

## IMPROVING ASTRONOMY EDUCATION IN THE UNITED STATES BY INVESTIGATING OTHER CULTURES

### MELHORANDO A EDUCAÇÃO EM ASTRONOMIA NOS ESTADOS UNIDOS PELA INVESTIGAÇÃO DE OUTRAS CULTURAS

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#### Abstract

*Our efforts in the U.S. to improve Intro to Astronomy courses has been futile in spite of our tenacity over the past three-quarters of a century. The TOAST is the widely used standard to evaluate students' gains in the Astronomy classrooms. A possible solution is to expand our horizons beyond our culture's borders and presumptions in order to bring our shortcomings in Astronomy Education research to light. Investigating other countries would give us insight into their teaching, language, and cultural advantages and/or disadvantages of their own unique process of developing an understanding of Astronomy. The process of translation itself will help us comprehend how other cultures think differently about astronomical concepts we are looking to obtain useful data of how other cultures develop their society's understanding of particular Astronomy aspects where we may fall short. In efforts to achieve this, we took several bilingual speakers and asked them to document their thoughts as they translated the TOAST. We are still in the preliminary steps and are still searching for more participants in order to collect a comprehensible, well-defined, and logical translation in various languages that are culturally sensitive and linguistically accurate.*

**Keywords:** Astronomy, Multiculturalism, Assessment.

#### Resumo

*Nossos esforços nos EUA para melhorar cursos de Introdução à Astronomia nos Estados Unidos têm sido fúteis, apesar da nossa tenacidade ao longo dos últimos três quartos de século. O TOAST é o sistema amplamente utilizado para avaliar a aquisição de conhecimento dos alunos nas salas de aula de astronomia. Uma possível solução é expandir nossos horizontes para além das fronteiras e presunções da nossa cultura, a fim de trazer à luz nossas deficiências em pesquisa em Educação em Astronomia. Investigando outros países nos daria uma visão sobre o seu ensino, língua, e vantagens e/ou desvantagens de seu próprio processo único de desenvolvimento de uma compreensão da Astronomia. O processo de tradução em si vai nos ajudar a compreender como outras culturas pensam de maneira diferente sobre os conceitos astronômicos que estamos olhando para obter dados úteis de como outras culturas desenvolvem a compreensão da sua sociedade sobre aspectos particulares da Astronomia onde podemos não alcançar. Nos esforços para conseguir isso, tomamos vários falantes bilíngües e lhes pedimos para documentar seus pensamentos sobre como eles traduziram o TOAST. Estamos ainda nas etapas preliminares e ainda à procura de mais participantes, a fim de coletar uma*

*tradução compreensível, bem definida, e lógico em várias línguas que sejam culturalmente sensíveis e linguisticamente precisa.*

**Palavras-chave:** Astronomia, Multiculturalismo, Avaliação.

## INTRODUCTION

Broad surveys and investigations such as TIMSS (Schmidt et al, 2002) and PISA (Sadler & Zeidler, 2009) have given us insight into effective instructional practices across the globe. From these studies, the data has enlightened the promising practices and weaknesses within each nation's educational system, as well as evidence that these investigations have led to international reforms in science education. The reformation of science education is exceptionally useful for general practices of science teaching and learning. However, these reforms give us limited insight for any particular content domain within the sciences. Reformed education is based on the preexisting knowledge students have, then building upon that foundation. To date, there has been no systematic or standardized effort to measure an individual's conceptual understanding of astronomy worldwide. The data from this study will be used assist international astronomy education and public outreach professionals improve practices globally. The U.S. astronomy education community has a long history of activity; the research has established that many practices are ineffective in the face of robust misconceptions (e.g. seasons). With an international sample, we hope to find subpopulations that do not conform to our existing knowledge of students' misconceptions, leading us to cultural or educational practices that hint at alternative, effective means of instruction.

This paper describes our motivations for a coordinated, multinational study of astronomy understanding. It is our hope that this first venture into a large-scale disciplinary collaboration will help us craft a set of common languages and practices; thereby, building capacity and leading toward long-term collaboration across the international education and public outreach community.

## CONTEXT

Our efforts to improve college-level introductory astronomy survey courses in the United States has been less than satisfying over the past three-quarters of a century. In recent years, the *Test Of Astronomy STandards* (TOAST), is the widely used standard to evaluate students' gains in the U.S. classrooms (Slater, Slater, & Bailey, 2010). Constructed in the U.S., the TOAST is a multiple-choice survey tightly aligned to the consensus learning goals stated by the American Astronomical Society (AAS) – Chair's Conference on Introductory Astronomy, the American Association for the Advancement of Science's Project 2061 Benchmarks, and the United States National Research Council's National Science Education Standards (1996). Since the TOAST was created prior to the newest standards in the U.S., the Next Generation Science Standards (NGSS), and concepts covered by the TOAST instrument slightly exceed those established by the NGSS, the TOAST is considered to be comprehensive. Recently, researchers have been conducting a question-by-question distractor analysis procedure to determine the sensitivity and effectiveness of each item. In brief, the frequency of each possible answer choice is determined and compared to the existing literature on astronomy comprehension. In addition to having statistical difficulty and discrimination values, a well-functioning assessment item will show students selecting distractors in the relative proportions to how we

expect them to respond based on known misconceptions and reasoning difficulties. For all cases, our distractor analysis suggests that all items are functioning as expected. The TOAST is now being used to provide a more modern evaluation of K-12 teachers' overall understanding of astronomy concepts outlined in these various standards documents.

## PROBLEM STATEMENT

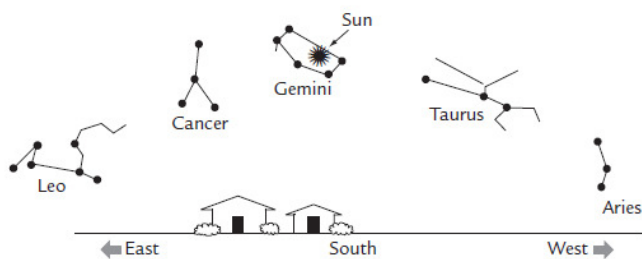
Quantitative research methods, mostly in the form of conceptual diagnostic instruments using multiple-choice response items, are a staple of our astronomy education research (AER) community's toolkit. Although the rapidly emerging and highly insightful qualitative studies for rounding out and enhancing the AER literature base are up-and-coming, well-constructed quantitative diagnostic instruments have the advantage of quickly establishing the range and frequency of students' ideas in astronomy. If well-conceived and executed, it offers valuable insight to instructors and curriculum designers who use a constructivist-oriented approach (Slater, Safko & Carpenter, 1993), an approach that purposefully takes into account students' understandings and beliefs prior to instruction.

In his 1998 award-winning paper, Phil Sadler (1998) proposed that the most insightful multiple-choice questions used for research on student understanding were those that were psychometrically driven. In this sense, he meant that psychometrically driven questions were ones that tapped previously established misconceptions widely held by students. He suggested that the multiple-choice options (or foils) should be those that have been established by systematic AER. Good test item and instrument development practices further compel assessment instrument designers to use students' natural language, as opposed to strict scientific vocabulary, and to keep the instrument succinct in presentation in order to maintain construct validity among volunteering students. Using Sadler's recommended principles, Slater and colleagues (2008, 2010) developed and validated the *Test of Astronomy Standards* (TOAST) to fill a needed void in the existing AER community's toolkit of resources. The TOAST is a 29-item, multiple-choice format assessment instrument that addresses the full range of topics commonly taught in a one- or two-semester introductory astronomy survey course typically taught to non-science majoring undergraduates as a general education distribution requirement for graduation in the U.S.

In an effort gain insight in how to improve the professional development of elementary teachers to teach astronomy, Brunsel (2004), systematically analyzed the range and frequency of teachers' responses to items on the *Astronomy Diagnostic Test-ADT*. His analysis proved highly valuable in demonstrating the range and domain of K-12 teachers' understanding of traditional astronomy topics. A parallel study is needed that uses more modern testing methods and is tightly aligned with national education reform documents (e.g. NGSS).

## RESULTS

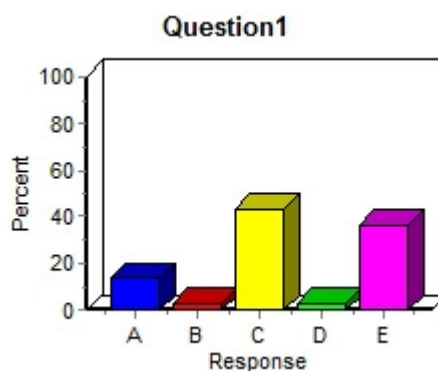
In order to understand the range and domain of college students in the U.S. of common astronomy concepts, we have administered the TOAST to 495 undergraduates. We are conducting an item-by-item analysis of the responses, and tying each to extant literature as well as identifying holes in the literature. It would be impractical to provide all of the data in this short paper, but an abridged sample is shown below.



1. If you could see stars during the day, the drawing above shows what the sky would look like at *noon* on a given day. The Sun is at the highest point that it will reach on this day and is near the stars of the constellation Gemini. What is the name of the constellation that will be closest to the Sun at sunset on this day?
  - a. Leo
  - b. Taurus
  - c. Aries
  - d. Cancer
  - e. Gemini
  
2. This picture shows the position of the stars at *noon* on a certain day. How long would you have to wait to see Gemini at this same position at *midnight*?
  - a. 12 hours
  - b. 24 hours
  - c. 6 months
  - d. 1 year
  - e. Gemini is never seen at this position at midnight.

**Item Analysis: Question 1**

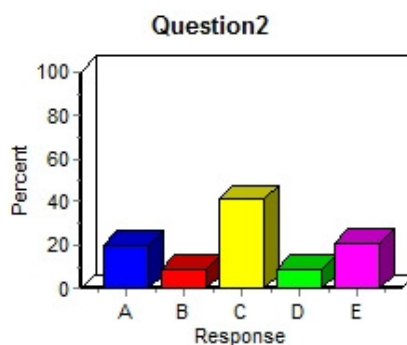
Label	Percent
A	13.68
B	3.30
C	43.87
D	2.83
<b>E</b>	<b>36.32</b>
Total	100.00



In the results for Question 1, we see that students preferred Distractor C to the scientifically accurate Answer A. This reflects the belief that stars (other than the sun) are “fixed” in the sky. This belief represents a “synthetic conception” as defined by Vosniadou and Brewer (1992). We also glimpse into students’ immature understanding of the observable consequences of Earth’s rotation (Slater, Slater and Morrow, 2008).

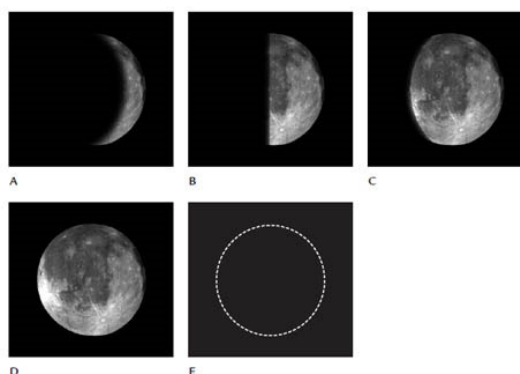
**Item Analysis: Question 2**

Label	Percent
A	20.28
B	8.96
<b>C</b>	<b>41.04</b>
D	8.49
E	21.23
Total	100.00



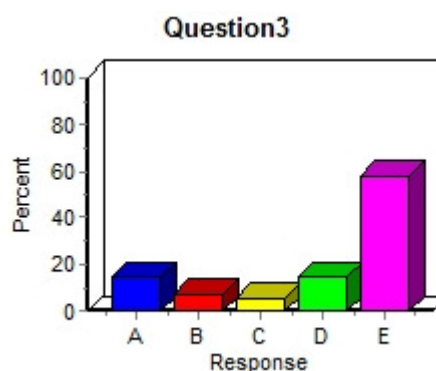
In the results for Question 2, students’ preferred Answer C, although a nearly equal number of students split their preferences between Distractors A and E. Distractor A appeals to students who, again, adhere to a “fixed” star model, in which the stars do not move on the background of the celestial sphere. Distractor C reveals a different manifestation of this same belief. This finding corroborates the data from Question 1, in that approximately 40% are inaccurately applying the notion of “fixed” stars that they have likely assimilated through cultural transmission.

3. You look to the eastern horizon as the Moon first rises and discover that it is in the new moon phase. Which picture shows what the moon will look like when it is at its high point in the sky, later that same day?
- A
  - B
  - C
  - D
  - E**



**Item Analysis: Question 3**

Label	Percent
A	14.62
B	7.55
C	5.66
D	14.15
<b>E</b>	<b>58.02</b>
Total	100.00



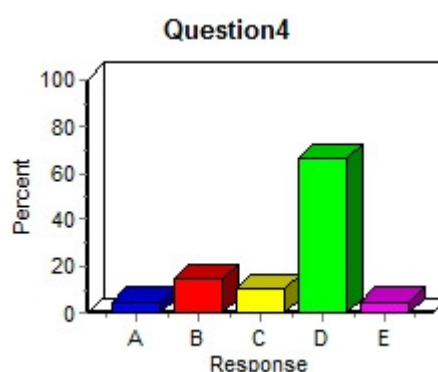
In the results for Question 3, students preferred Answer E, although there appears to be a significant number of students who are attracted to Distractors A and D. Distractor A appeals to students who, believe that the moon’s appearance changes significantly during one Earth rotation. The research literature has not probed this belief in fine detail, leaving room for work to be done. Distractor D is

reflected of the common misconception that the moon passes through the entire cycle of phases in one evening. See Taylor and colleagues (2003), Lindell and Sommer's (2004), and Sadler and colleagues (2009) work for more information on students' misconceptions on moon phases, as well as the references therein.

4. You are located in the continental U.S. on the first day of October. How will the position of the Sun at noon be different two weeks later?
- It will have moved toward the North.
  - It will have moved to a position higher in the sky.
  - It will stay in the same position.
  - It will have moved to a position closer to the horizon.
  - It will have moved toward the west.

#### Item Analysis: Question4

Label	Percent
A	4.72
B	14.15
C	10.38
<b>D</b>	<b>66.04</b>
E	4.72
Total	100.00



In the results for Question 4, students' preferred Answer D, with a smaller group of students splitting their preferences between Distractors B and C. These distractors indicate students' unclear understanding of the changes in the observable sky through the seasons. While there is still work to be done on the nature of students' conceptions in this area, particularly in populations where observations of the sky are hindered, this result agrees with findings such as those seen in work by Phil Sadler (1992) and Slater (2008).

#### IMPLICATIONS AND FUTURE DIRECTIONS

A possible solution to achieving higher scores is to expand our thinking about teaching beyond our own United States' cultural borders and presumptions in order to bring our shortcomings in AER to light. Investigating other countries would give us insight into their teaching, language, and cultural advantages and/or disadvantages of their own unique process of developing an understanding of Astronomy. The process of translation itself will help us comprehend how other cultures think differently about astronomical concepts we are looking to obtain useful data of how other cultures develop their society's understanding of particular Astronomy aspects where we may fall short.

In efforts to achieve this, we took several bilingual speakers and asked them to document their thoughts as they translated the TOAST. We are still in the preliminary steps and are still searching for more participants in order to collect a comprehensible, well-defined, and logical translation in various languages that are culturally sensitive and linguistically accurate. This project is sponsored and managed by the CAPER Center for Astronomy & Physics Education Research in the

United States in collaboration with members of the International Astronomical Union-Commission 46. We are actively welcoming and seeking partners in this work.

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