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Involving Undergraduate and High School Students in Research: Opportunities, Challenges, and Rewards

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Abstract
Historically student involvement in research at Universities and Colleges has primarily revolved around those in graduate programs. However, the NSF's *Research Experience for Undergraduates* program and ABET's evaluation criteria regarding undergraduate participation in research are examples of efforts and initiatives over the last decade to target and include undergraduate students in research efforts. Going one step further would be including high school students in such efforts. This paper summarizes efforts, experiences, and initiatives over the last six years at the UNLV Transportation Research Center to include undergraduate and high school students in research projects and lessons learned from the same – including examples of potential benefits and concerns. The paper also addresses innovative strategies and opportunities to fund high school students participating in research activities during the summer break.

Introduction

For well over the last half a century, the primary focus of student involvement in engineering and computer science research programs has been at the graduate level. The reasons for primarily targeting graduate students for inclusion in research programs and activities include the following:

- Programmatic emphasis on education and research at the graduate level as opposed to t the undergraduate level.
- A need for specific background, skills, and knowledge (e.g., successful completion of a certain set of courses or undergraduate degree).
- Perceptions or expectations regarding greater dedication, drive, and motivation among graduate students (when compared to those of undergraduates).
- Perceived levels of greater maturity and sense of responsibility of graduate students.
- Limitations posed by available or targeted resources (e.g., funding, space, equipment, etc.).

Some of the aforementioned reasons or "constraints" can be addressed or remedied through creative programming or by broader thinking. Based on the objectives and context of a research program, others can be overcome - although this might require significant changes in mindset, policies, and practices. With the current practices, in certain other settings and contexts it may be more difficult to overcome some of these concerns. Thus, there is a pressing need now to

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rethink some of the aforementioned "constraints" as being "normally accepted practice" in the academe. It is indeed time to re-evaluate the validity or meaningfulness of such reasons and concerns regarding the traditional approach to primarily involve only graduate student in research endeavors. Why is it necessary to limit student participation in research activities to graduate students? For example, are there not aspects of a research program that do NOT require graduate student standing (and the associated knowledge, skills etc.)? Are there not skills and knowledge levels that non-graduate students possess that will enable them to contribute to research efforts? Are there not skills and knowledge that non-graduate students can learn "on the job" working on research programs that will enable them to make meaningful contributions? What are the implications of including non-graduate students in research?

Indeed, a reexamination of the students targeted for participation in research has been underway in the recent past. The National Science Foundation's (NSF) *Research Experiences for Undergraduates* program and the Accreditation Board for Engineering and Technology (ABET)'s evaluation criteria including undergraduate participation in research are examples of efforts and initiatives over the last decade to target and include undergraduate students in research efforts [1, 2]. Thus, the trend to involve undergraduate students in research in engineering programs is relatively recent – perhaps, over the last decade or so. While such initiatives have helped include undergraduate students in research activities, including high school students in research programs has been extremely limited.

The remainder of this paper summarizes efforts, experiences, and initiatives over the last six years at the UNLV Transportation Research Center to include undergraduate and high school students in research projects, and lessons learned from the same. The paper also will address innovative strategies and opportunities to fund high school students participating in research activities during the summer break.

Motivation

The reasons to include undergraduate and high school students in research efforts are many. In cases where research efforts in Engineering or Computer Science require students with undergraduate degrees, or even Masters degrees, opportunities to include others may be limited. However, not all research efforts require such backgrounds of students. In such cases, the following is a list some possible reasons to include undergraduate and high school students in research:

- Limited access to qualified graduate students
- Potential to attract and recruit promising students
- Excite students about research, research outcomes and their significance to society
- Enhance retention of students in the program
- Satisfy funding organization requirements
- Obtain resources that may be dedicated to such purposes

Sometimes it may be the lack of access to qualified graduate students that leads faculty to seek out undergraduates. This may be typical in new graduate programs, or some universities where a significant proportion of graduate students are part-time students. The latter is typical of

"urban" programs where the graduate courses typically are scheduled to attract students who work "full time" or close to full time.

The potential to attract promising students to pursue a certain discipline of study is an important motivating factor to target undergraduate and high school students or participation in research programs. For example, one may pursue high school students to attract them to undergraduate programs, or promising undergraduates to choose an area of concentration in a particular field, or even to attract such students to graduate programs. In this regard, while "fundamental" or "basic" research may be more appealing to the academically gifted students, "applied" research is likely to be more appealing to others. This is NOT to state that applied research may not be of interest to the academically gifted students, or that basic research may not be of interest to those who are not academically gifted.

The prospect of influencing students to continue, and complete, their education is another motivation to target undergraduate and high school students for participation in research activities. This is particularly important for students who do not recognize their own potential, or who may have limited information to visualize their future potential. Affording interesting and meaningful research experiences to students who are not necessarily at the top of their classes, but who have the potential to make valuable contributions often makes a significant difference in their career path and lives. In some cases, such experiences are vital in helping students identify their interests and in helping them attain their potential. Examples of such situations include students who are among the first in their families or peer groups at their educational levels, and who may not have "mentors" or "role models" to help guide them. In particular, experiences that help students link their educational background to research efforts, and those which help them recognize implications of the outcomes of their research effort are powerful tools for recruitment and retention. As can be imagined, this consideration has not only scientific and technological benefits, but also tremendous long lasting social and economic implications. Further discussions on the benefits of helping such students continue and complete their academic program - at least the program they are pursuing – is beyond the scope of this paper. Such efforts are also important for attracting students and to improving retention.

Some stakeholders, sponsors and funding agencies influence the inclusion of undergraduate or high school students in research programs. The decision to include undergraduate and high school student is then driven by such conditions, requirements, or expectations of such individuals and organizations. Examples of such expectations, conditions and requirements include accreditation considerations (e.g., ABET criteria), specific / targeted research opportunities (NSF's Research Experiences for Undergraduates).

A discussion of some operational strategies to include and financially support undergraduate and high school students in research efforts is presented next.

Operational Strategies

Undergraduate and high school students can be provided research experiences in many ways. Exposure to research may range from a research paper or project that accounts for a portion of a course's requirements to volunteer efforts on organized research projects, to participation for

remuneration on organized research programs. These may consist of individual or group efforts. While course based requirements do provide some research exposure, students gain limited experience in conducting research on such efforts. The focus of this paper is on more substantive student participation in research efforts. In this paper, substantive efforts are defined as those which require a minimum of least 200 hours of effort per student – i.e., equivalent of about 5 full-time weeks of work.

Undergraduate and high school student participation on substantive research efforts may come in the form of volunteer efforts or on efforts for which the student receives monetary compensation. In either case, it is important that the students be provided appropriate and challenging assignments, access to necessary resources, opportunities to ask questions and provide input, good guidance, plenty of encouragement and support, and timely feedback. It is possible that there could be differences in motivation between those who participate as volunteers and those who get paid for their efforts. Typically, it may be expected that students who get paid are likely to be more accountable and responsible. An important reason for this may be that not performing satisfactorily could lead to being dismissed from the position, and a consequent loss of income for those who get paid and the volunteers do not have a similar consequence. However, the degree of interaction between the student and other members of the research team, the appeal of the research assignment to the student, and the ability of the faculty member to excite the student all play important roles in the degree of responsibility and accountability exhibited by the students.

High school and undergraduate students who work on research projects and programs at universities need to be provided opportunities that are not only exciting and appealing to them, but also those which help them develop new skills, acquire new knowledge, and apply the same in appropriate context. It is important to incrementally build the confidence of first time participants on such efforts. Assigning them increasingly complex tasks – but starting with small, tangible assignments – can help in this regard.

On tasks where students work on teams, it is important to start by first clearly identifying individual responsibilities, and subsequently gradually moving them on to situations where they are able to identify and assign individual responsibilities. An effective strategy to help undergraduate and high school students understand their roles on large complex projects is to hold a meeting of the entire team to discuss the broad overview of the project including its goals and objectives, and the proposed research approach. Discussions at this meeting should also include assignment of teams to work on individual components of the project, and how these components relate to each other. This is to be followed by meetings with individual teams to discuss in detail the activities of the team.

Teams should be established with care to ensure that the “new” participants, especially the undergraduate and high school students, are placed on teams with more “senior” participants who have the skills and abilities to encourage and support the new comers. The “senior” participants may be undergraduate, masters or doctoral students, post-doctoral researchers, professional staff, or faculty members. The senior participants and the faculty member would share the responsibilities to “guide” the new student. These responsibilities include identifying

any necessary skills and knowledge necessary to complete the assigned task, and ways to acquire the same. Oftentimes, when the new participant is guided by another more experienced / knowledgeable student, the learning and retention process is less intimidating and more efficient than when the new student has to learn the material independently or by working individually with a faculty member.

Regardless of the type of assignment given to the student and whether the student is working on it as an individual or as a member of a team, the student needs to be afforded opportunities to be exposed to various aspects of a research project. Examples of key aspects of research activities include problem identification, review of the literature, developing hypotheses, identifying necessary data and information, designing experiments to obtain the necessary information, conducting the experiment, obtaining the data, data validation (quality control and assurance), data management and analyses, model development, evaluation of results, synthesizing the findings. If practical, providing the student opportunities to participate in more than one project would useful in exposing the student to different types of research projects and to different research partners – both individuals and organizations.

While it may not be practical or possible for students to experience first hand all of the aspects of the research program in a short summer session, it is important that they be made aware of the importance and significance of these components of the program. However, it is imperative that the students be provided first hand experiences on at least a few of these components. In addition, they should be required to participate in periodic research meetings, and also to prepare and present verbal and written reports. They should be included not only in internal research team meetings, but also as appropriate in meetings with sponsors, clients, and other stakeholders external to the research team. Yet another strategy to expose the students to the practitioners and other researchers is to take them along to appropriate professional meetings and seminars – especially those that have dynamic speakers, topics that would be exciting or appealing to the students. It is important that the students meet at least a few prominent individuals. One strategy in this regard is to require that the students introduce themselves or have someone introduce them to such individuals, and for the students to come back with business cards of a of specified minimum number of individuals, say 5 business cards.

In addition to providing the undergraduate and high school students first hand research experience, it is important that the students also be helped to develop other "non-technical" skills that are important not only for success in student lives, but also for success and productivity as individuals or members of a family, as employees or employers, and as members of the society. Such non-technical skills include the following:

- Communication skills (reading, writing, listening, and speaking)
- Work place and societal etiquette – attire, telephone
- Accountability and responsibility
- Interpersonal skills (working on teams)
- Leadership skills
- Resource management (time, money, equipment, personnel, etc.)

Funding and Resource Procurement

While volunteer participants in research efforts do not need to be paid, their participation still requires other resources to help them make meaningful contributions. Examples of such resources include physical space (desk, seat, storage, etc.) computing resources, equipment, travel funds, etc. In addition, funds are necessary to pay students who receive "stipends" or financial compensation. Other resources required include some additional time commitments on the part of the "senior" participants who "guide" the new participants. There are several ways to obtain such resources.

One of the simplest means to obtain funds to support undergraduate and high school students to include in the proposal funds needed to support them. The proposal should clearly identify the role of these individuals and the funds needed to support them should be included in the budget. Examples of funds needed include those for wages / stipends, benefits, travel, equipment, and other operating costs. Typically, the wage rates of "new" undergraduate and high school students are generally lower than those of the more experienced students. Project sponsors are generally happy to support such budget requests provided it can be demonstrated that the project goals and objectives can be met with the resources identified in the proposal. An alternate, but somewhat similar, mechanism is to request the sponsor for permission to utilize funds budgeted for graduate students (or from other lines in the budget) to support undergraduate students. This assumes that doing so will not adversely affect activities on the project. In general, sponsors would be willing to permit such a reallocation of funds unless they are limited by some programmatic constraint.

Other examples of funding undergraduate and high school student participation in research include developing collaborations or partnerships with sponsors or organization who support such activities. In other cases, specific supplementary programs may exist to help include undergraduate students in the research activities. Examples of such programs include NSF's REU program and the WAESO program which is also supported by the NSF.

An example of an innovative partnership to support high school student participation in research is the Summer Business Institue (SBI) program in Clark County, Nevada [3]. The SBI is the result of collaborations between the Business Development Division in Clark County and the business community. The SBI program tries to foster participation by inner-city youth. The SBI program consists of an eight week (at 40 hours per week) internship in which high school students (typically juniors or seniors) participate in "on-the job" experiences. Each student works at a selected "employer's" site for 32 hours per week (Monday to Thursday). On Fridays, the students participate in workshops to complement the "on the job" training and to help them develop valuable professional and life skills. Participants in the program are selected based on applications and essays submitted by students, interviews of qualified applicants, and also based on identifying appropriate matches between applicants interests and employers' needs. The University participated as an employer offering "research" opportunities.

The WAESO program supports participation by minority and women undergraduate Engineering and Sciences students in research projects [4]. It is administered by the Arizona State University. Upon submission of a report by the student documenting the research efforts

and outcomes of the same, it will pay approximately $1,000 stipend to the student, and about $350 to the research project to cover other costs related to each student's participation in the research project. The student's efforts are typically expected to span a good portion of the summer break, or perhaps over a semester in an academic year. Accessing resources from programs such as the REU and WAESO typically involves the faculty member submitting a short, supplementary proposal to the sponsoring organization. Such funds "supplement" the existing funding and thus do NOT take away resources from the existing project. On the contrary, they help augment resources available for the project.

Specific Examples

Specific research experiences provided to undergraduate and high school students are primarily in the areas of transportation engineering and infrastructure management. Over the last six years the author has had four to six undergraduate students working on research projects at any given time during the calendar year, and between three and eight high school students working on research initiatives during the summer break. These students work with other graduate students (approximately 10 to 12 graduate research assistants at any one time), professional staff (about 4 at any time), and the author as a faculty advisor on a variety of projects – both as individuals and as members of teams.

A vast majority of these students receive stipends or "pay" for their efforts. Such compensation was made possible based on specific line items in budgets of sponsored projects and grants, and also by taking advantage of other innovative partnerships with funding agencies (e.g, the SBI and WAESO programs). The SBI program psrovided support for two or three of these high school students each summer, and the WAESO program also provided some additional support for undergraduate students. Other students were supported using funds from research projects.

Examples of individual research projects on which such students have worked include the following:

- Pedestrian Safety Analyses
- Analysis of Motor Vehicle Crashes and Occupant Safety
- Statewide Survey of Seat Belt, Child Safety Seat, and Bicycle Helmet Use Surveys
- Routing and Safety Analyses for the Transport of High Level Radioactive Materials and Spent Nuclear Fuel
- Transportation Emissions and Air Quality Modeling
- Development of Computerized Tools for Roadway Inventory Management
- Development of Internet based Tools for Infrastructure Management

Individual student assignments were made as best as possible to challenge the students and to excite them. Efforts were also made to help them understand the significance of their roles on the projects. Students were provided opportunities to learn about how research projects are conducted, documented, and disseminated, as well as the importance of technical and non-technical elements that are critical to the successful completion of projects. Examples of activities conducted by undergraduate and high school students include literature review, data

collection, data input and management, quality control and quality assurance, data analysis, evaluation of results, summarizing results in tabular, graphical and text formats, and preparation of short presentations. Some of the students also participated in the development of computerized tools using spreadsheets, geographic information systems software, and also programming languages.

SUMMARY AND CONCLUSIONS

The challenges faced in involving undergraduate and high school students include identification and procurement of resources - financial and otherwise – especially with space and computing resources, identification of appropriate and challenging research assignments especially to high school students, making time to provide adequate guidance, encouragement and feedback. Obtaining financial resources was perhaps the easiest of the challenges to overcome, and providing a reasonable working environment (space and computing resources) was among the more difficult obstacles to overcome.

Benefits to many of the undergraduate students of participating in the research activities is that they have been able to develop synergies between their research assignments and some of their course related activities (e.g., term papers / projects). Other benefits and outcomes of the efforts of including undergraduate and high school students in research activities include the following:

- build confidence and self esteem
- encouragement to continue their education and pursue higher education (retention and recruitment)
- develop a good work ethic and professionalism
- develop a sense of accountability and responsibility
- develop good communication skills
- develop technical, inter-personal, and other valuable life skills
- exposure to potential career opportunities and paths needed to attain career goals
- develop a sense of fulfillment and satisfaction from working as a team to attain a common goal

In summary, efforts to involve undergraduate and high school students have been found to be successful in helping student develop valuable technical and life skills. They have encouraged students not only to pursue college and graduate education, but also to recognize the significance of the application of research outcomes to address specific societal concerns. In this paper, some strategies have been identified that could help obtain financial support for such activities.

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