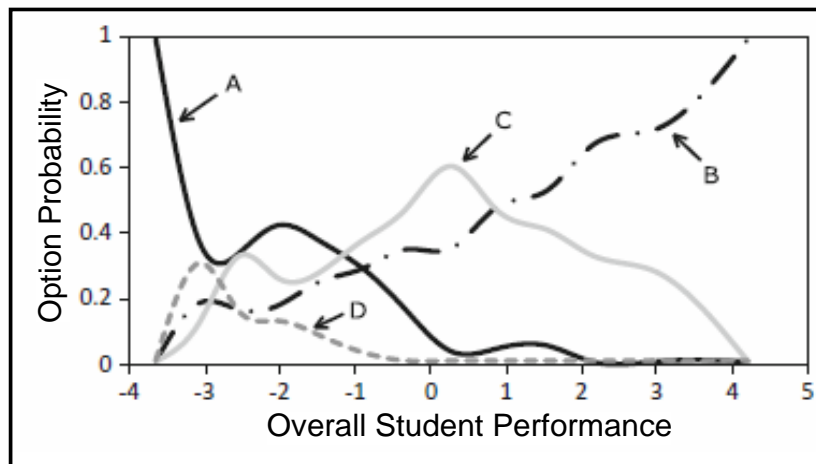


Figure 4: Option probability curves showing wide and narrow peaks

Information on the persistent nature of certain misconceptions can be helpful to curriculum developers and classroom teachers. Misconceptions with narrow peaks are not as persistent and perhaps do not require a lot of class time to address, whereas misconceptions with wide peaks are very persistent and will require multiple activities and phenomena to be presented to students in order to get them to let go of these misconceptions.

Additionally, we study the shape of the peak and look to see if the probability of selecting the distractor decreases as understanding of the topic increases or if there are regions of the ability spectrum during which the probability of selecting the distractor increases as understanding increases. Ideally, we would want the probability of selecting distractors to decrease monotonically as understanding increases and the probability of selecting the correct answer should increase monotonically with increasing understanding. However, this is not always the case. Commonly, the curves corresponding to misconceptions look like peaks (as discussed above). When this happens, there is a region of the ability spectrum during which students become more likely to select the misconception as they gain an understanding of the topic. Figure 1 shows an example of this type of misconception (answer choice C). The curve for this answer choice is a relatively wide peak in the middle of the ability spectrum that gradually increases with increasing understanding before gradually decreasing with increasing understanding. We typically think of answer choices that have a high probability of selection at very low levels of understanding correspond to misconceptions students bring with them at the start of their instruction on the topic. If this is the case, then answer choices with curves shaped like C in Figure 1 could indicate misconceptions that students “learn” as a result of instruction. This information would be helpful in evaluating the instructional activities used to teach the science idea. It is possible that there are aspects of the classroom activities that support students in developing these misconceptions.

In conclusion, option probability curves provide diagnostic information about how students’ thinking changes as they learn about a topic. Classroom teachers and curriculum developers can use this information when selecting and sequencing instructional activities. Since instructional time is limited, educators need to select activities that support students’ construction of the science ideas while contradicting the most popular and persistent misconceptions. The option probability curves can show which misconceptions are popular and persistent for which students.