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NSF S-STEM Scholarship Program Initiative via Recruitment, Innovation, and Transformation: SPIRIT Program Year-One Results

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NSF S-STEM Scholarship Program Initiative via Recruitment, Innovation, and Transformation: SPIRIT Program Year-One Results

The NSF S-STEM funded SPIRIT: Scholarship Program Initiative via Recruitment, Innovation, and Transformation program at Western Carolina University creates a new approach to the recruitment, retention, education, and placement of academically talented and financially needy engineering and engineering technology students. Twenty-seven new and continuing students were recruited into interdisciplinary cohorts that are being nurtured and developed in a community characterized by extensive peer and faculty mentoring, vertically integrated Project Based Learning (PBL), and undergraduate research experiences. The SPIRIT Scholar program attracted a diverse group of Engineering and Engineering Technology students, thus increasing the percentage of female and minority student participation as compared to the host department program demographics. Over the last academic year, fifty-four undergraduate research projects/activities were conducted by the twenty-seven scholars under the direction of twelve faculty fellows. Additionally, peer-to-peer mentorship and student leadership were developed through the program's vertically integrated PBL model, which incorporated four courses and seven small-group design projects. Academic and professional support for the student scholars were administered through collaborations with several offices at the host institution, including an industry-engaged product development center. The program participants reported strong benefits from engaging in the program activities during the first year. Specifically, this paper presents results from the program activities, including: cohort recruitment and demographics; support services; undergraduate research; vertically integrated PBL activities; and the external review of the program. Similar programs may benefit from the findings and the external review report, which contained several accolades as well as suggestions for potential continuous improvement.

Keywords: NSF Scholarship Program, Project-Based Learning (PBL), Undergraduate Research, Mentorship, Engineering, Engineering Technology

Introduction

During the 2014-2015 academic year, the SPIRIT (Scholarship Initiative via Recruitment, Innovation, and Transformation) Scholars program at Western Carolina University (WCU) provided 27 undergraduate students in engineering and engineering technology an opportunity to participate in a new approach to the recruitment, retention, education, and placement of academically talented and financially needy students. The SPIRIT program worked to establish a transformative learning environment through vertically and horizontally integrated interdisciplinary project-based learning (PBL), undergraduate research, peer-to-peer mentorship, and focused institutional support services.[1-8] WCU is classified as a regional comprehensive masters-granting university and was awarded the Carnegie Community Engagement classification in 2008.[9] This paper will present year-one results with the hopes of informing others who may be interested in establishing similar programs at their institutions.

Program Recruitment and Scholar Demographics

In 2014 twenty-seven students were recruited into the SPIRIT program and have subsequently contributed to a highly diverse and academically promising learning environment. The scholar selection process involved the directors working with the admissions office and the Honor's College at WCU to coordinate the invitations and prospective applicant packets. The directors reviewed and ranked each candidate based on past-academic records, desire to engage in the projected program activities, and financial need.

The 27 scholars were selected from 72 applicants yielding a scholar group comprised of 10 freshmen, 9 sophomores, and 8 juniors. Of the 27 scholars, 5 females represent 18.5% and 22 males represent 81.5% of the gender diversity as depicted in Figure 1. In comparison, the Department of Engineering and Technology at WCU reported 8.8% (35 out of 396) female students and 91.2% male students for the Fall Semester 2014.[10] WCU reported 66.4% female and 33.6% male freshman students in 2014.[10] The program also experienced a higher than expected diversity in the race of student scholars. The 27 SPIRIT scholars classified themselves as: White (78%); African American (11%); American Indian (5%), and Asian (6%). WCU's undergraduate class (n = 8787) of 2014 reported 82% White, 6% African American, 1% American Indian, and 1% Asian.[10] Figure 2 depicts the race demographics of the SPIRIT scholar group as compared to the host department and institution.

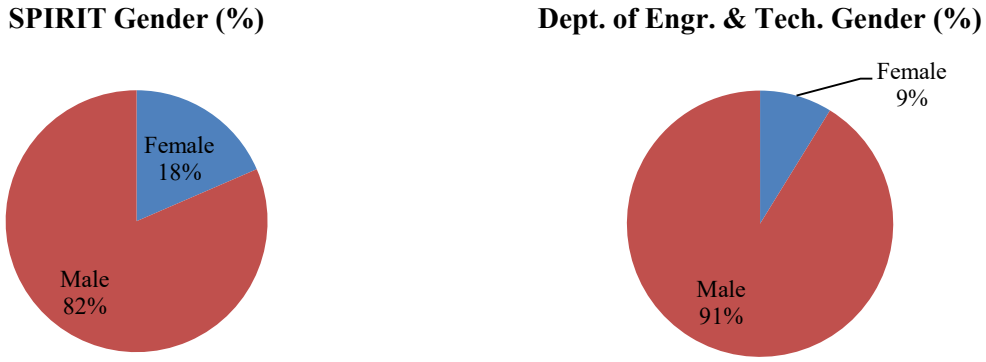

Figure 1: Gender Demographics SPIRIT Program
Compared to Department of Engineering and Technology at WCU

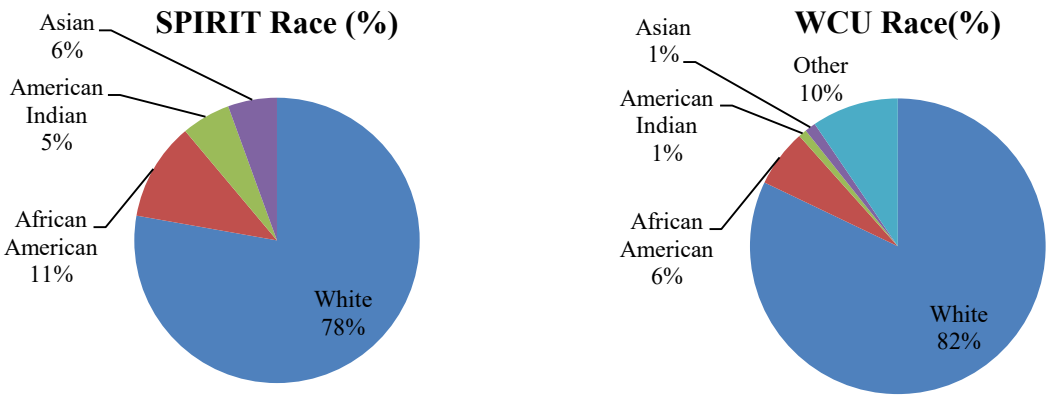

Figure 2: Race Demographics of SPIRIT Program Scholars
Compared to WCU's General Student Population

Degree program interests of the scholars were varied with 67% majoring in engineering, electrical or mechanical, and 33% majoring in engineering technology, electrical or manufacturing as depicted in Figure 3. Of the scholars reporting SAT scores, the average SAT Total score was 1600 with a standard deviation (SD) of 177; the average SAT Verbal score was 517 with a SD of 74; the average SAT Math score was 593, SD = 74; and the average SAT Writing score was 490, SD = 68, as depicted in Figure 4. Of the scholars reporting ACT scores the average ACT English score was 21 with a SD of 6; the average ACT Math score was 26, SD = 4; and the average ACT Comp score was 24, SD = 5, as depicted in Figure 5. The average WCU GPA for sophomore and junior scholars was 3.72, SD = 0.22.[11] In comparison, the average SAT Total for students enrolling at WCU in 2013 was 1039, with the average SAT MATH recorded at 512 and SAT Verbal recorded at 504.[12] Average ACT Composite scores for entering students at WCU in 2013 were reported at 21.4.[12]

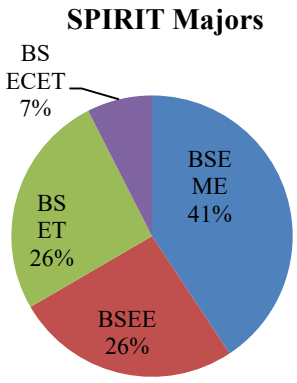

Figure 3: SPIRIT Scholar Group by Major

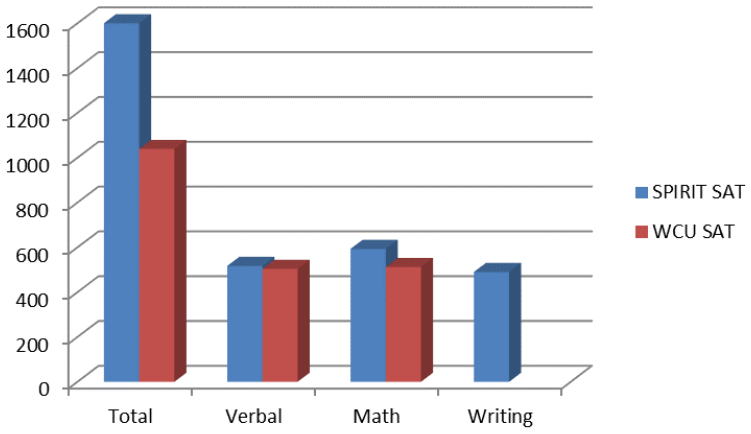

Figure 4: Comparison of SPIRIT Scholars SAT Scores with WCU Freshman SAT Scores

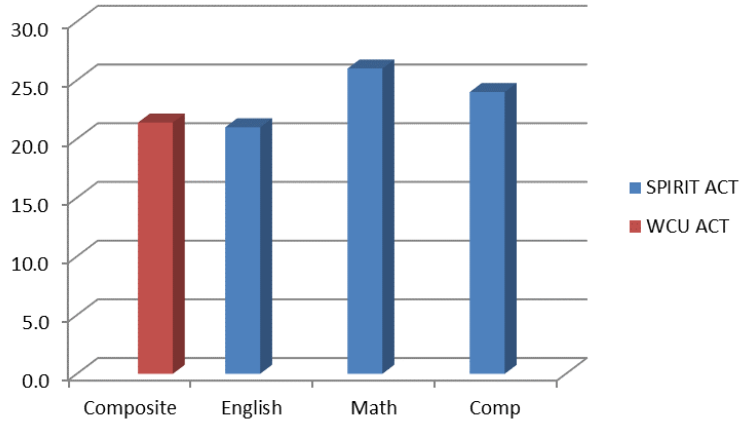

Figure 5: Comparison of SPIRIT Scholars ACT Scores with WCU Freshman ACT Scores

The Office of Financial Aid at WCU reported the average unmet financial need of the scholar group at $2561 with a SD of $4591.[13] Overall, survey data supported scholar financial need and satisfaction with the application and selection processes. Of the 27 scholars surveyed, 100% indicated the process was equitable and that the scholarship award mitigated their financial burden of paying for college. Ninety-one percent of the participants indicated that the selection criteria were laid out clearly, while 78% of the participants indicated that the program requirements were clearly understood. Scholar comments related to the understanding of program requirements ranged from, “I did not understand what was required until later in the program” to “Yes, the directors told us exactly what was expected at the beginning and throughout the program.”

SPIRIT Program Activities

Program activities consisted of scholar academic support services, undergraduate research, and vertically integrated project-based learning activities. The SPIRIT scholars met weekly during the Fall 2014 and Spring 2015 semesters. Project Based Leaning (PBL) courses associated with this program were used to incorporate vertically integrated peer-to-peer mentorship groups and coordinated student work on open-ended projects.

Scholar Support Services

The initial weekly meetings were dedicated to introducing the program, establishing mentorship relationships between the different student groups, and assessing the students' attitudes and potential academic support needs. Scholar survey results showed several areas of pre-program anxiety, including academic, senior capstone completion, employment after graduation, and financial support for college. Presentations and workshops from various institutional support services were scheduled based on results from scholar surveys and journaling responses, which included: WCU's Career Services; Writing and Learning Commons, Math Tutoring Center, Library Research Liaison, and the Honor's College. Additionally, peer-to-peer workgroups were established to discuss and journal the anxiety themes within each groups' activities.

Year-one activities also included the development of peer-to-peer and faculty-scholar mentorship groups. These student lead groups sought to build foundational support for each scholar by establishing learning communities with shared goals. The formation of these groups were both organic, with students self-selecting group membership, or highly structured by the program directors. Structured group membership was based on student journal responses, demographics, major, and number of hours completed in the program. Faculty-scholar mentorship activities were bound by undergraduate research/project topic, major, and career desire. Year-one survey results on mentorship activities were positive.[11]

Post survey results showed SPIRIT program activities remediated much of the pre-program anxieties held by the scholars. 88% of the scholars surveyed indicated that meeting activities involving peer discussion groups reduced their anxiety concerning time management. Ninety-four percent of the scholars indicated the WCU Career Services workshop alleviated their anxiety associated with career readiness and job seeking strategies. Addition survey results indicated 82% of the scholars believed peer discussions alleviated their anxieties associated with degree completion. Overall, 96% of the scholars indicated agreement to strong agreement with the level of exposure to student support services and other program opportunities, including undergraduate research, internships, industry, and careers.

Undergraduate Research

Each SPIRIT scholar was required to complete two undergraduate research projects activities during the 2014-15 academic year. The weekly meetings showcased eight faculty fellows, who present undergraduate research opportunities to the scholars during 10 minute presentation sessions. Scholars learned about faculty research areas, professional development, and laboratory resources. Based on these presentations, scholars worked with faculty fellows to define and begin research projects of mutual interest. Bi-monthly updates and final oral presentations were used to track the scholars' progress. The complexity of projects varied and were based on program year and interest. Several freshmen were approved to investigate career related subjects, while seniors were encouraged to explore more technical related areas. The Fall semester sought to establish the processes needed to complete an undergraduate research project. While relatively small in scope, each Fall project was used to reinforce the overall approach to conducting undergraduate research. Spring semester primarily focused on the literature review, experimentation, and detailed design. Table 1 provides a summary of year-one projects.

Table 1: Summary of Undergraduate Research Projects for Fall 2014 and Spring 2015

Scholar(s) ID #	SPRING 2015 SPIRIT Project Description (15 Weeks)
1006	Human Movement Patterns Research
1040	Hand Positioning Specific Distances Research
1072	Ionic Hovercraft Research
1093	Geometry and Physical Oceanography Research
1094	Simulation for Reconfigurable Manufacturing Systems Research
1031	Voice Recognition Techniques
1015	Fiber Reinforced Composites Research
1091	Gesture Recognition in American Sign Language Research
1086	Magnetorheological (MR) Fluids and Suspension Systems Research
1027	Communication and Interaction between Humans and Robotics Research
1014	Photovoltaic Technology
1051	Study of Magnetorheological (MR) Fluids
1061	Suspension in Mini Baja Club Research
1095	Gesture Recognition
1103	Optical Imaging Resolution Research
1019	Stationary Solar Panels and Solar Energy Research
1059	Manufacturing within Mini Baja Club Research
1037	Hovercraft Research
1003	Ceramic Matrix Composites (CMC's) Research
1032	Energy from Ocean Waves Research
1033	Ceramics Matrix Composites (CMC's) Research
1041	Alternative Design for a Proton Radiation Compensator
1050	Extracting IMEI and MEID from Cellular Calls

1081	Program 7-Degrees of Freedom Robot Arm using a Kinect Sensor
1023	Hypothermia Mitigation Device Research
1104	Extracting IMEI and MEID from Cellular Calls
1076	Laser Vibrometry Research
Scholar(s) ID #	**FALL 2014 SPIRIT Project Description (6 Weeks)**
1006, 1031, 1027, 1019	Investigation of gesture recognition techniques for assistive robotics
1003	3D modeling of a cube puzzle
1081, 1014, 1103	Digital design of a video game
1015	Mini Baja machining and manufacturing
1040	Hydraulic fracturing literature review
1072, 1037	Air ionization for a moving device (hovercraft)
1033	Establishing and accomplishing career goals
1032	Digital design of a Simon memory game
1051	Investigation of engineering employment opportunities
1061	Mini Baja electrical system
1059	Mini Baja frame assembly
1050	Microcontroller-based pulse detection
1093	Engineering Professional Conduct and Image
1091	Engineering Career research and preparation
1104	Digital design of a countdown timer
1094	Robot assembly programming
1086	Complex 3D modeling
1076, 1023, 1041	3D modeling and CNC Project

Both written and oral presentations of project milestones were required several times during the semester. Overall, the level of effort increased across all projects during Spring 2015. Post semester survey results inquiring about the undergraduate research experience were positive.[14] Outcomes from these activities were positive as well. Twenty scholars will present their undergraduate research at WCU's Research Expo, 6 scholars will present their work at the 2016 National Council on Undergraduate Research (NCUR), and one scholar will present his paper at the IEEE SoutheastCon 2016.

Vertically Integrated Project Based Learning

The SPIRIT program's Project Based Leaning (PBL) activities were developed to incorporate open-ended problem solving, teamwork, and project management. Overall the goals of these activities were to broaden student involvement in practical scenarios and to prepare students for the challenges of their senior capstone project and professional practice. Three planned PBL activities were conducted during the weekly meetings and involved structured teams working on

design challenges. SPIRIT scholars worked in teams comprised of Seniors, Juniors, Sophomores, and Freshmen to complete their projects, with each subsequent project increasing in complexity.

Additionally, five common courses were used in developing a vertically integrated PBL core, with each course expanding the levels of autonomy in the execution of related course projects. Courses in the vertically integrated PBL core included: ENGR 199 (Freshman Class), ENGR 200 (Sophomore Class), ENGR 350 (Junior Class), and ENGR 400/450 (Senior Class). Vertical integration among the SPIRIT scholars was accomplished by teaming students across the PBL core. ENGR 199 SPIRIT Scholars teamed with Scholars in ENGR 350. Similarly, ENGR 200 Scholars worked with Senior Scholars in ENGR 450. This paradigm is depicted in Figure 6.

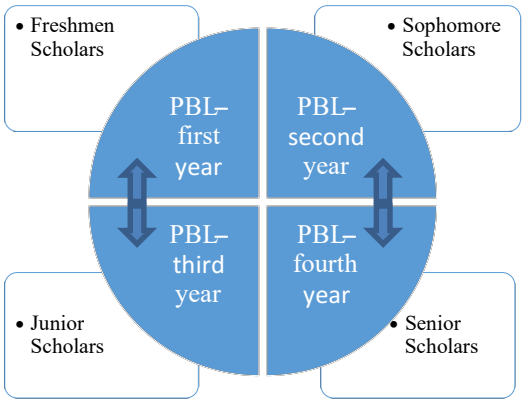

Figure 6: Vertically Integrated PBL Model

Course interactions were carefully planned to maximize student exposure to the mentoring aspects of having students work with those of other years across the PBL core. Freshman and junior students were provided with a set of project guidelines by the instructor. Juniors were expected to deliver an alpha prototype of a product whose requirements afforded multiple design approaches. Freshmen observed and supported the Juniors during development so as to obtain an understanding of the concept development process and project planning. Freshmen were evaluated on their demonstrated understanding of the project through a final presentation, while juniors were evaluated on the success of their prototype.

For sophomores matched with seniors, the integration was less interactive. Sophomores were required to attend group meetings, customer design reviews, and a final poster session with their Senior teammates who were working on their capstone projects. Sophomores were also required to write a reflection paper which demonstrated their knowledge of the project. This limited interaction was designed to expose the Sophomores to the fully open-ended nature of a capstone

project without imposing an undue burden on the Seniors, who are typically time-constrained due to project expectations.

Post review of PBL artifacts, journals, and surveys highlighted several positive outcomes from the PBL activities as well as several areas needing improvement.[15] Scholars strongly acknowledged the perceived benefits of working in teams, managing and conducting open-ended design projects, and gaining pre-exposure to subsequent capstone activities. They did not see any perceived benefits from several PBL activities occurring during the first half of the semester, prior to their PBL course projects beginning. The directors have subsequently coordinated the PBL meeting schedules to occur later in the semester and more in-line with PBL course activities. Additionally, documentation of design work was generally weak across the Scholar's PBL artifacts. Several activities designed to stress the importance of design documentation have been implemented and results from these activities will be analyzed post Fall semester 2016.

SPIRIT Program – Per Semester Scholar Evaluation Review

SPIRIT Scholars were evaluated each semester to determine the eligibility to continue in the program. Scholars who fall below a 3.25 or miss 30% of the required activities were considered to be "at-risk," placing them in jeopardy of being placed on probation. Scholars who fell below 3.0 GPA or missed 50% of the required activities were placed on probation during the following semester. For "at-risk" Scholars, the program administration worked with appropriate units (student support services, the honors college, the graduate school, etc.) to help the students get back on track. For Fall 2014 semester, five Scholars were determined to be "at risk" and were issued academic action plans and encouragement to seek student support services. Four of the five Scholars at risk for Fall 2014 improved their performance during Spring 2015 and were removed from at risk status. Four Scholars were placed at risk for the Spring 2015 semester; three of the four remain at risk.

Year-One External Review

The program initiated two on-site external reviews during year-one. The external reviewer was granted on-site access to all archived digital and binder data including: program procedures and protocols; Scholar undergraduate research and PBL artifacts; selection process data and criteria; Scholar journals and surveys. The reviewer also conducted face-to-face interviews with the Scholar group.

Findings from the external reviewer were overall positive with several suggestions for continued improvements. The reviewer pointed out that the directors had one of the most highly organized record-keeping systems ever observed over the many years of conducting external reviews of NSF programs. The directors were commended for their work in student support resources and assisting at risk Scholars, but were cautioned on a perceived divide between the engineering and engineering technology student's perceptions of project rigor. The reviewer additionally

acknowledged strong efficacy in the program's continuous improvement activities, peer-to-peer PBL mentoring, undergraduate research, and Scholar journal data. The external reviewer's summary statement was as follows:

> It is laudable that the Leadership Team identified areas in SPIRIT that could be enhanced, then developed plans to improve the program, and finally implemented improvements as Year Two begins. Further, the team leadership team is to be commended for designing and implementing an exemplary S-STEM program that could be emulated by other engineering schools.[16]

Conclusions

The SPIRIT Scholar program attracted and initiated an academically strong and diverse group of students. Support and development activities were comprehensive and utilized by the scholars who reported a perceived benefit through survey and journal data analyses. The program's undergraduate research initiative produced positive results with all scholars participating and publishing their study results through several scholarly venues. The vertical integration of PBL program activities and courses was successful and continuous improvement plans/actions developed from analyses of artifacts are currently underway. Overall, the program experienced a productive and impactful first-year with acknowledgement of program efficacy from two on-site external reviews.

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