Implementation and Assessment of Undergraduate Experiences in SOAP: An Atmospheric Science Research and Education Program

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ABSTRACT

The Student Operational Aggie Doppler Radar Project (SOAP) involved 95 undergraduates in a research and education program to better understand the climatology of storms in southeast Texas from 2006–2010. This paper describes the structure, components, and implementation of the 1-credit-hour research course, comparing first-year participants' experiences and career outcomes with students who were engaged in SOAP for multiple years. Groups of five or six students, led by a senior-level undergraduate and mentored by a graduate student and faculty advisor, performed several daily research tasks, including producing precipitation forecasts, archiving observations, and operating and analyzing data from an S-band Doppler radar for precipitation events on their assigned day. Anonymous surveys given to SOAP students at the end of each semester indicated that student confidence in performing most SOAP tasks exhibited statistically significant positive correlations with their interest and experience in doing them. In addition, students participating in SOAP for multiple years were significantly more confident in performing program tasks than single-year participants (with correlations increasing an average of 19%) and were more likely to obtain meteorology or science-related employment upon graduation (94% versus 69%). First-year participants were significantly more likely to indicate that their interactions with undergraduate student leaders or peers were most beneficial, whereas interactions with the faculty advisor or graduate student mentors were equally or more important to returning students. Students were also more likely to consider research careers and matriculate to graduate programs as they participated longer in SOAP, suggesting research and education programs have a strong influence on students' career outcomes in addition to fostering positive self-efficacy. [DOI: 10.5408/12-382.1]

Key words: undergraduate research, meteorology, confidence, career outcomes, peer mentoring

INTRODUCTION

Engaging undergraduates in research and educational field-based experiences in atmospheric science allows students to observe and analyze the environment outside the traditional classroom. These opportunities allow students to apply their existing knowledge while introducing them to higher-level concepts traditionally learned in more advanced courses. Undergraduate research has been regarded as an increasingly critical component of science education for several decades (Halstead, 1997; Hensel, 2012) that develops students personally and professionally and transforms faculty into "teaching scholars" (Lopatto, 2009). More than half (53%) of all science, technology, engineering, and mathematics (STEM) undergraduates participate in independent or mentored research activities (Russell, 2006). Studies consistently show that students clarify and confirm or modify their career goals after participating in authentic undergraduate research experiences (i.e., where students work on scientific research with practicing scientists), particularly with respect to their desire to attend graduate school (e.g., Lopatto, 2004; Seymour et al., 2004; Gonzales-Espada and LaDue, 2006; Hunter et al., 2007; Russell et al., 2007). Involving undergraduates in research experiences also increases the students' confidence in their scientific abilities, including perceived improvements in oral and written communication skills, computer and technical skills, and understanding of research processes (Kardash, 2000; Bauer and Bennett, 2003; Lopatto, 2004; Seymour et al., 2004).

In addition to authentic research experiences, many undergraduates participate in field-based educational experiences, ranging from field campaigns to single courses involving larger numbers of students, that provide them with a better understanding of scientific careers, principles, and processes. The Rain in Cumulus over the Ocean (RICO) field campaign in 2005 involved undergraduates with graduate students from several institutions in a variety of educational activities, ranging from seminars and training sessions to hands-on experience with instrumentation, culminating with a student-led scientific mission involving the use of research aircraft (Rauber et al., 2007). On a smaller scale, university courses have been documented in the geosciences that involve 1–3 weeks of intensive field experiences that often require significant travel with pre- and post-trip assignments (e.g., Aitchison and Ali, 2007; Lathrop and Ebbett, 2006). Analogous courses in atmospheric science are beginning to exist, such as those that couple forecasting and storm chasing experiences with professional development activities (Godfrey et al., 2011). Local fieldwork experiences involving greater numbers of students have also been incorporated into introductory and upper-level geosciences courses at several universities (e.g., Comrie, 2000; Knapp et al., 2006; Elkins and Elkins, 2007; Morss and Zhang, 2008),

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TABLE I: Number of weeks (out of 11) during which students interacted with the faculty advisor or one of the graduate student mentors during SOAP.

Interactions With Faculty Advisor or Graduate Student Mentors	2007 ($n = 26$)	2008 ($n = 29$)	2009 ($n = 29$)	2010 ($n = 30$)
8+ interactions	15%	62%	55%	67%
5–7 interactions	46%	21%	28%	27%
2–4 interactions	35%	17%	14%	6%
0–1 interaction	4%	—	3%	—

including a two-semester sequence in atmospheric science in which upper-division undergraduate and graduate students collected mobile radar data during fall semesters, with analysis occurring the following spring (Richardson et al., 2008). All of these projects integrate research and education by incorporating a period of data collection and subsequent analysis activities that expose students to inquiry-based learning and critical thinking.

This article evaluates undergraduate experiences and impacts from participating in the Student Operational Aggie Doppler Radar Project (SOAP), an atmospheric science research and education program at Texas A&M University (TAMU) that established a long-term storm climatology for southeast Texas while providing 95 students with applied experience. SOAP includes local fieldwork with authentic research tasks of collecting and analyzing data from the Aggie Doppler Radar (ADRAD) and supporting instruments as part of a research course offered each spring semester from 2006 to 2010. SOAP satisfies all seven principles for good practice in undergraduate education outlined by Chickering and Gamson (1999) by encouraging undergraduate student interaction with faculty and graduate students, cooperation among students, and active learning while providing prompt feedback, emphasizing time on task, communicating high expectations, and respecting diverse learning styles. However, SOAP is unique in that advanced undergraduate students led their peers (ranging from freshmen to seniors) in performing daily operational and research tasks, relying upon the faculty advisor and graduate student mentors for training materials, complicated logistics, and overall guidance. In addition to freeing time for faculty, peer-to-peer mentoring and instruction provide advanced students with the confidence-building experiences of leading and teaching students that promote scientific, student-centered cooperative learning (Rueckert, 2007; Judge et al., 2012). Engaging upper- and lower-division students in SOAP also involved many undergraduates in research early in their college careers. This is a critical factor because students who perform research over multiple semesters tend to exhibit stronger outcomes and report greater benefits than those with shorter experiences (Bauer and Bennett, 2003; Russell, 2006).

Sadler and McKinney (2010) emphasize that assessing the effectiveness of undergraduate research programs is essential for improving and advancing undergraduate science education. Evaluating SOAP is particularly important for the atmospheric sciences because most empirical studies of undergraduate research programs come from other STEM fields (Gonzales-Espada and LaDue, 2006) and focus on the program's research goals rather than the evaluation of participants' experiences and long-term impacts on career goals and outcomes. SOAP also appears to be unique because it integrates research and education through data collection and analysis with peer interactions and leadership involving many undergraduates instead of mentoring students through individual research projects. Therefore, this article investigates students' experiences and impacts from participating in SOAP by answering the following questions:

- How is SOAP structured and how may similar programs be implemented elsewhere?
- Do multiyear SOAP participants exhibit statistically significant differences from single-year participants in their confidence in performing SOAP tasks or career outcomes?
- Which types of program interactions did students find most beneficial?

SOAP PROGRAM DESCRIPTION AND IMPLEMENTATION

Course Structure

SOAP involved 25–30 undergraduates at TAMU each spring semester between 2006 and 2010, providing 95 unique students with forecasting and research practice. Students earned 1 research credit hour graded on a pass/fail basis by the faculty advisor, who was the principal investigator of the supporting National Science Foundation (NSF) Faculty Early Career Development (CAREER) grant and the second author of this paper (the first and third authors were graduate student mentors during all 5 y and the last 3 y of SOAP, respectively). Participants gained forecasting and research practice by predicting, observing, and analyzing a variety of precipitating systems while collecting data and providing useful results toward the broader NSF grant's research goals. SOAP students organized themselves into daily groups of five or six individuals who were responsible for producing a precipitation forecast, operating ADRAD if precipitation was in the radar domain on their group's assigned day, and performing several other tasks discussed in the next section. Each daily group was led by an upper-level undergraduate with past SOAP experience who was directly mentored by one of three graduate students and the faculty advisor. The graduate student mentors and faculty advisor also made a conscientious effort to regularly interact with SOAP participants, with most students reporting eight or more interactions with these mentors out of the 11 operational weeks of the program during the last 3 y of SOAP (Table I).

Organizational and training meetings were held during the second and third weeks of the semester after students finalized their course schedules, followed by 11 weeks of operations and a wrap-up meeting during the last week of the semester. Although some programmatic elements varied

TABLE II: Sample course schedule given in the spring 2010 SOAP syllabus.

Week	Dates	Meetings and Activities
1	1/18–1/22	No SOAP activities this week
2	1/25–1/29	Organizational Meeting on Monday 1/25 at 7 p.m.
3	2/1–2/5	SOAP Operations Training Meeting on Monday 2/1 at 7 p.m.
		Radar Operations and Cloud Observations Training on shift day
4	2/8–2/12	SOAP Operations Week 1; Radar learning module 1 (radar startup)
5	2/15–2/19	SOAP Operations Week 2; FX-Net learning module 1 (fronts and isentropic analysis)
6	2/22–2/26	SOAP Operations Week 3
7	3/1–3/5	SOAP Operations Week 4; Radar learning module 2 (image analysis)
8	3/8–3/12	SOAP Operations Week 5
	3/15–3/19	NO CLASSES OR SOAP OPERATIONS ALL WEEK (Spring Break)
9	3/22–3/26	SOAP Operations Week 6; FX-Net learning module 2 (sounding analysis)
		Intensive Operation Period (IOP) with Sounding Launches Begins (Week 1)
		Sounding Launch Training on shift day; meet at 5 p.m. (weather permitting)
10	3/29–4/2	SOAP Operations Week 7 and IOP Week 2
11	4/5–4/9	SOAP Operations Week 8 and IOP Week 3
12	4/12–4/16	SOAP Operations Week 9 and IOP Week 4; FX-Net learning module 3 (Q-vectors, ageostrophic motions, and local circulations)
13	4/19–4/23	SOAP Operations Week 10 and IOP Week 5; Radar case studies
14	4/26–4/30	SOAP Operations Week 11 and IOP Week 6; Radar case studies
15	5/3–5/7	Wrap-up Meeting on Wednesday 5/5 at 7 p.m.
16	5/10–5/14	No SOAP activities this week

each year (as discussed in subsequent paragraphs), the sample schedule from the spring 2010 SOAP syllabus provided in Table II outlines the general course structure followed every year except for 2006, when only 7 weeks of operations occurred. The first mandatory evening meeting occurred during the second week of the semester and provided a brief orientation to the program while allowing students to organize themselves into daily groups and set their daily meeting times. During the third week of the semester, each group met during their regular meeting time for training on radar operations and cloud identification, in addition to a second mandatory evening session covering forecasting and new program elements. Regular daily SOAP operations began during the fourth week and continued until the last week of the semester, when a final mandatory evening wrap-up meeting was held to summarize, recognize, and evaluate the progress made during the semester. Each group also presented their most interesting case study and competed in a wildly popular *Jeopardy!*-style game that tested the overall content knowledge students had learned by completing daily tasks described in the following section.

Description of Daily SOAP Tasks

Students were expected to be on call for their group's day from 8 a.m. until 10 p.m. to operate the radar and perform several other tasks, many of which were part of SOAP every year. Groups met in the morning and afternoon for 1–2 h to perform their daily responsibilities in a lab space designated for SOAP, meeting longer if rain was in the area. Daily tasks incorporated into every year of SOAP included the following:

- *Forecasting precipitation and writing the daily forecast discussion* during the morning hours, with a corresponding afternoon update. Each shift analyzed national satellite and radar imagery and upper-air maps before focusing regionally on southeast Texas. Students then posted a forecast discussion to the SOAP Web site (TAMU, 2009), indicating the likelihood that precipitation would occur before 8 a.m. the next day and over the course of the next 3 d. In addition to serving a practical operational purpose for SOAP, writing forecast discussions has been shown to improve student performance and confidence in the precipitation forecasts they produce (Market, 2006).
- *Identifying cloud types* according to the World Meteorological Organization (WMO) synoptic code (WMO, 1974) using the 10 classifications (including no cloud) for low, middle, and high clouds. Students took eight panoramic snapshots of the sky during the morning and afternoon from the 15th-floor observatory in the O&M Building, posting these images to the SOAP Web site in real time.
- *Operating the radar* on the roof of the O&M Building when rain was within 150 km between 8 a.m. and 10 p.m. local time. Students chose appropriate scan strategies from a preset selection depending on the depth of the storm system and monitored the radar to ensure data were being continuously collected. Group leaders organized their group members in covering the radar throughout the day and coordinated with

their graduate student mentor and the next day's group leader if overnight operations were necessary.
- *Analyzing radar data* in real time and from past cases using Sigmet's Interactive Radar Information System (IRIS). Each group also created representative images with IRIS and wrote and posted a precipitation summary to the SOAP Web site for each event that occurred on their day, presenting one case study in detail at the wrap-up meeting.

In addition to these daily tasks that students performed each year of SOAP, several activities were implemented for a few years as the program matured. The following tasks were included:

- *Analyzing online archives for the radar climatology (2007–2008)* to classify storms' dynamical forcing and structures using archived surface and upper-air maps, satellite imagery, and Next-Generation Radar (NEXRAD) imagery. Advanced SOAP students vetted these storm classifications the following fall semester and performed preliminary analyses for the rainfall climatology presented in Hopper (2011).
- *Using FX-Net software to forecast (2008–2010),* in addition to the Web-based resources used during the first 2 y of SOAP. FX-Net simulates the National Weather Service's (NWS's) Advanced Weather Interactive Processing System (AWIPS) graphical user interface, permitting students to create analysis products in addition to default products specifically created for SOAP.
- *Learning modules for FX-Net and ADRAD (2008–2010)* that taught students how to perform specific tasks or learn methods of analysis for forecasting using FX-Net or radar data in IRIS. Groups typically completed four to six learning modules a semester on relatively slow days when precipitation was not in the area.
- *Recording and submitting rain gauge data (2009–2010)* daily between 7 and 9 a.m. local time on the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) Web site (Colorado Climate Center, 2011) for gauges sited by each student, typically at that student's residence.
- *Creating a quantitative precipitation forecast (2009–2010)* based on past rainfall totals for their predicted storm type and structure, model output, and the Storm Prediction Center's short-range ensemble forecasts. Students forecasted the timing of rainfall and made a mean, minimum, and maximum quantitative precipitation forecast that they verified the following week using data from approximately 30 SOAP CoCoRaHS gauges sited within 10 km of ADRAD.
- *Performing sounding launches (2008 and 2010)* from the 17th green of the TAMU Golf Course. All groups released two radiosondes at 0000 UTC during the last 2 weeks of April 2008, whereas each group was given three radiosondes to release at 0000, 1200, or 1800 UTC on days of their choice during the last 5 weeks of SOAP in 2010.

Implementation Strategies

Although SOAP was originally designed as an undergraduate research and education program in atmospheric science for a research university with very high research activity (as defined by the Carnegie Classification of Institutions of Higher Education [Carnegie Foundation for the Advancement of Teaching, 2013]), the general course structure could be adapted to suit the needs of institutions with more limited resources or other degree programs in geosciences or STEM fields. In addition to peer mentoring, we recommend that research and education programs include an initial set of training sessions or modules at the beginning, advanced training and regular data collection and analysis tasks throughout the project, and a final product synthesizing each group's work at the project's end. Specific implementation strategies will depend on individual resources and objectives, but the following practices are recommended based on experiences in implementing and managing SOAP:

- *Recognize what is within the scope of your resources and time*. In agreement with White et al. (2008), implementing and running SOAP was initially time consuming for the faculty advisor and would have been difficult to maintain without one part-time and two full-time graduate students that spent 5–15 h each week on SOAP during the semester. Therefore, faculty at primarily undergraduate institutions (PUIs) may consider departmental or interdisciplinary collaborations with other faculty to share in mentoring undergraduates and handling logistics or scale back the size and scope of their research experiences. The first author has accomplished this at a PUI by using existing laboratory or seminar courses that are part of his regular teaching load to mentor groups of three to five students through semester-long research projects that satisfy course objectives.
- *Encourage all levels of students to participate by recruiting deliberately, facilitating enrollment, and including data collection and analysis tasks involving all students*. The faculty advisor and graduate student mentors recruited participants by advertising SOAP at student organization meetings and major courses, highlighting the unique opportunity to gain practical experience in radar operation and analysis; more than half of the participants identified this as a primary reason for joining SOAP. Ten of the 30 seats were reserved for lower-division students by cross-listing SOAP as a sophomore- and senior-level course at TAMU, but other institutions may need a different strategy. The faculty advisor recruited senior undergraduates with leadership abilities and radar experience to serve as group leaders the first semester, whereas subsequent leaders had SOAP experience. Once the program was established, returning SOAP participants indirectly recruited by sharing their experiences with potential students. One student even wrote that he was "referred to SOAP by a friend that had no experience in SOAP" and thought it would introduce him to "running a radar and having an extremely expensive machine at (his) disposal."
- *Establish an organizational framework with clear expectations, but give students autonomy in performing their research tasks and embrace flexibility*. Communicating expectations to the participants within the syllabus and during the first meeting is vital so that all students

understand that their leaders and the faculty advisor will hold them accountable if they abuse the autonomy they are given. Students who did not meet basic expectations or who had more than one unexcused absence were required to complete additional project work to receive a passing grade. In addition, establishing a course structure that is flexible enough to accommodate alternative plans is important in case things do not go as expected, such as an extended period when ADRAD was inoperable during several weeks of SOAP in 2008. Proactively planning for these events by having possible contingency plans (e.g., launching soundings in 2008 instead of radar operations) contributed to SOAP's success by providing useful research data while still generating excitement and benefitting students educationally.

- *Encourage students to pursue additional research opportunities*. Thirteen SOAP participants performed eight authentic research projects under the direction of the faculty advisor or a graduate student mentor during the fall 2007, 2008, and 2009 semesters, culminating with presenting their work at the American Meteorological Society's Annual Student Conference and TAMU Student Research Week. Most of these "Fall SOAP" projects incorporated data collected by spring participants or furthered the analyses performed by students during the regular program. Some of these advanced projects also influenced the research and data collection objectives of SOAP between 2008 and 2010 when many of the group leaders had participated in fall SOAP.
- *Utilize student feedback when implementing improvements or new tasks*. Monthly meetings among the group leaders, graduate student mentors, and faculty advisor were held during December–April for brainstorming, training, and feedback, particularly on new research objectives and activities. Improvements implemented during the semester were driven by suggestions from group leaders during these meetings, whereas changes made for future semesters primarily arose from comments made by participants who evaluated their experiences at the end of the semester. Several key educational findings from these student surveys are discussed in the following section.

SURVEY ASSESSMENT METHODS

Anonymous surveys approved by the Institutional Review Board at TAMU were administered at the end of the semester during the last 4 y of the program (2007–2010). The undergraduate meteorology program at TAMU had approximately 140–150 majors over this period, meaning about 20% of the department's majors were involved in SOAP at one time. Excluding 13 students who only participated in SOAP during 2006, 77 of the 82 remaining participants completed 114 surveys, 28 of whom completed surveys in multiple years. Survey items were generally the same each year with only slight variations. The average survey response rate was 95% (114 of 120) over the 4-y period ranging from 87% in 2007 to 100% in 2010.

SOAP involved 41 males and 41 females from 2007–2010, 18% (8 males and 7 females) of which were from underrepresented minority groups (primarily Hispanic or Latino), similar to the undergraduate student body at TAMU during this period. SOAP involved a higher percentage of females (50%) than typically enrolled in most atmospheric or earth science degree programs across the United States (Charlevoix, 2010), including the meteorology program at TAMU (58% male and 42% female). Seven non-meteorology majors (four environmental geosciences, two civil engineering, and one geology) and seven nontraditional students also participated in SOAP. Seniors, juniors, and lower-division students each accounted for 30%–40% of the students.

All questions on the anonymous, non-longitudinal survey were optional. Participants only identified their classification (upper or lower) and years of SOAP experience without identifying individual demographics such as age, gender, or ethnicity to ensure student privacy. In addition, students indicated which career goals they were considering upon graduation, including forecasting, research, and broadcast meteorology. Qualitative responses were solicited through open-ended questions, some of which prompted participants to identify how specific components of the program could be improved or what they would like to see added. Others asked students to indicate whether interactions with their peers, group leaders, graduate student mentors, faculty advisor, or a combination of these was most beneficial. Quantitative responses prompted students to specify how often they completed many of the SOAP tasks discussed in the previous section (i.e., experience), in addition to rating their confidence and interest in performing each task using Likert-type items rated on a discrete five-point scale. The exact wording of the question, items, and response scale descriptors used for each scale in the survey is provided in Table III. Although this paper focuses on quantitative results, qualitative responses are used in providing supporting anecdotes and in determining which student interactions were most helpful and why.

Although some studies (e.g., Norman, 2010) defend the use of parametric statistical measures for Likert (1932) scales, nonparametric statistical measures are less objectionable for analyzing ordinal data, including Likert scales and individual Likert-type items. This is particularly true for datasets that are small or do not exhibit normal distributions (Jamieson, 2004). Therefore, nonparametric statistics are typically used in this article, beginning with Table III that shows the median and mode student responses for confidence, interest, and experience for individual SOAP tasks. Students exhibited high confidence and interest in performing most program tasks each year, except for creating quantitative precipitation forecasts and completing learning modules when they were first implemented. Participants reported similar experience levels in operating ADRAD and analyzing its data each year but were least confident in 2008, when the radar was inoperable for several weeks. Aside from increased participation in sounding launches during 2010 relative to 2008, students reported similar levels of experience each year for other tasks.

Internal consistency of the confidence, interest, and experience scales were measured using the Cronbach's alpha estimate of the reliability coefficient, or the squared correlation between the observed and the true values of a variable (Table IV). Cronbach's alpha values indirectly indicate how well a set of items measures a single underlying construct, ranging from 0–1.0, with 1.0 expressing perfect reliability. Alpha values exceeding 0.7 are generally regarded

TABLE III: Median and mode responses for items comprising the confidence, interest, and experience Likert scales. Modes are given in parentheses when they differ from their respective medians. Items without values refer to activities not performed by students during that year's program.[1]

	2007 ($n = 26$)	2008 ($n = 29$)	2009 ($n = 29$)	2010 ($n = 30$)
CONFIDENCE SCALE: How CONFIDENT are you in performing the following activities?[2]				
(1) Operating the radar (ADRAD)	4.5 (5)	3	4	4
(2) Analyzing radar data (cross-sections, precipitation summary)	4	3	4	4 (5)
(3) Forecasting and writing the daily forecast discussion	4 (5)	4	4	5
(4) Utilizing the FX-Net software to forecast	—	4	4 (5)	4
(5) Creating a quantitative precipitation forecast (QPF)	—	—	3	3
(6) Performing sounding launches	—	4	—	4.5 (5)
(7) Learning modules for radar (ADRAD) and/or FX-Net	—	4 (3)	4	4
INTEREST SCALE: How much did you LIKE performing the following activities?[2]				
(1) Operating the radar	4.5 (5)	5	5	4
(2) Analyzing radar data	4	4	4 (5)	4 (5)
(3) Forecasting and writing discussion	4 (5)	4	4 (5)	4
(4) Utilizing software to forecast	—	4	4	4
(5) Creating a precipitation forecast	—	—	3	3
(6) Performing sounding launches	—	5	—	5
(7) Learning modules	—	3	4 (3)	4 (5)
EXPERIENCE SCALE: Approximately how many times/weeks (out of 11) did you perform each activity this semester?[3]				
(1) Operating the radar	3	3	3	3
(2) Analyzing radar data	3	3	3	3 (4)
(3) Forecasting and writing discussion	4 (3)	4	4	4 (5)
(4) Utilizing software to forecast	—	4	4	4
(5) Creating a precipitation forecast	—	—	3	3 (2)
(6) Performing sounding launches	—	2	—	4
(7) Learning modules	—	3	4	4

[1]Four participants in 2007, one in 2008, and one in 2009 did not complete the survey.
[2]Participants responded using a five-point Likert format (1 = no confidence, 3 = neutral, and 5 = very confident for confidence scale; 1 = disliked, 3 = neutral, and 5 = liked for interest scale).
[3]Participants responded using a five-point Likert format (1 = no experience and 5 = very experienced). Ranges of the number weeks during which participants performed each task were used in the place of discrete values on the survey as follows: 1 = 0, 2 = 1, 3 = 2–4, 4 = 5–7, and 5 = 8+ for Items 1–4 and 1 = 0, 2 = 1, 3 = 2, 4 = 3, and 5 = 4+ for Items 5–7.

as acceptable, whereas values below 0.5 are unacceptable (George and Mallery, 2003). Three SOAP tasks (identifying cloud types, recording and submitting rain gauge data, and analyzing online archives for the radar climatology) were removed from the analysis due to the confidence, interest, or experience scales exhibiting poor statistical relationships (i.e., low factor loadings) in multiple years. For example, virtually all participants performed daily rain gauge observations during 2009 and 2010 and rated this activity as "5" for both experience and confidence, therefore reducing the overall reliability of the metric. The reliability of the confidence and experience scales (for SOAP as a whole)

TABLE IV: Internal consistency of survey instrument scales by year.[1]

Likert Scale[2]	2007 α	2008 α	2009 α	2010 α
Cronbach's alpha for TOTAL CONFIDENCE scale	**0.76**	0.67	*0.51*	**0.80**
Cronbach's alpha for TOTAL INTEREST scale	*0.49*	**0.71**	0.61	**0.72**
Cronbach's alpha for TOTAL EXPERIENCE scale	*0.54*	0.67	0.64	*0.54*
Cronbach's alpha for RADAR CONFIDENCE subscale	**0.84**	**0.72**	**0.71**	**0.74**
Cronbach's alpha for RADAR INTEREST subscale	*0.53*	**0.76**	0.65	0.64
Cronbach's alpha for RADAR EXPERIENCE subscale	*0.57*	**0.82**	*0.58*	**0.76**

[1]Bolded Cronbach's alpha values are regarded as acceptable, whereas italicized values are "poor" or "unacceptable" (George and Mallery, 2003).
[2]Total scales use all items given in Table III, whereas the radar scales only use Items 1 and 2.

TABLE V: Confidence correlation coefficients with experience and interest for SOAP participants by year from 2008–2010.[1,2]

Activity/Scale	Confidence and Experience			Confidence and Interest		
	2008	2009	2010	2008	2009	2010
(1) Operating the radar	**0.37**	0.09	0.33	**0.38**	**0.45**	**0.48**
(2) Analyzing radar data	**0.59**	−0.29	0.29	0.35	0.06	**0.54**
(3) Forecasting and writing discussion	**0.54**	0.27	0.20	**0.49**	**0.68**	**0.51**
(4) Utilizing software to forecast	**0.72**	**0.52**	**0.39**	**0.54**	**0.60**	**0.42**
(5) Creating a precipitation forecast	—	0.31	**0.46**	—	**0.73**	**0.59**
(6) Performing sounding launches	**0.71**	—	**0.56**	**0.40**	—	**0.57**
(7) Learning modules	**0.51**	0.33	**0.53**	**0.39**	**0.72**	**0.47**
TOTAL SCALE	**0.54**	0.05	0.34	**0.48**	**0.38**	**0.57**
RADAR SUBSCALE (items 1 and 2 only)	**0.52**	−0.24	0.27	**0.44**	0.35	**0.54**

[1]Bolded values are statistically significant at the 95% confidence level ($p \leq 0.05$ for two-tailed test).
[2]Pearson's correlation coefficient between ranks is used to calculate the Spearman rank correlation coefficients because of tied ranks (Myers et al., 2010). Survey results from 2007 are not presented because of their low reliability.

increased when removing this task, whereas the reliability of the interest scales were largely unaffected due to having more variability among student responses.

Results are presented for an overall SOAP Likert scale created by summing together the seven tasks in Table III and a radar subscale including responses for operating ADRAD and analyzing the collected radar data. In general, the confidence and interest scales are more reliable than the experience scale, whose responses were converted to a five-point scale based on ranges of weeks students performed specific tasks (see footnote in Table III). Although a five-point experience scale was used to better match the confidence and interest scales and simplify selections for the survey participants, assigning discrete values to continuous data may have introduced errors that partially account for the experience scale's lower reliability. Although results presented for scales exhibiting poor (0.5–0.6) or questionable (0.6–0.7) reliabilities should be considered carefully, all scales and radar subscales exceed the unacceptable threshold except interest responses during 2007.

SURVEY ASSESSMENT RESULTS

Correlating Confidence in Performing SOAP Tasks With Experience and Interest

Empirical analyses of quantitative survey elements focused on analyzing student-reported self-efficacy, or confidence in performing specific SOAP tasks. Regardless of whether they are accurate or misguided, students base their judgments of self-efficacy on first-hand mastery experiences, comparing their abilities to others through vicarious experiences, social persuasion through verbal praise or discouragement from others, and reacting to physiological states such as fear and stress (Bandura, 1986). Defined as the "belief in one's capabilities to organize and execute the courses of action required to manage prospective situations" (Bandura, 1995), self-efficacy has also been shown to affect student interests, career choices, and performance in educational and career pursuits (Lent et al., 1994). Although the lack of a longitudinal set of surveys precludes direct investigation of the latter two assertions, a construct validity for the survey is established by correlating students' confidence in executing SOAP tasks (self-efficacy) with their breadth of experience and interest in performing them.

Table V shows that student-reported confidence exhibits positive correlations with their experience and interest in performing most SOAP tasks from 2008–2010, with correlations not presented for 2007 because the interest and experience scales demonstrate unacceptable or poor reliability. Correlations between confidence and interest are statistically significant for all SOAP tasks except analyzing radar data during 2008 and 2009. Correlations between confidence and experience are typically less significant, particularly for forecasting, operating ADRAD, and analyzing radar data, the latter of which demonstrates a negative correlation during 2009. However, drawing conclusions from the 2009 data is difficult due to the confidence scale's poor reliability (cf. Table IV). Nevertheless, the high correlations between confidence and interest for most SOAP tasks each year suggest the surveys are valid and imply that students' confidence in performing SOAP tasks is more strongly related to interest than experience.

Comparing Confidence and Career Outcomes for Single- and Multiyear Students

Previous studies indicate that undergraduates involved in research for multiple semesters report greater perceived benefits, including stronger career outcomes and higher levels of self-efficacy (Bauer and Bennett, 2003; Russell, 2006). Therefore, statistical comparisons between "multiyear" students with prior SOAP experience and "first-year" students without prior SOAP experience are performed using the Mann-Whitney *U*-test, which is the nonparametric version of the Student's *t*-test that is most appropriate for ordinal Likert scale data. The total confidence scale response distributions shown in Fig. 1 indicate that multiyear participants are significantly more confident than first-year participants in performing all SOAP tasks as a whole during each year of the program, with their mean confidence scores increasing 19% on average, ranging from 11% in 2009 to 28% in 2007. These confidence variations are not associated with significant differences between the experience and the interest reported by both groups each year (not shown).

Although the confidence variations are not statistically significant for each task, Fig. 2 shows that multiyear

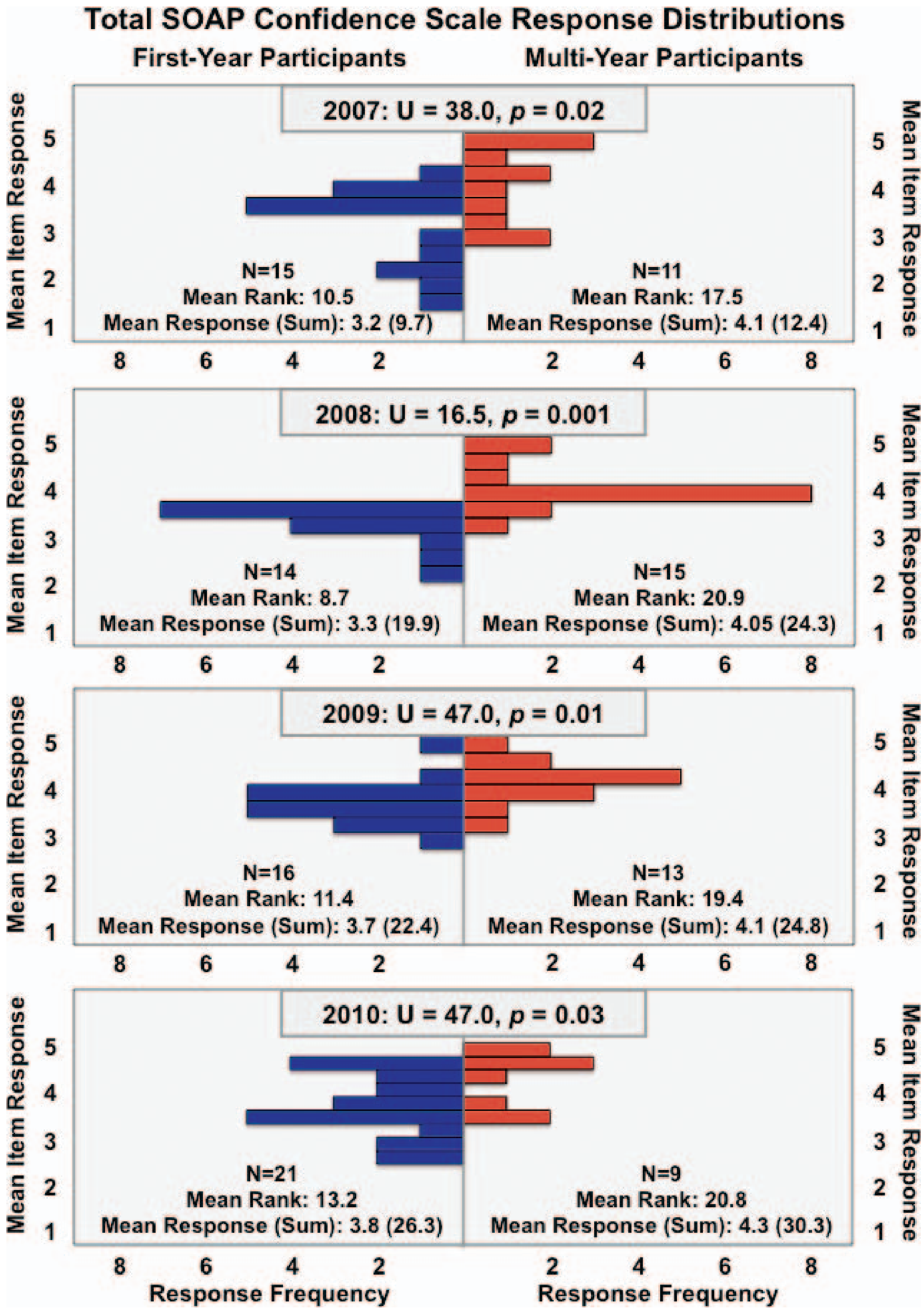

FIGURE 1: Total confidence scale mean response distributions (of the items in Table III that students performed each year) for first-year and multiyear SOAP participants during 2007–2010. Mann-Whitney *U*-test statistics, *p* values calculated using SPSS software, and mean ranks, item responses, and summated scores using three items in 2007, six items in 2008 and 2009, and seven items in 2010 are also provided. Participants responded using a five-point Likert format (1 = no confidence, 3 = neutral, and 5 = very confident).

participants are significantly more confident in operating ADRAD and analyzing radar data than first-year SOAP members during each year, with radar subscale mean confidence scores increasing an average of 25%. These confidence increases are most exaggerated during 2008 (36% increase) when ADRAD was inoperable for several weeks due to technical issues, causing returning SOAP students to have greater cumulative levels of radar experience that likely resulted in their higher confidence levels. Similarly, returning SOAP students are only 16% more confident than first-year participants in performing radar tasks during 2009 because SOAP students in their

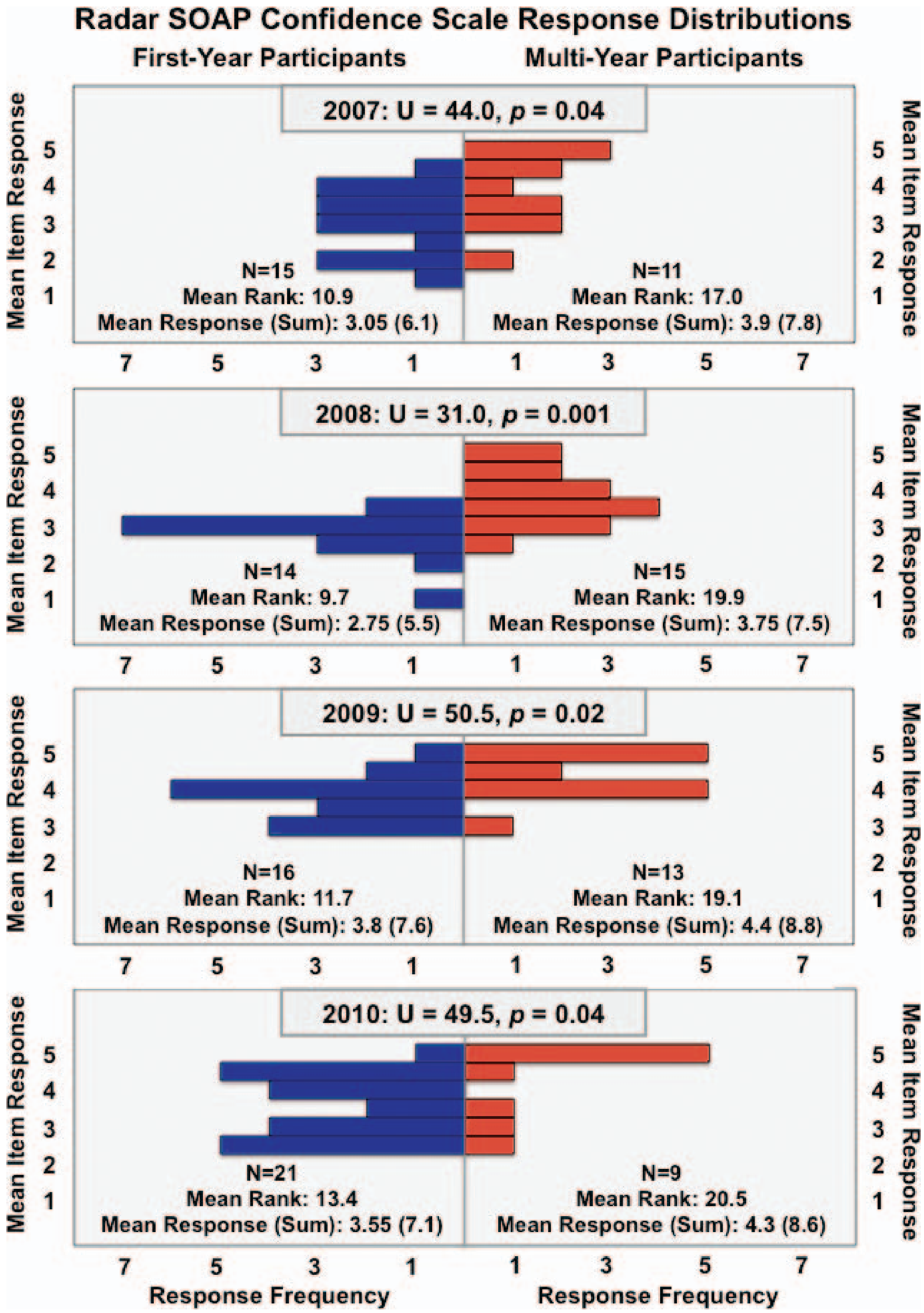

FIGURE 2: Radar tasks confidence scale mean response distributions (of Items 1 and 2 in Table III) for first-year and multiyear SOAP participants during 2007–2010. Mann-Whitney U-test statistics, p values calculated using SPSS software, and mean ranks, item responses, and summated scores fusing both items each year are also provided. Participants responded using a five-point Likert format (1 = no confidence, 3 = neutral, and 5 = very confident).

second year of the program did not have as much prior radar experience to draw from as their counterparts during other years. All of these results suggest that additional student experience with radar operation and analysis is critical to increasing their radar self-efficacy and their confidence in operating and analyzing data collected from specialized research instrumentation.

Participants also indicated their career goals after finishing SOAP, with 65% expressing interest in forecasting occupations, compared to 39% and 34% for research and broadcast meteorology professions, respectively (Table VI). Although many first- and second-year SOAP participants selected multiple career goals, students involved in SOAP for 3–4 y typically narrowed their career goals to one

TABLE VI: Stated career interests of SOAP participants during 2007–2010.[1]

Career Interests of SOAP Participants per Years Participation	1 y ($n = 66$)	2 y ($n = 32$)	3–4 y ($n = 16$)	All ($n = 114$)
Weather forecasting (e.g., private sector, NWS, military)	68%	69%	44%	65%
Research (i.e., graduate school)	36%	41%	44%	39%
Broadcast meteorologist	35%	41%	19%	34%

[1]Students were allowed to choose multiple careers or none of those listed. In addition, some multiyear participants are reflected in multiple student categories depending on which year they completed the survey.

occupation, indicating large decreases in forecasting and broadcast meteorology career goals with slight increases in attending graduate school and pursuing a career in research. In addition, participants interested in research careers generally exhibited slightly greater confidence and interest in performing SOAP tasks than those not interested in research careers, but these trends are only statistically significant for confidence during 2010 and are contradicted by nonsignificant trends of the opposite effect in 2008 (not shown). Although students interested in pursuing research careers were slightly more confident and interested in writing forecast discussions than those not interested in research careers during 2010, students not interested in research careers were significantly more confident in writing forecast discussions and enjoyed doing so more during 2008 and 2009 (not shown). Most of these students expressed an interest in forecasting careers, providing support for Lent et al.'s (1994) finding that self-efficacy affects career goals while suggesting that not all program tasks were strictly geared toward satisfying students interested in research.

Career outcomes of 74 bachelor's degree recipients that participated in SOAP during 2007–2010 were also determined through social networking sites (e.g., Facebook and LinkedIn) and other personal contacts. Similar to the national career statistics presented by Knox (2008) for 624 meteorology bachelor's degree recipients during 2003–2005, 34% of SOAP graduates obtained forecasting careers (39% if broadcast meteorologists are included) and 29% matriculated to graduate programs, primarily in atmospheric sciences (Table VII). Multiyear SOAP participants were twice as likely to obtain forecasting positions after graduation as single-year participants, a result that is statically significant ($p < 0.05$; Z-test for comparing two proportions). In agreement with Bauer and Bennett (2003) and Russell (2006), graduates participating in SOAP for 2 y were 39% more likely to attend graduate school and pursue research careers than were those involved in SOAP for 1 y; those participating for 3–4 y were 65% more likely. In addition, 94% of graduates that participated in SOAP at least 2 y obtained meteorology or science-related employment compared to 69% of single-year SOAP participants, differences that are statistically significant ($p < 0.01$; Z-test for comparing two proportions).

Finally, students were not surveyed on their initial career goals or their experience, confidence, or interest in performing tasks similar to those in SOAP before the program each year. Capturing students' thinking on careers before participating in SOAP would have been beneficial, because undergraduates are in a phase of their lives during which they are continually learning more about career opportunities and assessing their interest and ability in obtaining jobs they may desire. Environmental and involvement variables outside of SOAP may be responsible for some of the participants' changes in career goals and outcomes, including their parents' occupations, socioeconomic status, standardized test scores, prior coursework, participation in other activities (or internships), and peer groups (Astin, 1993). Reliable data on career goals and outcomes for meteorology students who were not involved in SOAP were also not available. However, many students credited SOAP with motivating them to pursue and obtain research assistantships, forecasting, or other scientific jobs upon graduation on departmental exit surveys administered to meteorology students after 2009. Nevertheless, our results comparing single- and multiyear participants in SOAP suggest that repeated exposure to the same type of applied research and educational experiences outside the traditional classroom increases the likelihood that students will remain in science after graduation, which is a retention issue that should be considered as important as graduation and university retention rates.

Comparing the Importance of Interpersonal Interactions for Single- and Multiyear Students

Involvement with and the nature of a student's peer group has been shown to influence student growth,

TABLE VII: Career outcomes of bachelor degree recipients as of summer 2012 that participated in SOAP during 2007–2010.[1]

Career Choices of SOAP Graduates per Years Participation	1 y ($n = 39$)	2 y ($n = 22$)	3–4 y ($n = 13$)	All ($n = 74$)
METEOROLOGY OR SCIENCE OCCUPATIONS	**69%**	**91%**	**100%**	**81%**
Weather forecasting (e.g., private sector, NWS, military)	23%	41%	54%	34%
Research (i.e., graduate school)	23%	32%	38%	28%
Other science occupations (e.g., analyst, technician, teacher)	18%	13.5%	—	14%
Broadcast meteorologist	5%	4.5%	8%	5%
NONSCIENCE OR UNKNOWN OCCUPATIONS	**31%**	**9%**	—	**19%**
Nonscience occupations	15.5%	4.5%	—	9.5%
Unknown occupations	15.5%	4.5%	—	9.5%

[1]Career outcomes of 13 BS degree recipients that only participated in SOAP during 2006, 5 students whose degrees are still in progress, and 3 students who did not graduate are excluded. The table includes 67 meteorology, 4 environmental geosciences, 2 civil engineering, and 1 geology degree recipient.

development, and academic success most during college, followed by faculty interactions, particularly those connected with academic experiences outside the classroom (Astin, 1993). Several students indicated they joined SOAP to interact and work with other meteorology majors or the faculty advisor or because peers or the faculty advisor recommended the program. Indeed, synergy between peers and undergraduate group leaders in performing program tasks and abundant informal student interactions with the faculty advisor or graduate student mentors (cf. Table I) are both critical components of SOAP that undoubtedly contributed to student learning. Although 41% of students said their most beneficial interactions were with the faculty advisor or graduate student mentors (Table VIII), first-year participants were significantly more likely to indicate that their interactions with undergraduate student leaders or peers were most beneficial ($p < 0.01$; Z-test for comparing two proportions). Several students also stated that they would like more interactions with students from other daily groups.

More than one-third of students found working with their peers and undergraduate group leaders to be as beneficial as interacting with the faculty advisor or graduate student mentors. One first-year participant summed up their different roles best by writing that the faculty advisor "taught me a lot of things about radar, and my team taught me things they learned in more advanced classes." Another multiyear participant reported that all interactions were helpful but thought "students learned the most from graduate students coming in and quizzing us because they were seen as an all-knowing person, while the group leaders were seen more as friends." This mentality may partially explain why multiyear participants were more likely to find their interactions with the faculty advisor and graduate student mentor most beneficial, particularly in discussing graduate school or career options. Multiyear students were also more likely to provide high praise for the graduate student mentors and empathize with the demand on the faculty advisor's time, as indicated by a student who wanted more interaction with the faculty advisor but realized "this is not always practical."

Allowing advanced undergraduates to direct less experienced students and assist in the implementation and selection of new program components and research objectives also enabled students to claim some ownership of SOAP. Many students, particularly first-year participants, indicated that peer interactions were as beneficial as those with the faculty advisor and graduate student mentors. Students also coined a program mascot (a rubber chicken appropriately named Rossby after Carl-Gustaf Rossby), developed the SOAP logo and Web site, and often volunteered for extra responsibilities (e.g., meeting at 5 a.m. to launch special radiosondes and overnight radar operations). All of these factors likely contributed to SOAP's 65% retention rate of nongraduating students and many graduating students declaring SOAP as either one of the experiences or the most important experience they had at TAMU on departmental exit surveys.

IMPLICATIONS AND LESSONS LEARNED

This article evaluates undergraduate experiences and impacts from participating in an atmospheric science research and education program (SOAP) and describes the structure, components and implementation of this 1-credit-hour research course at TAMU. Analyzing student surveys and reflecting upon implementing SOAP supports the following conclusions, many of which should apply to all geosciences instead of being unique to atmospheric science:

- Although specific implementation strategies will depend on individual resources and objectives, faculty beginning new research and education programs should establish an organizational framework with clear expectations that their resources and time will allow them to sustain. Faculty should give students autonomy in completing data collection and analysis tasks that all levels of students may perform with appropriate training, solicit their feedback, and encourage them to pursue more advanced research projects.
- Students who participated in SOAP for multiple years were significantly more confident in performing program tasks than single-year participants and were significantly more likely to obtain meteorology or science-related employment upon graduation (94% versus 69%). Although environmental and involvement variables external to SOAP may partially account for these results, they still suggest that research and education programs have a strong influence on students' career outcomes and fostering positive self-efficacy.
- Many students (41%) indicated that their most beneficial interactions were with the faculty advisor or graduate student mentors, but first-year participants were significantly more likely to indicate that their interactions with undergraduate student leaders or peers were most beneficial. Interactions with the faculty advisor or graduate student mentors were more important than or equal in importance to peer interactions for almost all returning students.

TABLE VIII: Most beneficial interactions stated by SOAP participants from 2007–2010.[1]

Most Beneficial Interactions per Years Participation	1 y ($n = 66$)	2 y ($n = 32$)	3–4 y ($n = 16$)	All ($n = 114$)
Faculty advisor or graduate student mentors	36%	44%	56%	41%
Undergraduate group leaders or peers	27%	9%	—	19%
Both (undergraduates and graduate students or faculty)	32%	41%	38%	35%
No response	5%	6%	6%	5%

[1]Students responded to the question, "SOAP incorporates interaction with your peers, group leaders, grad students, and the faculty advisor. Which interaction or interactions were most beneficial to you?" Some multiyear participants are reflected in multiple categories depending on which year they took the survey.

Experiences in implementing SOAP provided many lessons that investigators proposing new research and education programs may also consider. First, figuring out a way to continue the program in some form after the initial funding period expires is critical. Students were concerned about the void that would be left in the meteorology curriculum after SOAP ended in 2010, prompting other faculty in the Department of Atmospheric Sciences at TAMU to implement the original SOAP paradigm into follow-up projects like summer SOAP and the Student Operational Upper-Air Project (SOUP). Students in summer SOAP (TAMU College of Geosciences, 2013) learn radar, upper-air, remote, and in situ observation fundamentals and carry out follow-up investigations during summer semesters. SOUP students launch weather balloon soundings year-round during severe and hazardous weather situations and subsequently send their data to the National Weather Service to assist their forecasts. Both programs incorporate peer-to-peer interactions and accommodate up to 25 students overseen by one or two faculty and graduate student mentors. Funding has come from the College of Geosciences at TAMU to enhance high-impact learning by undergraduates, the National Aeronautics and Space Administration New Investigator Program, and the National Oceanic and Atmospheric Administration and Cooperative Program for Operational Meteorology, Education, and Training (NOAA-COMET) Partners Project.

Second, undergraduate group leaders, graduate student mentors, and the faculty advisor in SOAP had to consider their participants' capabilities, figuring out how to teach meteorological concepts without formal pedagogical training. This study suggests that mentors should be cognizant of their students' confidence in performing research, particularly for students involved in research for the first time who will likely be less confident than students with prior research experience. Balancing the number of novice and experienced students in each daily group while maintaining the regular presence of faculty and graduate student mentors typically ensured that struggling first-year SOAP students received greater assistance. However, administering ungraded assessments before, during, and after the program would better identify struggling students and present an opportunity to evaluate student learning for the program as a whole.

Third, the lack of individual assessments and surveys before and during the program made evaluating students' capabilities and performance in SOAP and attributing its effect on their career goals and outcomes more subjective than is preferred. In particular, we recommend administering longitudinal surveys before the program to better understand students' baseline differences in environmental and involvement factors, career goals, and general confidence, interest, and experience levels. If this is not practical, studying a valid comparison group of undergraduates with reliable datasets would help investigators better distinguish between student gains and changes caused by factors within and outside their program. However, content assessments should be minimized, because many students joined SOAP to gain hands-on learning experiences outside of class and as one student wrote, "learn without the stresses of exams."

Finally, although we had the foresight to assess student-reported experiences in SOAP, these surveys were primarily administered to improve the program and evaluate its impacts on students as opposed to investigating educational research questions. Libarkin and Kurdziel (2001) outline methods for carrying out deliberate educational research similar to the scientific method, with special emphasis on considering how assessments or surveys will be administered (including when and to whom) and analyzed. Charlevoix (2008) suggests that higher education may be required to provide evidence of student learning in the near future; if so, a strong base of scholarly research on teaching and learning is a prerequisite. She notes that Texas has already considered legislation to mandate testing requirements for graduating college seniors that undoubtedly would originate within individual departments, many of which are likely not well prepared for providing evidence of student learning and achievement. In addition, some funding agencies that already mandate an educational component for some proposals may call for more rigorous and deliberate educational research plans in the future. Therefore, sharing and properly assessing teaching and learning in traditional courses and other learning experiences would help universities proactively prepare for such changes while continuing to grow the knowledge base of teaching and learning in the geosciences.

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