Students' Impressions Concerning Optical Telescopes and Visible Astronomical Light

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We conducted post-instructional interviews with seventeen undergraduates from a general-science level astronomy class. Each interview lasted about fifteen-minutes, and students responded with a mix of verbal and graphical responses. The interview topics included roles of telescopes in astronomy, sources and properties of astronomical light, the relative importance of a telescope's magnification and light gathering ability, and light pollution. We concluded that students posses only a loose set of ideas regarding optical telescopes and visible astronomical light; however some potential common (mis)conceptualizations emerged.

Introduction

Each year in the United States over 200,000 students enroll in college-level astronomy courses.[1] Several researchers have investigated misconceptions and other cogitative obstacles barring students from learning material central to these introductory astronomy courses. One area that has received little attention, though, is the role played by astronomical telescopes and light from the cosmos. The telescope serves as the premier instrument for astronomical observation, so it is only appropriate for instructors to have a firm understanding of students' impressions of this important tool and the light it gathers.

Population and Course Structure

McDaniel College is a four-year liberal arts college, with an undergraduate population hovering around 1600 students. We based this preliminary study on an introductory Astronomy class that one of us (Jeff Marx - JM) instructed in the Spring Semester of 2003 at McDaniel. Enrolled were two freshman, eight sophomores, four juniors, and three seniors. The majors fell into four general categories: four Arts and Humanities, six Social Science, four Natural Science, and three Business and Economics. The gender ratio was eleven females to six males. The demographics for this class were typical of McDaniel's general science classes and roughly follow national trends.[2]

Class met Mondays and Wednesdays for ninety-minute sessions. JM typically divided class time into three broad categories: *lectures* roughly constituted 15% of class time, *group-work* filled 60%, and *discussion* ran the remainder of the class. There was no preferred sequence for these categories, and they often mixed. Furthermore, students discussed material with members of their three- or four-person group during group-work time. We selected group-work from the pages of *Lecture-Tutorials for Introductory Astronomy*, which are activities "designed to confront and resolve student difficulties with a particular topic."[3] For topics not covered in *Lecture-Tutorials*, students used worksheets that JM designed with a similar purpose in mind.

The course grades were based on nine homeworks (20%), nine ten-minute quizzes (10%), three tests (25%), naked-eye observation projects (20%), a cumulative final exam (20%), and the interview on which this paper is based (5%). (JM informed students, at the start of the term, that they would receive all five points for simply showing up and answering the interview questions.)

The topic of telescopes arose in the third week, following the manner material is presented in the text, *Discovering the Universe: Sixth Edition*.[4] For those discussions, the students looked *at* several types of telescopes, as well as images of some of the world's premier telescopes. The *Lecture-Tutorials* contain a single selection explicitly devoted to telescopes, but it only weakly related to the interview topics. All totaled, the students spent approximately 1.5 class meetings working on the *Lecture-Tutorials* and explicitly discussing issues directly related to telescopes. JM intentionally avoided holding a "star party" until after the interviews were completed. Eight students did view the Sun through a telescope prior to their interview. One student had, coincidentally, looked through a telescope, for the first time, the night prior to the interview. Explicit discussions of light, in general, and astronomical light, in particular, began in the third week, too, but continued well into the course.

Each homework set consisted of five short-answer questions and four numerical problems. There were three homework sets before the first test. (The first test covered the material for the interviews.) A part of one assignment covered telescopes. This set included two short-answer questions and one numerical problem on telescopes. Two of those three aforementioned sets also contained items devoted to light: five short-answer problems and four numerical problems. Finally, prior to the first test, one quiz covered telescopes, another light.

The Interview Schedule and Protocol

The interviews commenced three weeks after the first test. (JM was the interviewer.) Thus, seven weeks elapsed between their introduction to the material and the first interview. The last interview convened about four weeks after the first, but most of the students interviewed by the end of the second week. JM solicited students by passing around a sheet with available times, which they filled-in on a first-come-first-serve basis.

To keep the interviews under twenty minutes (the average was about 11.5 minutes), we prepared ten questions, but by the fourth interview JM added two more questions, each with a follow-up question. Also, if JM felt students had more to offer, he would probe student's answers further. We cleaved to standard guidelines for creating and posing research interview questions.[5]

When students responded to questions that required a drawing, JM asked them to explain their work and to elaborate on seemingly ambiguous aspects of their drawings.

JM started the interview by asking students what they felt the difference was between visible and invisible light. Following that, he informed them that, "The interview questions will be devoted to optical telescopes, which are telescopes that astronomers use to view objects giving off visible light." Since the students had discussed other types of telescopes, we hoped to avoid any confusion.

At the end of each interview JM reminded the student that he or she had received full credit for attending, and asked that person not to discuss the interview topic with classmates.

After all of the interviews were complete, JM made transcriptions based on the audio recordings, which along with students' drawings, served as the data and artifacts for the next section.

Artifacts and Summary of Interview Data

In this section we present interview artifacts and data that sheds light on students' impressions of the role of the optical telescope and properties of visible astronomical light. (JM did ask students about the optics of archetypal telescopes, as well, but we will not cover that topic in this paper.)

First, JM posed the following question, "Why do astronomers use optical telescopes to look at, say, the stars as opposed to just viewing them with their naked eye?" We categorized students' responses to this question as follows (some students offered several reasons): eleven responses related to seeing a clearer, more detailed picture; six concerned gathering more light; five were about magnification; four involved statements such as, "So we can see things far away"; one person felt telescopes helped, "… get around light pollution"; one student had, "No clue"; and two responses centered on aesthetics, for example, "Because I know that's what's pleasing to humans. You like to see things you can see by your eye, I guess."

We were also interested to determine how many students recalled which role of the telescope – light-gathering ability or magnification – is considered more important. To that end, JM asked students to comment on the following scenario, "Some people say telescopes are designed to gather more light, other people say telescopes are designed to magnify objects. Which, if either, of those two statements do you agree with more?" Eleven students, often quickly, stated that light-gathering ability was more important, while one said magnification was paramount. Two students agreed with both statements, one said light gathering-ability and magnification were the same phenomena, and two students made a link between magnification and light-gathering, but stated they were different.

JM queried students' about the science-based policy of placing telescopes at the tops of mountains by posing the following: “Astronomers often build telescopes at the tops of tall mountains. Can you tell me three reasons why?” He then followed up by asking the student to order their responses from the most to least important. Table 1 contains a summary of those tasks. (Some students could proffer only two reasons.)

Reason *Importance:*	*most*		*least*
Light pollution	15	1	1
Above weather, clouds	1	7	1
Closer to celestial objects	0	2	5
Higher in atmosphere	1	1	2
Obstruction-free horizon	0	2	2
Less air pollution and dust	0	3	0
Room for equipment	0	1	0

Table 1: Frequency table of students’ ideas regarding why astronomers place telescopes atop mountains.

It became clear many students felt light pollution was a problem, so we included a question, “Can you explain how light pollution works? For example, why does a light over here [hand gesture] effect your view of the night sky up there [hand gesture]?” The followed-up question went something like, “If you have a light on over here [hand gesture], but there is a large wall [or other such obstruction] between you and the light source, so you can not see the light directly, will that light source effect your view of the night sky?”

Thirteen students had the opportunity to respond to the question. Three offered physiologically-oriented answers, such as, “You brain doesn’t know where the light is coming from” or “it effects your pupils.” Two of those students felt light pollution would go away when there was an obstruction; one of those was a pupil-explanation person. The interviewee who thought light effected your brain, provided an incorrect reason for why light pollution would go away with the obstruction. Three students responded to the question with an answer suggesting a “blending” effect. Of those, two thought light pollution would remain with the placement of the obstruction; however one provided an incorrect explanation, “Light waves pass through the wall.” Two students felt ground-based light “blocked” starlight, and both felt light pollution would go away with the obstruction. Another student said light pollution effects the clouds, and JM did not follow-up. Two students had no idea how light pollution worked, one thought it would go away with the obstruction, the other still had no idea. Two other students stated that light bounces off the atmosphere and comes back to your eye; they felt light pollution would be unaffected by the obstruction.

Later, JM asked the following question, “If you looked at a star through a telescope, draw what you think you would you see?” The responses fell into two classes – circle or dot. Sixteen students drew circles of various sizes. A single student made a dot (the student who, the night before, viewed stars through a telescope.) Eleven of the sixteen circle-drawers included on their sketch and/or made remarks about stellar details. JM often pressed them for more information regarding these details, to which they offered such particulars as “dots”, “haziness around the edges”, “flares”, and “color(s)”. The other five said you would see no detail, which, after prompting, we came to learn meant a disk of a single shade or white.

JM asked students to explain the phenomena of twinkling, to which they responded with mixed results. The data we present, though, centers on the follow-up question, “Imagine you are looking at a twinkling star in the night sky. Now you look at that same star through a telescope. Will the star seem to twinkle more or less or will the twinkling not seem to change when you view it through a telescope?” Eleven students said it would twinkle less and provided various explanations. Examples include, “They build them [telescopes] that way,” it is the effect of “the mirrors and lenses,” and “… telescopes gather more light.” One student felt it would make no difference, one had “no idea”, and three assumed the stars would twinkle more, but only one gave a remotely reasonable explanation.

Near the end of each interview, JM queried students about the origin of light from stars, with a follow-up question about the contribution our Sun played in supplying starlight. This question and the follow-up occurred to JM after remarks made by students in the first few interviews, so, again, we do not have data for the entire group. Of the thirteen students JM posed the opening question to, four students immediately stated that starlight originated at our Sun. In the follow-up question, which JM posed to six of the nine students who said starlight originated at or in the star itself, three said sunlight contributed at least some visually significant, but small fraction, of the light we see from stars.

Reflections and Suggestions

One interpretation of some of these data centers on how students regard telescopes as instruments. For example, students understood twinkling to be a problem. The telescope, being designed to look at celestial objects, must, in their minds, somehow diminish the undesirable twinkling. Also consider, when viewing terrestrial objects, magnification (not light-gathering) is frequently considered the most important aspect of cameras and spotting scopes, and students are frequently exposed to this fact. (News film crews and movie directors "zoom-in" on the action so it can be better viewed.) Conceptualizing the telescope as a souped-up camera would strongly influence their notions of the view through an eyepiece. Although most students stated light-gathering ability was more important (a fact we will return to later), their star drawings depicted greatly magnified stars. One may conclude that students figured since stars are a subject of study, telescopes would facilitate observation by zooming-in, revealing nuances.

Most students quickly *recalled* that light-gathering ability is a more important aspect of telescope design than magnification. However, later in the interview nearly all of them drew a magnified star. This, of course, does not preclude the idea that students actually *believed* and *understood* what it meant for light-gathering ability to be the predominate role of the telescope. In all fairness, drawing tasks are poorly suited for indicating brightness, so the students were at a disadvantage. Nevertheless, not a single person mentioned a brighter image while drawing their star, which contrasts with their oral responses to two earlier questions. One interpretation suggests students say "brighter image" but visualize "bigger image." Investigating students' notions of how brighter, magnified, and, possibly, highly-resolved images differ would be, no doubt, fruitful.

Students seemed clearly aware of the problem posed by light pollution. Regrettably, they were unclear of its mechanisms. Between the physiologically-oriented and "reflection" responses, only five of the thirteen students managed to express even a part of the problem. In the future we intend to include more explicit materials on light pollution. We feel a thoughtfully designed worksheet stressing the basic phenomena of reflection/scattering, absorption, and transmission, as well as the eye's response to light-levels, may positively impact their understanding.

The fact that students listed "closer to the celestial objects" as a rationale for placing telescopes on mountain summits suggests they fail to grasp the vastness of the cosmos. Utilizing this compacted universe view, students might also conclude our Sun's light would need travel only a short distance to reach nearby stars and reflect back to our eyes, which, of course, happens for objects lying close to our Sun (the Moon and planets). Also, in a compacted universe, even a modest telescope might reveal stellar disks. This final point raises the question: Did the students draw stellar disks because they misunderstood the distances involved, felt the telescope helps zoom-in, combined these two notions, or dreamed of something altogether different? More detailed investigation regarding student's estimates of cosmic distances is required.

One note, after the interviews JM threw a "star party" for the class, including telescopic views of celestial beauties such as Jupiter, Saturn, the Orion nebula, and some stars. The students were shocked to observe that stars looked simply like points of light, even when magnified hundreds of times, and equally surprised to see stars twinkle more when viewed through a telescope. (We viewed several stars to convince everyone of both results.) We gathered no evidence on which to found the claim that this experience altered their misguided notions, but such dissonance often makes a strong impact.

References

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