Opportunity to Learn: Investigating Possible Predictors for Pre-Course *Test Of Astronomy STandards* TOAST Scores

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ABSTRACT

As discipline-based astronomy education researchers become more interested in experimentally testing innovative teaching strategies to enhance learning in undergraduate introductory astronomy survey courses ("ASTRO 101"), scholars are placing increased attention toward better understanding factors impacting student gain scores on the widely used Test Of Astronomy STandards (TOAST). Usually used in a pre-test and post-test study design, college faculty might naturally assume that the pre-course differences observed between high- and low-scoring college students might be due in large part to their pre-existing motivation, interest, experience in science, and attitudes about astronomy. To explore this notion, 11 non-science majoring undergraduates taking ASTRO 101 at west coast community colleges were interviewed in the first few weeks of the course after taking the TOAST as a pre-test to better understand students' pre-existing affect toward learning astronomy with an eye toward predicting student success. The goal is to contribute to a better understanding of the incoming knowledge of students taking undergraduate introductory astronomy classes and provide guidance for how faculty can best meet those students' needs and assist them in greater achievement. Perhaps surprisingly, there was only weak correlation between students' motivation toward learning astronomy and their pre-test scores. Instead, the most fruitful predictor of TOAST pre-test scores was the quantity of pre-existing, informal, self-directed astronomy learning experiences, sometimes occurring many years before course enrollment. This data suggests that professors should be wary of correlating low incoming pre-course scores with student apathy toward their subject.

Keywords: Astronomy Education Research; Community College; *Test of Astronomy Standards* TOAST

Why is it important to understand the nature of students taking introductory astronomy classes, in particular? The introductory college astronomy survey course is a wildly popular option in the United States for fulfilling common general education distribution requirements. In the United States alone, approximately a quarter million students per year around the year 2000 took astronomy as a general education requirement or elective. Data from the American Institute of Physics shows the number of students taking astronomy to be around three times higher than those taking conceptual physics or an introductory multi-disciplinary physical science course (Fraknoi, 2001). While, it is, of course, vital to understand these students in order to best meet their needs and help them succeed in their astronomy classes, the importance stretches further. If around 250,000 undergraduates per year take astronomy, it is reasonable to assume that a large number of pre-service teachers are among that group, whether they are declared education majors or choose to go into the teaching profession later. Therefore, astronomy faculty have a significant opportunity to have an effect both on current students' views of science and how those views may be passed on to the next generation of students. Taken together, providing effective teaching and enhanced learning in introductory astronomy classes is vitally important to the nation's scientific enterprise.

The contemporary posture in college teaching is that students do not come into classes as *tabula rasa* (Ausubel, 1968), but instead have pre-conceived ideas about how the universe of astronomy works. Since there is surprisingly little astronomy content prescribed in the K-12 curriculum, we can't assume that students have been exposed deeply to any particular astronomical concepts before they reach college (Schleigh, Slater, Slater, & Stork, 2015; Slater, 2000). The limited astronomy content that is often present in the K-12 curriculum generally consists of concepts about seasons and moon phases, but is most often taught at such a young age that students likely don't remember many details by the time they reach college. Whether they've had formal coursework in astronomy or not, students have built up their ideas from their experiences in the world, since everyone has seen the motions of the Sun, Moon, and stars and experienced the seasons (but may not have given the reasons behind them much thought). These ideas may or may not be accurate, and misconceptions can hinder students' abilities to understand the concepts they learn in our classes. Andrea diSessa describes these inaccurate, naive ideas about situations as phenomenological primitives and stresses the importance of being aware of how these ideas can negatively impact student learning (diSessa, 2015). It is therefore incumbent upon faculty to analyze the differences between students who have accurate and inaccurate ideas about astronomical concepts as they initially enter college courses, in order to best assess how to meet students where they are and teach them accordingly. As Ausubel (1968) proposed, "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (p. vi). Such a perspective gives faculty the best chance to present astronomy concepts in such a way as to ensure success for as many students as possible in the current generation and beyond.

BACKGROUND AND CONTEXT

In considering the multitude of variables poised to influence astronomy students' success in introductory astronomy besides incoming prior knowledge about astronomy, one might wonder about the impact of students' pre-existing motivation toward learning astronomy. Some faculty tacitly assume that their students have no real interest in learning astronomy and do not expect their students to allocate sufficient time to study astronomy due to apathy. Moreover, faculty often assume that non-science-majoring students have no innate interest in studying astronomy. Although a literature review shows almost no empirical support for such positions, one wonders whether such faculty worldviews impact what happens in astronomy classrooms.

As a first step toward better understanding students in community college astronomy classes, we wondered why do some students succeed and others fail in their astronomy class? Although not astronomy-related specifically, there are certain aspects of community college students' experiences that are frequently cited as broad predictors of college success. These include students who have parents who attended college, parental support in general, previous academic success, motivation, and self-efficacy.

While all students in college have encountered some science in high school in order to graduate, the amount of exposure can vary, and thus the effect on success in college science courses varies as well. Schwartz, Sadler, Sonnert, and Tai (2008) compared the effect of depth versus breadth in high school courses, finding that covering at least one topic in depth in high school correlated with higher grades in college science courses (Schwartz, Sadler, Sonnert, & Tai, 2008). But what else could be at play?

Research repeatedly confirms that students who are first-generation college students often struggle. There are several reasons for this mentioned in the literature, including poor academic preparation in high school, a tendency to work more hours, and the fact that their parents often lack knowledge of skills and information that are crucial for college success (Dennis, Phinney, & Chuateco, 2005). Lacking the ability to get this information from their parents, these students need to have outside support (or need to know that they should seek it out) to navigate college life. Parents of first-generation college students may or may not be supportive, but even if they are, they may not know how to be supportive when it comes to the details of college life. Naumann, Bandalos and Gutkin (2003) stated that in order for often isolated first-generation college students to succeed, motivational factors are more influential than for more traditional students. These motivational factors include self-efficacy, goal orientation, task values, and belief in their ability to succeed.

Motivation is not only a factor in student success for these first-generation students. For example, one study by Neuville, Frenay, and Bourgeois (2007) examined the impact of several motivational factors on behavior associated with student achievement. They reported direct impacts of motivational factors on learning strategies, which in turn has a direct effect on performance, indicating that motivation may be a necessary, but not sufficient, factor in predicting student success.

Bean and Eaton (2000) cited Bandura's self-efficacy model as being relevant to a discussion about student success and persistence in college. Self-efficacy, in Bandura's model, is a person's perception of whether or not they are able to accomplish certain tasks or reach particular goals. Self-efficacy is acquired both through experience and observing others. It can increase both as a student gains self-confidence and begins to see themselves as someone who can succeed and if they observe others succeed, even if they have not had strong experiences of success in their own past (Bean & Eaton, 2000). Self-efficacy has been shown to correlate with academic success, including in a meta-analysis by Multon, Brown, and Lent (1991). Related to self-efficacy is an individual's view of their own intelligence, and whether that is a fixed or learned trait.

Certainly, students' previous experience with and knowledge of astronomy varies considerably. Student expectations of their own intelligence have been studied in recent years and found to influence their academic success. In a study of middle school students, belief that intelligence is malleable (incremental theory, popularly known as "growth mindset") was predictive of an improvement in math achievement over the next two years of school. A second study in a lower-performing school repeated the assessments of the first study and then conducted an intervention, providing workshops on the brain and study skills to all the students, and training in incremental theory to the experimental group. Between the beginning of the study and the beginning of the intervention, both the experimental and control group students displayed a decline in math scores. After the intervention, the control group's grade trajectory continued to decline, while the experimental group's grade trajectory reversed (Blackwell, Trzesniewski, & Dweck, 2007). A similar study (also with middle school students) had similar results and also showed an elimination of the stereotypical gender and race gaps in the experimental group that received an intervention of training in incremental theory (Good, Aronson, & Inzlicht, 2003). These results have received a great deal of public attention in recent years, as the researchers made an effort to get the research out of the journals and into practice. Caution is necessary when attempting to apply these results to student learning, however. Carol Dweck (2015), one of the leading researchers in the area of "mindset," has written that two things keep her up at night. One is that the mindset concepts could be used to perpetuate what she terms "the failed self-esteem movement" by encouraging people to simply praise students for effort, rather than using these concepts to help students find the techniques they need to succeed. Dweck's second concern is that educators may just learn to parrot the growth mindset language because it's the "right" way to think. Rather, she says, it is important to acknowledge that everyone probably has a mixture of fixed and growth mindset, and it takes a journey to move from one to the other.

While the issues surrounding improving college astronomy teaching could emerge in a variety of educational settings, in this study we are focusing specifically on students attending community colleges. The age distribution of community college students tends to be slightly older than students at other types of post-secondary institutions, while the ethnic diversity tends to be a bit greater. According to the National Center for Education Statistics' data for the fall semester of 2013, 40% of 17.5 million undergraduate students in the United States attended 2-year institutions (National Center for Education Statistics, 2015). This population of students was split between 41% full-time and 59% part-time attendees. At public 2-year institutions, the setting for this study, 73% of full-time students were under 25 years of age (classified as young adults), 16% were between 25 and 34, and 11% were over 35. The ethnic diversity at public 2-year institutions is greater than that reported at public 4-year institutions, though with a smaller percentage of whites (54% to 62%) and correspondingly larger percentages of African Americans and Hispanics (15% to 12% African American and 22% to 15% Hispanic) (National Center for Education Statistics, 2015).

One might think that teacher expectations can have an effect on students in their classrooms. In the late 1960s, a controversial study (Rosenthal & Jacobson, 1966) seemed to indicate that teacher bias could influence students' academic performance. In that case, IQ score gains resulted allegedly from teachers being told that those students would "bloom" academically that year. However, a number of studies (e.g., Claiborne 1969; Evans & Rosenthal 1969; Fleming & Anttonen 1971; José & Cody 1971; Dusek & O'Connell 1973) failed to replicate the earlier result. Dusek and O'Connell (1973) (followed up by O'Connell, Dusek, and Wheeler, 1974), for example, did not notice improvement in assessment scores as a result of teachers being told that specific students would "bloom" that year (a manipulation of bias not indicated by test scores). They did, though, find that teachers' initial ranking of their students (based on prior-year work and their impressions from the first two weeks of school) did correlate with the end-of-year assessments (though all students improved, the teachers' assessments of which ones would do best were accurate). So, while it seems that test performance is not affected by teacher bias, teacher expectation may affect how teachers treat students, which could influence students' self-efficacy.

Focusing intently on the influence of students' pre-existing knowledge or their motivations to learn astronomy, a difficult aspect of working to improve education is finding the right tool to assess student understanding. The most widely used instrument currently available is the *Test Of Astronomy STandards*, or as it is colloquially known, TOAST, developed by Stephanie Slater at the Center for Astronomy and Physics Education Research (CAPER) (Slater, 2014). The TOAST was developed with an eye toward sampling student understanding of astronomy across the broad domain of general astronomy content knowledge and is generally used as a pre- and post-test. For the present purposes, it is worth mentioning that the TOAST is not intended to be a measure of students' academic talent or their reading level (in fact, it was specifically designed not to be dependent on reading level). Items are designed to elicit common misconceptions and uncover student thinking. With the TOAST in hand as an appropriate tool to segregate incoming students into high- and low-scoring students, we are in a position to consider our overarching research question: What are the differences among community college students with high and low TOAST pre-test scores?

If we understand this, then professors can modify teaching approaches and expectations of students to the class to more fully meet the needs of students and help students to learn and succeed in the class.

METHOD

Participants

Participants in this study were enrolled in introductory astronomy courses at two Northern California community colleges in the Fall 2015 semester. There were initially 48 students in the study population who began the assessment. Interviewees included 11 students, 7 women and 4 men. Most ranged in age from 18 to 24, though several were non-traditional age. Three were in their first year of college, while others were either in their second or later years of school or were in their first year of a return to college after a previous attempt. Institution 1 has a majority African American/Hispanic student body of almost 9,000, slightly more than half of whom receive financial aid. About half of the student population expressed an intention to transfer to a four-year institution. The college serves a region with a middle-class population, approximately 80% of whom have not earned a 4-year college degree (Anon, 2014). Institution 2 has a student body of 11,000. The college serves a region with a predominantly middle-class population, approximately one-quarter of whom have earned a 4-year college degree. The study was completed under IRB approval from the University of Wyoming.

Two-Group Comparison Study Design

All study participants took the widely used, multiple-choice astronomy knowledge assessment known as TOAST *Test Of Astronomy STandards* in an online format (Slater, 2014) during the first week of class. After removing any incomplete scores, any students who had previously taken introductory astronomy at the college level, and any students who opted out of having their data used for research, there were 36 qualified students in the study population. Eleven of those students were determined to have scored "low" on the assessment, while eight students were categorized as having a "high" score. These 19 students were then invited for interviews. A total of 11 students completed interviews.

Data analysis of interviews focused on identifying items of potential interest in all the notes/transcripts. This Grounded Theory approach, pioneered by Glaser and Strauss (1967), was selected because we observe an unexplained phenomenon of a bi-modal distribution of pre-test TOAST scores in most classes. In Grounded Theory research, we do not begin with any preconceived notions, and endeavor to allow the data to speak for itself, with a goal of generating a theory that comes from, and is grounded in, the data. Since we want to know about the differences between these two groups of students, we allow the students to tell us what those differences are.

Interview Protocol

The interviews with student participants were mostly conducted via Skype video, though a handful were conducted by phone or Skype audio if a student didn't have access to Skype or sufficient bandwidth. The interviews were not scripted, but designed to get the students to feel comfortable sharing information about their background and thought processes.

Interview subjects were asked to describe themselves and their educational background. If they didn't offer enough information, background questions were asked about current major, performance in school, prior science courses in high school and college and how they did, parents' educational backgrounds and careers, and why they chose astronomy out of all the options they may have had for science classes.

In the second part of the interview, students were asked about specific questions on the TOAST. Primarily, they were asked about their atypical responses, either questions they answered correctly that most students miss. They were asked to talk through any reasoning they may have used when they initially answered the question or whether they just guessed. Follow-up probing questions were asked to determine if a student could answer where they think they may have acquired any knowledge of the topic of the question.

Interview Coding

We coded the interviews first to specifically look for the traditional predictors of successful students: overall academic success, quantity of prior science courses, success in prior science courses, motivation (including an assessment of self-efficacy), whether they are on a traditional direct from high school to college trajectory, whether they are first-generation college students, and whether their parent(s) is/are in STEM fields. We also included their level of success in the astronomy course they were enrolled in at the time of the study. That doesn't have bearing on their pre-course assessment score, but we were curious to see whether there would be any correlation.

The students' past and current levels of academic success were coded high, medium, or low, based on their self-reported grade point averages and their descriptions of themselves as students, both in high school and currently in college (if they were past their first semester of college). We recorded a high score for students who reported being largely A-range students, medium for B-range students, and low for C-range-or-below students.

The score for quantity of prior science courses was also coded low, medium, or high. A low score represents students who took only the minimum number of science courses (two) required for high school graduation in the state of California. If a student had three prior science courses, we coded a medium, and four or more earned a high rating (medium and high ratings could be only high school science courses or a combination of high school and college science courses). The rating for student success in those courses was based on their self-reporting.

Student motivation can be a more nebulous description. We chose to rate them based on three aspects: their self-efficacy, the value they appear to place on their education in general and this course in particular, and whether they seem to believe that they have outside support for their education. We assigned a low score if the student's comments only showed one of these three aspects, a medium score if they had two, and a high score if they demonstrated all three.

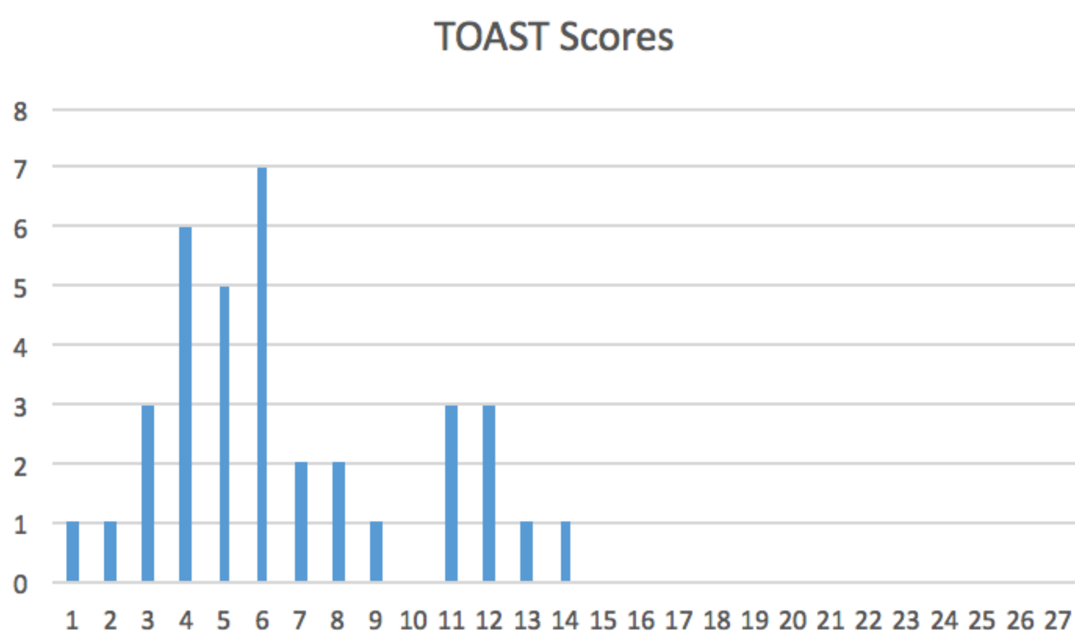
The final three ratings were simple binary coding. We refer to students as being on a traditional trajectory if they started college (whether part-time or full-time) immediately following high school graduation. We labeled them first-generation college students if they did not have at least one parent or grandparent who graduated from college, and whether or not their parent(s) is/are in a STEM field is a relatively straightforward description.

RESULTS

TOAST scores

Thirty-six students completed the online TOAST assessment who were new to college-level introductory astronomy. The range of scores was 1 to 14 (out of 27), with a mean of 7 and a median of 6. The mode was also 6 (7 scores), though there were 6 scores of 4 and 5 scores of 5. We established the four lowest scores (1 through 4) as "low" and the four highest (11 through 14) as "high." There were a total of 11 low scores and 8 high scores. We chose to focus on these, as the mid-range scores of 5 through 9 are more typical of what is seen in TOAST results, and we wanted to examine what differences there might be between students who scored unusually low or unusually high. A histogram of the 36 scores is shown below.

Figure 1. Histogram of TOAST scores of incoming introductory astronomy students



Interview Results

Participant 1 is a 19-year-old who had a low pre-test score of 4. She earned an A in the course. Her high performance in this class is reflective of her strong overall academic performance. At the time of the interview, she had a 3.66/4.00 GPA despite a rough first semester in college when she earned a low grade in a chemistry class. She has earned all A's in her courses since then.

In high school, she received 2 As and a B in three science courses. She enjoyed high school science. In fact, she intended to major in a STEM field, wanting to be a dental hygienist, but decided not to after her experience in first-year college chemistry.

Her mother is a registered nurse. Her father did not go to college, but she described him as one who has always been highly supportive of her academics. There was never a question that he expected her to go to college.

She took astronomy to fulfil a general education requirement. Of the available choices, astronomy sounded the least boring to her. Moreover, her friends had taken astronomy and told her that "it was cool." She did not take astronomy in high school and thinks she might have learned some astronomy topics in middle school as part of a larger Earth science course.

For the question about how the Sun produces energy, which she answered correctly, she stated she "probably guessed." She also correctly answered the Big Bang question. She was more confident on that one, and actually knew the answer before the class started. She went to a religious, Christian high school, and they allocated considerable class time to talking about the Big Bang. One might find this surprising that a religious high school would be talking about seemingly controversial scientific theories, but she emphasized that her high school teachers, as well as her parents, wanted her to gain a wide breadth of knowledge.

Participant 2 is a 23-year-old student. She scored quite high on the pretest (12) and earned an A in her course. Both of her parents were college educated. As the child of college-educated parents, she was fully expected to go to college.

She choose astronomy because she had a high school friend who loved astronomy but was having some mental problems, so they took the class together. Beyond that, she was hoping she would learn knowledge that she could use recreationally, for example, when camping. She also pointed out that there is something inherently romantic about astronomy.

Surprisingly, for such a high-performing student, she describes herself quite negatively as,

> … a bad high school student and bad college student. I tried college before, but I wasn't determined, I didn't care about learning. I didn't do the homework. I was only going to put my parents' minds at ease. In high school, I signed up for astronomy, but only attended for two weeks.

She took chemistry and biology in high school and reports that they were "interesting" and did reasonably well. She understood the concepts, but also said that those high school courses had too much memorization.

She answered the frequently missed question about cosmology correctly. She knew that galaxies sort of orbit around each other, and stated she knew that from popular culture, probably from YouTube or television shows, and that is how she answered it correctly.

For the question about size and scale of the Solar system, which she also answered correctly, she knew that answer from "the two weeks of high school astronomy" she attended. When specifically asked how she knew to exclude stars from the list of solar system objects, she clearly stated that stars are in the background, simply for decoration when talking about the Solar System. She correctly reasoned that stars are much, much bigger, so they must be very far away, so they can't be part of our Solar System.

She also correctly answered the commonly missed pretest question about gravitation and weight. She accurately and insightfully said, "I figured that we weigh so much because of Earth's mass. Gravity on Earth is related to Earth's mass. Two times the distance would do a lot, but not change your mass. And, the atmosphere doesn't control weight. [The atmosphere] is just a blocking chemical [and irrelevant to the problem]."

Participant 3 is 23 years old. He scored very low on the conceptual pre-test (4) and did not complete the course. He self-described himself as having ADHD and being a "slow learner."

This was both his first astronomy course and first college science course. He took high school geology and biology. He had studied some astronomy in previous college courses, including in his college history courses. He was surprised how much history relates to astronomy; for instance, they discussed physicist Isaac Newton, the accuracy of Greeks at keeping track of time, and the importance of sundials in his history courses. Regarding his other interactions with astronomy, he reports seeing astronomy concepts in the news, for instance recently released pictures of Pluto. He recalls seeing on television that black holes have nearly "infinite mass," but, otherwise, everything else in the astronomy course seemed to be new information to him.

His family has little to no interest in astronomy, although they know some constellations. Unique compared to other students, he had a specific occupational justification for taking this astronomy class. When he transfers, he intends to study child development, working with pre-school-aged children who have learning disabilities. He said, "I am taking astronomy so that I can teach it to [the pre-school children]."

His answers were typical of many other students with similar scores, so he was not asked specifically about any of his answers to questions on the TOAST.

Participant 4 is a first-term freshman, directly out of high school. She had a very high scoring pretest (12) and earned an A in her astronomy course. She has an extensive high school science background, including biology, chemistry, and honors physics. Her perception is that science courses are more challenging than humanities courses. She likes science in general and the difficulty in college science coursework didn't bother her because, "I work harder than most people."

She actively seeks online astronomy presentations on YouTube to watch. But, other than going to the nearby aquarium, she didn't report doing science-like activities with her family. Both of her parents went to college, and her mother is registered nurse.

She stated that she didn't previously know that material, but was able to reason her way through most of the TOAST questions using science that she learned from elementary school. As an example, on the question related to gravity, she specifically said she learned to answer that question correctly from information she learned in her high school honors physics course.

Participant 5 is a traditional aged, pre-pharmacy major. She scored very high on the TOAST (13) and earned a high A in the astronomy class. Both of her parents were college graduates, both being nurses.

Clearly, she is a high-performing student. Her previous college-level science courses include biology and chemistry courses. Unlike all of the other students interviewed, she reports taking this astronomy course, "…for fun" rather than for a distribution requirement. She has not had an astronomy course before.

She reasoned her way through the TOAST questions using prior knowledge. She also scored unusually well on the questions related to spectra; when asked how she knew those, she stated she used her knowledge from her previous chemistry classes.

Participant 6 is a 22-year old transfer. He scored quite low on the TOAST (4), and earned a mid-level B at the end of the astronomy course.

A reticent interviewee, he reported taking Earth science, biology and chemistry in high school. He stated that his best subjects were related to English, then science, and finally mathematics. His motivation overall is that he is a first-generation college student, and that he needs to finish college so that he can make a difference for his family.

He enrolled in this astronomy class because it was, "the least evil of the gen ed choices," and he was interested in the sky since he was a kid. He says that when he was younger, his family would go camping and that they had a telescope. He reports that he knows a few of the constellations. He was unable to meaningfully explain why he answered the pre-course survey questions in the way he did.

Participant 7 scored lowest of all interviewees on the pre-course survey (3) and dropped the astronomy class before completing any of the course assignments in order to take the class face-to-face rather than in an online format. She grew up and went to high school in Zimbabwe. She was tracked into the biological sciences because she found it extremely easy to learn. Her school was very strong academically. Both of her parents went to college. The interviewer noted that she seemed to be a bright student and enthusiastic about learning.

She had no opportunity to learn astronomy concepts in Zimbabwe schools. She stated, "We didn't talk about [astronomy] growing up. We knew the Sun, Moon, and stars. And, that's it." However, she noted that she was born in the month of September, which is the end of winter in Zimbabwe and the end of summer in North America, and she wondered how it could be that way given that we are all on the same planet.

It is notable that although she scored quite low on the pre-course survey, she answered the questions correctly about moon phases, seasons, and the Big Bang. When questioned about her selection of the correct answer on the Big Bang item specifically, she stated that the correct answer seemed most correct not because she had learned that information in school, but because she watched the television series, *The Big Bang Theory*.

Participant 8 is a non-traditional student. She scored quite low (4) on the TOAST and earned a high B in the class. She graduated high school in the mid-1980s and briefly entered college before leaving to raise a family. When asked why she had come back to college, she said, "I'm not sure. I think it is for personal satisfaction."

Her previous science coursework included a biology course in college and high school courses in physical science and biology. She describes herself as a B student. She took astronomy to fulfill her general education distribution requirement. She also commented, "I mean, it's the stars. I prefer that to learning about dirt." She was motivated because of her science-related interactions with her family. "We camp, and my husband points out the stars. He just KNOWS, and I just want to know, too."

Participant 9 is a traditionally-aged student. He scored high on the pre-course survey (11), and failed the course because he stopped participating. He said, "…college isn't for me" and stated his father is generally more supportive of him getting a job rather than taking college courses. However, his mother is willing to put "a roof over his head" while he is going to college. He is a first-generation college student, and reported taking this astronomy course to further his knowledge about the cosmos. His previous high school coursework includes four years of science: biology, chemistry, physics, and physiology.

He attributes his relative high score on the pre-course survey to, "random bouts of learning." For instance, in response to the item about size and scale, he said, "I understand the universe is really big and we never see things as they really are. Small looking stars must be far away. And the word Sun is just a name; it is still a star… I don't know why. It is hard to remember why I know. I think I learned it from [television celebrity] Neil DeGrasse Tyson. Or, maybe it was my father. He watches shows that interest him."

Participant 10 is an 18-year old who describes herself as being academically motivated. She scored extremely low on the pre-course survey (3), the lowest of all those interviewed, and she earned a B in the course.

Her science choices were either astronomy or chemistry. Since she did not like chemistry in high school, so selected astronomy. A friend of hers had taken astronomy and loved it. Her friend was able to point out the stars and constellations after her class and she wanted to be able to point out the stars, too.

She took minimal science courses in high school and reported that she always struggled, finding English classes to be easier. She is "not the best learner" and feels as if by the middle of class, she feels lost. Despite this, she has always loved to learn and while she struggled her first term in college, she was able to persevere because "my family puts education first." She looks up to her grandmother, a recent master's degree recipient at the age of 44, as a role model.

Participant 11 finished high school 6 years ago. He scored very low on the pre-course survey (4), and eventually he earned a C in the astronomy course due to personal issues.

He tried many jobs in order to, as he said, "answer the question 'how well can I do without education?'" He reached the maximum salary in his most recent job, realized it wasn't his passion in life, and took the opportunity to go to college.

He had not taken any science class in about 10 years. His major reason to take astronomy class was to learn to identify constellations. At the end of the course, he said that his taste for astronomy knowledge had been piqued, and he really wants to learn more. He watches [celebrity] Neil DeGrasse Tyson talk about astronomy on television or on YouTube.

He correctly answered the Big Bang item on the survey by reasoning, "when it said it threw everything into space, I knew that space didn't already exist then" and that notion just "makes sense to me." He went on to say, "the Big Bang created everything…it makes sense somehow…the wording [of the question] struck me."

When asked about his response to the question about ordering objects from closest to most distant, he describes his thinking as, "…because the Sun is in our Solar System, we are closer to the Sun. If the North Star was closer, it would be larger. It makes more sense to me that it is farther." He added, "it never dawned on me that someone would think otherwise" and "when I see stars, I don't really see little dots; I see the scale." These answers are judged to be evidence of deep understanding.

DISCUSSION

We attempted to glean information from the students about eight general areas, based on the traditional predictors of success in college science courses. In general, we did not see any of these traditional predictors (or combination thereof) correlating with the students' pre-course TOAST assessment scores (see Figure 1).

Figure 2. Comparison of Expected Predictors

	TOAST Score	Academic Performance	Family attended college	Family STEM	Prior Science	Prior Science Performance	Motivation	Traditional Trajectory	Astronomy Performance	Astronomy Exposure
1	Low	High	1 of 2	Mom	High	High	High	Yes	A	Low
2	High	Low	Both	Both	Low	Med	Low	No	A+	Med
3	Low	Med	UNK	UNK	Low	Med	High	No	W	Low
4	High	High	Both	Mom	High	High	High	Yes	A+	Med
5	High	High	Both	Both	High	High	High	Yes	A	Med
6	Low	Med	No	No	High	Med	Med	No	B	Med
7	Low	High	Both	No	High	High	High	Yes	W	Low
8	Low	Med	UNK	UNK	Med	Med	Med	No	B+	Low
9	High	Low	No	No	High	Low	Low	Yes	F	Med
10	Low	Med	Grandma	Yes	Low	Med	Med	Yes	B	Low
11	Low	UNK	No	No	Low	Low	Low	No	C	Med

First of all, six of the eleven students had at least one parent (in one case, a grandparent, which we included) who graduated from college, making the students not first-generation students. Almost as many (5) have a parent who works in a STEM field. Participants 1, 2, 4, 5, 7, and 10 are not first-generation students, and all of these save #7 have parents in STEM fields, both traditional indicators of a slightly higher chance of success in college. However, of these, only participants 2, 4, and 5 scored high on the TOAST assessment. Participant 9 scored high despite being a first-generation college student and not having a parent in a STEM field. So, we see no clear correlation between family educational/STEM background and TOAST scores.

Continuing with the students' background, six were assessed as having a high level of prior science class experience. Participants 1, 4, 5, 6, 7, and 9 were rated high, yet only half (4, 5, and 9) scored high on the TOAST. Might success in high school science then correlate? No, as four of the six (participants 1, 4, 5, and 7) self-reported high levels of performance in their high school science courses, and again, only half of these (4 and 5) scored high on the TOAST. Medium levels of high school science performance also did not correlate with TOAST performance. Participants 2, 3, 6, 8, and 10 rated themselves as having moderate success in high school science, yet of these only #2 had a high TOAST score. Nor did low success in high school science correlate, as participant 9 reported poor performance in high school science (in a high number of high school science courses), yet scored high on the TOAST. High school science courses (neither in number nor success), therefore, did not correlate with TOAST performance for these students.

Moving on to the students' college experience, a traditional trajectory could be said to be potentially predictive of a student's success in college, as students returning to college after some time off have issues ranging from work and family commitments to having to relearn how to be students. However, of the six participants (1, 4, 5, 7, 9, and 10) who entered college immediately after high school, only three (4, 5, and 9) scored high on the TOAST. There also was no correlation in the other direction. Students 2, 3, 6, 8, and 11 are "non-traditional" age (some older than others), yet student 2 scored high on the TOAST.

Levels of academic success in college might also be considered to be predictive of success on the TOAST, yet our results do not bear that out. Four students self-reported being currently strong students (1, 4, 5, and 7), and half of them (1 and 7) scored low on the TOAST. Two students self-reported poor college grades (2 and 9), yet both scored high on the TOAST. The four students who self-reported medium-level grades all scored low on the TOAST, but the aforementioned lack of correlation with low and high grades make any correlation between medium grades and TOAST performance meaningless.

Self-efficacy and other indications of motivation are high on the list of traditional predictors, as faculty often assume that low performers on pre-course assessments are unmotivated. However, here again, we see no correlation. Students with assessed high levels of motivation (displaying signs of all three of our indicators of motivation: self-efficacy, value placed on education, and belief in external support) were no more likely to score well on the TOAST than others. We rated five students as having high motivation (1, 3, 4, 5, and 7), but only #4 and 5 scored high. We rated three students as having low motivation (2, 9, and 11), and two of them (2 and 9) scored high. Our medium motivation rankings did correlate with low TOAST scores (6, 8, and 10), but again, the lack of correlation on either the high or low end renders any correlation in the middle to be without value.

There was one final coding theme we considered that was more nebulous than the others, and that was students' level of experience with astronomy. None of the students reported a high level of experience, but about half of them reported some experience (which we initially rated as medium). Of the six who reported some amount of experience with astronomy (2, 4, 5, 6, 9, and 11), four scored high on the TOAST. In fact, no student scored high on the TOAST who did not report some level of experience with astronomy, although two who did report experience scored low (6 and 11). While not a true correlation, this factor came the closest to being predictive of student performance on the TOAST assessment.

While it obviously cannot be used as a potential predictor, we also looked at how students performed in the rest of the semester in their astronomy class. Of the four participants (2, 4, 5, and 9) who scored high on the TOAST, three did very well (A or A+) in the class, while the fourth failed, but mostly due to reasons in his life beyond his control. Of the seven participants who scored low on the TOAST, two withdrew from their astronomy class, one earned an A, one a B+, two earned Bs, and one earned a C. Perhaps not coincidentally, the student who earned a C (#11) was also the one with the fewest potential predictors for success. The only potential predictor he had going for him was some prior exposure to astronomy. To examine the opposite example, let's look at students who exhibited all or nearly all of the potential predictors: students 1, 4, and 5 all were not first-generation college students, had at least one parent in a STEM field, had high numbers of high school science courses in which they did well, are on traditional college trajectories with high grades, and were rated high in motivation. All three earned As in their class, but only two of them (4 and 5) had scored high on the TOAST. What's the difference between student 1 (who scored low) and students 4 and 5? Prior astronomy experience. Students 4 and 5 had both been exposed to astronomy before, and student 1 had not. The other two students who scored high similarly had prior astronomy experience, despite not having all of the other traditional predictors of success.

CONCLUSION & IMPLICATIONS

While these interviews essentially led to a null result in that we observed no systematic differences among students that correlated with high or low pre-course TOAST scores, we are guided to a very important implication—one on which faculty can act in order to improve student success in our classrooms. When faculty encounter students who fearfully react like deer in the headlights at the beginning of a course, it is an easy assumption that the students have low incoming knowledge due to reasons that are out of our control. It is also easy to follow that assumption with resignation that the student will likely not do as well as others in the class. There is a tacit assumption that students who perform poorly on incoming knowledge surveys are unmotivated. The results here strongly suggest that this untested assumption is false. In fact, it appears that the opposite is true. As shown above, students who we rated as low in motivation (based on self-efficacy, value placed on education, and belief in external support) were no less likely to score low on the TOAST than were students rated as high in motivation. We observed mixed results in that half of those who scored high were rated high in motivation, and the other half were rated low.

These results tell an important story: Any generalized faculty claim *a priori* as to why students have the incoming knowledge scores they do is likely spurious. It is clear from these interviews that students do not fit into easily identifiable boxes and shouldn't be treated as though they do. These results strongly suggest that it is unwise to assume anything about a student who knows almost nothing about astronomy, except that they simply have not had an opportunity to learn astronomy. Those of us entrenched in the field are so familiar with the concepts we are teaching that we forget how we came to know them in the first place. We had the opportunity to learn. Whether we were fortunate enough to encounter astronomy through a knowledgeable teacher in elementary or middle school, or happened to attend a high school that offered an astronomy course, or even if we didn't discover the subject until college, we all have had that opportunity. That is not the case for many students. The 2007 NCES report *The Condition of Education* shows that in 2004, only 3.3% of U.S. high school students had taken an astronomy course, and even that was tripled since the 1980s. This pales in comparison to the percentage who had taken engineering (8.9%), physics (37.1%, including 4.4% AP or honors physics), geology/Earth science (22.6%) or both biology and chemistry (60.5%) (National Center for Education Statistics, 2007). This small percentage of students studying astronomy in high school is a result of high school curriculum changes made in the early 1900s, which also led to the subject virtually disappearing from elementary curricula (with the exception of some study of Earth motions in geography (Pasachoff & Percy, 1990).

With minimal opportunities to learn astronomy in formal settings, most students only get the opportunity to learn about astronomy if they happen to have a teacher, parent, youth group leader, friend, etc. who is interested, and can provide them with informal opportunities. Some students will have acquired an interest somehow and pursued it themselves through books, documentaries, Internet sources, museums, and the like. However, this leaves faculty with the conundrum of how to best teach an introductory class when there is no baseline level of knowledge among the students. In a college biology or chemistry class, one can safely assume that all of the students have at least studied one year of introductory high school biology or chemistry, as most high schools require a minimum of two years of science for graduation, and students usually take some combination of these. California, for example, requires two years of science that encompass both physical (physics, chemistry, or Earth science) and biological science (California Department of Education). This leaves students with few opportunities to learn astronomy before taking a college class, which seems to be the most important impactor on incoming score predictions.

So what can astronomy faculty do? First and foremost, we need to make an effort to foster a growth mindset in ourselves and to encourage the same in our students. Just because they are unfamiliar with the vocabulary of astronomy at the outset, doesn't mean they won't be able to learn well if the information is presented in a way that helps them. Trying to remember what it felt like to not know about the concepts we now know so well can go a long way toward helping us to devise lessons and activities that encourage students to learn without making them feel stupid for not already knowing things. Nickerson (1999) discussed the idea that communication difficulties can arise from assuming that others know what we know. This was demonstrated in an experiment run by Elizabeth Newton (1990) at Stanford University in which participants were either "tappers" or "listeners." The tappers were given a list of songs to tap out on a table, while the listeners were to guess the song. Listeners guessed only 2.5% of the songs correctly. However, the tappers had been asked to predict how many would be guessed correctly, and they predicted 50%. The explanation for the discrepancy is simply that the tappers were hearing the songs in their heads, and so the tapped rhythms seemed quite obvious to them (Newton, 1990). This experiment is cited in the popular book *Made to Stick* (Heath & Heath, 2007) as an example of what the authors call the "Curse of Knowledge," which is the idea that the more you know about something, the harder it is to remember what it felt like to not know it. As astronomy faculty, we need to realize that we too are often saddled with this "Curse of Knowledge." We can too often not remember what it felt like to not know why the Earth has seasons or why the Moon has phases. It is therefore easy to fall into the trap of ruefully shaking our heads when students fail to grasp these seemingly "simple" concepts after our (obviously) clear and engaging lectures on the subject. We need to put ourselves in our students' shoes. They're often being introduced to these concepts either for the very first time or for the first time in their adult lives, and we need to give them the opportunity to learn without judgment. We have the privilege of introducing our students to the wonders of the universe, and it falls to us to remember that for most of them it really is just that…an introduction.

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