Going big: scaling up international engineering education to whole college initiatives

Dr. Eck Doerry, Northern Arizona University

Eck Doerry is an associate professor in Computer Science at Northern Arizona University. His research interests fall mainly within the areas of Groupware Systems, focusing on computer support for widely-distributed research and learning communities; and in Engineering Pedagogy, focusing on interdisciplinary and international teaming approaches to teaching engineering design. Internationalization of engineering education has been a particular passion for Dr. Doerry. He has been a leader in internationalization of Engineering at NAU since arriving in 1999, expanding this initiative to the Natural Sciences starting in 2005. Significant milestones in this area include the development of an effective model of reciprocal "exploratory trips" to motivate international study in engineering; the International Engineering and Natural Sciences certificate program; and the Global Engineering College project, an NSF-funded exploration of a comprehensively internationalized curricular model for engineering education. These efforts culminated in 2010 with the creation of the Global Science and Engineering Program (GSEP), an innovative initiative to establish a comprehensive framework for internationalization uniformly spanning all engineering, math and natural science disciplines at NAU.

Dr. Harvey Charles, Northern Arizona University

Dr. Harvey Charles is vice provost for International Education at Northern Arizona University. He provides institutional leadership on strategic planning around global education, helps to facilitate global learning opportunities for students, supports faculty development opportunities through international teaching and research, and consults with colleges and universities on curriculum and campus internationalization. The Global Science and Engineering Program is one of the signature programs housed in the Center for International Education that he directs.
Abstract
Comprehensive globalization in engineering design and manufacturing in the last decades has led to fundamental new imperatives, as we consider how to effectively train and prepare our Science, Technology, Engineering and Mathematics (STEM) workforce to succeed in this diverse, multicultural, widely-distributed, multi-lingual research, design and production network. Over the past 10 years, many forward-looking institutions have experimented with internationalized curricula and programs to meet this need, but many remain smaller scale initiatives limited to one or two participating departments or programs. In order to take STEM internationalization to the next level, we need to efficiently make internationalized tracks available as a regular, attractive option to all STEM majors, requiring a comprehensive, uniform approach at the institutional level. In this paper, we provide a starting point for this conversation by discussing our development of the Global Science and Engineering Program (GSEP), a broad internationalization initiative uniformly spanning all engineering, math, and natural science programs offered at Northern Arizona University. To help pave the way for others, we pay particular attention to discussing obstacles, critical design features, and best practices.

1.0 Introduction
Globalization has been the predominant economic theme for the past decade, leading to broad global distribution of research, design, and production teams and facilities spanning the full spectrum of science and engineering disciplines [9]. Modern STEM graduates will be expected to communicate and collaborate across cultural, linguistic, and national boundaries on a daily basis; and globalization of the labor market means that U.S. STEM graduates must be prepared to compete with international candidates for choice positions [4][18].

While other countries have invested heavily in developing globally competent engineers, institutions in the United States have generally been slow to respond to this trend, leaving our graduates ill-prepared to compete in the modern global marketplace. In Germany, for instance, upwards of 25% of all engineering students engage in at least one study-abroad or international internship experience [2]; by sharp contrast, only 3.5% of U.S. engineering students go abroad during their studies [1].

Given the recognized national urgency of better preparing our engineering graduates for global practice [21][12][7][4][15], it is surprising how little progress has towards this goal has been made on a broad national level. Some institutions have responded to these new imperatives by working harder to integrate global perspectives on campus, typically within the “general studies” curriculum. At Northern Arizona University, for example, our campus-wide Global Learning Initiative [3] provides support and incentives for faculty across campus to develop internationally-informed curricular elements for their existing classes, as well as organizing a host of cultural events, lectures, and other activities aimed at enriching international and multicultural exposure on campus. Most institutions also have some sort of international office that encourages students to engage in some sort of study or internship abroad. Although such broad efforts are certainly important, they fall well short of providing focused, specific preparation for STEM practice in a global economy. More to the point, the abysmal 3.5%
participation rate of engineering majors clearly indicates that current offerings are not viewed as attractive, relevant, and easy to integrate into already packed engineering curricula. As a result, nearly all U.S. engineering graduates still leave college with little or no significant international exposure.

A small but growing handful of institutions have begun responding to these new imperatives by exploring a variety of more in-depth international preparation programs. For instance, Iowa State University’s Language and Cultures for the Professions initiative [17] encourages students to incorporate specialized language study and cross-cultural coursework into their curricula, as well as aid in finding internships abroad. Similarly, the GEARE program at Purdue [10, 14] offers engineering majors the opportunity to integrate introductory language study, a semester of study plus summer internship abroad into a four-year curriculum. The International Plan at Georgia Tech [11] offers students a range of options for internationalizing their studies, requiring a combination of globally-focused coursework, basic foreign language exposure, and a total of 26 weeks of study, research, or work abroad. Many of these programs have been inspired by the International Engineering Program (IEP) [13, 16] at the University of Rhode Island, an early, pioneering effort in engineering internationalization that still remains one of the most comprehensive and cohesive program models today.

Despite these successes, the number of institutions offering comprehensive, broadly-accessible internationalized training remains relatively small, and internationalization at most institutions, if available at all, is limited to one or two select programs. One obstacle to broad, nationwide deployment of internationalization in STEM education is the custom-constructed, mix-and-match nature of many existing programs, which often began as experimental initiatives based on a particular existing relationship to a particular university abroad. This often makes such initiatives both difficult to scale beyond the natural capacity of the initial partnership and, more importantly, difficult to expand to other departments, colleges, or institutions. What is needed is a robust, broadly-applicable model for pursuing internationalization of STEM education on a college-wide basis.

In this paper, we provide a starting point for this conversation by discussing our development of the Global Science and Engineering Program (GSEP), an ambitious internationalization initiative uniformly spanning all engineering, math, and natural science programs offered at Northern Arizona University. As a top-down initiative that offers comprehensive Science, Technology, Engineering and Mathematics (STEM) internationalization tracks on a broad, college-wide scale, GSEP has had to overcome a range of challenging curricular and logistical obstacles. At the same time, GSEP demonstrates that addressing these challenges uniformly at a college or institutional level offers economies of scale that can make the cost of establishing such large-scale programs surprisingly modest while greatly increasing their accessibility and impact.

In the next section, we begin by describing our Global Science and Engineering Program in detail, followed by an in-depth discussion of program design considerations and rationale for key program features, with particular attention devoted to design decisions that impact program scalability and efficiency. In Section 3, we turn to a broader discussion of best practices in planning and implementing comprehensive, college-wide internationalization initiatives for other institutions exploring large-scale internationalization of their engineering and science programs.
2.0 The Global Science and Engineering Program (GSEP)

As noted in the introduction, there are many possible approaches to internationalizing engineering education, and several other institutions have developed successful models in this area. Our own experimentation with internationalization spans nearly 15 years, and the design of GSEP is informed both by our successes and failures in the area, as well as by insights and inspiration adapted from initiatives elsewhere. In this context, the GSEP initiative is primarily motivated by one compelling question:

*What would it take to move STEM internationalization to the next level, moving from small-scale program-centric initiatives to a broad college or campus-level model that makes intensive internationalization a routine enhancement available in every STEM degree program?*

This focus moves program design and internationalization pedagogy into the spotlight; our aim has been not merely to design “yet another program”, but to understand how specific aspects of program scope and design influence the scalability, operational efficiency, and long-term sustainability of internationalization initiatives. GSEP is our attempt to realize this broad vision of a uniform, scalable “production” model for intensive internationalization. Our hope is that a clear discussion of not just GSEP program structure but also its design rationale will help others in planning their own initiatives. We begin by first describing the structure of the GSEP program, then turn to a detailed examination of its design rationale.

2.1 GSEP Program Structure

The primary goal of GSEP is to make internationalization a routinely available, easily-accessible option for all STEM majors on our campus; GSEP creates parallel internationalized tracks for all STEM degree programs (Figure 1) on our campus that augment the core STEM degree with intensive foreign language learning, cross-cultural training, and an immersive international professional experience. Particular emphasis is given to lowering barriers to program participation by providing (just as for conventional degree tracks) pre-planned, turn-key curricular plans for every supported degree program, routine support from the college’s professional advising staff, and comprehensive planning and logistical support for the year abroad. The overall aim is to maximize program accessibility and volume by making the international tracks no more difficult to negotiate than conventional degree programs. Certainly adding intensive language and cross-cultural training to an already challenging STEM degree program requires additional work and exceptional commitment from students, but this should be the only challenge that participants must overcome.

![GSEP Program Structure Diagram](image-url)
GSEP scholars may choose from five supported languages: German, French, Spanish, Chinese, and Japanese. The choice of these particular GSEP languages was driven by a strategic aim to (a) maximize coverage of languages and regions with strong global STEM leadership; and (b) leverage existing degree programs in our Modern Languages department. In the German, French and Spanish variants, GSEP scholars augment their primary STEM degree with a second BA in their chosen foreign language, performing both coursework and their internships in the foreign language while abroad; in Chinese and Japanese variants, GSEP scholars earn a minor in the language and, accordingly, pursue English-centric study and internships while abroad. The reasons for this two-tiered distinction between European and Asian languages are purely practical: our institution does not currently offer Bachelors degrees in these languages; and, even when these are added, it is questionable whether six semesters of study in these particularly difficult languages [8] will be sufficient to prepare students to perform coursework or internships in the language. Finally, English is not supported as a GSEP language simply because extensive linguistic and cultural training is not necessary to prepare STEM majors for study-abroad, foreign internships and professional practice within the English-speaking world; Northern Arizona University offers many popular study-abroad programs in the UK and Australia that are easily accessible without further preparation.

GSEP Status. GSEP was established in 2011, augmenting our existing conventional short-term internationalization offerings to become Northern Arizona University’s signature STEM internationalization initiative. Student response has exceeded expectations, with about 50 freshman entering the program each year; we expect this number to grow to about 70-80 incoming freshmen annually as the program becomes fully established and begins drawing STEM majors to our institution expressly because of GSEP. We currently have 72 students in the program, spanning nearly all STEM majors and languages (Figure 2). Attrition has been relatively high, approaching 50% over the first two years. While retention remains one of our top priorities, the high attrition is not surprising given that given that students are recruited into GSEP as inexperienced freshmen; those dropping out unanimously cite the challenge of GSEP’s ambitious integrated STEM/foreign language curriculum as the reason. We do not consider these students to be “internationalization

---

1 Exceptions include Construction Management and Mathematics, where we’ve found it more difficult to articulate the value-added for internationalization. Chinese currently has no students due to reorganization of foreign language instruction in that area.
failures”; rather, they typically remain interested in international experience of some sort, and we are often able to re-direct them into one of the many more conventional short-term experiences abroad offered through our Center for International Education. As the five-year GSEP pipeline fills to capacity, we expect GSEP to support between 250 and 300 students, sending approximately 50 students abroad each year.

2.1.1 GSEP curricular model

The GSEP program is based around a five-year curricular model, with an integrated fourth year of study and internship abroad as the program apex (Figure 3). This model is directly inspired by the International Engineering Program at the University of Rhode Island [16][13], where it has proven its effectiveness for comprehensive international preparation for over two decades. Custom-tailored 10-semester curricular plans for each supported major highlight how the unique curricular elements, course offering schedules, and prerequisite chains for each major can be arranged to fit within the five-year curriculum, providing GSEP scholars with a clear roadmap for internationalizing their science or engineering studies. For the off-campus year abroad, GSEP scholars may select from a short list of specially approved GSEP partner institutions for a semester of study-abroad, followed by a six-month professional internship placement within their discipline. Design of the international year is discussed in more detail in Section 2.1.3. The investment of an additional year of undergraduate study is rewarded with a second BA (or minor, in the case of Chinese and Japanese) in a foreign language, a formal Certificate in International Engineering and Natural Science … and, of course, an incredible international professional experience. The GSEP program is free of cost to all STEM undergraduates; participants simply pay regular tuition and fees at their home institution throughout, as well as covering their travel and accommodations while abroad.

As indicated in Figure 3, students are recruited into the program as they begin their freshman year. Because six semesters of language coursework are required before going abroad, it is critical that students not transferring language credits (e.g., via CLEP test) enroll in the language training track in their first semester. Our recruiting goal is to enroll GSEP scholars before they arrive on campus; GSEP recruiting materials are included in every informational packet distributed to potential STEM undergraduates by university recruiters, and followed-up with further invitations sent to each freshman and to the parents of each freshman newly enrolled in a STEM degree program. In general, students may enter GSEP at any time in their freshman year, provided they commit (e.g. through summer courses) to getting on track in the GSEP language curriculum by the end of their sophomore year.

In the second and third years, students continue their engagement in GSEP cross-cultural training and other activities (see next section) as they progress into the upper division of both their STEM and foreign language studies. Our initial experience has shown that it is challenging to maintain...
momentum and enthusiasm during this period and continually work to expand program activities and engagement. In addition to on-campus programming, we are currently developing short, optional group trips abroad in the summer of participants’ sophomore year to provide a motivating preview of the upcoming year abroad. We have used this “exploratory trip” concept with great success to recruit engineers into study-abroad in previous initiatives, and anticipate that this intermediate highlight will help motivate and retain students through the difficult preparatory period.

The fourth year is the apex of the GSEP curriculum, providing a full year of intensive language training, cross-cultural exposure, and internationalized professional immersion. Destinations are chosen from a short list of special GSEP partner institutions at which the STEM degree programs have been vetted by our faculty, and for which we have developed a list of upper-division courses in targeted STEM disciplines, language studies, and general studies that are pre-approved for transfer towards GSEP’s STEM and language degree programs back home. Following a semester of studies at a partner institution, participants are provided with an internship placement within their STEM discipline in a local company or research laboratory. During their year abroad, GSEP scholars regularly participate in “webinars” integrated into GSEP meetings for the on-campus participants, helping to engage, motivate, and prepare future cohorts for their upcoming year abroad.

Finally, GSEP scholars return to NAU to complete Capstone experiences and remaining coursework in their STEM major. As experienced global professionals, these students continue to participate in GSEP meetings, serving as role models and mentors for younger GSEP cohorts.

### 2.1.2 GSEP’s comprehensive, committed program concept

In many ways, the broad, college-wide GSEP concept is comparable to the Honors Program concept, in that provides no new degree programs in and of itself, but serves to optionally augment or “upgrade” any existing STEM degree program on campus. Even more so than an Honors program, however, GSEP is based on a “committed participation model”, meaning that students explicitly apply to the program in their freshman year, and are expected to participate in a continual series of mandatory meetings and program activities throughout. This reflects our philosophy that true internationalization is not achieved via an isolated event or trip abroad, but involves the shaping of an entire professional world view and thus should infuse and influence the entirety of undergraduate training. More practically, the committed five-year program model creates a strong sense of identity within the cohort, contributing to program engagement and retention. Thus, the only exception for students entering GSEP after the freshman year is for transfer students with appropriate existing language credits (i.e. to be “on track” in language training). There is also no provision for “a la carte participation”, i.e., allowing students to participate randomly in some GSEP program activities and not others; it is not possible to do only a semester abroad, or only the international internship². In addition to the year of study and internship abroad, key elements of the GSEP on-campus preparatory program include:

- A required, repeatable 1-credit “GSEP seminar” course that GSEP participants enroll in each semester, which provides the formal academic framework for all GSEP meetings, trainings, and guest speakers. To avoid overloading the already packed schedules of

² Of course, any student may elect to pursue such a “stand-alone” international experience on his or her own initiative; traditional short-term study-abroad programs at Northern Arizona University provide extensive support for such individuals.
GSEP scholars, events are conscientiously spaced throughout the term, to achieve an average of one mandatory event every three to four weeks. Cross-cultural training includes presentations on history, major political movements, famous engineers or scientists, religious practices, and differences in professional communication and practice; the aim is to allow GSEP scholars to enter their foreign communities of practice as sensitive and knowledgeable colleagues. The third year sub-cohort is singled out for additional training related to travel planning, health and safety, foreign academic practices, and preparing for internships abroad.

- Social events and outings aimed at building cohort identity and cohesiveness. Examples include international potlucks, group outings for hiking or sightseeing, and international movie nights.
- The International House. The International House is housed in one of the newest and most desirable dormitories on campus, and is dedicated to providing a thoroughly multicultural, international living and learning experience. Although all students above the freshman level with international background or interests are eligible to apply for residence in the International House, GSEP participants automatically have top priority in the competitive selection process. Residence in the International House is not required for GSEP participation, and GSEP scholars living elsewhere are invited to participate in all activities.

In sum, building and maintaining a strong, cohesive “international learning community” through a variety of rich, mandatory on-campus activities is a key element of the GSEP concept, and is vital for supporting retention and academic success of GSEP scholars by embedding them within a supportive social framework centered around international themes. Our aim is to meld GSEP scholars into an “international fraternity” that learns together, studies together, eats together, plays together…and ultimately goes abroad together.

2.1.3 International Study and Internship

A full year of study and professional internship abroad represents the “capstone experience” of the GSEP program, and has been carefully designed to maximize the value of this substantial investment. In general, students are abroad between 10 and 15 months, depending on semester timing at the foreign partner institution and the timing of their internship commitment. In general, the basic requirement for the GSEP international experience is: One semester of study in a non-English-speaking country, and an international internship or research experience of at least 20 weeks duration.

Some important features of the GSEP international experience include:

- Exact coursework taken abroad varies based on individual curricular needs of participants, but students must attend courses full time, and at least two courses taken must be taught in the foreign language to satisfy the requirements of the special BA in Modern Languages subplan developed for the GSEP program.
- The study-abroad term is fully leveraged to allow students to finish in five years by prioritizing transferable coursework needed for graduation. This is particularly critical for engineering, where degree programs allow for few or no general electives; this means that some required engineering coursework must be pushed into the semester abroad to make room for language studies in the first three years. Special care was taken avoid conflicts with ABET-accreditation in Engineering programs by working hard to push
only liberal studies coursework and major electives abroad; no core courses (where ABET instruments are typically attached) appear in the year abroad. This preserves as much flexibility as possible in selecting courses at foreign partner institutions that might be eligible for transfer in degree programs back home.

- Aside from the two required courses in the foreign language, students may elect to take some coursework in English, if such courses are offered at the partner institution. Indeed, availability of some coursework in English was a secondary criterion in selecting GSEP partners abroad to allow for a little (linguistic) relaxation in a full-time class schedule.
- The international professional internship may be paid or unpaid, and is closely-related to the student’s major discipline. Placements in a corporate context are preferred for engineers; placements in a university or governmental research facility or laboratory are often more suitable for natural scientists.
- 15 hours of immersion language learning credit are assigned to the internship in special BA in Modern Languages subplans developed for GSEP, meaning that all internship placements are required to be in a primarily non-English-speaking environment. This rules out some placements in overseas offices of US companies to focus on internship placement in small and mid-sized local enterprises.
- The internship also satisfies the Capstone requirement for the BA in Modern Languages subplans developed for GSEP scholars. The deliverable for the Capstone are due in the semester after returning from abroad, and consist of a formal technical paper in the foreign language, paired with a formal public presentation on the paper’s topic.

Clearly, developing and maintaining a network of partnering institutions and internship providers that covers five languages and 14 STEM majors represents an enormous logistic challenge. It also represents a difficult financial puzzle, given our goal of designing GSEP to be self-supporting while avoiding special program fees beyond regular tuition. We have addressed this challenge by negotiating a special tuition remission arrangement for GSEP scholars (detailed under Section 3 on Best Practices), and by focusing intensively on maximizing efficiency in program design. This efficiency is achieved through a combination of standardization, volume, and minimization of program overhead, and is discussed in detail in Section 2.2.1, where we discuss the advantages of scale in program design.

2.2 GSEP Design Rationale
Northern Arizona University has invested nearly 15 years in exploring internationalization of engineering education through a variety of initiatives ranging from special recruiting and introductory trips to European partner institutions, to an International Engineering and Science certificate program, to an NSF-funded exploration of a comprehensive college-wide internationalization concept [5, 6]. Although these efforts enjoyed some modest success, student interest and participation was always limited by a variety of logistical and practical obstacles, including:

- Curricular issues. It was difficult to find space for study or internship abroad (much less language study) in already packed engineering curricular plans; many students were reluctant to extend their undergraduate studies without a clear and tangible benefit. Worried about ABET accreditation, many engineering chairs expressed concern about crediting coursework taken abroad and required students to collect extensive documentation on courses taken, resulting in effort and high perceived risk for students.
International logistics. The need for transferable coursework taught in English severely limited the choice of potential partnerships and coursework available to participants. Although many institutions abroad now offer some engineering coursework in English, the selection is small. In practice, this meant maintaining many low-volume partnerships and struggling to find suitable coursework between them for students.

Inadequate infrastructure. Given the high level of customization needed for each student, it was impossible to provide adequate advising and planning support to each individual. As a result, students were essentially left to work out the detailed design and logistics of their international experience for themselves.

These negative dynamics left us continually struggling against a “death spiral” in overall initiative sustainability: left to themselves to work out many details, student participation was limited to relatively few, exceptionally motivated and risk-tolerant students; low volumes made it difficult to justify further investment and led to stagnating foreign partnerships; reduced support then led to even more limited student participation. Ultimately, what was meant to be a broadly accessible internationalization initiative ends up as a sparse set of unreliable niche opportunities for students in one or two disciplines championed by a particular faculty member with connections at a particular foreign institution.

2.2.1 The Case for Going Big

In an age of limited resources, many engineering administrators and educators will be skeptical about committing to a comprehensive, college-wide internationalization effort. Wouldn’t it be wiser to start with a small pilot, perhaps starting with one or two programs, then consider expanding it if successful? We suggest that just the opposite is true. A truly robust program and infrastructure is too costly to develop and sustain for just one or two programs, leading to inevitable compromises and, ultimately, the resource-starved “death spiral” we experienced. At the same time, a carefully designed generic program model and a uniform core infrastructure can, with relatively modest incremental investments, just as easily serve (and be amortized by) 14 degree programs as one, while at the same time offering internationalization opportunities across a much more meaningful percentage of degree programs.

This observation simply recognizes a fundamental principle that will be familiar to any production engineer: mass production is far more efficient than producing individual prototypes, but requires both designing the product for the widest possible market and a comprehensive focus on process efficiency; production infrastructure is sustainable only through high volume at minimal “cost per unit”. This commitment to a “production philosophy” from the very outset – to “going big” – represents a fundamental shift in the strategic approach to STEM internationalization at Northern Arizona University, and has played a role in shaping nearly every facet of GSEP program design and implementation. Two implications of this approach have been particularly important:

Focus on broad appeal, easy access. To ensure high volume, GSEP was designed based on a simple program model attractive to the full spectrum of STEM majors at our institution. Particular attention was given to communicating the value proposition (“Add one year of studies, get two degrees, an international certificate, and an unbeatable résumé”) to both students and their parents. Complexity, planning investment and perceived risk are minimized to keep barriers to participation low, with pre-planned curricular plans, no initial language requirements, and comprehensive advising and logistic support throughout. The strong focus
on building a vibrant GSEP community, priority access to the International House, and specially developed curricular accommodations are all aimed at presenting students with a compelling, turn-key vision for internationalizing their studies.

Focus on uniformity and efficiency. To reduce overhead, every effort was made to design every possible aspects of the GSEP program and its infrastructure to be as generic and uniform as possible: All GSEP participants in all disciplines follow the same general path through the program; the model GSEP curricular plans that help guide students in each degree program all follow a similar design; the customized foreign language tracks developed for GSEP are essentially identical across languages; all GSEP students go abroad in the same (fourth) year; mandatory group meetings ensure that all students receive the same consistent preparation; and program policies are uniform across all disciplines. Efficiency is further maximized by carefully working to leverage existing on-campus resources: all mundane logistics (travel, visas, lodging, etc.) are handled by existing international student services in our Center for International Education; existing professional advisors in the college were trained to routinely handle most aspects of GSEP curricular advising, based on the model plans developed for each degree program. The focus on efficiency extends to international partnerships as well: students may choose from just a small set (no more than two in each country) of designated GSEP partner institutions; and partner institutions were carefully selected based on the number of GSEP degree programs covered by the institution, the ability to help arrange internships for GSEP students, and the capacity to accept larger numbers of exchange scholars as our program expands. This sometimes involved conscious sacrifices of expediency for long-term efficiency, e.g., forging a single new partnership rather than spreading GSEP scholars over a collection of existing partnerships; or declining a partnership with an institution where a faculty member happens to have a connection but that otherwise fails to meet the above criteria.

These two fundamental program design principles ensure the basic long-term viability of the GSEP program concept: the substantial initial investment in program startup and comprehensive support infrastructure can be amortized by broad program breadth and appeal, while careful attention to program efficiency ensures that infrastructure costs are minimized. It is important to emphasize that this focus on efficiency applies to design of the overall program framework and policies only, and is not meant to suggest that every participant is identical. Indeed, it is the rare student that follows exactly the suggested GSEP program of study for his or her major; some specialized advising is always needed to accommodate individual differences. Similarly, GSEP scholars with strong preferences may elect to spend their study semester at any of our institution’s over 100 bilateral exchange partners, but must then commit to take primary responsibility for planning this exceptional arrangement themselves. Thus, the general aim of our program design philosophy is not to forbid all exceptions, but rather to focus from the outset on maximizing the appeal and versatility of a small number of “standardized” choices so that exceptions are rarely needed.

In sum, a “production philosophy” based on maximizing volume while minimizing overhead is the core rationalizing principle behind GSEP, shaping nearly every aspect of program design. In the remainder of this section, we build on this foundation by examining the detailed rationale behind a few of the key features of the GSEP program that might be particularly relevant to those planning their own programs.
2.2.2 Analysis of key GSEP program features
Within the framework established by our overall discussion on the dynamics of program scale, we now turn to a brief discussion of several defining features of the GSEP program model itself. As noted earlier the overall five-year, dual-degree program concept for GSEP is directly inspired by the exceptionally successful International Engineering Program (IEP) developed over the past 20 years at the University of Rhode Island [13, 16]. This itself is a carefully considered design decision and it is useful, in particular, to illuminate some of the practical considerations that motivated us to adopt key features of this model.

Why adopt a five-year model for the GSEP program?
Given the rising costs of higher education, adopting a model that extends students’ studies by a year may appear counterintuitive. Why not offer a condensed program, that minimizes the time-consuming cultural and language preparation to focus on a semester abroad and/or a summer internship, and that allows most students to finish in four years? This was essentially our orientation throughout the 10 years of engineering internationalization efforts preceding GSEP, and our reasons for abandoning it in GSEP are both philosophical and very practical. From a philosophical standpoint we have recognized that, as difficult a hurdle as it represents, achieving operational competency in a second language is a key part of becoming a true global professional [19, 20], and greatly enhances the impact of study and internship abroad. Having local language competency is simply critical to understanding and participating fully in the academic and professional environment of a foreign culture. There is, of course, value to simply getting students abroad and, indeed, we promote our institution’s many stand-alone English-centric study-abroad opportunities for students as a second-tier option for students unable to commit to or complete the demanding GSEP program.

There are strong practical reasons to build intensive language learning into a program model as well. Limiting oneself to partner institutions that offer coursework in English greatly reduces options, both in terms of partner institutions and in terms of the coursework students can hope to satisfy abroad. The same dynamic applies to internships: few companies or laboratories are willing to take on interns that speak only English, particularly in challenging economic times when internship slots are limited and hotly contested by local candidates. In addition and regardless of language proficiency, most internship providers abroad expect a six-month commitment, and very few will settle for an 8-12 week summer commitment. The practical outcome of these realities in past internationalization initiatives was that, despite best efforts, most students who went abroad ended up delaying graduation in order to take at least a few semesters of foreign language and to accommodate semester or internship timing abroad.

The GSEP approach is to simply accept that meaningful international training will require an extra year, and to focus on maximizing the return on this investment, i.e., by providing a second degree and a high-value international internship experience. The specialized BA in Modern Language subplans specially developed for GSEP scholars focus narrowly on rapid attainment of working competency, meaning that actual classroom studies to attain the additional degree are extended by a single semester, with the remaining six months devoted to the internship. This allows GSEP to provide a value proposition that is compelling to students and parents alike: invest an extra year, earn two degrees, an international certificate, and an invaluable foreign professional experience.
Why should students go abroad in the fourth year of the program?

Our primary aim in targeting the fourth year for the experience abroad is to ensure consistent, synergistic, and high-quality program dynamics and outcomes. In our previous internationalization efforts, participants were encouraged to schedule their experience abroad as it fit best in their individual study plans. Some went as sophomores, some as seniors, some over a summer; the level of language preparation varied widely as well. Accordingly, the outcomes of these experiences were highly variable, with some students becoming fully integrated into their study or internship environments, while others had superficial experiences due to poor professional or linguistic preparation. Requiring three years of on-campus preparation before going abroad guarantees a consistent level of preparation that yields a number of important benefits:

- **Linguistic maturity.** While the rate of language acquisition varies considerably among individuals, we have found that requiring six semesters of focused language training ensures that nearly all students will have achieved basic functional competency… what we call “the take-off point”, where comprehension and speaking are adequate to provide engagement and traction for rapid further advancement in an immersed learning environment.
- **Professional maturity.** As fourth-year students, participants have reached a level of professional skill in their discipline that allows them to contribute meaningfully in a research or corporate internship context.
- **Simplified logistics.** Finding and vetting transferable coursework can focus mainly on courses at the senior level in each discipline, and coursework in both English and the local language can be considered. Similarly, the uniform preparation of all students greatly simplifies finding internship opportunities; skilled interns with strong language abilities are very attractive to providers.
- **Partner satisfaction.** Being able to offer partners a consistent stream of technically and linguistically-competent students is an incredibly powerful asset in building and maintaining a partnership network for the program. This is particularly true of internship providers, who are keen to invest in interns that can reliably contribute real productive work to their operations.
- **Program Quality and Outcomes.** Consistent linguistic and professional preparation ensures that participants can fully engage in study and internship experiences, maximizing the impact of learning experiences. This is critical for the GSEP program model, which is built on the expectation that students will take transferable engineering and science coursework while abroad.

Given the focus on preparation, it is interesting to consider allowing (by exception or design) students to go abroad in their fifth year, i.e., essentially after they have graduated with their primary STEM degree. Indeed, a number of GSEP students have requested this postponement, e.g., in order to be able to graduate with friends in their STEM program. There are several good reasons for insisting on the fourth year abroad, however, with a fifth year to finish up back on the home campus:

- **Pedagogical dynamics.** Philosophically, it is important that the experience abroad be an integral part of the undergraduate experience, rather than an addendum tacked on the end. Participants need the time back on campus to properly digest, reflect on, and integrate
their international experience, as they return to share their experiences with classmates, and apply newly-acquired skills in their Capstone coursework. This opportunity would be lost for students returning to face the upheaval and new priorities involved in finding jobs and starting their working careers.

- Program dynamics. As described in Section 2, our focus on a strong, self-sustaining cohort is a key element in GSEP’s recruitment and retention strategy. Interactions between students returning from successful years abroad with those in the preparation phase are incredibly valuable for motivation and retention; there is nothing more meaningful and credible than an enthusiastic report from a peer.

In sum, sending students abroad in the fourth year provides for a broad variety of logistical and practical benefits, striking a good balance between preparation before going abroad and time to digest the experience and give back to the program upon return.

**How important is the comprehensive, committed nature of the program model?**

The comprehensive preparatory program of meetings and activities is a core design feature of the GSEP concept, playing important roles in retention, student preparation, and program efficiency. GSEP is inherently a challenging course of study, and three long years of preparation before the pay-off year abroad leaves a lot of time for participants to become discouraged, overwhelmed, or to lose focus. The program of regular, mandatory cohort meetings and activities serves as the core retention mechanism in GSEP, engaging each participant in a robust three-dimensional support matrix within the GSEP cohort as a whole:

- **Discipline-based connections:** Students can draw on connections to others in the same discipline as tutors, study partners, and inspiring role models as they work their way through the curriculum.
- **Language-based connections:** Interdisciplinary identity groups centered around study of the same foreign language can support each other in language learning, providing a natural basis for study and conversational practice groups.
- **Academic-level:** Students in the same year of the program form a distinct subgroup identity, particularly as they come together for the series of pre-departure preparations in the year before going abroad.

This multi-dimensional sense of identity and connection to the program and a common cause helps keep students engaged through the inevitable rough patches, providing frequent motivating reminders of the ultimate goal and a supportive network of peers on whom to draw.

A second vital role of the GSEP community-building activities is program efficiency: overhead is significantly reduced by training, advising, and preparing students as a group, rather than presenting the same information many times in individual one-on-one advising sessions. In addition to targeted training workshops, group social activities, and external speakers, some segment of every meeting is devoted to educating or training on a specific topic (e.g., finding funding for the year abroad, language learning resources, travel safety, country and cultural overviews, etc.). The training and mutual support provided by meetings and activities are so vital to GSEP program dynamics that they are *mandatory for program participation*; participants missing more than three meetings are dropped from the program.
In sum, there are endless variations possible in the design of an internationalization initiative, and many detailed program design decisions will necessarily be shaped by unique local contingencies and targeted scope and outcomes. The purpose of this section has been both to explain the rational behind key features of the GSEP model presented as a model in Section 2, and to reveal complexity and potential consequences associated with program design decisions that may not be immediately apparent to those planning their own programs, but may have significant impact on the ultimate success or sustainability of an initiative.

3.0  Best Practices in Initiative Development
Developing a STEM internationalization initiative, particularly on the broad multi-disciplinary scale advocated here, is a major undertaking that requires not only a robust program model, but also careful strategic planning to bring together the necessary personnel, resources, curricular elements, and foreign partnerships. The GSEP initiative is somewhat unusual in that it is essentially our second try at engineering internationalization, taking the lessons learned from 15 years of previous experience to create a comprehensive new program from the ground up. In this section, we work to distill the lessons learned in this process into a set of best practices for planning and implementing a STEM internationalization initiative.

Best Practice: Develop a detailed vision, refine your sales pitch. A successful program will require buy-in from a broad range of campus entities ranging from upper administration to deans, department chairs, curricular committees, and individual faculty. A detailed white paper describing the program vision, motivations, and structure can provide an efficient means to capture and communicate the program vision. Particular attention must be paid to clearly articulating the cost-benefit equation at the university, college, and departmental levels. For instance, an international program that attracts new, highly-motivated students to the department with little or no faculty or financial commitment will be attractive to any chair or dean.

Best Practice: Drive from the top, design from the bottom. The value of a strong mandate and consistent supportive messages from the upper administration cannot be overstated, especially in establishing broad college-wide initiatives like GSEP. Given the vagaries of campus politics, such support is not in itself any guarantee of success, but at least identifies the initiative as an institutional priority and provides some initial incentive for key players to engage in the detailed program design. Framed by this broad vision, detailed development of the program should proceed from the bottom, e.g., how specific internationalization elements are to be integrated with existing STEM and foreign language degree programs. For instance, GSEP development was driven by faculty familiar with specific degree programs, working closely with professional advisors and program chairs to develop realistic, customized internationalized plans of study that integrate preparatory coursework and the year abroad into each degree program. Balancing the motivating force of a top-down vision with collaborative bottom-up design of curricular details provides for quick progress while building strong buy-in at the program level.

Best Practice: Work with upper administration to develop a viable funding model. Although an initial grant (internal or external) can provide seed funding to get started, careful attention must be paid to long-term financial viability of the program. Even the most efficient program design must account realistically for compensating leaders, providing basic administrative support, funding visits to foreign partners, and adequate operating funds. One effective approach to funding programs of this sort involves returning all or some of the tuition paid by participants during their year abroad to support the program. The case for this arrangement is compelling:
students use few campus resources while abroad and, given the five-year program, the university is still collecting the very same four years of tuition monies as it does from conventional students – all while tallying up second degree awarded, strengthening international connections, and establishing a high-visibility program. Basing program funding directly on the number of students served in this way also provides a strong incentive and support for program growth.

Best Practice: Invest in strong partnership with the Modern Languages. The importance of a strong partnership with Modern Languages faculties goes far beyond finding seats for participants in foreign language courses. It will be practically impossible for engineering majors with already overfilled curricular plans to earn a second modern languages degree without special curricular accommodations in the language training area. GSEP participants enroll in exclusive, specially developed “GSEP professional language” degree subplans that focus narrowly on rapid acquisition of basic language competency and provide extensive language degree credit for the immersive year abroad. Given declining enrollments in Modern Languages nationwide, a strong partnership with a STEM internationalization program that offers a steady stream of new majors will be very attractive to many Modern Language faculties.

Best Practice: Focus on structure, clarity, and limiting choices. With the exception of a few highly motivated individuals, undergraduates as a whole are not particularly motivated planners or decision-makers. Our approach in GSEP has been to offer students comprehensive, pre-planned, turn-key internationalization tracks; students merely need to decide which GSEP language to pursue, and then follow the plan. Comprehensive support is provided for all logistics: GSEP staff and professional advisors work with students to negotiate individual adaptations to curricular plans, approved GSEP partners are defined for each language, students have a list of coursework pre-approved for transfer to choose from at each partner site, housing and registration logistics are taken care of for approved partners, and internships are arranged for them. Our experience indicates that lowering every conceivable barrier to participation in this way is a key to attracting larger number of students and achieving the volume necessary to sustain a program. As discussed in Section 2.2.1, high uniformity (in student preparation, in paths through the program, etc.) and high volume is the key to making internationalization work on a large scale.

4.0 Conclusion
In this era of rapid globalization, developing a globally competent STEM workforce has become an urgent national priority. Modern engineers and scientists will need to be able to work seamlessly across national, cultural and linguistic boundaries to collaborate in globally distributed research and design teams. Although a number of institutions have developed successful engineering internationalization programs of some sort, both the number of such programs and the volume of students they serve must be increased dramatically if American engineering graduates are to fill leadership positions in growing international engineering enterprises.

The Global Science and Engineering Program (GSEP) represents our exploration of a high-volume “production model” for internationalization, combining our own experiences with models and insights developed within the engineering internationalization community in the last decade to create a college-wide initiative that uniformly serves 14 STEM disciplines. Like all production frameworks, GSEP is based on maximizing volume while minimizing production costs. In practice, this means applying a maximally generic internationalization framework to as
broad a population of students as possible to create an economy of scale that can justify an extensive support infrastructure, extensive specialized on-campus programming for the cohort, and investment in a strong network of international partnerships.

This focus on a production philosophy also embodies the central strategic insight that we offer in this paper, namely that when it comes to launching a successful internationalization initiative, “going big” with a comprehensive uniform, college-wide initiative that establishes a common infrastructure shared across many constituent degree programs may ultimately be easier, higher quality, and more sustainable than small-scale efforts at the program or department level. Shifting our thinking and program design from small-scale experimentation to broader, campus-wide initiatives is ultimately the key to taking STEM internationalization to the next level.

As a broader vision for the future, internationalization must become a common, universally accessible enhancement to all existing professional degree programs on campus, much like the Honors Programs commonly available at every institution. Following this paradigm, international tracks (a) should complement (rather than replace) existing degree programs; (b) should be explicitly credited on diplomas and via other formal certificates; and (c) should be supported by an explicit administrative and support infrastructure separate from and complementary to the academic units served.

Finally, there is no reason that college-wide programs like GSEP can’t be extended to other professional programs where international preparation in becoming vital as well. We are currently evaluating an expansion of GSEP to the Business programs on our campus, which would further expand access to internationalization, while increasing program volume to further amortize program infrastructure investments.

Bibliography