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## Conceptual Astronomy Knowledge among Amateur Astronomers

by **Margaret L. Berendsen**

Astronomical Society of the Pacific

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### Abstract

Amateur astronomers regularly serve as informal astronomy educators for their communities. This research inquires into the level of knowledge of basic astronomy concepts among amateur astronomers and examines factors related to amateur astronomy that affect that knowledge. Using the concept questions from the Astronomy Diagnostic Test Version 2, an online survey was developed as an assessment. In particular, astronomy club members with at least some college-level astronomy education score substantially higher on the assessment (mean score: 85) than do college undergraduates after taking their first astronomy course (mean score: 47). Astronomy club members scored up to 17% higher than unaffiliated amateurs, an indication that regular contact with like-minded hobbyists improves basic knowledge. Proportionally more astronomy club members report doing outreach than do unaffiliated amateurs (87% vs. 46%). It appears that those who are likely to be more knowledgeable are also those doing more outreach.

## 1. INTRODUCTION

Amateur astronomers regularly volunteer to share their knowledge, time, and telescopes with their communities. They should be knowledgeable enough to accurately share information about astronomy with the public they serve. Amateurs themselves are interested in providing accurate information to their audiences (Storksdieck, Dierking, & Jones 2002).

For this work, an "amateur astronomer" is defined as any respondent to this study who self-identifies as an amateur astronomer or who is involved in astronomy-related outreach, who has belonged to an amateur astronomy club, or who has had any formal training in astronomy-related subjects. "Astronomy outreach" is defined as the act of conveying information on any aspect of astronomy (including observing) with other people, be they members of the public, students, or fellow amateur astronomers.

Published research on the role of amateur astronomers as informal astronomy educators is extremely limited. In 2002, the Astronomical Society of the Pacific (ASP), in cooperation with the Institute for Learning Innovation (ILI) in Annapolis, Maryland, conducted a Web- based survey on education and public outreach practices among amateur astronomers. This unpublished survey and its results will be referred to as the 2002 ASP Survey (Storksdieck et al. 2002). The 2002 ASP Survey did not attempt to assess the level of astronomy knowledge among amateur astronomers.

Most research on the knowledge of astronomy has been among students in formal education settings. Examples of such studies among college students are DeLaughter et al. (1998), Sadler (1993), and Schoon (1993), which used assessments with several astronomy-related questions. The Astronomy Diagnostic Test Version 2 (ADT 2), with 21 basic astronomy concept questions, was developed to determine the incoming state of knowledge of undergraduates taking college-level introductory astronomy courses and to assess the effectiveness of those courses (Zeilik 2003). Several thousand students have been assessed using this test in a national survey (Deming 2002).

Because of amateur astronomers' levels of interest and likelihoods of pursuing opportunities to learn about their hobby, amateurs in general, and those doing outreach in particular, might be expected to show a level of understanding above that of the college students who took the ADT 2 prior to taking an introductory astronomy course. As stated by Falk and Dierking (2000), free-choice learning is facilitated by personal interest in a subject, and interest strongly influences how much one learns.

No research or assessment of the level of basic conceptual astronomy knowledge among amateur astronomers has apparently been published.

The research questions were:

1. What factors related to amateur astronomy affect knowledge of basic astronomy concepts?
2. Do amateur astronomers doing outreach represent a knowledgeable group of informal astronomy educators?
3. If they are knowledgeable, how much more knowledgeable are amateur astronomers about astronomy basics than are members of the public they serve?

## **2. METHODS**

### **2.1 Research Design**

In order to assess the level of astronomy knowledge among amateur astronomers, an online survey was developed that contains the astronomy concept questions from the Astronomy Diagnostic Test Version 2 (ADT 2). This online survey will be referred to as the Astronomy Concepts Survey (ACS). The survey as it appeared online is shown in

Appendix A.

The ACS was conducted online over a period of three months, June through August 2003. Data from the 2002 ASP Survey (Storksdieck et al. 2002) suggested that amateur astronomers participating in outreach for the most part belong to astronomy clubs. Therefore, the survey was advertised, primarily by e-mail, to individual amateur astronomy club officers in the United States. The e-mail provided a link to the online

survey. Reminders were e-mailed approximately one month after the first e-mail.

To obtain e-mail contacts for clubs, an extensive list of over 600 astronomy clubs in the United States was compiled from lists published by the ASP, the Astronomical League, and various other online listings, such as astronomy magazine Web sites. An online search of each club's Web site for current e-mail contacts of club officers was made. If the club had no Web site or contact e-mails listed, the contact e-mail (if provided) in the online listing was used. The e-mail letters requested the recipients to forward the survey information to their club members. The survey was also advertised on e-mail lists and discussion boards frequented by amateur astronomers. These were considered potential sources of unaffiliated amateur astronomers.

Two incentives were chosen in an attempt to attract a wide selection of amateur astronomy club members to participate. The Learning Zone contributed funds to provide a gift-drawing incentive, and the second incentive was offering to return the responses from all participating members of any club that submitted 15 or more responses. The intention was to elicit responses from a cross-section of the club, particularly its outreachers, and not just the most knowledgeable few. Because the survey was unsupervised, there is a possibility that some respondents may have shared or looked up answers. The survey question asking if respondents sought outside help attempted to uncover these respondents. There is no guarantee that the question was always answered truthfully.

## **2.2 Instrument Development**

The survey had three parts. The first part was a page explaining the survey and asking the respondents if they self-identify as an amateur astronomer. The online survey was designed such that respondents could not review the questions to be asked without recording a response on the first page.

To provide a measure of the knowledge of amateur astronomers, the second part of the survey was the set of multiple-choice astronomy concept questions taken directly from the 21 assessment questions on the ADT 2. The ADT 2 is a research-based assessment tested to be reliable as an indicator of United States undergraduate non-science majors' understanding of basic astronomy concepts (Deming 2002). The Collaboration for Astronomy Education Research (CAER) developed the ADT 2 to be administered to college students at the start and end of an introductory astronomy course (Zeilik 2003). Amateur astronomers are a new audience for the ADT 2, mainly adults over the age of 30 with an expressed interest in astronomy. Amateur astronomers responding to this survey could potentially be answering the questions many years after their last astronomy course.

The ADT 2 does not cover all the areas in which amateur astronomers might share information during their outreach. On the 2003 ASP Survey, in response to the question, "What are the subjects or topics that you cover in your educational outreach activities? (Check all that apply)", 91% reported "Observable objects in the night sky." Seventy percent or more reported covering observation-related topics, such as eclipses and meteor showers, the Solar System, and constellations. Telescopes and other instruments were covered by 73%. Fewer than 30% reported covering topics in astrophysics (25%) or cosmology (27%). Of the 21 concept questions from the ADT 2, about nine could arguably be classified as relating to observational phenomena in the sky and other topics reportedly covered by a large majority of amateur astronomers in their outreach. So, the concept questions are likely to underestimate the outreach-related knowledge of amateur astronomers.

The third part of the survey included various demographics adapted from the 2002 ASP Survey. To compare concept question scores with factors based on the respondent's experience as an amateur astronomer, demographic questions were included related to astronomy club affiliation, extent of outreach, and astronomy-related education.

### **3. ASTRONOMY CONCEPTS SURVEY (ACS) RESULTS**

#### **3.1 Sampling Bias and Results**

A potential self-selection bias exists among the respondents. Those who felt more knowledgeable about astronomy concepts may have been more likely to choose to take a test of their knowledge. Even though some completed surveys were eliminated for various reasons discussed in

Appendix B, from the total 1,628 times the survey was accessed, 1,164 submissions were completed and included demographics. Nine hundred of the respondents identified themselves as doing outreach.

After the survey was closed, a few members from each of the 21 clubs with 12 or more submissions were contacted and asked to report the estimated number of their clubs' members engaged in outreach and the total number of members in their club. As determined from these reported numbers, on average, about 10% of the 21 clubs' total memberships responded, while about 52% of those clubs' members who do outreach responded. One-quarter of these 21 clubs had memberships of 60 or fewer. Using reported membership numbers from the 250 clubs on the Night Sky Network (<http://nightsky.jpl.nasa.gov/>), half of Night Sky Network clubs have memberships of 60 or fewer. So, this study's sample may have disproportionate representation from larger clubs.

To determine if the ACS survey sample of 900 outreachers is likely to be a representative sample of outreachers in general, the mean scores of the 321 outreachers from the 21 clubs were compared with the mean score for all outreachers responding to the survey. The mean score (as a percentage of correct answers) for these 321 outreachers is 79 ( $SD=19$ ). The median score is 86. The mean score of the 900 outreachers responding to the survey is 78 ( $SD=19$ ), with a median score of 86. Statistically, these scores are the same. The outreachers in the ACS sample are likely to include a representative sample of amateur astronomy club members who do outreach.

Professional astronomers and instructors in formal education settings may be included in the results, and if so, they are likely to be a subset of the 9% of the respondents who indicated having a degree in astronomy, physics, or astrophysics. These respondents may have considerably enhanced knowledge and could bias the averaged results for this subset, referred to as "degree" in this study.

There is no guarantee that those respondents who are not affiliated with an astronomy club or who do no outreach are likely to be representative samples of those groups. Results from these respondents are included for reference and comparison to indicate potential trends.

Members of astronomy clubs without Web sites or e-mail contacts are less likely to be represented in this sample.

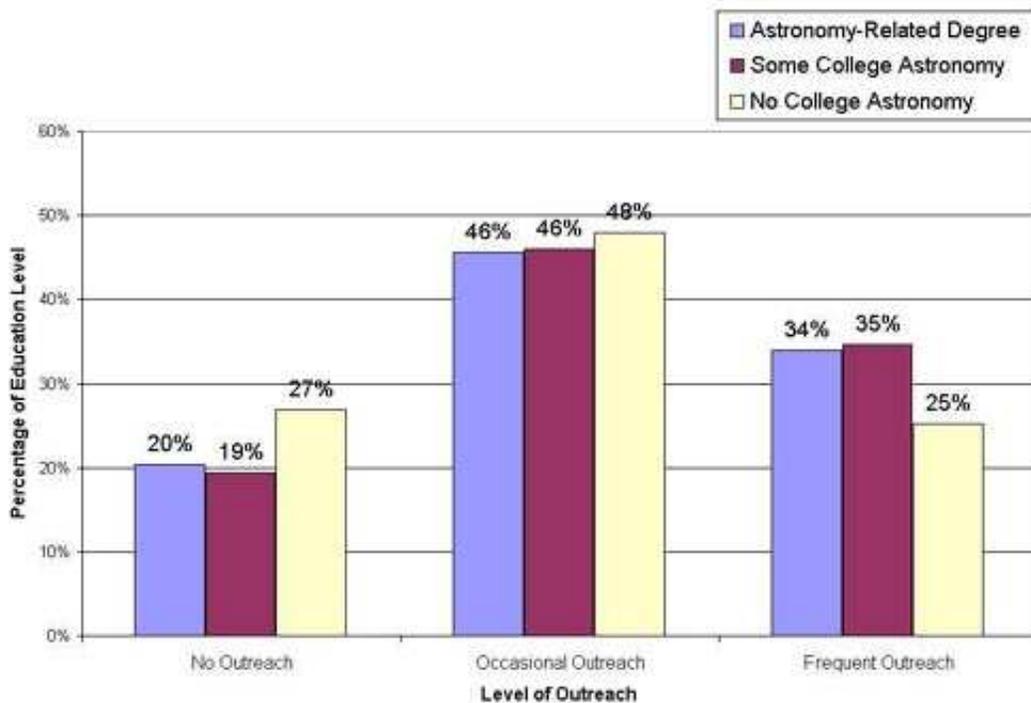
The respondents are predominantly male (83%), Caucasian (87%), and between the ages of 31 and 65 (85%). Over half (57%) have at least some formal college-level training in astronomy, physics, or astrophysics, while 13% report having only high school astronomy, and 30% report no formal astronomy-related training. As to club membership, the vast majority (85%) have belonged to an astronomy club, with 59% belonging for two or more years.

About three-quarters (77%) of the respondents report being involved in some level of astronomy outreach. Thirty percent participate seven or more times a year, and 47% participate "occasionally" (one to six times a year), leaving 23% who report no outreach.

### 3.2 Results for Who Is Doing the Outreach

As shown in Figure 1, 25% of those with no college-level astronomy, compared with 35% of those with any college-level astronomy-related education, do "frequent" outreach (seven or more times a year). Forty-eight percent of those with no college astronomy and 46% of those with any college astronomy do "occasional" outreach (one to six times a year). Twenty-seven percent of those with no college astronomy and about 19% of those with any college-level astronomy-related education reported no outreach activity.

There is a difference in the rate of *frequent* outreach between those with no college astronomy and those with at least some college astronomy. The difference in the proportions of those doing *no* outreach is also significant between those with no college astronomy and those with at least some college astronomy. There is no statistically significant difference in the rate of *occasional* outreach (approximately 47%) among the education groups.



**Figure 1.** Effect of Astronomy-Related Education Level on Level of Outreach

Table 1 shows the percentage of 900 respondents who report doing outreach, compared with their number of years of membership in an astronomy club. For those respondents who have never belonged to a club, 31% report occasional outreach, and 15% report frequent outreach. For respondents who are new club members (less than 2 years), 57% engage in occasional outreach, and 15% engage in frequent outreach. For the longer-term club members, about 46% report occasional outreach and about 41% report frequent outreach.

**Table 1.** Outreach Rate by Years of Club Membership

<b>% Of Club Membership Category Doing Level of Outreach</b>	<b>Occasional Outreach</b>	<b>Frequent Outreach</b>	<b>Percent of Total in Club Membership Category</b>
Never Belonged to a Club	31% (N=54)	15% (N=27)	46% (N=81)
Less Than 2 Years Club Membership	57% (N=173)	15% (N=44)	72% (N=217)
2-10 Years of Club Membership	47% (N=219)	39% (N=183)	86% (N=402)
More Than 10 Years of Club Membership	45% (N=99)	46% (N=101)	92% (N=200)
<b>Percent of Outreachers</b>	<b>61%</b> (N=545)	<b>39%</b> (N=355)	<b>100%</b> (N=900)

### 3.3 Mean Scores on the Astronomy Concept Questions

ACS respondents overall had a mean score (as a percentage of correct answers) of 76.

Mean scores by level of formal education in astronomy, physics, or astrophysics are shown in Table 2. Analysis of variance (ANOVA) examines if variability between the means of groups is significantly greater than the variability of the scores within the groups. To be statistically significant, the probability ( $p$ ) that there is no variance must be less than 5% ( $p < 0.05$ ). If the ANOVA reveals differences among the means, the Bonferroni post-hoc test is used to determine which of the means are different.

An ANOVA revealed differences among these mean scores ( $p < 0.05$ ). A Bonferroni post-hoc test revealed that the following groups differed in their mean scores: Degree was different from all the other scores; None and High School were different from all the college-level categories; 1-2 College Courses and More Than 2 College—No Degree were different from Degree, None, and High School.

None and High School mean scores are not statistically different from each other, nor are mean scores for 1-2 College Courses and More Than 2 College—No Degree. So, for reporting mean scores, the statistically significant groupings for astronomy-related formal education based on this analysis are as shown in the Significant Groups column in Table 2, with No College Astronomy having a mean score of 67, Some College Astronomy at 81, and Degree at 92.

**Table 2.** Mean Scores by Formal Astronomy-Related Education

<b>Formal Education in Astronomy, Physics, or Astrophysics</b>	<b>Number of Respondents in Category</b>	<b>Mean Score</b>	<b>Standard Deviation</b>	<b>Significant Groups Mean Score +/- SD (N)</b>
None	352	66	22	No College Astronomy 67 +/-21 (N=503)
High School Class(es)	151	68	19	
1 - 2 College-Level Courses	375	80	17	Some College Astronomy 81 +/-17 (N=558)
More Than 2 College-Level Courses But No Degree in the Field	183	84	18	
Degree in Astronomy Physics or Astrophysics	103	92	10	Degree 92 +/-10 (N=103)

Mean scores by years of club membership are shown in Table 3. An ANOVA revealed differences among the mean scores ( $p < 0.05$ ). A Bonferroni post-hoc test revealed that the following groups differed in their mean scores: Never Belonged to a Club and all the other scores, and between Less Than 2 Years and all the other scores. The difference in mean scores between 2 to 10 Years and More Than 10 Years is not statistically significant. So, for reporting mean scores, these last two categories will be reported as one category.

The statistically significant groupings of club membership status based on this analysis are shown in the Significant Groups column in Table 3, with Never at 66, Less Than 2 Years at 71, and Two or More Years at 81.

**Table 3.** Mean Scores by Years of Club Membership

<b>Approximate Years of Membership in a Local Astronomy Club</b>	<b>Number of Respondents in Category (N)</b>	<b>Mean Score</b>	<b>Standard Deviation</b>	<b>Significant Groups Mean Score +/- SD (N)</b>
Never Belonged to a Club	177	66	24	Never 66 +/-24 (N=177)
Less Than 2 Years	302	71	20	< 2 yrs 71 +/-20 (N=302)
2 to 10 Years	467	79	18	2+ years 81 +/-18 (N=685)
More Than 10 Years	218	83	17	

Mean scores by frequency of outreach are shown in Table 4. Respondents who report no outreach (Zero) have a mean score of 69, Occasional outreachers (1 to 6 times a year) score 76, Monthly (7 to 18 times a year) score 81, A Few Times a Month (19 to 40 times) score 80, and those doing outreach Every Week (more than 40 times a year) have a mean score of 85.

An ANOVA showed differences among these scores ( $p < 0.05$ ). A Bonferroni post-hoc test revealed that the following groups differed in their mean scores: Zero and all the other scores, and between Occasionally and all other scores. The difference in mean scores between Monthly, A Few Times a Month, and Every Week is not statistically significant. So, for reporting mean scores, these last three categories will be reported as one category. The statistically significant groupings based on this analysis are as shown in the Significant Groups column in Table 4. Zero outreach has a mean score of 69, Occasional outreach at 76, and Frequent (seven or more times a year) at 81.

**Table 4.** Mean Scores by Outreach Frequency

<b>On average, how often did you participate in astronomy outreach this past year?</b>	<b>Number of Respondents in Category (N)</b>	<b>Mean Score</b>	<b>Standard Deviation</b>	<b>Significant Groups Mean Score +/- SD (N)</b>
Zero	264	69	22	Zero 69 +/-22 (264)
Occasionally / 1 - 6 Times	545	76	20	Occasional 76 +/- 20 (545)
Monthly / 7 - 18 Times	219	81	18	Frequent 81 +/-18 (355)
A Few Times a Month / 19 - 40 Times	85	80	18	
Every Week / More Than 40 Times	51	85	14	

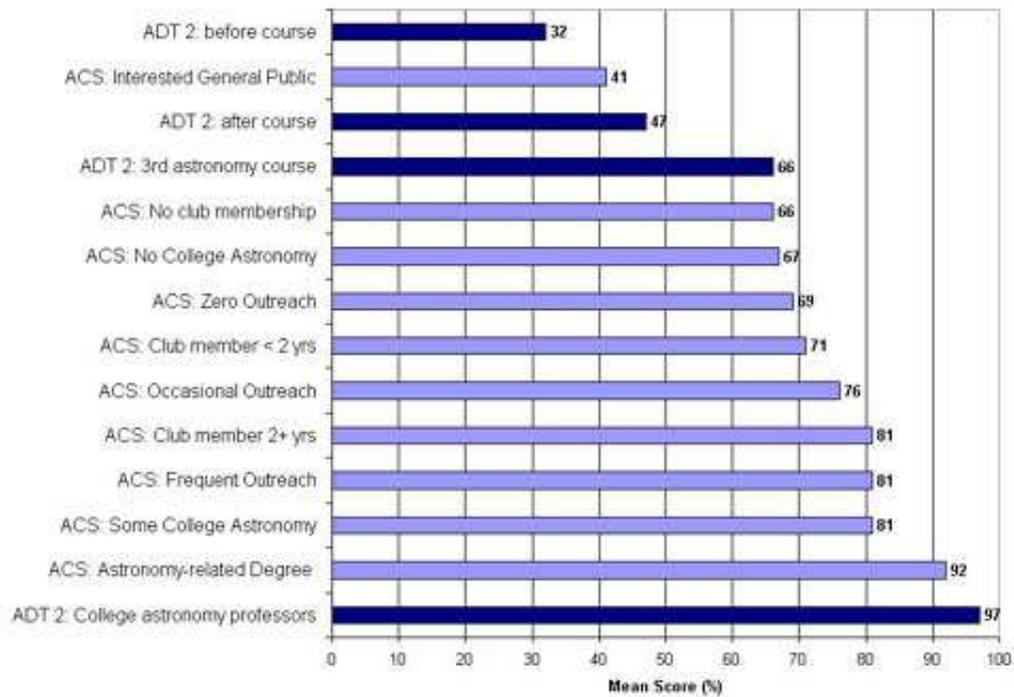
In order to set baselines for comparison of the ADT 2 results with the ACS results, mean scores for various groups as tested by the Collaboration for Astronomy Education Research (CAER), the group that developed the ADT 2, are reported in Table 5. Available statistical data are included. College undergraduates, before taking an introductory astronomy course, had a mean score of 32. After the course, their mean score was 47. Undergraduates taking a third astronomy course had a mean score of 66, while college astronomy professors scored 97.

**Table 5.** ADT 2 Results

<b>ADT 2 Results: Sample Source</b>	<b>Mean Score</b>	<b>Standard Deviation</b>	<b>Data Source</b>
Undergraduates—before taking an introductory astronomy college course	32	5	Hufnagel et al. (2000)
Undergraduates—after taking an introductory astronomy college course	47	20	Deming (2002)
Non-science majors taking a third astronomy course at the University of Maryland	66	Not reported	Hufnagel (2002)
College astronomy professors	97	Not reported	Hufnagel (2002)

In Figure 2, the mean scores of various groupings of ACS respondents (lighter lines) are shown along with reported results from ADT 2 groups (darker lines).

Those identified on Figure 2 as ACS: Interested General Public are the 18 respondents who do not fit the definition of "amateur astronomer." They have never belonged to an astronomy club, report no formal astronomy education, do no astronomy-related outreach, and do not self-identify as amateur astronomers. This group has a mean concept score of 41+/-15, which, based on analysis, is not statistically different from the 32+/-5 scored by ADT 2's students before taking their first college-level astronomy course (identified on the Figure as ADT 2: before course).



**Figure 2.** ADT 2 Mean Scores Compared with ACS Mean Scores

Table 6 shows the mean scores of each astronomy-related education level compared with years of club membership.

**Table 6.** Mean Score by Level of Astronomy-Related Education and Years of Club Membership

Mean Scores (Number of Respondents)	Years of Club Membership			
	None	Less than 2 years	2-10 years	10+ years
Formal Education in Astronomy, Physics, or Astrophysics				
No College Astronomy	55 (N=83)	64 (N=156)	71 (N=193)	74 (N=71)
Some College Astronomy	72 (N=78)	77 (N=129)	85 (N=234)	86 (N=117)
Astronomy-Related Degree	93 (N=16)	87 (N=17)	91 (N=40)	94 (N=30)

An ANOVA revealed differences ( $p < 0.05$ ) among these scores. A Bonferroni post-hoc test revealed that the following groups differed in their mean scores:

- For those with no college astronomy, the mean score for those who never belonged to a club (55) is statistically different from mean scores for all levels of club membership. The mean score for new (less than two years) club members (64) is statistically different from all other mean scores. Mean scores for 2 to 10 years (71) and more than 10 years (74) are not statistically different from each other.
- For those with some college astronomy, the mean score for those who never belonged to a club (72) is statistically different from mean scores for all levels of club membership. The mean score for new club members (77) is statistically different from all other mean scores. Mean scores for 2 to 10 years (85) and more than 10 years (86) are not statistically different from each other.
- For those with an astronomy-related degree, there is no statistically significant difference in mean scores (87 to 94). Statistically, there is no change in astronomy concept score with changing years of club membership for those with an astronomy-related degree.

**Table 7.** Statistically Significant Mean Scores by Astronomy-Related Education and Club Membership

<b>Mean Scores (Number of Respondents)</b>	<b>Years of Club Membership Statistically Significant Mean Scores</b>			
<b>Formal Education in Astronomy, Physics, or Astrophysics</b>	None	Less than 2 years	2-10 years	10+ years
No College Astronomy	<b>55</b> +/- 22 (N=83) (Median: 57)	<b>64</b> +/-20 (N=156) (Median: 64)	<b>72</b> +/-20 (N=264) (Median: 76)	
Some College Astronomy	<b>72</b> +/- 22 (N=78) (Median: 76)	<b>77</b> +/-18 (N=129) (Median: 81)	<b>85</b> +/-14 (N=351) (Median: 90)	
Degree in Astronomy, Physics, or Astrophysics	<b>92</b> +/- 10 (N=103) (Median: 95)			

Next is a look at the impact that doing outreach has on mean scores over club membership, keeping the level of college astronomy equal. Taking the largest group, those respondents with some college astronomy but no degree ( $N=558$ ), the mean scores for the respondents by years of club membership are shown in Table 8 by outreach level.

**Table 8.** Mean Score by Level of Outreach and Years of Club Membership for Respondents with Some College Astronomy

<b>Mean Scores (Number of Respondents)</b>	<b>Years of Club Membership</b>		
<b>Outreach Level</b>	Never Belonged (N=78)	Less Than 2 Years (N=129)	2 or More Years (N=351)
None	66 +/-24 (N=34)	80 +/-15 (N=34)	85 +/-15 (N=40)
Occasional	75 +/-22 (N=30)	73 +/-19 (N=72)	85 +/-14 (N=155)
Frequent	78 +/-17 (N=14)	84 +/-16 (N=23)	85 +/-14 (N=156)

For long-term club members (two or more years) with some college astronomy, there is no difference in mean scores with increasing frequency of outreach.

For club members of less than two years with some college astronomy education, an ANOVA shows a difference among the mean scores ( $p < 0.05$ ). A Bonferroni post-hoc test revealed that the following groups differed in their mean scores: those engaged in frequent outreach and those engaged in occasional outreach. There is no statistically significant difference between frequent and none, or between none and occasional.

For those who have never belonged to a club and have some college astronomy, analysis shows no statistically significant difference among the mean scores at any of the outreach levels. An ANOVA shows that the probability of this result ( $p=0.13$ ) is not statistically significant. The mean score for the three outreach levels of the Never Belonged group combined is 72 (see Table 7).

## **4. DISCUSSION AND IMPLICATIONS**

### **4.1 What factors related to amateur astronomy affect knowledge of basic astronomy concepts?**

To a point, mean scores on the concept questions rise with increasing years of astronomy club membership, increasing levels of college astronomy-related education, and increasing frequency of outreach. Which of these three factors has the most influence?

Higher levels of formal astronomy-related education result in higher mean scores, but respondents appear to have gained no more understanding of basic concepts in astronomy from taking more than two astronomy-related college courses over those who have only had one or two courses. A degree in astronomy, physics, or astrophysics results in the highest likelihood of achieving mastery of the basics.

Mean scores increase as years of astronomy club membership increase. The club may provide its members with more opportunities for learning over opportunities available to unaffiliated amateurs. Alternatively, it may indicate that members with a higher level of astronomy-related education tend to remain longer in the club, while those with a lower level drop out. The data suggest, however, that the club experience itself, independent of formal astronomy education, has a positive effect on conceptual astronomy understanding. Except for those with an astronomy-related degree, the longer an amateur astronomer has spent in a club, the more understanding he or she gains of astronomy concepts.

The change is greatest for those with no college-level astronomy: a difference of 17 percentage points in mean score for long-term (2+ years) club members over those who have never belonged to a club (mean score: 72 vs. 55), equivalent to the mean score of those with some college astronomy but who never belonged to a club. For amateur astronomers with some college astronomy, an improvement in mean score of 13 percentage points is shown among long-term club members (85) over unaffiliated amateurs (72). Club membership does not entirely compensate for a lack of formal education, but it does appear to give one an edge, indicating the impact of associating with like-minded enthusiasts.

To a point, the more outreach amateur astronomers participate in, the greater the likelihood of a higher mean score. This suggests that the act of doing outreach may improve understanding. However, the data suggest that long-term club members are more likely than unaffiliated amateurs to be doing the most frequent outreach. Because long-term club members score higher than unaffiliated amateurs, the difference is due primarily to the larger representation of long-term club members among those reporting outreach, rather than outreach itself.

Among those with at least some college-level astronomy, when comparing the level of outreach with years of club membership, club membership appears to have the greater impact on improving understanding of basic astronomy concepts than doing outreach does. In fact, for new club members, doing a *little* outreach appears to increase their level of confusion (see Table 8)!

Having at least some college level astronomy education (one or more courses) and remaining a member of an astronomy club for more than two years appear to be more predictive of greater knowledge of basic astronomy concepts than doing outreach.

## **4.2 Do amateur astronomers doing outreach represent a knowledgeable group of informal astronomy educators?**

Regardless of their level of college astronomy, all amateur astronomers are equally likely to participate in occasional outreach. Those with no college astronomy are only slightly less likely to do frequent outreach than those with at least some college astronomy. The amount of astronomy-related education appears to have only a small effect on the likelihood of doing outreach.

Years of club membership, however, do seem to make a difference in the likelihood of doing outreach. Results suggest that both the likelihood of doing outreach and the frequency of outreach increase the longer an amateur astronomer has belonged to a club. The 2002 ASP Survey (Storksdieck et al. 2002), unlike the current research, did not target astronomy club members, but amateur astronomers in general. Eighty-three percent of their respondents who participate in outreach also reported that they belong to astronomy clubs. Combined, these results suggest that club members do more outreach than unaffiliated amateur astronomers.

Neither survey is assured of having a representative sample of unaffiliated amateurs, nor is either survey assured of having a proportionally representative sample of amateur astronomers who do outreach in general. The question of whether club members actually do represent the large majority of outreachers needs further investigation.

The results do show that long-term astronomy club members, particularly those with at least some college-level astronomy, are the ones who tend to have the better grasp of basic astronomy concepts. So, if long-term club members actually do more outreach, these results suggest that those who are more knowledgeable are also the ones doing more outreach.

### **4.3 How much more knowledgeable than the public they serve are amateur astronomers about astronomy basics?**

Comparing the results of this study (ACS) with the results from the Astronomy Diagnostic Test 2 (ADT 2), college-level studies of non-science major undergraduates, the ADT 2 and the ACS have similar results for comparable populations at the low and high ends. ACS respondents who are not amateur astronomers but who were interested enough in astronomy to take the survey scored statistically the same as college students before taking their first college astronomy course (mean score: 32). This suggests that the low-end ADT 2 results agree with results from a somewhat similar sample of respondents from the ACS. At the high-scoring end, those ACS respondents with an astronomy-related degree score only somewhat lower (mean score: 92) than the ADT 2 College Astronomy Professors (mean score: 97).

The ADT 2 and the ACS results differ considerably for the groups in between. Amateur astronomers with no college astronomy score essentially the same (67) as the ADT 2 Third Astronomy Course undergraduates (66)—an interesting result considering that one might expect a structured classroom environment to be a more efficient method of conveying knowledge than informally pursuing a hobby. Considering astronomy education level alone, the ACS respondents with some college astronomy might be expected to be comparable to the ADT 2 Third Astronomy Course students. But the amateur astronomers with some college astronomy actually have a higher mean score (81) than the college students (66). Long-term astronomy club members with some college astronomy score even higher (85).

This result adds more evidence to Falk and Dierking's (2000) premise that interest in a subject strongly influences how much one learns. In addition, it suggests that most of the amateur astronomers doing the highest levels of outreach have attained considerably more knowledge about astronomy than have the public they serve.

A wide range of scores was revealed among those doing outreach, indicating that there are some amateur astronomers doing outreach who may not have adequate knowledge of basic astronomy concepts to share accurate information about astronomy with their audiences. The results indicate that at least two years of membership in an astronomy club and having at least some college-level astronomy education is likely to significantly increase one's knowledge. Amateur astronomers engaged in outreach who lack confidence in their knowledge of astronomy may want to consider both of these avenues to better understanding.

For programs that support amateur astronomy outreach and for teachers and other community educators who rely on amateur astronomers to be equipped to provide accurate information, a quick assessment would be to ask how long the amateur astronomer has been an astronomy club member and if he or she has taken any astronomy-related college courses. There are certainly exceptions, but answers of two or more years of club membership and at least one or two college courses are likely to provide a reasonable level of confidence in the knowledge of the amateur.

#### **Acknowledgments**

This research was inspired by encouragement from Dr. Michael Zeilik of the University of New Mexico. I wish to sincerely thank Dr. Zeilik and his company, The Learning Zone, for sponsoring the survey and for providing insights to help produce these results.

I also wish to acknowledge extensive assistance from Martin Storksdieck of the Institute for Learning Innovation.

## Appendix A

Click

here to bring up Appendix A, which is in PDF format.

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## Appendix B

### **Eliminating Submissions from Final Survey Results**

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From the 1,628 submissions, 464 were eliminated from the final tally for the reasons outlined below. The final number of submissions retained was 1,164. The following classifications of survey submissions were eliminated from the final survey tally (refer to the summary in Table 9 below):

- **Inspected (N=255):** In these submissions, the respondent answered the introductory question, "**Are you an amateur astronomer?**" which then took him or her to the first page of the concept questions. At this point, the respondent abandoned the survey without answering any questions. Some returned later to complete the survey, shown as Inspected but Participated in Survey (N=38) in Table 9.
- **Duplicate entries (N=10):** In these submissions, it appeared that the same person answered some or all of the concept questions and submitted the survey more than once.
- **Abandoned submissions (N=65):** Some of the concept questions were answered, but the survey was abandoned before the last page of concept questions was answered. This represents only 4% of the entire sample. This may indicate that among the completed surveys, there is unlikely to be a bias toward people who knew the answers to the concept questions.
- **No demographics (N=26):** A total of 1.6% of the submissions had all the astronomy concept questions answered but no demographics included. I had limited ability to do comparisons without demographics, so these submissions were eliminated.
- Submissions from outside the United States (N=42): These were eliminated because of potential language or cultural barriers that would cause questions to be misinterpreted.
- **Submissions from Hawaii (N=3):** The astronomy concept Question 1 has no correct answer for locations within the tropics.
- **Submissions from respondents who admitted that they sought and found outside help (N=25).**

**Table 9.** Submissions Eliminated from Final Tally

<b>Type of Submission Eliminated</b>	<b>Number Eliminated</b>	<b>% of Total Submissions Received</b>
Inspected and No Answers	255	15.7%
Inspected but Participated in Survey	38	2.3%
Duplicate Entries	10	0.6%
Abandoned	65	4.0%
No Demographics	26	1.6%
Submissions from Outside the USA	42	2.6%
Submissions from Hawaii	3	0.2%
Sought and Found Outside Help	25	1.5%
<b>Total Submissions Eliminated</b>	<b>464</b>	<b>28.5%</b>
<b>Total Submissions Retained</b>	<b>1164</b>	<b>71.5%</b>
<b>Total Number of Submissions</b>	<b>1628</b>	<b>100.0%</b>

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