

A Pair-Researching Approach for Undergraduate Atmospheric Science Researchers

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The commonly favored and familiar approach for mentoring undergraduate (UG) students in the atmospheric science community has been to match one student with one or more research mentors who are typically faculty, postdoctoral researchers, or graduate students. An alternative pedagogic approach implementing UG student pairings (i.e., pair-researching), which constructs a student–student–mentor group, has been used with success since 2005 while conducting research during a multiweek (i.e., 8–10 weeks) UG summer research program at Hobart and William Smith Colleges (HWS). We have found this approach especially beneficial to bringing greater numbers of rising sophomore and rising junior UG students into our research program.

Pairing students to complete course-related laboratories or projects is not a new concept; however, the approach is not widely used with UG researchers, and discussion of the pair-researching approach is very limited in the education and STEM published literature. Grindstaff and Richmond (2008) used the pair-researching approach with high school students in a multiweek research program and found benefits toward three types of support: social-emotional, social-technical, and social-cognitive. Several articles discuss the approach of pairing a UG researcher with a graduate student during STEM research experiences (e.g., Hutchison and Atwood 2002; Hayes 2018) or the use of the pair-programming approach in the computer science community (e.g., Dyba et al. 2007). Many articles also discuss UG research multidimensional and multitiered mentoring (Pandya et al. 2007; Blake et al. 2013), communities of practice (Wenger 1998), and learning communities (e.g., Zhao and Kuh 2004).

A discussion of the UG pair-researching approach used by the authors, as well as the challenges, benefits, and student perspectives, are shared to encourage the use of an alternative pedagogy when conducting research with UG students within the atmospheric and related sciences.

Pair-researching with undergraduates

Collectively, the authors have mentored 27 collaborative UG student pairings (54 total students) during summer research experiences over 13 years from 2005 to 2017. Our application

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of the UG pair-researching approach incorporates both collaborative and group-supported individual research. The two UG researchers in each pairing typically spend the first several weeks working together on a paired project in collaboration with their mentor (Fig. 1). They focus on identifying, reading, and discussing relevant scientific literature, analyzing data connected to their overarching topic, and crafting their own individual scientific question/hypothesis. As an example, UG paired projects from past summer programs have explored a dataset (e.g., radar, satellite, surface map analysis, NCEP re-analysis) to identify the climatological occurrence of specific weather events (e.g., synoptic fronts, severe thunderstorms, lake-effect snowstorms, atmospheric rivers). The remainder of the summer research experience allows each UG within the pairing to pursue the goal of completing a unique individual project by addressing an original research question that builds upon the paired early summer collaborative effort. This individual portion of the research experience for each UG occurs while maintaining a close partnership with their mentor and the other UG researcher in their pairing.



Fig. 1. Neil Laird discussing the overarching research topic and background scientific literature with a pair-researching group in the first week of their research experience.

Based on our extensive experience using the UG pair-researching approach, we have found each UG in a pairing substantially contributes to the paired research and then often surpasses expectations during their individual research investigation. Interaction between paired UGs has not resulted in conflict or the establishment of leader–follower roles. Each UG tends to bring their own perspective and skills to the pairing to enhance and/or complement those of their research partner. In situations when paired students are more familiar and comfortable with working individually, a transition from collaborative paired research to the related individual research investigations is encouraged sooner by the research mentor. The timing of this transition typically occurs in weeks 3–4 during an 8–10-week summer research program and varies based on UG pairing and research project. The overall effectiveness of pair-researching is aided by a critical design element of an interactive and responsive mentor whereby the UG researchers have daily access to their mentor, who establishes an environment with a sense of “working in collaboration with their mentor” rather than “working for their mentor” (Fig. 2).

Benefits and challenges

Our use of UG pair-researching was initially born to balance the desire to offer more UG research opportunities for deserving students by a limited number of atmospheric science mentors and the reluctance to take on an unmanageable number of individual research projects, thereby hindering the quality of mentoring provided to UGs, especially first-time UG researchers. The execution of the UG pair-researching approach by the authors has continually evolved since 2005, and only recently—after discussion with colleagues and some former UG researchers—did we fully recognize that sharing this pedagogical approach may be beneficial to other UG mentors. In 2018, we solicited nonanonymous feedback via direct email from former UG researchers about their experiences in being a part of a pair-researching group during the HWS Summer Research Program. These former UG researchers are now in various stages of graduate studies and careers spread across the atmospheric and related sciences, as well as a few careers in different disciplines. In total, feedback



Fig. 2. Nicholas Metz working with two paired undergraduate researchers to collect field measurements with mobile rawinsonde system during their research experience.

from 24 former UG researchers was received in response to the open question: “What are your thoughts about your experience of being paired with another student to conduct research during the summer research program at Hobart & William Smith Colleges?” Based on UG researcher feedback and our experience, we have identified benefits and challenges from the perspectives of both the UG researchers and mentors.

While each of the 24 responses featured a unique perspective, the following four benefits of a pair-researching experience were stated repeatedly by the respondents. Students (a) acclimated to a collaborative and comfortable learning environment that mimics the “real world” (i.e., active communication and collaboration), (b) felt as though they were able to accomplish more since two students initially worked together on a project, (c) perceived an environment that was not intimidating and took solace during less productive research periods with another student to share in the same struggles and provide peer support, and (d) felt added accountability given an additional person to brainstorm with besides their mentor.

From a mentor perspective, the greatest benefits for UG researchers largely parallel those identified by students, with the following additional benefits of pair-researching: (a) building confidence and decision-making ability, (b) producing high-quality results in less time, and (c) leading to students being highly satisfied with their research experience.

The greatest benefits of the pair-researching approach for the research mentor are that it

- allows efficient mentoring of fewer research projects (i.e., one rather than two separate projects) while concurrently providing research opportunities for more UG students (i.e., two students per project rather than one);

- contributes substantially to building student cohort within each research group and across summer program; and
- more effectively provides an environment that supports students involved in a research experience early in their UG studies, such as following their first or second year (i.e., rising sophomore or junior).

None of the 24 UG researchers noted challenges in their pair-researching experiences. The authors do acknowledge that there are limitations on evaluating the information provided by former UG researchers about their pair-researching experience since the method used to collect feedback was via nonanonymous email. However, a few UG researchers did speculate on ways difficulties might arise in the design of the experience, such as (a) one student in a pairing taking a substantially greater leadership role in some areas of the paired project given background skill sets, or (b) disagreement about ideas that could lead to unwelcome outcomes or a lack of research progress. The authors have not observed these types of problems with their pair-researching groups, but note that if one of these (or any unforeseen difficulties) were to arise, the research mentor would need to mediate and resolve any issues. If difficulties remained, the best option would likely be to transition each paired UG researcher into their individual project earlier in the summer.

The greatest challenges of the pair-researching approach for the research mentor are

1. deciding on an overarching research topic for each pairing that is (a) interesting and approachable for first-time UG researchers, (b) reasonable in scope to meet the expectation of project “completion” during an intensive summer program, and (c) multifaceted whereby researchers could choose from numerous avenues of investigation that are unique and important contributions to the scientific community. As part of the pair-researching approach, we have found that working with the UG researcher to determine their own research question with guidance from the mentor is a nontrivial effort and should be a substantial portion of the research experience. This allows UG researchers to cultivate ownership of their project and participate fully in the entirety of the research process.
2. achieving a “correct” balance of paired and independent research for each student. This requires close mentorship of each student in the pairing and continued assessment of the dynamics of the pairing. Each pairing may transition to independent avenues of investigation on different schedules based on the overarching research topic they are investigating, decisions on method of research analyses, quality of interactions between students in pairing, and skill sets that each student brings to the research experience.

Direct from UG researchers

We feel it is important for readers to hear directly from UG researchers who have had the experience of participating in a pair-researching group. Here we provide insight from a sample of UG researchers who were part of a pair-researching group as they reflect back on their experience.

- a. “When I was a UG student, I preferred to work on my own. I was apprehensive to be paired with another UG student to conduct research at HWS, and was worried that I would end up doing most of the work. Luckily for me, I am happy to report that my experience working with my wonderful and motivated research partner changed my mind about collaborative research projects. I learned valuable information about communicating with a coworker, the benefits of delegating tasks, the occasional need for patience and understanding, and the importance of being able to trust your team.” (Student A)

- b. "Overall, I really enjoyed being paired with another student to conduct research during the HWS summer research program for several reasons. From a workload perspective, it was helpful to have another student to divide the tasks between. As far as professional development, it was a great opportunity to work on collaboration and communication skills. Personally, this was my first real foray into structured research. After this experience, I had the opportunity to conduct independent projects where I found it could feel isolating and had a higher potential for going through periods where I felt 'stuck' or was spinning my wheels going down a number of dead-ends. Working closely with another student on a project helped to keep from getting 'stuck' for a number of reasons. There was a level of accountability to keep on track, an additional source of encouragement coming from a peer, and another resource to utilize, especially if the mentor is busy or if the student thinks a particular question is beneath the mentor and might be too shy to ask it." (Student B)
- c. "I really appreciated the unique partner approach that was implemented. This was my first internship and the largest research project I had yet to undertake during my education so it's reasonable to say that my confidence in myself as a 'scientist' was underdeveloped. Being able to discuss ideas with my partner not only boosted my confidence but encouraged me to pursue different ideas during our research. As our project progressed, we each naturally developed different interests in our topic. Then, during the second half of the summer, it was valuable to pursue our own ideas and rewarding when we could see how we contributed to a collaborative project." (Student C)
- d. "This was my first formal research experience. Psychologically, I feel that it was better to have someone that was experiencing the same thing with me every step of the way for the first few weeks of the program. We could celebrate our successes and commiserate over the more tedious parts of the project. I feel like having someone with whom I could fully discuss all aspects of the project on my level (rather than solely a mentor-student relationship) helped me to not feel overwhelmed in this new experience." (Student D)
- e. "I had a positive experience with being paired with another student to conduct research during the summer program. I thought it was helpful to have a partner to exchange ideas with and brainstorm when we were just getting started with the project and trying to figure out which direction to take. It was also helpful to be able to ask each other questions and assist each other with small tasks, and if we had a larger problem we could ask our mentor. I think this is beneficial because you can share knowledge with your partner and utilize both of your strengths. This experience definitely helped prepare me for my future career. Throughout graduate school I was constantly working on group projects and it was helpful to have experience in working with others, dividing up tasks, and making decisions when you disagree on something about the project. Also, all of the jobs I am applying for involve teamwork rather than working alone on a project." (Student E)
- f. "As the type of person who likes to work individually, I was initially skeptical about being paired with another student to conduct research. However, I found being paired with another student enjoyable and valuable. Through paired research, I was able to work with other students to brainstorm different ways to approach a problem. I especially valued the experience of cowriting manuscripts and learned a lot about the process of collaborating on papers, submitting papers to journals, and providing feedback to reviews." (Student F)
- g. "As a younger student who had been accepted into the summer research program (rising sophomore), I was very grateful to have another student paired with me for our project. As she was a rising senior, her experience was extremely helpful. It was great to be able to run ideas past each other, utilize our respective strengths to maximize our efficiency, and talk through strategies with another person. When we met with our mentor, it was helpful to have multiple perspectives both asking the questions that we wanted to raise, but also have

- multiple perspectives taking in the answers. Although some may see trying to balance two personalities in one project difficult, I think it was a great way to learn how to work with another person so closely, which is extremely important in the ‘real world.’” (Student G)
- h. “I think that being paired with another student was very beneficial. My first position after receiving my graduate degree gave me the opportunity to work on applied research, and within that context I collaborated with individuals at NOAA labs, universities, and NWS forecast offices. This gave me an opportunity to observe a wide variety of work environments, and I found that the most successful scientists were generally those that were comfortable working within a collaborative environment. Since that first job, my focus has shifted toward operations, where teamwork and the ability to work with a wide variety of collaborators is even more important. Based on my experiences, I think that today’s UG students will rarely, if ever, find themselves working by themselves in a research or operational environment after they graduate.” (Student H)

Summary and discussion

In this article, we have presented an alternative pedagogical approach for the interaction of research mentors and UG researchers. Our experiences have demonstrated the pair-researching approach to be a successful alternative to the typical one-to-one student–mentor approach commonly used in the atmospheric and related sciences.

As mentioned previously, pairing or partnering UG students is not a new concept, especially for academic coursework (e.g., laboratories and projects); however, it appears the approach is not widely used for mentoring UG researchers based on the lack of published education and STEM articles on the topic. Although not adopted by the authors with this in mind, the pair-researching approach has linkage to the think–pair–share cooperative learning technique (Lyman 1981) most often used in a classroom environment. Numerous studies have investigated the use of the think–pair–share technique within a variety of classroom settings, including STEM disciplines (e.g., Vergara et al. 2014; Khatri et al. 2015). An approach similar to pair-researching is most widely used in computer science and is called collaborative programming or pair programming (e.g., Nosek 1998; Williams et al. 2000). Pair programming offers numerous benefits, including (a) higher-quality code/results in less time; (b) greater student satisfaction with the experience; (c) enhanced teamwork, knowledge transfer, and learning; and (d) improved student retention, confidence, and program quality (e.g., Bipp et al. 2008).

The authors have used both the pair-researching approach and the one-on-one approach for UG mentoring during the HWS Summer Research Program. While both approaches have been productive and lead to positive UG research outcomes, we have found more benefits to UG researchers and mentors using the pair-researching approach. It replicates the collaborative nature of conducting a scientific investigation, develops a strong peer-to-peer supportive partnership, and allows UGs to advance more rapidly on their research compared to working in isolation during a one-on-one experience with their research mentor.

Research internship opportunities are steadily becoming more widely available for UGs, but at the same time these opportunities are becoming more competitive to obtain. These opportunities help introduce UG students to the concept and process of conducting research and can provide a more informed, experienced workforce for the broad atmospheric science community; however, from the mentoring perspective, considerable preparation is necessary when proposing, planning, and conducting research interactions with UG students—especially given that these experiences are potentially transformative stepping stones for continued UG studies, graduate school, and a career in the atmospheric and related sciences. The pair-researching approach has the potential to greatly benefit research programs with a limited number of mentors and especially mentors at primarily UG institutions that may not have a

large atmospheric science program or well-established research infrastructure. However, it also has potential for established Research Experience for Undergraduates (REU) programs to provide a greater number of UG research opportunities without an increase in their number of mentors and a relatively small, but worthwhile, increased workload for each mentor toward maintaining quality experiences for UG students. More UG research opportunities would reduce the possibility of overlooking hidden (or unrealized) talent by our scientific community and provide great benefit to our students by having more students experience research. This would allow more students to consider research careers who did not otherwise think they would like—or were unaware of what is involved with—that career pathway. Further, more UG students would develop or enhance research skills (e.g., data handling; data quality control; data analysis, visualization, and modeling; as well as written and oral communication) that they could apply in any number of productive ways in a variety of career pathways.

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