



## Continuous Improvement in an NSF S-STEM Program

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## Introduction

In conjunction with a National Science Foundation-sponsored scholarship program, we have developed and maintained a multidisciplinary peer mentoring support system at a comprehensive university in the Midwest. This program is designed for STEM students and addresses key professional development areas. The student scholars receive financial support and an opportunity to develop academic, professional and life skills through a weekly scholars' seminar. The seminars familiarize scholars with various university support services, allow participation in multidisciplinary discussions addressing broad academic and career issues, and build relationships with other scholars from diverse STEM disciplines. The seminar coursework is centered on semester-long investigative projects designed and completed by teams, typically multidisciplinary ones. A small group of faculty oversees the seminar and selection of scholars.

Our approach in this program is to provide faculty mentoring for the scholars while also developing stepping-stone peer-mentoring for professional development. This structure supports students and helps them develop leadership qualities. The recipients, as defined by the program criteria, are diverse: multiple majors (all eligible STEM majors are included), male, female, and non-traditional students, as well as students with different ethnicities, religious affiliations, backgrounds, and family structure. Our program has demonstrated past success in addressing issues important to the field and accreditation boards, such as functioning on multidisciplinary teams, understanding ethical responsibilities, developing a sense of the global and societal context of STEM work, and supporting the idea of life-long learning.<sup>1-4</sup>

In the eight years since the program was founded, it has grown and developed considerably. Structural changes throughout these years include adding distance students in an off-campus program 280 miles away, broadening the program to include multiple science majors, funding a half-time graduate assistant, and staffing changes in the faculty mentors. Program improvements have included annual retreats for scholars, thematic projects that connect with student values and interests (e.g., STEM focused themes related to garbage, water, and energy), a focus on ethical concepts and decision making, the addition of graduate students from our nationally ranked experiential education program, and a faculty mentor from technical communication.

This paper describes the structure of the multidisciplinary scholarship cohort, its advising program, and associated seminar. We provide a brief overview of the continual improvement process over the past eight years, highlighting key structural changes in the end of semester assessment process over the past two years. Qualitative assessment of student experiences and learnings are presented. Discussion of results includes faculty observations of student learning experiences and the overall continuous improvement process.

## Continuous Improvement, Structure, and Goals

The Mentored Academic EXperience (MAX) scholarship recipients include second-, third-, and fourth-year students majoring in mathematics; biology; chemistry; physics; information technology; electrical, computer, civil, mechanical and general engineering; and automotive,

computer, electronics, and manufacturing engineering technology. The students represent a diverse mix of gender, race, socioeconomic background, and cultural experience and have demonstrated a financial need. Scholars are awarded a \$5,000 scholarship, funded by an NSF S-STEM grant, which is renewable for up to three years. The multidisciplinary cohort of scholars participates in a weekly mentoring seminar, an annual retreat of 1-2.5 days, and up to three extra-curricular activities on campus.

The multidisciplinary nature of the program extends to the program administrators as well. Each year, four or five faculty serve as curriculum designers, seminar leaders, and mentors to the students. The faculty mentors have represented biology, computer science, computer information science, engineering, engineering technology and math. In addition to the faculty, a graduate assistant from the Department of Experiential Education helps coordinate the seminar and other activities.

Over the past eight years, the MAX scholarship program has engaged in a continuous improvement process. The students provide feedback at least once per semester through online surveys and, most recently, reflection essays. The faculty mentors and graduate assistant observe what is working well and where improvement is needed during the weekly seminars. They discuss and reflect on continuous improvement ideas at their weekly planning meetings and an annual reflection and assessment meeting at the end of the year. This process is guided by the organizational goals and implemented through interventions to the supporting structure of MAX (See Table 1). Some examples of changes include annual retreats, common reads assigned over winter break, and formally assigning primary faculty mentors so students feel more comfortable connecting with the MAX mentors when there are not direct matches with their major.

**Table 1: Program Goals and Structural Supports**

MAX Scholar Program Goals	Community development Increase student engagement Personal/professional development
Structural Supports for Goals	Weekly seminar Multidisciplinary group project Annual retreat Primary faculty mentor assignment Peer-mentoring amongst faculty Continuous improvement process

At the beginning of the academic year, faculty plan a curriculum for the weekly seminars featuring discussion topics about professional and life skills, as well as a multidisciplinary project based upon on a theme (or two). The project theme and the curriculum are informed by the previous year's reflections and assessment, including student surveys that are conducted at

the end of each semester. During the academic year, informal feedback is also gathered during large group seminars, individual meetings between students and their mentors, and students' reflection journals. Adjustments to the curriculum are made in reaction to student experiences and needs and to help the continuous improvement process and overall success of the program.

The continuous improvement process has prioritized changes to the MAX scholarship program to support the overarching goals. See Table 2 for an outline of the structural changes over the eight-year history of the program. A description of each structure, the ways they support goals, and the improvements made follows.

**Table 2: Project Themes & Implemented Changes in the Scholarship Program**

Theme	Changes
2007-08: Effects of Climate Change	Initiated seminar for scholarship recipients in CS, IT, engineering, engineering technology, math and biology Group project work Goal writing & reflection Resume writing & interview
2008-09: Election Process & Environmental Issues	Initiated a common read via fiction book ( <i>Zodiac</i> by Neal Stephenson) "Affinity Groups" to build broader sense of community More unstructured time for student interaction in the context of structured group work Campus sports and arts events as group activities
2009-10: The Human Condition & The Physical Universe	3 of 4 faculty mentors on sabbatical or leave; 3 interim mentors participated. Non-fiction: <i>What is Your Dangerous Idea? Today's Learned Thinkers on the Unthinkable</i> edited by John Brockman
2010-11: Natural Disasters & Impact on Society	Conference attendance (Nobel Conference, local alternative energy conference) Fiction: <i>I, Robot</i> by Isaac Asimov
2011-12: Sustainability & This I Believe (statements of belief published as a collection)	2 of 4 faculty on sabbatical or leave; 1 interim mentor participated Distance students included All eligible STEM majors included in program Began annual retreat Graduate Assistant support began (10 hours per week) Non-fiction: <i>This I Believe: The Personal Philosophies of Remarkable Men and Women</i> edited by Dan Gediman & Jay Allison
2012-13: Election Process & Major-focused Ethics Case Studies	Elevator speeches Initiated ethical framework Non-fiction: <i>The Immortal Life of Henrietta Lacks</i> by Rebecca Skloot
2013-14: Garbage & Personal Finance	Required meetings with assigned faculty mentors Ethics embedded in project work Phone interviews Non-fiction: <i>Young, Fabulous &amp; Broke</i> by Suze Orman
2014-15: Water & Leadership	Theme of water strongly integrated into retreat to support information gathering during group time Included faculty mentor from Technical Communication Non-fiction: <i>Leadership for Engineers: The Magic of Mindset</i> by Ronald Bennett & Elaine Millam

### *Weekly Seminar*

All scholars are expected to participate in the weekly seminar. In 2011, the scholars program was extended to include 3-5 engineering students at a satellite campus located 280 miles from the main campus. These students at the satellite campus participate in the seminar via ITV or video conference using Skype or Adobe Connect. The curriculum of the seminar is designed to increase familiarity with university resources, provide useful information about a wide array of personal and career issues, and foster relationships with students and faculty across disciplines. Instructional methods for the seminar vary from week to week as the MAX faculty mentors take turns serving as the lead instructor. The seminars include large and small group discussion as well as guest presentations from other university faculty and staff, industry partners, or alumni scholars. This adaptive structure is motivated by best educational practices, especially for a diverse STEM community.<sup>5-11</sup> Weekly assignments, such as resume building, personality styles assessments, and personal and professional goal setting are designed to promote student engagement and reflection and help scholars develop professional skills.

Community development between the scholars is fostered through team building activities early in the semester that focus on communication, teamwork, and leadership styles. Summary discussion and debriefing methods help transfer this learning to improve group dynamics in the multidisciplinary group projects, and together the students create vision statements and goals for their teams.

Since 2013, the MAX scholarship program has also included a community engagement element in which students share their developing technical expertise through volunteerism. For example, students have volunteered to judge projects at the regional science fair, given presentations in lower division classes in the college to highlight STEM careers, and engaged a local Girl Scouts troop in hands-on engineering activities.

In the eight years of the program, the seminar has expanded from a traditional classroom seminar to include more topic-based, free discussion time for students to learn from each other. Although we have always invited guest speakers to share expertise on topics related to personal and professional development, we have begun to focus more on life skills development also. Topics such as time management, study skills, and work-life balance have been incorporated into the seminar to support students in meeting the GPA expectations of the scholarship, as well as personal finance and job negotiation skills. For example, mock phone interviews were added to the seminar last spring to help develop interviewing skills.

### *Group Project*

Since the beginning of the program, each semester's seminar has been structured around a multidisciplinary group project addressing a different societal issue that we ask students to analyze given their developing technical expertise. For example, the project theme for the 2014-15 academic year is water. Group project topics feature various water issues including desalination techniques, hydraulic fracking, and bottled water. The students presented their preliminary findings using a Pecha Kucha style presentation this past fall. In the spring, they continued to explore their research topic and learned how to create and present a research poster. Time is allocated within the seminars for group meetings, but students also meet a few hours

throughout the semester outside of class to complete the projects. There are three main goals for including group projects in the scholars program:

1. To help students grow both personally and professionally by developing collaboration and leadership skills.
2. To encourage students to use their technical knowledge to analyze a societal problem.
3. To practice communicating their technical knowledge with others during project development and through presentations to others.

Continuous improvement of the group project process has been a priority because of its importance to the MAX scholar experience. Project themes, content, and presentation expectations change every year in order to present students with novel challenges. In 2008, unstructured time for group work during class was implemented to foster creative problem solving, outline goals and expectations for projects, and build relationships with their fellow scholars through informal conversations.

In 2011, students began working in geographically dispersed teams after a distance cohort was added. In addition to connecting the distance students to the local students, the experience helps the students develop collaboration skills that are necessary for the geographic dispersion seen in the current workforce.<sup>3</sup> These workgroups have engaged in both researching themes and examining ethics case studies.<sup>4</sup>

#### *Annual Retreat*

With the addition of the distance students in 2011, the faculty decided that an annual fall retreat would help the two groups become acquainted in an experience outside of their familiar environments. In the first retreat, the main campus students, the faculty mentors, and the graduate assistant traveled to the Iron Range Engineering program at the satellite campus in Virginia, Minnesota, to visit the other members of the geographically dispersed cohort and build community amongst the scholars through face to face project work, industry tours and social activities.<sup>3</sup> In 2012, the distance students visited the main campus where they participated in structured team building activities lead by experiential education facilitators to develop communication skills and build trust amongst the group. The group project presentations were also a main feature at each of these first two retreats.

In 2014, the retreat's focus shifted to supporting the project theme of water by examining sites around the state on a 2.5 day bus tour. The retreat's itinerary was planned with the assistance of the Minnesota State University, Mankato Center for Water Resources and included a riverboat trip on Lake Pepin to examine vertebrates, ecology, and sustainability; a stop on the Minnesota River to study stream ecology and invertebrates; and a visit to a Discovery Farm in southern Minnesota to learn about current land use research. The combination of structured and unstructured time during the retreats allow for community, personal, and professional development.

#### *Mentoring*

Mentoring is an essential facet of the MAX program because it provides an avenue to help students create and achieve both personal and professional goals. Each student is assigned a primary faculty mentor who is closely related to that student's field of study, and returning

scholars serve as role models and mentors for the new scholars. The faculty mentors meet with their mentees at the beginning of each semester and as needed throughout the academic year.

In addition to undergraduate mentoring, faculty peer-mentoring is also an important component of the program. The faculty mentors for the MAX program consist of a mix of professors, associate professors and pre-tenure assistant professors. The weekly planning meetings are used for continuous improvement of the MAX program, but they also provide an outlet for peer-mentoring and building community amongst the MAX faculty. Topics such as academic writing, professional presentations and conferences, academic and career advising, applying for tenure and sabbaticals, and teaching techniques are common conversations during the faculty meetings. These informal conversations provide the faculty and graduate assistants with professional development and peer mentoring outside of their department colleagues.

When the program expanded in 2011 to include more majors, we experienced greater diversity in the student scholars, but an unintended tradeoff has been fewer opportunities for peer-mentoring amongst the students within academic majors. To compensate for this change, the weekly seminars regularly break up for discussion into groups clustered by major or academic year, as well as by affinity relationships based on things such as common experiences (e.g., fatherhood, hobbies, learning styles and research vs. industry experiences) to create new opportunities for peer-mentoring.

#### *Student Assessment Techniques*

The MAX scholarship program uses student feedback as a main component of the continuous improvement process. Students have completed end-of-semester surveys since the beginning of the program in 2007, which measure outcomes in relation to program goals through 19 Likert scale and four open-ended questions. Assessment techniques have been added over the years in order to gather more feedback and provide students with more opportunities to cement semester learning.

Student interviews, conducted by an external evaluator, were used to assess students' experiences working with multidisciplinary teams in 2010. At various points between 2007 and 2012, internal interviews were used to gather information from various major types for major-focused assessment. In the fall of 2014, an additional end-of-semester assignment allowed students to reflect more thoroughly about questions that related to the program goals. This type of assignment serves the dual purpose of allowing for student reflection to support the internalization of their learning citing a loop for semester learning,<sup>12</sup> as well as measuring the effectiveness of the learning experiences in the seminar.

In the context of this scholarship program, goals, and current assessment, we report here the results of our qualitative analysis from the fall 2014 reflection assignment and discuss it in the context of our eight years of program implementation. Our motivating questions, methods and results follow.

## Assessment Methods

This particular study explores student development over the course of their time in the program (whether one semester or longer) to address the following objectives: 1) to understand the effectiveness of the structural supports for program goals and 2) to use these understandings to inform next steps in program development. The goal of this study was to determine whether the student scholars were gaining experiences that they found valuable. Specifically, we wanted to determine whether the group project and annual retreat were valuable community building experiences for the students. We also wanted to examine whether the students felt that the MAX scholars program helped them develop personal/professional skills. Finally, we wanted to determine what we can add/change to continually improve our program. These goals resulted in four guiding research questions:

1. Did the group project (structural component) support program goals?
2. Did the retreat (structural component) support program goals?
3. Did students personally and professionally develop?
4. What next steps can the program take in the continuous improvement process?

### *Procedures*

Data was collected from 26 end-of-semester student reflection assignments during the fall semester of 2014 following procedures approved by the local Institutional Review Board. In Table 3, the participants are organized by major and categorized by gender, class level, and whether they were returning scholars.

**Table 3. The number of students that participated in the end of semester surveys**

Majors	Gender		Class Level			Returning Scholars
	Male	Female	Sophomore	Junior	Senior	
Automotive/ Manufacturing Engineering Technology	3	2	1	1	3	3
Biology/Chemistry	3	2	1	0	4	3
Civil Engineering	1	1	2	0	0	1
Computer Engineering/ Information Technology	2	0	0	0	2	2
Electrical Engineering	0	1	0	1	0	1
Integrated Engineering	4	2	0	3	3	2
Mathematics	1	0	0	0	1	0
Mechanical Engineering	4	0	1	3	0	2
<b>Totals</b>	<b>18</b>	<b>8</b>	<b>5</b>	<b>8</b>	<b>13</b>	<b>14</b>

The reflection assignment consisted of the following questions and prompts:

1. Describe how you have changed over this semester.
2. Thinking back to the goals you developed at the beginning of the semester, are you on track to meet the goals for this semester? This year? How has MAX helped or hindered achieving these goals?
3. Have you felt more connected to the MAX community over this semester? Your major? Our college? Or less? Describe a time (or two) that shows your experience with feeling connected or disconnected this semester.

4. What aspects of MAX this semester have been beneficial to you?
5. What could be changed about MAX to support your learning or growth?
6. Returning scholars: Describe how your experience with MAX has changed from your first semester as a MAX scholar?
7. New scholars: How has the experience of MAX matched the expectations you had at the beginning of the semester? How have your expectations evolved now that you have been a MAX scholar for a semester?

Faculty members analyzed data from their respective mentee groups for responses that addressed our research questions based on four categories: group project, retreat, personal and professional development, and continuous improvement. Portions of responses related to these four topics were gathered, regardless of which question elicited the response. After compiling all of the student data, themes emerged in each of the four categories and are described below.

### **Results & Associated Next Steps**

In this section, we address the first three research questions. Research question 4 (What next steps can the program take in the continuous improvement process?) is addressed at the end of the discussion for each of questions 1-3.

*Group Project Effectiveness: Did the group project (structural component) support program goals?*

Our main goals for having the students work on group projects during the semester was to expose them to working in multidisciplinary groups and help them gain leadership experiences that could be applied to their future careers. Emerging from the student responses was an awareness of the benefit of working in multidisciplinary teams and how these experiences would transfer to their future careers:

*“Also working on an interdisciplinary research project has made me realize that a discipline cannot fully understand a problem, but when many disciplines come together we can accomplish many things.”*

*“I think the most beneficial thing to me was the group work...It is always valuable to work with diversity and work on interdisciplinary teams. That is how it will be in the real world more likely, so I think it was the most valuable experience throughout MAX.”*

Students also expressed how the group project helped them learn how to work with and connect with their peers:

*“From this interaction, I learned how dealing with people from diverse backgrounds can be difficult and what one should adopt in some situations while preserving a fair climate of exchange.”*

*“Also, working with groups has given me the opportunity for a more personal connection.”*

*“I felt that our group learned about each other on a deeper level. We were able to develop deeper relationships while working on the project. We also learned about each other’s strengths and weaknesses.”*

The program goal of professional development was also supported by the multidisciplinary nature of group work. Community development and student engagement were supported through the navigation of intrapersonal dynamics, however most of the constructive feedback of the program focused on the work load of the projects:

*“As a CSET [College of Science, Engineering & Technology] student, we already have a ton of presentations and projects that are required for our classes. We also seem to have exceptionally challenging courses to juggle while also doing a project for the seminar.”*

*“I found it difficult to have a project while taking classes at the same time. It gets to be difficult with the homework from class and then having to work on projects for MAX.”*

Some students provided more insight into usefulness of group project work post-presentation:

*“I feel that the interdisciplinary teamwork would be more effective if it had a focus on improving the community. Something that would be a class project utilizing our differing areas of expertise.”*

*“Also, if there is a way to implement the group’s projects or to use their outcomes that will be great.”*

The value of working with multidisciplinary groups, as well as the learning involved in better understanding group dynamics and personal leadership styles, helps students professionally develop and engage with the community. Maintaining the current structure of group work is pivotal to achieving these outcomes. Faculty have also seen variation in the ability of students to juggle group projects and academic workload over the years of the program. Reacting to the needs of current students is an important aspect of the improvement process. Faculty discussed the importance of consistently clarifying expectations of group work: a focus on the process of group work rather than the product (presentation) and the ability to use this learning in the workplace are the elements that support personal and professional development. Providing more class time for project work can help balance the workload, as the shared scientific inquiry serves as the means in examining the group process. Future planning can include presenting more options of community engagement such as presenting group work outside of class or engaging with service learning. The key is to have buy-in and early engagement in the process of choosing activities so that students are motivated to participate without feeling like it is an externally applied burden.

*Retreat Effectiveness: Did the retreat (structural component) support program goals?*

The program goals of fostering community development and increasing student engagement were overwhelmingly supported by the annual retreat. The 2014 retreat focused on water issues relevant to our location in the agricultural Midwest so that examples were relevant, concrete and personal. Students appreciated the time away from campus as a group, which was the main

catalyst for overall group cohesiveness. Students became more connected and valued learning aspects of our water issues theme from different perspectives in the field:

*“I have definitely felt more connected with the community more than I ever have as a MAX scholar. The retreat has been a great time to connect with MAX scholars and other students in different majors.”*

*“It was nice to have the retreat to see the connection between water and all the STEM majors that are connected to water.”*

*“The networking and life experience that I had with the fellow MAX scholars on the retreat was not only fun, but possibly one of the most rewarding things yet.”*

There was concern about losing that connection over the semester:

*“But when we got back there was no time to really keep those connections...I didn’t feel that bond was strong enough to last outside a classroom setting.”*

*“...I didn’t feel like I got to get that much more connected with my small group. Our last meeting helped to bring this back together when we got to meet in our major groups to talk about what is going on in each other’s lives...I believe another team building day or event to re-energize the group would be very helpful.”*

The balance of free-time and place-based learning allowed students to connect with one another, as well as connect to multidisciplinary perspective concerning water. Finding other ways to maintain cohesiveness and connectedness will be important moving forward. Mentors can continue to encourage the group to seek social engagement opportunities to maintain connections, using funds from their university-recognized student organization. Also, a mid-semester check-in and/or teambuilding exercise during a portion of the seminar could serve to assess the group dynamic and allow the students to figure out next steps for improving their experiences of connectedness to the group.

*Personal and Professional Development: Did students personally and professionally develop?*

Our major goal for the MAX scholarship program is to provide students with personal and professional development experiences that they will be able to use in both their undergraduate and professional careers. An important aspect of developing these skills is the ability to recognize, respect, and learn from different perspectives. Over the course of the semester, students recognized an improvement in their professional and personal skills. The theme of personal growth was described by students in many different ways:

*“Another beneficial aspect of the class was the emphasis on reflective learning. By writing in our journals after an activity, I felt that I was able to process information better. The writing forced me to think back to the activity and summarize what I have learned. I believe that the reflective learning we practiced this semester helped me retain information better.”*

*“The interaction which I have experienced from MAX community from teachers, fellow students, and even the surrounding community has changed the way I view [and understand] things...”*

*“I am now a firm believer in experiences that force you out of your comfort zones and challenge you in new ways. The growth has been tracked and thought about during my sessions with the MAX scholars. Reflection and explanation can really help self-realization.*

Students specifically emphasized that networking and resume building exercises were key aspects of their professional development:

*“When I was invited to join I had good grades. Since then I have actively pursued internships and programs that I may not have even known about before the program. While I still try my best to maintain good grades, MAX has played a vital role in making my undergrad career about so much more. Without MAX I probably wouldn’t have pursued an internship so early in my studies, and then I wouldn’t have been invited to participate in many of the amazing opportunities since.”*

*“At the beginning of the semester, I was very skeptical of the weekly seminars. I didn’t want to have this extra class, with extra assignments. It also prevented me from working on Monday nights. However, I’ve realized that the assignments are more beneficial to me than I had anticipated, such as the resume assignment.”*

In addition to professional skill development, students greatly valued the many mentorship opportunities provided by our diverse faculty members:

*“[My connection with Dr. Bates] was/is really helpful because she always provides special feedback on what I am working on, struggling with or reflecting on...This kind of support is priceless because in our journey as student[s], even small things matters and could easily become factors of irreversible decisions. Also, I had a great time getting help on my resume from Dr. Jennifer...She said whenever I need help I should just send her an email. In a nutshell, the MAX faculty were there throughout the semester to help me out whenever I needed them and had a great connection with my classmate[s] too.”*

*“[The faculty] are there to hear me out and listen. I really like the fact that there is a diverse group of advisors this year compared to previous years. This way if you need the help of different advisors I have that tool in my tool box.”*

The goal of personal and professional development is clearly supported by intentional faculty mentoring, professional skills training, and providing students with challenging, growth-oriented experiences, both inside and outside of class. Faculty regularly hold each other accountable concerning mentoring responsibilities and focus on developing relationships that personally and professionally challenge students. One improvement will be to continually use all faculty mentors in each seminar. Incorporating the diversity of the mentors into the seminar more explicitly will improve access for all students, and not just the mentees or students that seek out

the relationship outside of seminar. The professional skills training is modified each semester to not become repetitive. Assessing student backgrounds prior to training could better individualize curriculum, which could address overlap in assignments. Furthermore, providing even more opportunities for group reflection and processing could improve both the connectedness felt among the community throughout the semester and help further understanding and actualization of personal development.

## Conclusion

The MAX scholarship program was implemented to provide student scholars with the tools and resources to become successful and productive citizens. With a constant eye on continuous improvement, MAX has become more responsive over the years through implementing appropriate modifications based on feedback, theory, and best practices. This paper's examination of the history of the continuous improvement process, combined with a better understanding of the effectiveness of the structural supports for program goals via student feedback and faculty reflections, provides a foundation for moving forward and continuing to improve the student experience and development of professional, academic and life skills. Future research will analyze and compare survey results across time in order to identify significant differences in outcomes, as well as pairing qualitative reflections with quantitative survey data for deeper understanding. This analysis will provide yet another perspective to examine, further supporting the scholarship program in continuous improvement.

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