Assessment of Educational Expectations, Outcomes and Benefits from Small Satellite Program Participation

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ABSTRACT

This paper begins to characterize the educational outcomes that can be produced from student participation in a small spacecraft development program. We asked students what benefits they expected to receive from program participation and we asked them, at the end of the semester, what benefits they had received. We also characterized student performance through the use of post-participation Likert-like scale questions and the use of a widely-used questionnaire for assessing student research participation outcomes. We compare benefit expectation and attainment, characterize the level of benefits received across multiple types of participation and assess the effect of program participation on subject-specific learning. We also discuss plans to expand this study to a wider-scale analysis of the impact of small spacecraft participation.

INTRODUCTION

The use of small spacecraft development programs has been used as part of the pedagogical approach in numerous fields of education; however, the impact of this – from an educational perspective – has received little scrutiny. This paper presents work conducted at the University of North Dakota, as part of an exploratory study to begin to characterize the educational outcomes that can be produced from student participation in a small spacecraft development program.

To this end, across multiple semesters, we asked students what benefits they expected to receive from program participation (upon program entrance or at the start of the semester) and we asked them, at the end of the semester, what benefits they had received. We also characterized student performance through the use of post-participation Likert-like scale questions and through the use of a widely-used questionnaire that assesses outcomes of student research participation. For students participating in the project as part of a project management class, we also assessed gains in subject material knowledge using a pre- and post-test methodology.

We compare the expectation of benefit receipt to benefit attainment, the level of benefits received across multiple types of participation (senior design project, independent study course, experiential learning course, class-component project and extracurricular enrichment) and assess the effect of program participation on subject-specific learning. We also discuss how we plan to expand this initial study to a wider-scale analysis of the impact of small spacecraft participation on students' educational experience and careers.

BACKGROUND

This section provides a brief review of prior work in two relevant areas: small spacecraft development programs and project-based learning education.

Small Spacecraft Development Programs

Small spacecraft development is as old as spacecraft development itself: mankind's initial spacecraft, Sputnik, with a mass of approximately 90 kg, was well within many definitions of a small spacecraft.[1] More recently, a class of small spacecraft – CubeSats – have generated significant interest in small spacecraft development. In 2013, approximately 80 CubeSats were manifested for launch, over a three-fold increase from 2012.[2] This was also a significant percentage of the small spacecraft launched in 2013.[3] CubeSats have found continued uses in education, as well as being used for science[4, 5], government / military[6, 7] and commercial[8, 9] missions. Low-cost[10, 11] and free-to-user launch services (such as those available from the U.S. Air Force[12], NASA[13] and ESA[14]) are driving greater access to space and interest in small spacecraft development.

Project-Based Education

Project-based learning (PBL) also has deep roots: the apprenticeship style of learning[15, 16] has been commonly used throughout history. PBL and other experiential learning styles have generated interest from the benefits that the departure from the traditional lecture-based style of education brings. PBL has been shown to be effective across multiple age levels[17, 18], in numerous fields of study[19] and across multiple education types (course, independent / directed study, senior design, extramural enrichment, etc.)[19]. It has been shown to improve students' creativity[20], motivation[21], self-image [21], knowledge understanding[22] and retention[23] as well as aid preparation for workforce entry[22] and job placement [24].

A BRIEF OVERVIEW OF THE OPENORBITER PROGRAM

The OpenOrbiter Small Spacecraft Development Initiative (OSSDI) was launched in 2012 as an offshoot of a thematically-similar precursor program. OpenOrbiter seeks to develop and demonstrate the efficacy of the Open Prototype for Educational Nanosats (OPEN) designs[25]. OPEN aims to develop a framework for CubeSat development allowing universities and others to create spacecraft with a parts cost of $5,000 or less[26].

Student participation in OOSDI is through participation on topic-specific teams. Each team has a student team leader and a faculty mentor. Students have participated in a variety of contexts, including for academic credit (course project, senior design), extracurricular enrichment and as paid workers.

ASSESSMENT OF EDUCATIONAL BENEFITS

This section considers the educational benefits achieved by students. It begins by considering students' expectations and then assesses whether these expectations have been attained. The educational impact is then characterized with a, subsequent, particular consideration of the impact of program participation on undergraduates. Finally, the impact of the program, from the perspective of a commonly used undergraduate research assessment tool is presented.

Expectations

Student participants were asked what types of benefits that they expected from program participation. They were asked to identify what areas they would like to receive benefit in from a list including[27]:

- Knowledge about spacecraft design
- Knowledge about structured design processes
- Knowledge about a particular technical topic
- Knowledge about project management
- Knowledge about time management
- Leadership experience
- Improving technical skills
- Improving time management skills
- Experience working with those from other
- disciplines
- Real-world project experience
- Item for resume
- Improved presentation skills
- Inclusion as author on technical paper
- Experience working on a large group project
- Experience with a structured design process
- Experience related to a particular technical topic
- Project management experience
- Time management experience
- Improving leadership skills
- Improving project management skills

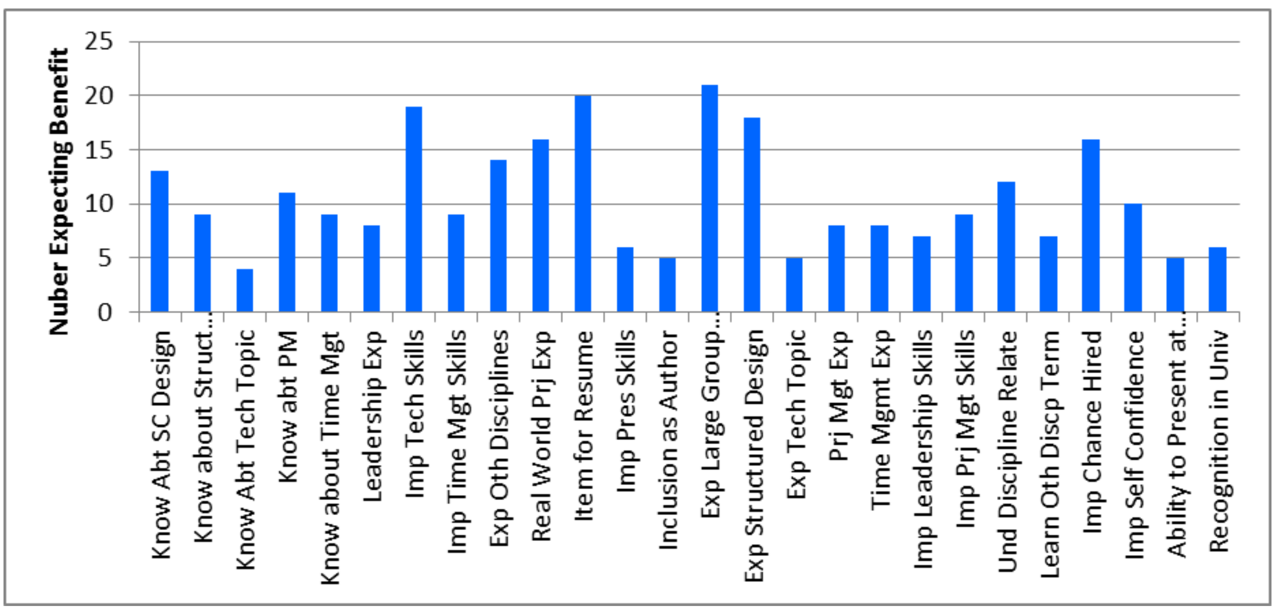


Figure 1. Benefits Sought by Participants.[27]

- Understanding of how my discipline relates to others
- Learn other discipline's technical
- details/terminology
- Improved chance of being hired in desired field
- Ability to present at professional conference
- Ability to present at professional conference
- Recognition in the university community

Their responses are presented in Figure 1. Note that these responses span a wide variety of different expected sources of value. Students were also asked why they were participating and these results were correlated by level (undergraduate versus graduate). These are presented in Figure 2, demonstrating that primary interest stems from participation in their particular technical area and students' excitement regarding space.

Attainment of Expected Value

At the end of a semester of participation, students were asked to identify the benefits that they had received from the same list. These were correlated with students expectations. A comparison of the benefits expected and received by students is presented in Figure 3. A correlation between the top benefits expected and received is presented in Figure 4. Note the generally strong correlation between benefit expectation and receipt in Figure 3. This correlation is less pronounced in Figure 4, as students were asked to identify the top benefits that they expected and received. Thus,

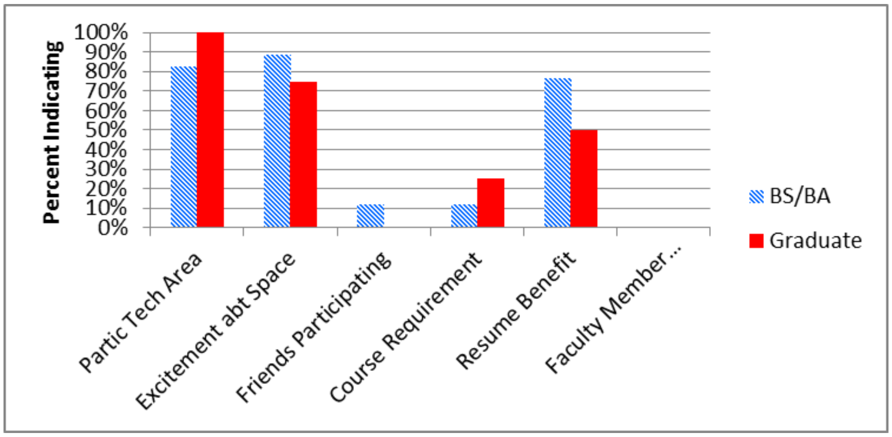


Figure 2. Reasons for Participating.[27]

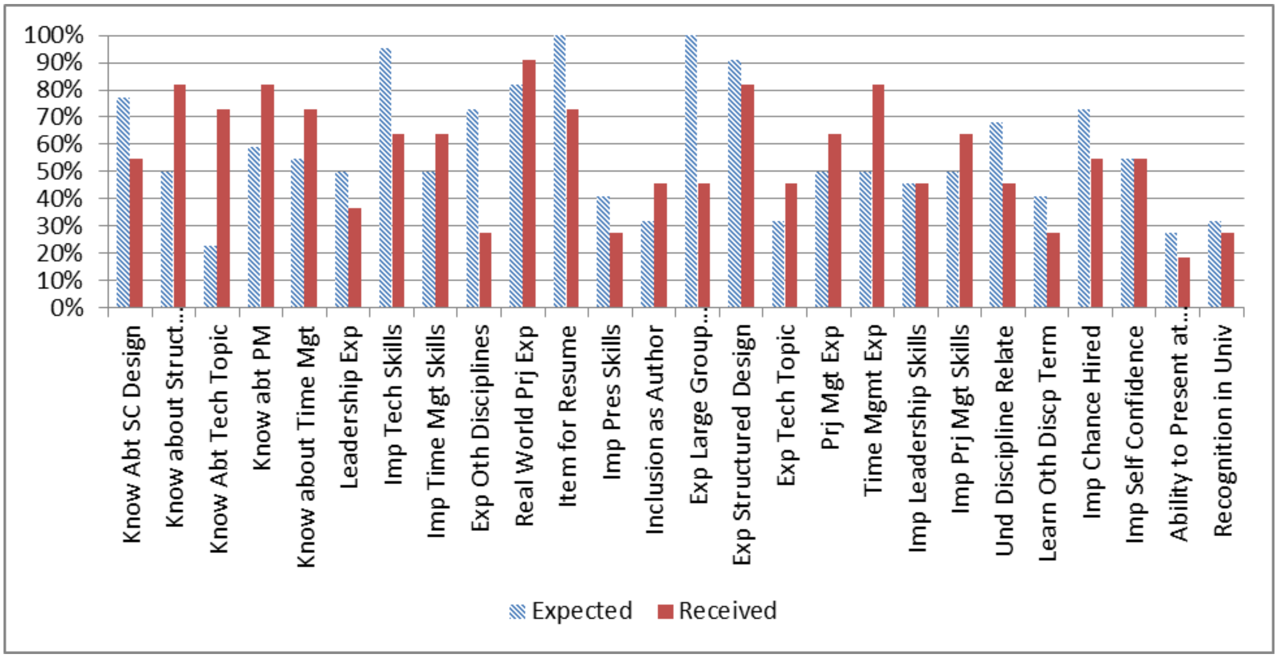


Figure 3. Benefits Expected and Received.[29]

discrepancies between expectations and attainment don't necessarily mean that the top benefits that were desired were not received (in fact, Figure 3 suggests that most benefits desired were – in fact – received), but instead that other benefits were more pronounced.

Educational Impact

In assessing educational impact, focus was initially placed on five areas (and later expanded to several others, based on respondent feedback). In Figure 5, the percentage of undergraduate and graduate participants showing improvement in each area is presented. The average level of benefit (based on a 7-point assessment scale) is presented in Figure 6. From these figures, it is clear that the primary areas of benefit enjoyed by student participants were in their technical skill area and spacecraft design. Undergraduates also evidenced significant improvement in their excitement about space. The improvement, for those who attained it, was significant, ranging between 1.5 and 2.5 (out of a seven-point scale, so approximately 20% to 35% of the scale) for technical and spacecraft design skills, space excitement and presentation comfort.

Impact on Undergraduates

While a limited consideration of the differences in impact between graduate and undergraduate students has been provided by their separation in several prior figures, the benefits to undergraduate students were also separately characterized. In Figure 7, the average level of improvement for undergraduates is characterized, comparing team lead and non-lead participants. This

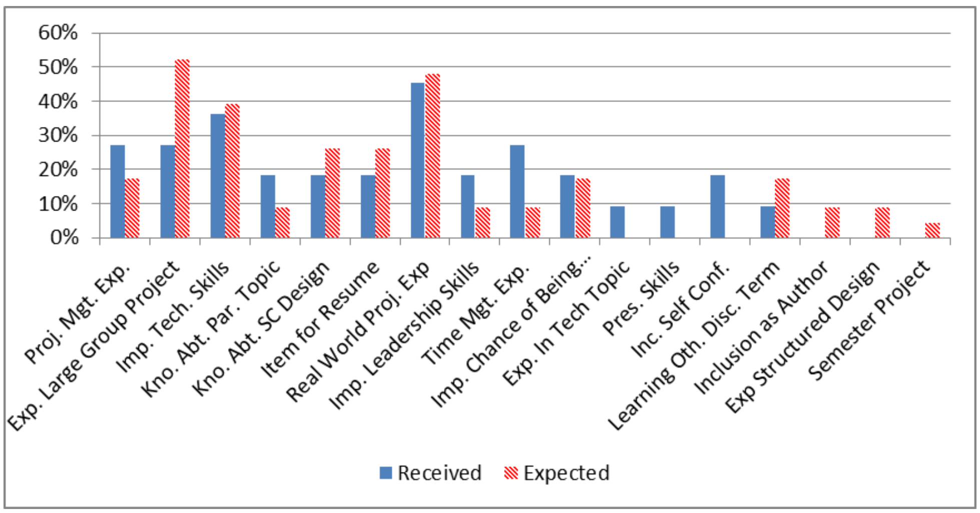
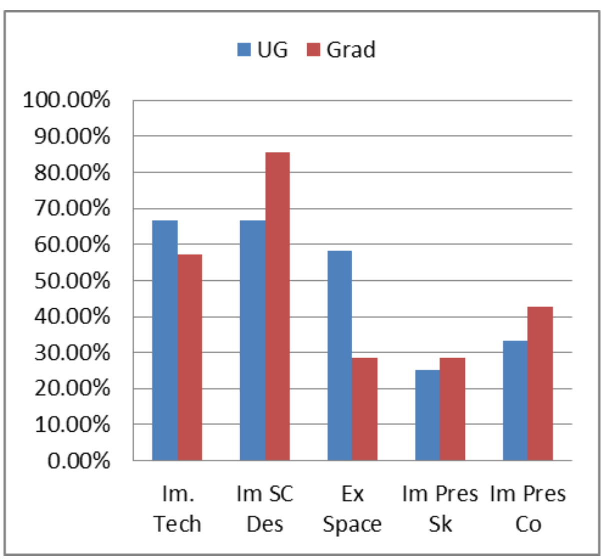


Figure 4. Benefits Expected and Received (similar categories combined).[29]



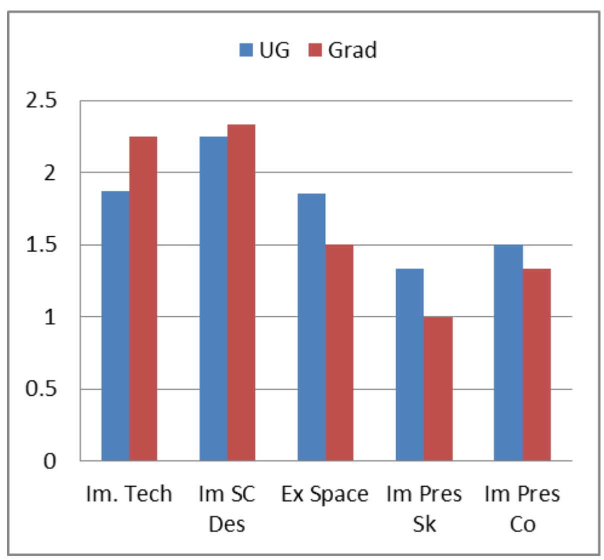


Figure 5. Percentage of Students Improving in Each Area (left).[18] Figure 6. Level of Improvement for Students Showing Improvement in Each Area (right).[18]

demonstrates that leads enjoyed a higher level of average benefit as well as a higher level of benefit attained, when benefit was attained in the category. It is unclear, however, whether this is due to the particulars of the lead position, the greater commitment (and work levels) generally exhibited by leads or a correlation between factors that lead to individuals undertaking the team lead role and the level of benefit attained.

Research Outcomes

Using the Undergraduate Research Student Self-Assessment (URSSA) mechanism[28], the impact of participation was characterized. One area of particular interest is the increased confidence provided by participation. Students were given categories to respond to, in this regard:

2.1 Confidence in my ability to contribute to science.
2.2 Comfort in discussing scientific concepts with others.
2.3 Comfort in working collaboratively with others.
2.4 Confidence in my ability to do well in future science courses.
2.5 Ability to work independently.
2.6 Developing patience with the slow pace of research.
2.7 Understanding what everyday research work is like.

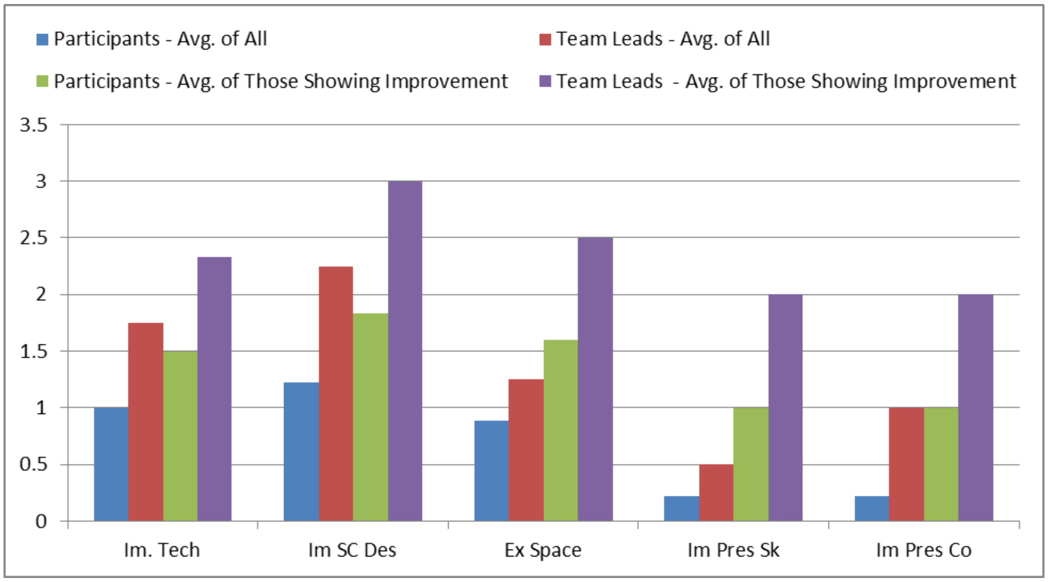


Figure 7. Comparison of Improvement by Status for Undergraduates.[30]

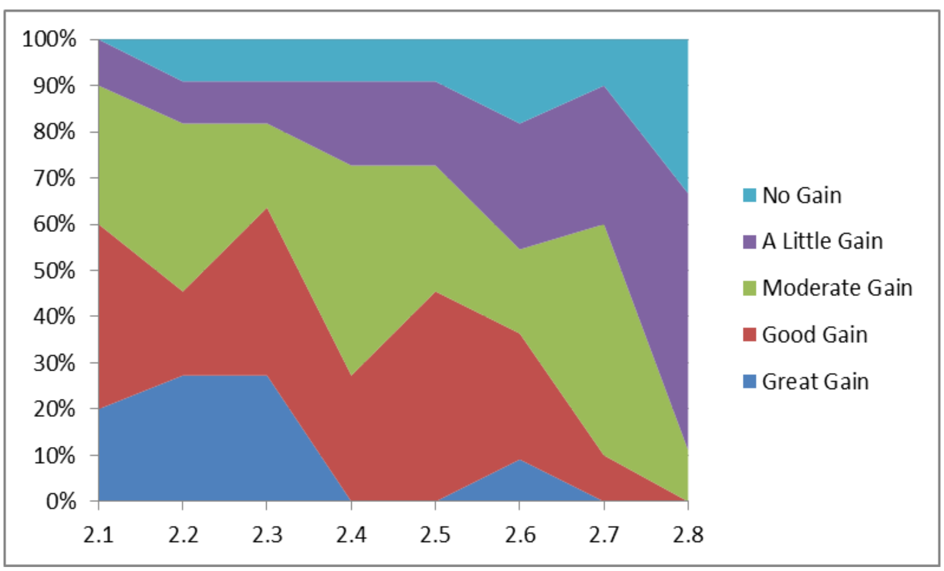


Figure 8. Comparison of Improvement by Status for Undergraduates.[31]

2.8 Taking greater care in conducting procedures in the lab or field.

Their responses are presented in Figure 8. Notably, 90% of respondents indicated at least moderate gain in confidence in their "ability to contribute to science", with 100% evidencing at least some gain in this area. In six of the eight areas, 90% or more of respondents indicated at least a little gain, and at least 70% of respondents indicated moderate gain in most of the areas.

CONCLUSIONS

This paper has presented an overview of the work performed related to the assessment of the benefits attained by student participants in small spacecraft development programs. It has utilized the University of North Dakota's OpenOrbiter program to demonstrate how this evaluation can be performed and to collect preliminary data. The data presented has demonstrated the positive effect of this type of a program and the prospective efficacy of the analysis techniques.

FUTURE WORK

Two areas of future work are planned. This will include continued work on the assessment of small spacecraft development programs, using similar techniques but on a larger (national / international) scale. Another area of focus is on the assessment of student benefits specific to the small spacecraft software development area, in conjunction with a Research Experience for Undergraduates program that will be conducted at the University of North Dakota (with NSF / Department of Defense Support) over the course of the next three years.

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