Opportunities in Manufacturing of Advanced Materials for Second Career Seeking Students

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Abstract

Many non-traditional students face challenges, which may negatively affect their academic success and degree persistence rates, including lack of institutional support networks and difficulties connecting with other students on campus. Additionally, the lack of financial support has been acknowledged nationwide as a critical barrier for STEM students including second-career seeking (SCS) students. The second career is defined as an occupation or course taken by the current engineering student prior to enrolling to engineering college program. The prior career can relate to a range of aspects of an individual's life including learning, and work and is undertaken for a significant period of a student's life and with opportunities for progress. We target academically talented SCS students at Old Dominion University (ODU) with demonstrated financial need, which can be addressed by an NSF Scholarships in STEM, while developing the academic support networks that provide SCS students with the opportunities in professional development, research, and outreach in the area of manufacturing of advanced materials.

Introduction

Many non-traditional students, including second-career seeking (SCS) students in engineering majors face significant challenges including financial hardship and lack of institutional support networks, which may negatively affect their degree persistence and graduation rates [1-2]. Many non-traditional students in engineering majors face significant challenges including financial hardship and lack of institutional support networks, which may negatively affect their degree persistence and graduation rates [2]. The term 'career' is defined as an occupation, which relates to a range of aspects of an individual's life, learning, and work and is undertaken for a significant period of a person's life and with opportunities for progress [1-2]. In addressing the needs of SCS engineering students in the context of workforce development, the present program, supported by NSF S-STEM, focuses on manufacturing of advanced materials (MAM) as one of the key driving factors for innovation and economic development both within the United States and internationally. Specifically, our goal is to develop a system of effective interventions that leverage SCS engineering students' interests in the research and development of advanced materials for manufacturing as the means to build positive self-efficacy beliefs and outcome expectations [3-5]. The focus on manufacturing and materials was selected as a good concentration area due to the following: (1) broad nature of various engineering careers available to the students, (2) available faculty experience in these areas (3) strong interest from SCS students in the college of engineering. The latter one is primarily due to many SCS students at ODU having prior working experience with various blue-collar positions, such as HVAC technicians, welders, machine shop operators, construction and other positions.

Low self-efficacy beliefs and outcome expectations can negatively affect interests, goals, and activities related to education and careers in STEM, as well as establish a career path dependence for low skilled jobs often leading to limited career choices resulting in reduced human capital [6-8]. Career adaptability can be significantly improved among adult workers considering second career options within engineering if effective supports and resources and key barriers and demands are identified and targeted by interventions. We found in our research that even though SCS engineering students showed higher self-efficacy beliefs and lower school burnout than traditional engineering students, they faced more challenges outside of the classroom, which were not typical for their traditional counterparts. More specifically, SCS engineering students reported lack of childcare, employment work interfering with schoolwork, and other family responsibilities as more significant barriers than did traditional engineering students. In order to build successful academic and social support networks and develop effective interventions to address the needs of SCS students, a deeper understanding is needed of the specific barriers and demands they experience. Furthermore, it is important to evaluate the effectiveness of any designed interventions and programs aiming to foster degree persistence and academic success among SCS engineering students. Consequently, the following two research questions were examined:

***Question 1*:** What are the barriers to academic success of second career seeking (SCS) students?

***Question 2*:** How effective is the proposed system of interventions, including professional development, hands-on research projects, and mentoring, in providing SCS students with a versatile support network that incorporates curricular and co-curricular activities for professional development?

The proposed program emphasizes manufacturing of advanced materials (MAM) as a way to connect SCS students to faculty and industry mentors who facilitate their academic success and career placement in the STEM workforce [4-5]. The educational research element of the program is focused on identifying barriers, while developing supports and resources, which affect academic success of SCS students. To ensure sustained retention and success of low-income, academically talented SCS students entering the engineering field, the project explored socio-psychological aspects of career transition, while identifying the key supports and barriers related to academic success, retention, and degree attainment of SCS students. Students enrolled in the program are provided with a versatile support network, which includes curricular, research, outreach, and professional (CROP) activities (Fig. 1). The present NSF S-STEM program leverages the existing technological base of scientific labs and faculty experience to incorporate novel manufacturing processes and characterization methods for composites and additively manufactured materials. SCS participants are engaged in project-based learning activities, including MAM hands-on outreach workshops on various manufacturing technologies, educational seminars, as well as capstone and research projects in partnership with industrial and government research labs.

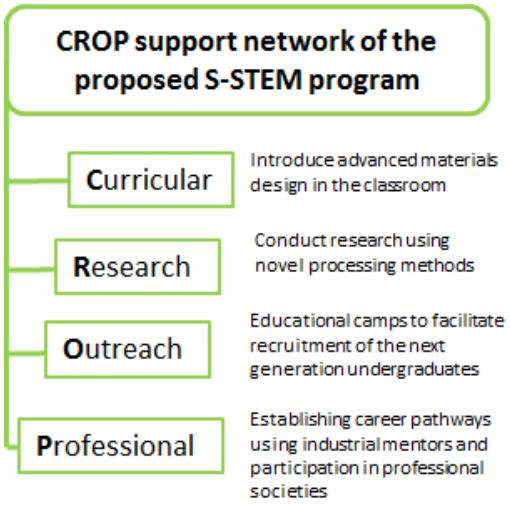

Figure 1. Proposed network of interventions for supporting SCS students in MAM program

By introducing students to various career opportunities through series of educational MAM seminars and workshops, the current program prepares SCS students for the path they will need to take upon graduation in joining the engineering work force. The proposed support network also includes curricular, research, and professional opportunities for SCS students. These activities were assembled based on findings from two focus group interviews conducted prior to the beginning of the program. The focus group interviews involved invited SCS students and were conducted by the faculty in the casual setting. Students were encouraged to share their insights on challenges they faced in everyday life as non-traditional students that affect their academic performance. At the end of the first semester of the S-STEM program, an anonymous survey was administered to the program participants to determine the effectiveness of the proposed activities. The results of the survey showed that the developed CROP support network positively affected self-efficacy and academic success of SCS students, while allowing greater connectivity with other students and campus resources. As a result of the program activities students had the opportunity to develop their skill base in a STEM field and achieve higher level of engagement, such as working on collaborative research projects and teams outside of the classroom. The SCS students positively responded to the mentoring opportunities within the program, whether it involved the faculty associated with MAM program or the engineering professionals outside of the university. Overall, the S-STEM recipients were positively affected by the proposed activities, indicating that they offered them the additional support that was lacking before and served as a source of knowledge that would be beneficial in their STEM careers.

Program Needs Assessment

The two focus group interviews were organized and conducted to collect data on the demands and barriers to academic success that were typically faced by non-traditional, SCS engineering students. The students were invited to join for an hour-long casual discussion over the lunch break and were given the opportunity to express and share the challenges they faced in everyday life as SCS students, while managing a significant amount of the responsibilities and obligations outside of the classroom. Based on their responses four key groups of demands and barriers were identified, which included: (*i*) financial difficulties, (*ii*) difficulties with campus involvement,

(*iii*) decreased motivation due to workload and stress, and (*iv*) lack of consideration from faculty. The common descriptors of the specific demands and barriers were formulated verbatim from the responses provided by the students (Table 1).

Table 1. Summary of various demands and barriers faced by SCS engineering students

Financial Difficulties	
Description:	***Proposed Intervention:***
• Having difficulties paying tuition costs • Having difficulties finding or being eligible for scholarships/financial aid for working, part-time students • Having difficulties paying for materials (books, notebooks), parking passes • Having difficulties paying student loans and other debts • Having difficulties paying accommodation and travelling (e.g., need for a car, gas) • Not qualifying for parents' and ODU graduate student health insurance plans	• Provide a monetary scholarship during the fall and spring semester that covers majority of the tuition expenses for the full time registered students. Students must maintain the average GPA of 3.0
Difficulties with Campus Involvement	
Description:	***Proposed Intervention:***
• Having difficulties socializing with other students because of age difference • Having difficulties interacting with other students because of different priorities and mentality/mindsets • Having difficulties relating to other students because of different priorities	• Build research project groups, which are interest-driven and introduce SCS students into the larger teams of students within and outside of MAM program • Organize hands-on workshops for project-based learning to strengthen the direct connection between program activities and practical applications
Decreased Motivation due to Workload and Stress	
Description:	***Proposed Intervention:***
• Feeling "burnt-out" • Having ups and downs • Taking a long time to complete coursework because of having to take fewer classes due work or personal issues • Thinking of going back to work • Lack of energy • Stressing out about grades; being successful at school and work	• Organize educational seminars and mentoring meetings with the practicing engineers to learn about different career paths, increase intrinsic motivation, and understand and learn how to manage commonly experienced demands and stressors
Lack of Consideration from Faculty	
Description:	***Proposed Intervention:***
• Faculty having myopic view of adult/second	• Educate faculty on SCS students' needs and

career engineering students and their needs • Faculty don't always understand the issues and challenges of adult/second career engineering students	demands/barriers • Identify and develop faculty as a key resource for SCS students and encourage faculty-student interactions and mentoring based on academic interests and career goals

Description of the MAM program

The results of the conducted two focus group interviews were used to inform the proposed CROP activities within the MAM program. The MAM program aimed to provide the supports and resources needed by SCS students by focusing on the identified demands and barriers and introducing curricular, research, outreach, and professional training interventions for the enrolled SCS students. Specifically, to address the decreased motivation due to workload and stress experienced by some second-career students, the participants were invited to attend the MAM Seminar Series that introduced students to various opportunities in this broad field. The following MAM Seminar series included speakers from government (US Army Aviation Development Directorate and NASA Langley Research Center) and academia (Old Dominion University and University of North Dakota). The educational activities during the first year of the program included tours of the research labs by the respective faculty involved in the MAM program. The tours aimed to provide introduction for the SCS students to the various opportunities within the MAM program, and the seminars enabled SCS students to directly interact with researchers and practicing engineers. The second year of the program will involve industry tours of companies involved in various manufacturing and materials work. The benefit of such tours is the opportunity to place the academic and research contexts of the previous activities in real world engineering problems and how those problems are addressed in the industrial setting.

Therefore, students involved in the MAM program were able to participate in educational seminars and learn about various career opportunities in the field. The conducted tours of the university lab facilities and scheduled industrial and government labs visits were aimed to increase the exposure and knowledgebase about the existing and novel advances in the MAM area. Through this exposure, SCS students were expected to broaden their exposure to various engineering career paths. As students became more familiar with the different applications of their engineering background, they were invited to join different on-going research projects with the respective faculty members, which included the 3D printing of composites and studying the errors in printing induced by ship environment, through-thickness reinforcement of composite laminates, characterization of long discontinuous fiber composites for compression molding, developing the framework for characterization of compression over molded composites and dynamic mechanical characterization of ice-templated ceramic. At the end of the first semester of the program, SCS students in the program had to prepare and make a presentation describing their progress with their research work. This task provided an important element for professional development for the students in the program, as they were participating in group discussions and practiced to improve their career "soft" skills, like oral communication and collaborative, project-based learning skills [9].

To address the outreach element of the program, special hands-on workshop series offered training and exposure to various manufacturing techniques for advanced materials. This included the composite fabrication sessions, where students learned how to fabricate polymer reinforced composite materials using standard layup techniques with processing in autoclave and thermal

forming. The session on additive manufacturing included key elements of developing a 3D printed structures and how to tailor the fabrication conditions for better mechanical performance. Students also learned about technical writing and presentation skills organized by the Writing Center on campus at ODU. This session allowed students to discuss and practice the key elements of technical and research writing. The future seminars during the second year of the program will involve technical proposal writing sessions to offer support in achieving the know-how for various external opportunities for financial supports and fellowships, including opportunities for post-graduation employment in STEM. About 30% to 50% of the current undergraduate SCS students in the MAM program are considering the possibility to enter the graduate studies, while others are looking to go to industry. The practical significance of knowing how to work on developing the proposal ideas into well-formulated plans spans far beyond the academic environment and can offer the early training to SCS students, who want to apply to various funding opportunities either as a graduate student or engineer of the respective organization.

This above-described system of activities engaged almost every SCS students involved in the MAM program in conducting research projects (10 out of 12 students in Cohort I). Furthermore, students recognized the importance of the mentoring opportunities when working with the faculty, other students, and outside collaborators and professionals.

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Results of Summative Evaluations of MAM Program

An anonymous survey was administered to determine how successful the developed CROP interventions were in meeting the goals of the MAM program. The respondents were asked how strongly they agreed or disagreed with statements about the S-STEM MAM program. The survey was conducted at the end of the first year of the program. The response rate was 80% based on 10 students in MAM program at that time. All respondents agreed with the following statements:

- As a result of my participation in the MAM Scholarship program, I have collaborated with other students.
- As a result of my participation in the MAM Scholarship program, I have developed skills to do research.
- The MAM Scholarship program has provided me with additional academic support that I was lacking.
- As a result of my participation in the MAM Scholarship program, financial barriers to completing my degree have been eliminated/reduced.
- I believe that participating in the MAM Scholarship program will help me finish my degree.
- I believe that participating in the MAM Scholarship program will prepare me to find a job after graduation.

All eight of the students who responded to the survey indicated that they were very satisfied with the MAM Scholarship program. Survey respondents were asked to comment on the strengths of MAM program. Below are the various comments and thoughts that students had about the strength of the program.

- Being a part of the program led to opportunities that students would not have otherwise had. Recipients were able to "interact with professionals in the field of engineering that otherwise would have been difficult."
- Having tuition paid for allowed students to be able to gain more experience working in research labs because they were not having to look for outside work.
- "The gain in research experience was invaluable."
- The program "allowed students to be informed and prepare or plan ahead for future goals."
- The "extra time spent attending seminars and doing research ended up cutting into my study time a bit.

Conclusions and Future Work

Typically, SCS students are among the highest performing students, but require more intricate support network that can address the critical demands and barriers experienced by these non-traditional students. The support from NSF S-STEM program with focus on manufacturing of advanced materials provided opportunities for the low income, academically talented SCS students to benefit from a support network that was ultimately focused on their professional and personal development. Every student who was engaged in the program told a unique story through their previous career paths and their future goals in engineering. Significant challenges for second career undergraduate engineering students included financial difficulties, difficulties with campus involvement, decreased motivation due to workload and stress, lack of consideration from faculty, and demands outside of school, such as lack of childcare, employment work interfering with schoolwork, and family responsibilities. The combination of monetary scholarship, research project involvement, faculty mentoring, and professional development increased the students' academic and career interests and motivation and provided a relief in balancing their obligations and commitments outside of the school.

The future work will build on the activities in the first year of the program. Specifically, the technical proposal writing seminars and seminars on commercialization of engineering research, as well as continued MAM Seminars and hands-on workshops will be conducted and focus on developing research ideas for technical proposals. The off-campus, industrial tours will be organized to visit local research labs and the industrial partners. The research projects lead by NSF S-STEM recipients will continue during the second year. The students involved in these activities will have the opportunity to attend professional meetings and present their results. The faculty team involved in the MAM program will continue to search for the right balance between incorporating these new activities for SCS students without straining the academic schedule for these full-time non-traditional students.

Systematically studying the existing needs of SCS students and how to best address them will allow us to learn more about institutional changes that are required to create a welcoming and supportive environment for second-career engineering students in and outside the classroom.

Acknowledgement

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Table 2. The results of the anonymous survey by students involved in NSF S-STEM MAM Program

Please indicate whether you agree or disagree with the following statements about the S-STEM MAM program:	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**
As a result of my participation in the MAM Scholarship program, I have collaborated with other students.	6	2	0	0
As a result of my participation in the MAM Scholarship program, I have developed skills to do research.	6	2	0	0
The MAM Scholarship program has provided me with additional academic support that I was lacking.	3	3	0	0
As a result of my participation in the MAM Scholarship program, financial barriers to completing my degree have been eliminated/reduced.	7	1	0	0
I believe that participating in the MAM Scholarship program will help me finish my degree.	8	0	0	0
I believe that participating in the MAM Scholarship program will prepare me to find a job after graduation.	8	0	0	0
As a result of my participation in the MAM Scholarship program, I have other students with whom I can rely on for support.	4	0	0	4
The MAM Scholarship program has helped me do well academically this semester.	4	3	1	0
The MAM Scholarship program has provided me with the additional support that I was lacking before.	2	5	1	0

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