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Taking on astronomy misconceptions isn't easy

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With the help of surveys and statistics, we tried to optimize the order in which we presented astronomy concepts. But students persisted in retaining wrong ideas about them.

Many commonly held astronomical beliefs—for example, that black holes last forever or that Saturn's rings are a continuous solid—are actually wrong. Students carry those and other sometimes deep-seated misconceptions into the college classroom and continue to believe some of them even after instruction. We have been working to develop surveys and statistical tools to help us learn how persistently students hold on to misconceptions and, given that data, to devise pedagogical strategies that will help students overcome their astronomical prejudices.

Our astronomy beliefs inventory (ABI) is a survey that includes a wide range of common astronomy misconceptions. When taking it, students indicate when or if they ever believed the ABI statements. We administered the ABI over the period 2009–13 to a total of 639 students who had just completed the University of Maine's introductory astronomy course. In one version of the ABI, some of the statements were true, some false. But in this Quick Study we'll be considering the format in which all the propositions were misconceptions. Of course, for both formats the students were not told if any or all of the statements would be false.

PROPOSED ORDER TO ADDRESS 12 GALAXY MISCONCEPTIONS

The numbers to the left are the transition coordinates described in the main text. Higher numbers represent misconceptions that are more easily corrected.

VISUAL PROPERTIES

2.93	The Milky Way is the only galaxy.
2.76	The solar system is not in the Milky Way (or any other) galaxy.
2.63	All galaxies are the same in size and shape.
2.56	All galaxies are spiral.
2.56	New planets and stars don't form today.
2.50	The Milky Way is just stars—no gas and dust.
2.21	There are only a few galaxies.

BEING IN THE CENTER

1.65	The Sun is at the center of the universe.
1.58	The Milky Way is the center of the universe.
1.46	The Sun is at the center of the Milky Way galaxy.

SPATIAL DISTRIBUTION

1.93	We see all the stars that are in the Milky Way.
−0.05	The galaxies are randomly distributed.

For each statement on the ABI, we asked the students if they (1) used to believe it only during their childhood or adolescence but ceased to believe it before taking the introductory astronomy course, (2) had believed it until learning otherwise from taking the course, or (3) still believe it even after taking the course. We then coded the responses as relative degrees of misconception retainment, with "1" denoting minimal retainment and "3" the most persistent retainment. Our papers (with Geoffrey Thorpe) in the additional resources give a complete list of the 215 misconceptions in our study and information on the validity of our inventory. If the number 215 sounds like a lot, keep in mind that more than 1700 astronomy misconceptions have been documented.

Item response theory

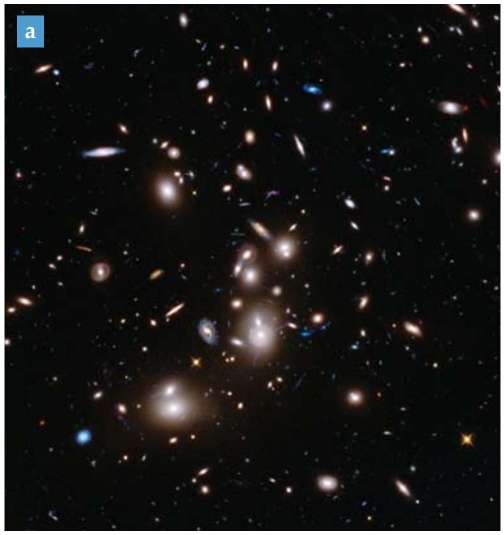
Is the order in which topics are presented crucial in helping students correct their misconceptions? Our intuition was that within a suitably identified subtopic, the optimal approach was first to address misconceptions that were least strongly held and only then move on to more persistent ones. To help us construct what we hoped would be optimal pedagogy, we applied item response theory (IRT) to quantify the inherent persistence with which the misconceptions are held. But we found that our intuitively optimal ordering pedagogy was not particularly effective.

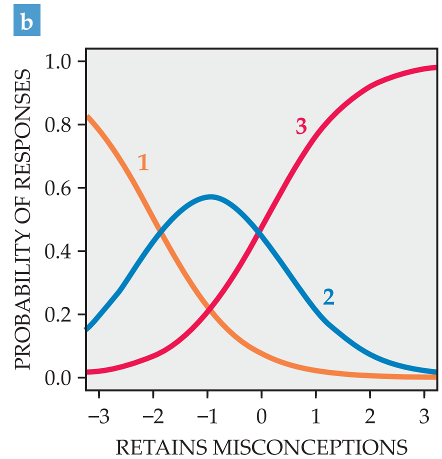
If IRT analysis is to be valid, the data must be unidimensional. That is, a single trait, such as the tendency to retain a belief that may be a misconception, should account for the variance in the responses to the ABI. To generate subtopics that in our estimation would yield unidimensional data, we first grouped misconceptions topically; for example, one topic included statements about galaxies. We then used a statistical software package called SPSS to determine subtopics—the basis for our IRT analysis—that consisted of tightly correlated misconceptions. The box to the left displays the three subtopics related to galaxy misconceptions. It shows, for instance, that students who believe that new planets and stars don't form today are also likely to believe that the solar system is not in the Milky Way or any other galaxy.

Based on the responses to a statement in our beliefs inventory, IRT calculates how likely a student is to have a particular misconception given the student's overall tendency to retain misconceptions. The plot in the figure shows the results for the misconception that galaxies are randomly distributed. The variable along the horizontal axis represents the student's overall proclivity to retain misconceptions and is defined so that its mean is 0 and its standard deviation is 1.

The horizontal coordinate where the curves labeled 2 and 3 in the figure intersect corresponds to a transition from "believed the misconception but learned otherwise from taking AST 109" to "still believe the misconception even after instruction." A characteristic 2–3 transition coordinate exists for each statement in the ABI. A low transition coordinate means that the misconception is retained even by students who have a weak tendency to hold fast to wrong ideas; low transition coordinates thus correspond to misconceptions that are hard to shake if a student has believed them for a long time.

That galaxies are randomly distributed is one of a dozen galaxy-related misconceptions in the ABI. The box shows all 12, along with their 2–3 transition coordinates. As mentioned earlier, they have been subdivided into three groups as determined by an SPSS analysis. In each galaxy subtopic, we determined an optimal order in which to teach individual galaxy-related statements by ranking their corresponding transition coordinates. We ordered the subtopics as a whole similarly; for example, the box indicates that misconceptions associated with the visual properties of galaxies are, collectively, the least strongly held. Thus, reading from top to bottom, the box shows our proposed order for addressing the 12 galaxy misconceptions in the ABI. The analogous 1–2 transitions, which may produce a different ranking than the 2–3 transitions, give an optimal order that may be better tailored to children and adolescents.





A PERSISTENT MISCONCEPTION among astronomy students is that galaxies are randomly distributed. **(a)** This Hubble Deep Field image shows that galaxies are clustered together, not randomly located. (Courtesy of NASA/ESA/STScI.) **(b)** The probabilities shown here specify the likelihood of responding with a low (1), medium (2), or high (3) degree of misconception retainment, as predicted by item response theory, based on responses to the statement "The galaxies are randomly distributed." The axis labeled "Retains misconceptions" describes the overall tendency for a student to hold on to misconceptions. The overwhelmingly high probability of responding with a 2 or 3 indicates that even those students who do not strongly retain misconceptions are likely to believe that galaxies are randomly distributed—even after instruction.

Order in the court

To test whether our proposed ordering would do a better job than conventional ordering in helping students to abandon their misconceptions, we designed single-lecture videos on black holes (to serve as a consistency check) and galaxies, to be presented to classes as a replacement for live lectures. The videos shown in the spring 2012 semester presented the concepts for both black holes and galaxies in the optimal order as suggested by our analysis. In the spring 2013 semester, we retained the proposed optimal ordering for the black hole videos but presented the galaxies lectures with the concepts in the order normally taught at the University of Maine.

Immediately before and after each video lecture, we assessed the students' preconceived beliefs using a multiple-choice test whose questions were tailored to the video of the day. As a consistency check, we confirmed that test gains on the black hole topic were nearly identical between the two years. We expected, though, that our optimal ordering of galaxy topics would give overall higher test gains than the conventional ordering. In fact, gains on the galaxy test scores between the two arrangements of topical material were also identical. Perhaps misconceptions about galaxies are more persistent than we originally thought, and we suspect that the same may be true in other astronomical topics as well. Fortunately, even though we didn't find an optimal order to help students abandon their own mistaken beliefs, we still learned a lot about the persistence of individual misconceptions. And that information, we think, will enable instructors to improve their pedagogy by spending more time addressing student misconceptions that most strongly persist.

Additional resources

▶ A. Favia, N. F. Comins, G. L. Thorpe, D. J. Batuski, "A direct examination of college student misconceptions in astronomy: A new instrument," *J. Rev. Astron. Educ. Outreach* **1**(1), A21 (2014).

▶ A. Favia, N. F. Comins, G. L. Thorpe, "A direct examination of college student misconceptions in astronomy II: Validity of the astronomy beliefs inventory," *J. Rev. Astron. Educ. Outreach* **1**(3), A3 (2015).

▶ J. Morizot, A. T. Ainsworth, S. P. Reise, "Toward modern psychometrics: Application of item response theory models in personality research," in *Handbook of Research Methods in Personality Psychology*, R. W. Robins, R. C. Fraley, R. F. Krueger, eds., Guilford Press (2007), p. 407.

▶ G. L. Thorpe, A. Favia, "Data analysis using item response theory methodology: An introduction to selected programs and applications," Psychology Faculty Scholarship, paper 20. PT