The Size, Scale and Structure Concept Inventory (S3CI) for Astronomy

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Introduction

Many undergraduate students harbor strong and persistent misconceptions regarding the size, scale, and structure of the universe (e.g., Miller & Brewer 2010, Trumper 2001). These misconceptions can affect not only student understanding of the geometry of the universe, but also their understanding of how objects in the universe interact and evolve.

These misconceptions can be grouped into three general and related categories:

- distance underestimation: "Stars are far away, like ten times farther away than the Sun is."
- distance compression: "Stars are really far away, all at about the same distance from us."
- crowding: "The distance between us and the stars is really big, but the distances between stars is smaller."

A valid and reliable concept inventory has the potential to evaluate undergraduates' understanding of size, scale, and structure concepts in the astronomical context, as well as assess conceptual change after targeted instruction. Currently, no concept inventories focus exclusively on these geometrical ideas, so we have started to develop the Size, Scale and Structure Concept Inventory (S3CI) to address this need. We present the results of the early development and initial testing of the S3CI here.

The current version of the S3CI contains 24 multiple choice questions designed to probe student understanding of size, scale, and structure in a variety of ways. When possible, we paired numerical and non-numerical, analogical questions in an effort to separate the effects of rote memorization from a deeper understanding of these concepts. The concept inventory also contains a demographic survey, with questions regarding gender, race, and previous academic preparation.

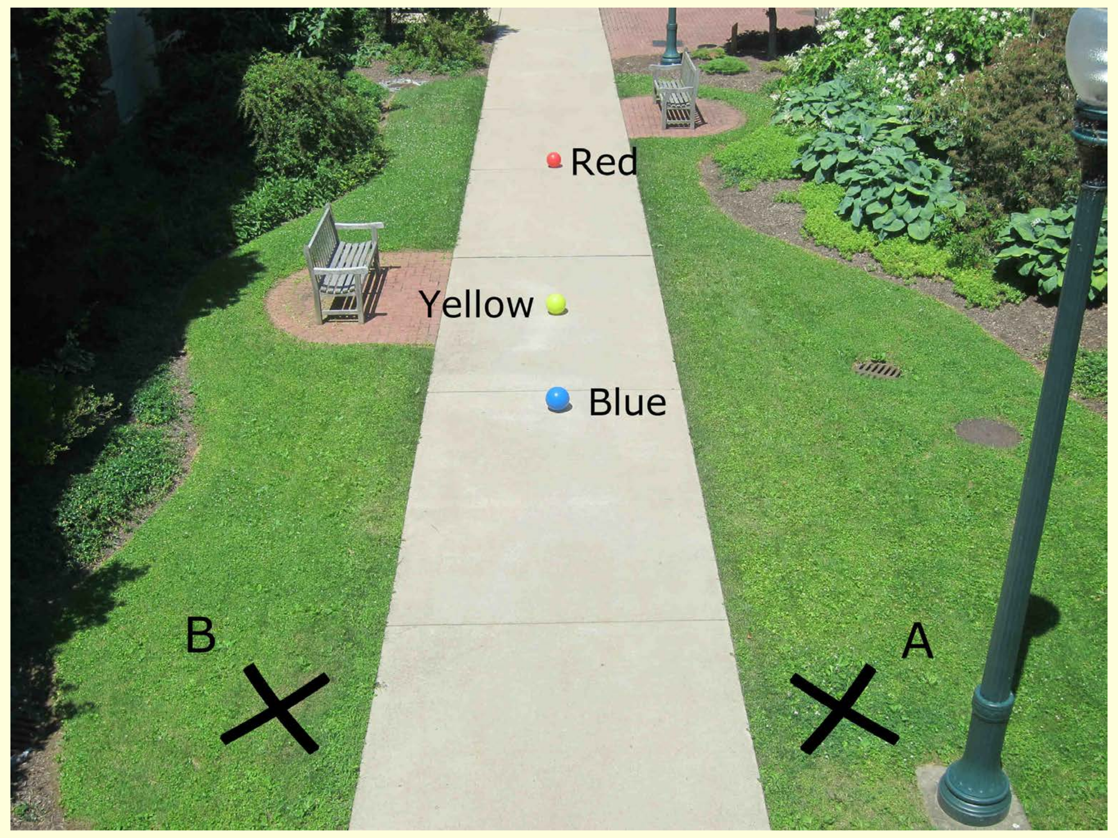
Main Points

- We are developing a concept inventory to address common misconceptions dealing with size, scale and structure in the universe.
- We have tested the S3CI on a class of undergraduates and revised the inventory based on their responses.
- S3CI V2.0 is ready for additional testing.

New Question

A blue ball, yellow ball, and red ball are located in a sidewalk as shown in the overhead photograph above. As you walk from position A to position B in the grass,

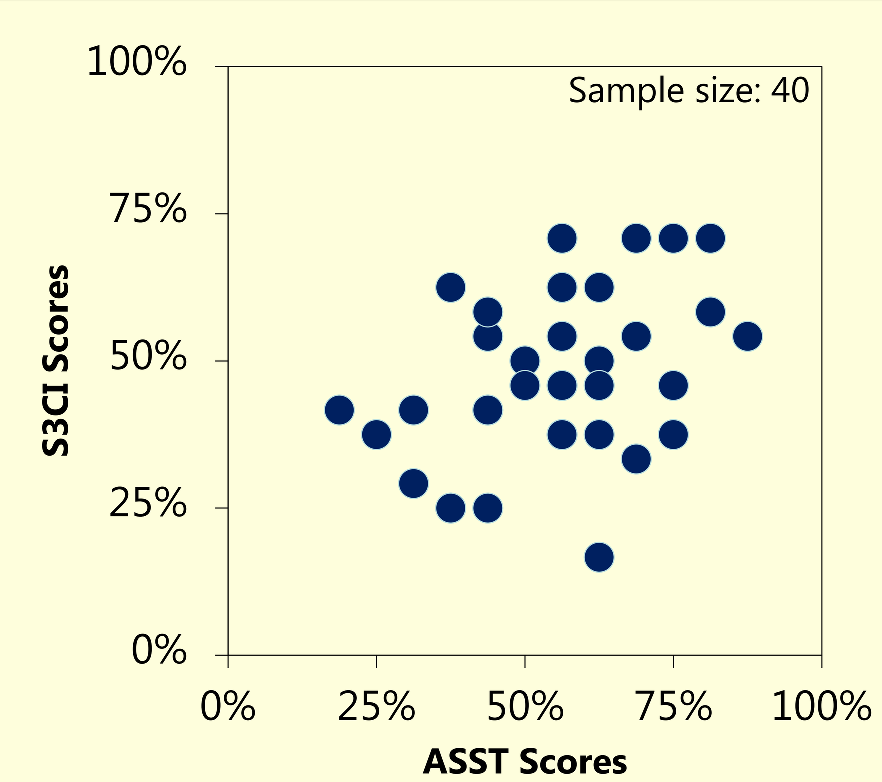
a. The blue ball appears to move from the right side of the yellow ball to the left side of the yellow ball, but remains to the right of the red ball.
b. The blue ball appears to move from the left side of the other balls, to the right side of the other balls.
c. The blue ball appears to move from the left side of the yellow ball to the right side of the yellow ball, but remains to the left of the red ball.
d. The relative order of the balls from left to right remains the same.



This question is designed to probe students' ability to visualize balls from two different perspectives. It tests some of the basic concepts underlining astronomical parallax.

Analysis of Student Performance

To the right is a plot of student scores on the S3CI versus their scores on the Astronomy/Space Science Test (ASST; Sadler et al. 2010). The correlation coefficient is 0.45 which indicates consistency between the two inventories. We do not expect a particularly tight correlation because the ASST is a broad based astronomy assessment while the S3CI focuses on size, scale and structure.



Below are plots of the difficulty and discrimination of each of the questions in the S3CI. Questions that perform well have high discrimination and moderate difficulty.

Sample Questions

Question 11:
All of the stars in the Milky Way galaxy are
a. distributed evenly in a roughly spherical volume of space.
b. concentrated together in a flattened, pizza-shaped disk.
c. concentrated together in a circular band at the edge of our Solar System.
d. distributed evenly in a shell just beyond the edge of our Solar System.

The distractors were equally attractive to those who answered incorrectly. Taken along with a discrimination rating of 0.58 makes this question particularly strong.

Question 22 Version 1:
How would the night sky look to you if you observed it from the surface of Pluto?
a. The stars and constellations would look the same as they do from Earth.
b. The constellations would look different, but the brightnesses of the stars would be the same.
c. The constellations would look different, and the stars would be brighter.
d. The constellations would look different, and the stars would be fainter.

Question 22 Version 2:
How would the constellation Orion look to you if you observed it without a telescope from the surface of Pluto?
a. The constellation would look the same as it does from Earth.
b. The constellation would look distorted, but the brightnesses of the stars would appear the same.
c. The constellation would look distorted, and the stars would appear brighter.
d. The constellation would look the same as it does from Earth, but the stars would appear brighter.

This question was particularly difficult perhaps because of the wording. Based on the results we have revised the question and answers to stress the relative orientation of the stars.

S3CI and WWT

The S3CI is being developed as part of a larger project to incorporate the Microsoft's WorldWide Telescope (WWT) visualization software into introductory astronomy laboratory activities. This National Science Foundation funded program seeks to integrate hands-on exploration with WWT visualization to improve student understanding of the size, scale, and structure of the universe. The poster "Combining Real World Experiences with WorldWide Telescope Visualization to Build a Better Parallax Lab" by Ladd et al. contains additional information on the lab development portion of this project.

An Invitation

V2.0 of the S3CI is available for additional testing and evaluation. It has been coded into an online format using Qualtrics survey software, and can be administered over the internet. Introductory astronomy instructors interested in helping to evaluate this concept inventory by administering it to their undergraduate classes should contact Ned Ladd (ladd@bucknell.edu). Further information on this project is available at http://www.wwtambassadors.org/wwt/astro101/.

References

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