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CUR Focus

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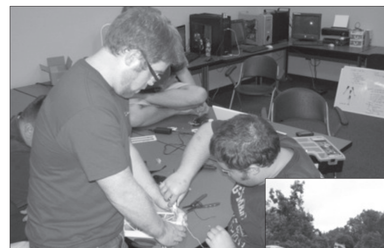
Peer Mentoring at a Space Science Undergraduate Research Program: Students' Voices and Lessons Learned

Morehead State University (MSU) is one of a handful of institutions that offers a Bachelor of Science degree in space science. Its curriculum emphasizes theoretical and hands-on academic preparation in physics, astrophysics, satellite telecommunications, electrical engineering, mathematics, computer science, and wireless technology.

The faculty and leadership of the university's Space Science Center have advocated and implemented a model of peer mentoring in the program, a model partly inspired by the way undergraduate and graduate students interact professionally in California Polytechnic University San Luis Obispo's space systems program, especially its CubeSat group. By implementing peer training and learning at Morehead State, we will produce an efficient way to achieve various space-related, grant-funded project benchmarks, foster engineering skills among the students early in their undergraduate careers, reduce student attrition, and promote a more team-like relationship between upperclassmen and lowerclassmen and between students and faculty.

The Space Science Center's peer-mentoring model includes the following major components:

- Developing a self-perpetuating mentoring system in which mentees become mentors, maintaining the scientific and technical knowledge base in-house, transmitting essential skill sets to subsequent classes, and providing invaluable experience for the students serving as mentors;
- Expecting students to serve as guides, allies, advocates, and role models for other students and the community in general;
- Expecting students to learn from other students and faculty members through direct experience in projects, applied coursework, and personal guidance;
- Transforming the role of faculty members from infallible authority figures to learning facilitators in the tradition of constructivism;
- Integrating student mentors and mentees in realistic (not simulated or scaled-down) engineering-design efforts and systems characterization, since faculty and staff members need to rely on their help to handle the faculty's grant-funded commitments; and
- Focusing on increasing students' confidence and self esteem.



Left: Students work in informal pairs on an orbital deployment system to verify all work done is acceptable, to spot errors, and to combine knowledge and form new ideas.
Right: Students practice operating a mobile satellite Earth station and capturing data packets from an orbiting satellite rising above the horizon.

Space-science faculty assist students in the development and improvement of specific skills, such as systems design, electronic board layout, use of test and measurement equipment, Earth station systems operation, space-mission modeling software, clean-room techniques, systems integration, and pre-flight qualification testing of micro and pico-class satellite systems. Undergraduates are integrated into faculty projects early on. Some of these projects include: (a) operating a 21-meter space tracking antenna for NASA and commercial space programs; (b) designing, assembling, testing, tracking, and operating small satellites; (c) developing Nanoracks and Cubelabs to be used for microgravity experiments onboard the International Space Station; (d) designing and building research payloads for high-altitude balloons; and (e) monitoring active galactic nuclei (AGNs) and extragalactic supernova remnants (SNRs) using radio-astronomy techniques. These projects have led to student authorship and co-authorship of multiple publications and presentations at state, regional, and national conferences.

After completing the mentorship program, and through peer mentoring and team learning, students will be knowledgeable about a number of engineering processes. Some of these include: (a) design reviews (requirements reviews, preliminary and critical design reviews, mission-readiness reviews, and flight-readiness reviews); (b) cost and performance trade studies; (c) numerical modeling; (d) use of space-science computer systems and processes; (e) applications of materials science, space environments, orbital mechanics, and payloads; and (f) how to write and communicate technical information verbally and through documents (design-review reports, interface-control documents, or engineering reports).

In its short history—less than five years—some informal measurements point to the early success of the Space Science Center's peer-mentoring program. These include the findings of written annual performance reviews of mentors and mentees completed by a lead faculty member; a written assessment of each student's effectiveness as a mentor, completed by his or her supervisor; and an assessment of the mentors and mentees related to specific project goals and benchmarks.

The study described below, however, is the first formal, research-based attempt at understanding, capturing, and defining—from the students' viewpoint— the essential characteristics of a successful faculty-implemented, peer-mentoring model. This type of assessment is consistent with Kirkpatrick and Kirkpatrick's description (2006) of the first level of a training evaluation. This first level aims at identifying the students' reaction to the peer-mentoring program, how well it was applied, what areas can be improved, and the students' perceived learning and improved career preparedness.

Peer Mentoring: An Overview

Educational research has documented the essential contribution of "significant others" during the learning process, including mentors (Erickson et al. 2009). Mentors can be defined as non-parental, role-model adults who take a special interest in the personal and academic lives of less-experienced students and who serve as a source of knowledge, advice and support (Jacobi 1991). A subcategory of mentoring is that of peer mentoring, which was defined by Terrion and Leonard (2007, 150) as follows:

> Peer mentoring is a helping relationship in which two individuals of similar age and/or experience come together, either informally or through formal mentoring schemes, in the pursuit of fulfilling some combination of functions that are career-related and psychosocial.

This form of mentorship is non-hierarchical, making communication, mutual support, and collaboration easier (O'Neil and Marsick 2009).

Undergraduate peer mentoring has been successfully implemented in a variety of courses. It is reported to increase social support, coping skills, research abilities, and training in such areas as business, industry, K-12 school teaching, graduate education, and the academic tenure-track (Driscoll et al. 2009; Glazer and Hannafin 2008; Grant-Vallone and Ensher 2000; Santucci et al. 2008).

Research shows that young people tend to benefit from having mentors (Hall 2007; Lahman 1999; Rodger and Tremblay 2003). Didier and Rennie-Hill (1999) described this benefit as a transformative event that enriched the students' college experience and helped them in choosing a major or careers. Ko and Chau (2010) noted an increase in both the mentor's and the mentee's sense of belonging to the academic department. Johnston and McCormack (1997) reported that mentees are informed sooner about "the system" (formal and unwritten policies and procedures), thus avoiding misunderstanding and potentially awkward situations. Ehrich et al. (2004) discovered that peer mentoring improved the effective sharing of content knowledge. Budge (2006) indicated strong intra-group cooperation, more motivation, and enhanced commitment between mentors and mentees.

Of course, peer mentoring is not perfect. Some of the shortcomings of its implementation might include not creating a true collaborative experience (Arrington et al. 2008), not emphasizing the development of theoretical and practical knowledge equally (Amenta and Mosbo 1994), immersing inexperienced students in projects beyond their expertise (Mickley et al. 2003), or not addressing on frictions related to time between mentors and mentees.

Although peer mentoring has been explored in the literature, important gaps exist in this knowledge. For

Students prepare for an Earth station communications simulation exercise by reviewing procedures and verifying each other's work. A senior (right) serves as advisor.

example, few studies have empirically examined how the mentors, especially informal ones, provide support to their peers. Many peer-mentoring programs do not have a formal design and evaluation model in place that helps determine which program strengths to retain or suggests ways to improve the mentoring process (Gosser et al. 2001; Hall 2007).

Methods

The purpose of a study I conducted was to understand how peer mentoring is implemented by faculty and students enrolled in the MSU space-science program. Also of interest are the students' opinions about ways to improve the peer-mentoring process as the cohort of students enrolled in the program increases over time. The following research questions guided this study: How have participants experienced the peer-mentoring process, both as mentors and as mentees? And, how can the process be enhanced?

Four juniors and seniors were asked to participate. At the time of this study, all of the participants were receiving stipends either from MSU's Undergraduate Research Fellowship Program, a popular scholarly opportunity mainly funded by university monies or outside grants (González-Espada 2009) or from Kentucky Space, Department of Defense, and NASA/Johns Hopkins Applied Physics Laboratory contracts obtained by faculty for research or commercial services.

The students received a written consent form describing the project, the standard human-subject protections, and the assurance that the researcher would use pseudonyms to preserve their identities. Data were collected through a semi-structured interview protocol, a standard qualitative research data-collection technique (Rubin and Rubin 2004; Wiersma 2000). Students were asked to describe experiences in which they were peer mentors and peer mentees and to list aspects of the peer-mentoring process that were frustrating to them. They also were asked to assess to what extent faculty members promoted peer mentoring and to recommend ways to make the process more effective. The interviews were recorded to accurately gather the participants' comments. The interviews then were transcribed and prepared for analysis using qualitative techniques suggested by Creswell (2003; 1998) and Merriam (2001).

Research Findings

The Undergraduate Research Experience at MSU. All four students, under the pseudonyms "Jacob," "Michael," "Ethan," and "Joshua" reported a positive but challenging experience as undergraduate researchers. Adjectives they used to describe their research duties included "very rewarding," "infinitely valuable," "a rollercoaster trip," "every day feels like a crash course," and "really neat."

The four participants noted that they felt fortunate to directly participate in intensive, hands-on learning with "really expensive equipment" that most universities do not have. Jacob also noted a synergy between the "academic world" and the "real world" and how that helps students in finding their own niche based on their strengths, making the graduates more marketable. Michael liked that fact that as a sophomore, he quickly went from assisting other students to leading projects and making important decisions related to satellite projects. He also praised the opportunity to present posters and talks at professional conferences.

Ethan was very impressed at the fact that he could collect data from supernova remnants himself to compare with computer models. Joshua commented on the large number of national and international collaborations that allowed students to learn from other undergraduates, graduate students, professional scientists, and "a lot of really big names in the small satellite community." He also said that the fact that there is no graduate program in space science at MSU is an advantage because the undergraduates can become engaged in the nuts and bolts of truly important projects.

The Peer-Mentoring Experience. All the participants reported that they have directly experienced the roles of mentors and mentees during their semesters at MSU. Their description of the dynamics of the program showed faculty members carefully designing open-ended projects in which students applied what they learned and worked together solving problems of practical importance. Students were strongly encouraged to use each other's strong suits to figure out problems, and to prepare careful justifications of design and building suggestions before asking faculty members for guidance. Although peer mentoring was perceived as "an everyday thing" and not an occasional add-on to their academics, several students perceived that it was not a rigid, formal "official" process, but rather more of a "de-facto standard" for upper level students.

Jacob pointed out that mentoring developed trust, friendships, and leadership skills. He also noted that since his roommate is also a space-science major, he was a mentor both inside and outside of the Space Science building, addressing both academic and social issues.

As a mentor, Michael liked the opportunity to help younger students, seeing them go from directed tasks to more independent ones. Eventually, he could "throw them into more complicated tasks" and more interesting projects, he noted. Ethan described how the designated operator of the 21-meter antenna, an undergraduate, trained him on the capabilities, mechanics, operations, and software systems of the instrument. Ethan himself is now responsible for operating the instrument for various satellite missions and radio-astronomy research programs, as well as for identifying who is ready and willing to be trained on the antenna next.

Evidence of the success of the mentoring process, according to Joshua, was seeing first-hand how the group dynamics evolved from mentor-mentee to teams in which all students had their own tasks and required less advice from their peers. In addition, Joshua remarked

Students look on as a faculty member (standing on the truck) prepares to hoist a satellite into the air on a bucket truck in preparation for a communications test of the student-build satellite.

that the peer-mentoring process diminishes some students' feelings of being overwhelmed in situations in which they would prefer "a decent background beforehand instead of getting the [technical] experience while getting the background."

Ethan noted that being a mentee was unlike anything he had experienced before; previously teachers had been the knowledgeable authorities and students followed instructions and worked individually. He liked being mentored by another student because "since faculty might be more intimidating … it is a lot easier to communicate with students." Jacob stressed the fact that as a mentee he belonged to a "support structure" in which making mistakes, even expensive ones, was an acceptable part of the learning process. Another aspect of this support structure was that it allowed mentees to ask questions without feeling inadequate. He added that the support structure helped participants both academically and personally, for example "if somebody has a girlfriend that breaks up with him, or their dog dies, or a family member gets sick."

Michael compared his menteeship to learning a foreign language. He said it felt like "going to another country," where the knowledge "slowly soaked in, coming together at the end." Joshua, on the other hand, used a "sounding board" analogy to describe his mentee experience. He liked the fact that he could engage the peer mentors in back-and-forth discussions.

All four participants expressed positive feelings towards the peer-mentoring experience. Ethan felt a sense of accomplishment because he was able to take some of the workload off his mentor, who was working with one of the antennas. Some of the students also expressed concerns. Jacob said that it was "a bit scary" to feel that he was responsible for the mentee. Both Michael and Joshua expressed disappointment that they were so busy working on priorities and deadlines that they could not do more peer mentoring.

According to the students interviewed, faculty members play a critical role in promoting peer mentoring. Many students mentioned that faculty members required older students to informally mentor younger ones. One of the roles of the professors is to serve as a resource to answer questions if the students cannot figure something out. The professors also dealt with "half-baked" ideas that had not been thoroughly examined. Joshua said that on several occasions as the students proposed a solution to a problem, a professor would "tear it apart," "point out every little flaw in it," and "send you out to come up with a better solution." Eventually, the team would arrive at a viable solution and be able to address any potential flaw in its argument. Joshua admitted that this approach helped him learn better than having the professor tell students the correct answer. A third role of faculty members was to assess whether, after the peer-mentoring process, students were ready to operate the equipment or to make design-level decisions related to the various satellite-development programs under way at the Space Science Center.

Curiously, although the space science program is designed to promote working in teams, give students independence, and develop problem-solving skills, faculty members were sometimes perceived as a bit "hands-off." This perception is not uncommon and is consistently reported in the literature by students who are experiencing inquiry as an instructional approach for the first time.

Frustrations of Peer Mentoring. Even though the participants strongly endorsed peer mentoring, the process was not seamless. Jacob and Joshua agreed that it was frustrating to deal with students who did not have a good work ethic. They perceived that students with intelligence and potential who are unwilling to work hard or who leave the program altogether are missing an excellent opportunity that could lead to a successful future career. Jacob added that occasionally two mentors taught a student contradictory things. Michael found it frustrating that some of his ideas for scientific work were shot down during brainstorming sessions.

Ethan recognized that all the students involved were undergraduates and thus often did not have a high level of competency in specific aspects of space-systems design. He said he sometimes felt that, since they were all learning as they went along, they were travelling in the dark with respect to some technical detail or area of knowledge. Ethan noted that he was not a professional teacher, so learning how to communicate accurately and become a good mentor took time and effort.

Participants' Recommendations. Despite a consensus for keeping peer mentoring in its current form, the participants did identify areas for improvement. Michael, Jacob, and Ethan suggested making the peer-mentoring system slightly more structured, with more explicit roles and responsibilities. This structure, they said, should not be so rigid as to present peer mentoring as a task that must be done, but rather to structure it as something that comes naturally out of the students' willingness to help and move the program forward. Jacob noted that being a mentor is "a social thing as much as it is a learning or work thing."

Jacob suggested that faculty members should ensure that if an upperclassman wants to assist in peer mentoring, he or she must be "seriously vetted," that is, the students must have demonstrated the content knowledge, technical skill, and personality traits that will prevent lowerclassmen from being confused or misinformed. Jacob also suggested more involvement and oversight from faculty members in order to catch problems early on before they became frustrating and affected group dynamics.

Michael, Ethan, and Joshua proposed integrating students into projects as soon as possible to ensure hands-on learning and more awareness of the projects currently under way. There was no consensus for how early this should occur. Michael suggested that students in their sophomore year were ready for the peer-mentoring experience. Joshua and Ethan said that some first-semester freshman students were up to the task of working with project teams.

Ethan suggested expanding the role of the peer mentor from a strictly academic one to a role in which the mentor could help underclassmen adjust to college life. Other suggestions included making brainstorming and progress meetings more orderly and productive (Michael), and having students from the space-science program live together on campus, a "cohort" system that could improve team cohesion and friendships (Joshua).

Although not explicitly verbalized, a few additional issues seemed apparent from the interviews. First, many of the participants appeared to experience tensions in balancing their course loads, their project work, and their peer mentoring, especially in the face of looming deadlines. They mentioned working late at night and on weekends and reported feeling overwhelmed sometimes, probably because the Space Science Program is very young and still does not have a large number of upperclassmen who can keep the projects' work load manageable. One recommendation might be to make sure that project work is distributed more evenly among as many students as possible.

Second, although faculty members are implementing what is essentially identified in the science-education literature as a "project based learning" approach rooted in "open inquiry" instruction, it is very likely that they have not examined the wealth of science-education research informing these strategies. It is recommended for faculty members and students involved in peer mentoring to become familiar with the basic tenets of project-based learning and open inquiry.

Limitations and Conclusion

This study aimed at answering two research questions: How have participants experienced the peer-mentoring process, both as mentors and as mentees? And how can the peer-mentoring process be enhanced? Interview data strongly suggest that, in general, the participants are enjoying their peer-mentoring experience and perceive that they achieved meaningful theoretical and practical learning. They spoke very positively of the program and the projects they worked on, the support of their peers and faculty members, and the level of independence that they felt.

Left: Students develop personal and professional bonds by working in harsh weather conditions, such as winter outdoor activities requiring the operation of mobile Earth stations.
Right: Students inspect a Terrier-Malemute sounding rocket on the launch pad at NASA's Wallops Island Flight Facility. The rocket carried a student-built suborbital satellite into space in March 2010.

The participants would not significantly change the program or their role in it, but did provide a number of recommendations to make the process and their academic experience more enriching and less stressful. As the program grows in enrollment and matures, many of the participants' recommendations will surely be considered and implemented.

Since this study relied solely on the views of participants, future research might include interviews with faculty members and classroom observations comparing the conceptualization and the implementation of the peer-mentoring model. The use of multiple sources of data, known as triangulation, has the potential to reveal important details about how the undergraduates experience the mentoring process. Also, the study of participants could be replicated with random sampling and a larger sample size.

Despite some limitations, this study suggests that the first iteration of the peer-mentoring model at the Space Science Center was successfully implemented, thanks to a series of changes. Faculty members moved from being passive lecturers to facilitators in an open-inquiry, project-based context. Students moved from being passive listeners and recipients of ideas to creating ideas

Mentors and mentees react joyfully to the reception of data packets from their satellite during the sub-orbital mission launched from NASA's Wallops Island facility in March 2010.

and becoming hands-on collaborators who can make decisions and build complex devices while working as a team. At the center is the idea that faculty members can create a learning environment in which students can teach each other, learn from each other, build from each others' strengths, and make mistakes that can provide faculty members with teachable moments.

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