Application for Mildred Dahne Award
Department of Technological Studies — Spring 2011

A recent update on the National Academies report "Rise above the Gathering Storm" indicated that K-12 students in the USA ranked 48th in the world in terms of math and science capability. This is extremely poor performance and has dramatic implications on our economy since innovation by scientists and engineers overwhelmingly dominate our economic health. Not surprisingly, 69% of public school students in 5th through 8th grade are taught mathematics by teachers without a degree or certificate in mathematics. In science this figure is 93%! Concerns about technology and engineering skills in K-12 students are similar. Currently the National Assessment of Educational Programs (NAEP) is undertaking the development of a national test for technological literacy. This is the same organization that administers a variety of tests to assess the effectiveness of our nation's education system. Unfortunately, the National Academies report is only one of dozens of reports that quantify the rapidly weakening capability of K-12 students in Science, Technology, Engineering and Mathematics (STEM). As noted in the Academies report, achieving an effective K-12 teacher population is critical to overcoming this STEM education problem. The Department of Technological Studies, located in the School of Engineering, has positioned itself to play a key role in ameliorating this downward spiral of STEM capabilities both regionally and nationally by designing and implementing nationally unique and successful multi/interdisciplinary STEM education teacher preparation programs. In addition, for more than 15 years the Department of Technological Studies has worked closely with the School's *Center for Excellence in STEM Education* to provide high quality Professional Development for many hundreds of K-12 teachers and high quality STEM activities for many thousands of K-12 students.

I. EXCELLENCE IN TEACHING AND/OR SUPPORT OF TEACHING

Our fundamental goal is to graduate highly qualified STEM-capable K–12 teachers. Therefore, we personally strive for **excellence in teaching** and we organize events and activities that strongly **support teaching**.

Well-designed curriculum is key to an effective education program. In addition to curriculum evaluation as part of the NCATE accreditation process, our department has implemented several field-leading curriculum innovations: (i) in ~1985, a switch to design-process centered curriculum (from an industrial education base), (ii) in 1998 our department led the development of the Math/Science/Technology (MST) K-5 major which is now the largest K-5 major on campus and is attracting substantial national attention as a STEM teacher preparation model and (iii) in 2005 a switch to a "pre-engineering" focus, integrating more math and science. More information about these nationally unique curricular innovations is presented in Section II. In addition to curriculum there are several other attributes of our department that exemplify excellence in, and support of, teaching. These include (i) the establishment of an effective learning environment, (ii) high quality advising and (iii) faculty teaching effectiveness.

(i) Learning environment: Our department has established a unique learning environment that provides easy access to teachers, unique & effective physical space, diverse populations and a high level of out-of-class professional and social activity. The physical space we designed provides, in the immediate proximity, lecture space with multimedia and SMART board capability, computer space (with ~15 computers) and laboratory space. Separate rooms are used to provide the necessary prototyping capability in a safe and low noise environments while large windowed walls provide the desired transparency and visual access needed for effective instruction. We have also used externally funded grants to acquire many key pieces of equipment to support modern materials fabrication in our pre-engineering curriculum. In addition to formal instruction, this space has clearly become the social and professional center for our students and faculty, which substantially benefits our teaching and learning. Out-of-class activity for students in our majors is very substantial. Our department hosts an annual professional conference as well as bimonthly workshops. These activities bring in 40–80 active K–12 teachers into our building for professional events, enabling multiple benefits including interaction with our students. The department organizes an offsite thematic Fall Picnic to welcome all new students, as well as a Spring Formal to celebrate a successful year. Each of these events also bring together 30–60 alumni and ~50 undergraduate students. We have a very active professional student

organization [Technology Education Society (TES)] that organizes several professional and social activities every year. These activities include annual trips to the Technology Education Collegiate Association (TECA) for collegiate activities and competitions (typically against ~10 other Eastern region universities). At TECA five years ago our students placed in only 1-2 events out of 9, compared to the last 3 years where our students performance has increased substantially, placing in 6-8 events out of 9 with many being 1st place recognition. We also host ~1500 grade 6–12 Technology Student Association (TSA) students per year for a variety of design-oriented events. Other out-of-class activities that strongly support teaching include: (i) sponsoring a Summer Pre-Engineering Academy, (ii) hosting annual Jr./Sr. and Teen Tech (female high school students) design challenges, (iii) hosting FIRST FTC Robotics competitions and (iv) securing over $8M of funded K–12 curriculum development. Another important out-of-class activity is the formation and participation in the Alternative Break Club (ABC), a TCNJ club in which one of our students was a founding member. Over the past ~3 years ABC has organized trips to New Orleans over Spring, Winter and Summer breaks to help with building projects (working through *Presbyterian Disaster Assistance* and *Project Homecoming*). Approximately 15 of our students have participated with several completing 2-4 trips, and ~50 TCNJ students participate per year.

Our learning environment also reaps important educational benefits by supporting diverse populations. Our MST majors are primarily female while the Technology/Pre-engineering Education (T/PrEE) majors are primarily male. This has led to substantial social interaction, out-of-class learning and, importantly, a deep appreciation for female roles in STEM education. Additionally, MST majors are passionate about teaching K–5, while T/PrEE majors are focused on grades 7–12. This diversity in intended teaching age-range leads to fruitful interactions in both formal and informal settings, giving both populations substantially more skills and experiences compared to their counterparts in other teacher preparation programs.

Our learning environment also encourages students to participate in scholarly work. In the last three years ~10 students have been involved in our scholarly work, including one MUSE program. Projects have included research survey design and database formation for MST graduates, definition of a measure of quality of lesson planning (comparing MST vs. non-MST majors), robotics lesson plan designs for K-5 and the design of underwater robotics hardware and a bio-reactor.

(ii) Advising: Academic programs can be difficult for students to manage, so our faculty members actively advise ~200 students, resulting in an advising load of 40-50 students per advisor. Only 6-10% of TCNJ faculty members have this level of advising load, so our faculty take extra time for this activity to ensure high quality advising. Our faculty also advise our very active TES student group. A student survey administered by the School (2009) finds that MST students are highly satisfied with "Academic advising in their major." Anecdotally, the department was pleased to learn from a group of SGA senators attending the 2007 Senate Service Award reception for J. Karsnitz that students have expressed appreciation for how well the department advises and serves its students.

(iii) Teacher effectiveness: Faculty typically receive rankings on the teaching surveys of ~4.5 out of 5. Also, a student survey administered by the School (2009) finds that our students are highly satisfied with "Faculty who communicate course material effectively" and "Opportunities to develop the personal skills and abilities needed to prepare for a successful career." There are also external measures of our teaching effectiveness. These include:(i) NCATE accreditation, where the department received a commendation for its national leadership and program innovation, (ii) ~100% pass rates for multiple PRAXIS exams (K-5, 6-8 and secondary), (iii) TCNJ graduates have received ~60% of the coveted Innovative Technology Educators Awards (to date ~fifty $10,000 unrestricted grants have been given), (iv) Danielle Romero, an '09 graduate from our department, received the NJ Distinguished Student Teacher award; (v) nine graduates now teach as TCNJ adjunct professors, all typically receiving 4.5 out of 5.0 on their teaching surveys, (vi) the number of students in our majors have increased from ~80 to ~200 in the last 6 years and (vii) Julie Ryan, a current student, has been elected to the National TECA Board.

II. INNOVATION AND CREATIVITY

Many of our department's successes have been due to innovation and creativity applied to teacher preparation program definition and implementation. Our department manages two STEM teacher preparation programs, each of which is nationally unique and successful.

Technology/Pre-Engineering Education major (T/PrEE)

In recent years, "pre-engineering" courses in high schools have become much more common. A key difference in pre-engineering curriculum is a stronger quantitative basis (math and science). To participate in these educationally powerful programs, schools need teachers capable of teaching courses that range from graphical design to honors pre-engineering or advanced robotics. In 2004, our department proactively convened an Advisory Board meeting. The Advisory Board consisted of seven prominent engineers and educators active nationally in K–12 STEM education. With input from the Advisory Board, a new pre-engineering curriculum was defined, including the STEM principles needed for producing vibrant and capable STEM educators in K–12. This effort put TCNJ on the leading edge of the field, being one of the first institutions to (i) define a pre-engineering curriculum and (ii) hire engineers with a strong K–12 education focus as new faculty. Many Technology Education programs across the USA have still not integrated more science, math and engineering into their programs, making TCNJs program relatively unique. By example, TCNJ's program requires both calculus and engineering math courses, enabling our graduates to attain higher quantitative literacy, an important capability in STEM education. Our transition to a leading pre-engineering curriculum was certainly influenced by our department being an integral part of the School of Engineering at TCNJ, a unique and strategic situation in its own right since of the majority of Technology Education Departments are housed within Schools of Education. Being located within the School of Engineering gives us a broad and complete vantage point of engineering education — viewed as it should be, as a pipeline extending through K–12 and beyond. Our faculty has also led the way with textbooks for pre-engineering curriculum. In 2009, faculty members published *Engineering Design: An Introduction,* the lead textbook for Project Lead The Way (PLTW) curriculum. [PLTW is a leading middle and high school pre-engineering curriculum with >300,000 students engaged in PLTW classes in nearly 3,500 schools.] This textbook, with >11,000 copies in circulation, is starting to be widely used in high schools, including honors-level pre-engineering courses.

Math/Science/Technology (MST) Multi/Interdisciplinary Major

This STEM major was proposed by the department in the late 1990s. The major resulted from a multidisciplinary collaboration between our department and departments in the Schools of Science and Education. The major was approved by the TCNJ Board of Trustees and the NJ Council of Presidents in 1998 and as a disciplinary major for K–5 education by NJ-DOE in 2000. Our nationally unique K–5 MST program has grown quickly, becoming the largest K-5 major on campus. This major is also gaining national recognition as a possible new model for training K–5(8) STEM teachers. [Grades 6-8 are also directly impacted because MST graduates typically obtain endorsements for middle school math and/or science.]

Historically, STEM education has centered on grades 9–12. However, K–5(8) school years are crucial, setting the framework for all subjects as well as developing critical thinking skills. The single most important component in a classroom is the teacher. However, the number of K–5 teachers who are trained with a STEM specialization is extremely small. A lack of STEM subject matter expertise and experiences, coupled with high anxiety and low self-efficacy, can lead to low teacher effectiveness, which negatively impacts the K-5 students. Research has shown that students affect towards STEM is largely determined by grades 5-8, so teacher roles in K-5(8) are critically important. Two key motivations for the MST program were (i) to achieve a higher number of STEM-trained teachers and (ii) to bring pedagogically valuable contextual experiences to our future teachers, and subsequently their K–5(8) students, through substantial and relevant Technology and Engineering (T&E) content. Another unique pedagogical element of our program is a substantial focus teaching STEM subjects in an integrated (interdisciplinary) fashion [i.e.- "integrated-STEM"]. That is, there are substantial pedagogical synergies if STEM subjects are mixed and taught together. To our knowledge, the MST program was the first undergraduate STEM K–5 teacher preparation program in the USA. Due to the successes of our program and recent research that is starting to show the beneficial effects of T&E content on STEM learning, several other

universities now offer or require T&E-oriented STEM courses in their K-5 teacher preparation programs. Our department is responsible for coordinating the MST program. Currently, there are ~160 students in the MST program, which is at capacity for the current department resources. The MST program is starting to attract national attention. For example, the National Academy of Engineers (NAE) and National Research Council's (NRC) committee on *Engineering Education in K–12* invited Dr. O'Brien to talk about this unique program. Also, a paper on our MST program at a major national conference [2010 American Association Engineering Educators (ASEE) annual conference] was 1 of 4 papers (out of 93 papers) nominated for Outstanding Paper. Some important measured attributes of the MST program are summarized below.

- Growth*:* In the last 7 years, the size of the MST program has increased from 2% to ~30% of the total K–5 graduates.
- Gender benefits*:* (i) Over a 5-year period ~25% of the MST graduates have been male, as opposed to ~4% in all other TCNJ K–5 majors. These data suggests that the MST program is attractive to males, a substantially under-represented population in K–5 nationally. (ii) The primarily female MST population provides a strong female presence in all areas of STEM. Literature indicates that this will result in valuable positive STEM role models for female K–5(8) students.
- Content knowledge, anxiety & self-efficacy: Teacher effectiveness depends on attaining a high level of appropriate content knowledge. A concern with a multidisciplinary program like the MST program is that the breadth may reduce the depth of content knowledge. However, measurements indicate that MST graduates score high on national tests for math and science while also scoring high on important non-STEM subjects. Graduates also demonstrate high skills in T&E content, enabling powerfully synergistic teaching skills that encompass standards for technological literacy and 21st Century Skills. Measurements of math anxiety and math teaching self-efficacy also show that MST graduates exhibit low math anxiety and high teaching self-efficacy, which breaks a deleterious chain-reaction that historically exists in K-5; female K-5 teachers with high math anxiety preferentially passing this anxiety onto their female students.

III. DEPARTMENT IMPACT

Even though the department is relatively small, the ***impact of our department*** on TCNJ, regional and national communities has been significant. Faculty members have provided leadership and service at all levels of the institution, as well as the State, Regional and National levels. Our impacts are summarized below by category.

School: **[1]** John Karsnitz [Department Chair, College Governance, Senator and SXO, Interim Dean, Provost Search Committees, Strategic planning committee]; **[2]** O'Brien [Faculty Senator, Dean search, Strategic Planning Chair, and a variety of service including Curriculum Committee, and 5 search committees covering 3 departments); **[3]** Cathell [Interim-Chair (during Karsnitz sabbatical), Coordinator of the PLTW Pre-Service Affiliate Program, and service on a variety of School committees.]

STEM Education Center: **[1]**From 1993 to 2007 published TIES (Technology Innovation and Entrepreneurship for Students) magazine with an international circulation of ~40,000; **[2]** $2+M NSF grant "*Project UPDATE and UPDATE II*," establishing content and strategies for design in technology within a five state region; **[3]** TSC Thrust I site of the $10M *NJ Statewide Systemic Initiative* (SSI); **[4]** $1.3M *Children Designing and Engineering (CD&E)* project; **[5]** $2.4M *Exploring Designing and Engineering* (ED&E) project; **[6]** Various recent regional engineering education outreach projects funded by the Martinson Foundation (~$1M) {Trenton Boys & Girls club, Future Engineers and TSA Expansion}.

College: John Karsnitz has provided leadership in college-wide governance. From 1990–2000, John served as a member of the Steering Committee, mostly as the chair. From that position, he was asked to lead an effort to create a new governance system that would be more effective and efficient. Most would agree that the "Governance Structure and Processes" (2000) achieved the intended goals. In June 2007, President Gitenstein received the American Association of University Professors' Ralph S. Brown Award for Shared Governance. John's work in governance was recognized in 2008 by a Faculty Senate Resolution of Appreciation for his efforts in shared governance. John has served on the Faculty Senate and the Senate Executive Board since 2000. Between 2000-2004, John served as a faculty-elected representative to TCNJ's Board of Trustees. John has also served on

several executive administration search committees, most recently the Provost search in 2009. John is currently working with a committee on establishing guidelines and support for faculty-elected chairs. Steve O'Brien serves on the newly formed Teaching & Learning Program Council. J. Karsnitz, S. O'Brien and S. Donohue have also served on the Teacher Education Program Council. M. Cathell has twice been a facilitator of freshman summer reading seminars, and was a scorer for the college-wide Sr. Writing Assessment (2009). M. Cathell also serves as TCNJ resource person for the NSF Graduate Research Fellowship program.

Our department's early work in technological studies as a new liberal art led to the creation of a required college-wide Society, Ethics, and Technology (SET) course in the new liberal learning program introduced in 1990. The work was recognized by the National Association of Science Technology and Society (NASTS). In 2007 the Department working with Richard Kamber, Coordinator of Self-designed majors and Interdisciplinary Concentrations, established a SET Option-A to the Liberal Learning Program.

State: **[1]** Drs. Karsnitz, Weber and Hutchinson's leadership on the NJDOE Science Framework group defining the technology standard (5.4) in the 1996 Core Content Standards and in 2004 working with leadership from State, industry, and professional associations led to the establishment of the NJ Core Content Technological Literacy Standards (8.0). **[2]** Dr. Weber's leadership through the NJ SSI grant helped establish technology as an essential component of math and science now recognized as "STEM" education nationally.

Nation: **[1]** NAE/NRC committee on *Engineering Education in K–12* invited Dr. O'Brien to talk about our unique K-5 MST program (2007). **[2]** Dr. O'Brien was specially invited to a national workshop *Convening a Dialogue on K-12 Engineering Education* with the goal of defining and documenting major national issues facing engineering education in K-5 (2010). **[3]** Dr. O'Brien was invited to a national summit on *P-12 Engineering & Design Education Research* spearheaded by Purdue University, a leading institution in engineering education in the USA (2010).

International: **[1]** Presented "*Liberal Learning Requirements for Engineering Degree Candidates at TCNJ (and Technological Studies, Literacy and Humanities),"* at Association for General & Liberal Studies (AGLS) conference on Integrating Engineering and Humanities in Higher Education: The Bologna Process & Beyond, Darmstadt, Germany (O'Brien & Karsnitz, 2008) {*European universities wish to add more liberal studies to engineering school requirements so they initiated a dialog with USA institutions*}. **[2]** Presented workshop titled *Designing and Building Amish-Style From Recycled Bicycles* at Design Principles and Practices International Conference, Rome, Italy (Cathell, Hornberger & Foti, 2011). {*This interdisciplinary project is a collaboration between Technological Studies and Elementary Education and intimately involved a Sr. Elementary MST major (Ms. Foti).*}

Profession: **[1]** Books: *Society, Ethics, and Technology* (2010) Dr. Edelbach & Dr. M. Winston; *Engineering Design: An Introduction* (2009) Karsnitz, O'Brien & Hutchinson (2nd edition in progress); *Designing with Pro/D* (2005) Dr. J. Hutchinson; *Design & Problem Solving in Technology* (1993) Karsnitz & Hutchinson; *Society, Ethics, and Technology: Selected Readings* (1993) original edition Editors: Winston, Karsnitz & Goldberg); *Graphic Communication Technology* (1992) Karsnitz; *Graphic Arts Technology* (1984) Karsnitz. Dr. O'Brien has also been asked to write a chapter on a national perspective on pre-service engineering education in a book titled *Engineering in Pre College Settings: Research into Practice* (Sense Publishers). **[2]** NJ-TEA: For the past 20+ years our department has provided TCNJ representation on a very active NJ Technology Educations professional organization. Typical service has included work on state standards, education legislation, conference planning and outreach. **[3]** TECA Service: For the past 20+ years TCNJ has continuously provided leadership, planning, competition design and implementation and judging for this annual collegiate conference. **[4]** Summer Pre-engineering Academy: With financial support from the Martinson Foundation, the department has designed and implemented a summer residence Pre-Engineering Academy for high school students. **[5]** With the creation of the T/PrEE major in 2005, the department sought and was approved to be a PLTW Affiliate, which enables our students to be pre-service certified to teach PLTW content. Dr. Cathell coordinates the PLTW pre-service program. **[6]** P. Hutchinson, a former member of our STEM education Center and adjunct faculty member, spearheaded the advisory board of the *Technology for All Americans* project, eventually leading to the process of "Design" being named as one of the five major divisions in the national standards for technological literacy.