Introduction

Technology and engineering technology programs currently find themselves at the same crossroads as engineering education did in the early 20th century. The choices that engineering educators made have resulted in industry practitioners expressing a perceived lack of skills in graduating engineers deemed important to successful design activities. Technology program developers are asking many of the same questions about technology’s roles and responsibilities as were being asked by engineering educators. Technology programs are experiencing many of the same pressures at the beginning of the 21st century as the nascent engineering education programs did at the beginning of the 20th century; how do we get people to take us seriously, as professionals? How do we best serve our students and the industries into which they are hired? How do we best prepare people to go directly to work versus preparing to enter advanced education or research? What courses are important to what makes the graduate successful? Research indicates that engineering educators’ answers to these questions lead to the knowledge gap that was filled by technology programs. Now that technology educators are asking the same questions, it is important to understand what the impacts of the answers engineering education chose were, and to learn from engineering’s mistakes and successes.

The Evolution of Engineering Education

The Mann Report1 - In 1918 a study of the state of the engineering education was undertaken and presented under the authorship of C.R. Mann. This study was one of the first organized assessments of engineering education which was still in its infancy as an academic pursuit. The purpose of the study was to document the state of engineering education with respect to curriculum content and goals, entrance qualifications, the roles and responsibilities of engineers, and the needs of engineering graduates as it impacted the formal education of engineers.

The content of the report is as valid today as it was in 1918 and has direct implication to the choices being considered by engineering technology educators today.

In the Mann report, the concept of reconciling the role of engineers to apply knowledge and skills to a physical task and the desire to be considered professional were first introduced. Mann suggested that the role of the engineer was to take the materials and energy of nature and make artifacts and systems which made life better. In comparison, the professional degrees resulted in
physicians, lawyers and clergy. This dichotomy was expressed throughout the document and continues to be an important question today.

At the same time engineering education was dealing with the dichotomy of professionalism versus application, it was also facing an educational dichotomy. Engineering education was developing as an academic pursuit at a time when universities were traditionally viewed as bastions of classical learning. The universities questioned the appropriateness and value of science and application-based programs as opposed to the more classical philosophy and arts. Universities were where people learned to think, not to do.

The report also endeavored to answer the questions of what engineering education curricula contained as compared to what was perceived to be needed. These questions included how long should the program be? Should the program have advanced degrees and if so what kind? Did there need to be more specialization in the undergraduate program or less?

Mann concluded that engineers were responsible for building artifacts and systems. To reconcile this responsibility with an engineer’s role as a professional, Mann concluded that engineers were professionals but of a different type than physicians, lawyers or clergy. His assessment was that the differences were great enough that an engineering program should not try to emulate education any of the traditional professions, but rather develop as a profession itself. With respect to the development of the science of the discipline, the report suggested that theory followed observations. This meant that individuals working in the fields of engineering would explore and develop theories which explained the observations they made of the physical world.

The Grinter Report\textsuperscript{2} – While there were a number of reports and surveys between the Mann Report and the Grinter Report written in 1955, the Grinter Report continues to be one of the most frequently referenced engineering education reports. During the graduate research which forms the basis of this paper, very few interviews, conference discussions, and academic papers discussing curricula after 1955, did not eventually use the Grinter report by name or content. Like the Mann Report, a survey of the state of engineering education was desired and reported under the authorship of L.E. Grinter. The desired investigation also included many of the same questions as were being asked in 1918; how long should the undergraduate program be? What should the curriculum content look like? What were the roles and responsibilities expected from an engineering graduate?

Based on Grinter’s research, the report suggested that the emphasis of the curricula should respond to educational research stimuli. There was a requirement for research-oriented faculty which resulted in a research emphasis in the curricula. Suggestions that the role of education was to train thinkers, not laborers, were observed in the language of the report and it was specifically stated that the role of the engineer was to serve society and the social good, not to build things. This was a step away from the role of the engineer as a person who controlled energy and matter to develop artifacts and systems which made life better. Grinter specifically stated that it was the responsibility of engineering education to advance the scientific knowledge of the field.

Additionally, the ubiquitous question of how to be perceived as professional was still being asked. But by 1955 the path to professionalism was stated as being an emulation of the

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physician’s education as opposed to creating a perception of engineering as a profession of its own. The report stated directly that applications-based activities and education were sub-professional. The report went on to enumerate recommended changes to the curricula which would remove the sub-professional content. The report recommended that students develop science from scratch as opposed to investigating and iterating an existing artifact. It further suggested that shop classes and hands-on laboratories be removed. Grinter stated that in the professional role, an engineer directed application activities by technicians through the development of theory. Rather than explaining an observation made during the application of knowledge and skills, the theory guided the application of knowledge and skills. To do this, the engineer was responsible for creating a theory and then having someone look for evidence to support the theory.

Grinter’s report suggested that the Technology Institutes which existed at the time were better suited for providing the applications-based education that was necessary for the technician and laborer. These institutes were generally located near large industrial facilities and provided education specific to the industries they served. The programs were shorter, generally two years, and were taken by individuals who had specific desired knowledge content from the program.  

Historical Summary – Over 40-60 years engineering curricula responded to the societal pressures and the perceived needs of scientific research, removing the applications content from the engineering curricula. Engineering educators and practitioners believed that sufficient application knowledge was provided by the Technical Institutes, at which technicians and laborers would be trained. In addition, research funding supported and fostered the perceived importance of developing new theory. This need for new technologies by industry elevated the perceived importance of the researcher.

Through the early 1960s there was sufficient applications experience and corporate knowledge in the workplace that the skills gap for industry was the ability to develop theory. Based on historical literature and the current engineering curricula at representative engineering colleges and universities, the shift in educational philosophy considered the education content to be an either/or choice. Industry on the other hand, seemed to expect the theory content to be in addition to, not at the expense of application content. Furthermore, the impact of the change in curricula was chronologically delayed. Traditionally the time between a request from industry representatives and the educational impact are separated by as much as 10 to 20 years. This would mean that the results of the shift in curricula were not seen until the early 1970s.

Through the 1950s, technologists were viewed as having equivalent professionalism as engineers with a different role in the design and production of products. It was suggested that a separate title be used for graduates from these technical programs, that of technologist. It was felt that this title would distinguish graduates of the technical institutes from those of technicians. But the title never gained wide-spread use primarily because the industry employers saw little difference between engineers and technologists once they went to work. The largest difference cited was in the mathematics background and in a manufacturing environment this was not considered important. As the perceived importance in theoretically trained researchers and scientists grew, the perception of the application-oriented technologist was gradually reduced. Reports such as Dr. Grinter’s, in which applications-based skills were specifically classified as sub-professional, further denigrated the role of the technologist as compared to the engineer.
Technologists filled many of the same professional positions as the engineers. Through the 1950s the technologists filled professional positions which the theory-educated engineers could not appropriately fill such as supervision, manufacturing engineer, and failure analyst. In the Study of Technical Institutes it was specifically noted that many of the engineering scientists were not appropriate for the manufacturing environment because their education did not prepare them for the fast changing environment, the need for rapid answers and for working on the manufacturing floor. For these positions, a technologist was considered more appropriately trained and educated than an engineer.

By the late 1950s, the skills that the more application-oriented technologists and engineers possessed were adequately meeting the manufacturing needs of America’s industries. Grinter’s research specifically inquired industry representatives as to how they felt about the content of engineering curricula and the skills of the engineering graduates. They responded that they had sufficient individuals with applications-based education in place, but that there was a need for individuals who had more theoretical-based education.

However, as the emphasis and perceived importance of engineering science grew at the expense of application technology, the perception of technologists as professionals also decreased. The perception that engineer could do anything a technologist could plus the extra science resulted in an industry perception that they could get more from a single person with an engineer than from a technologist. This preferential hiring further degraded the perception of the technologist as a professional. This is presented as one reason for the loss of hiring opportunities which ultimately resulted in the closing of many of the Technical Institutes that Grinter himself suggested were important contributors to the applications-based education.

The Legacy of the Choices Made in Engineering Education

It has been observed by industry practitioners involved in aerospace systems that there is an increasing trend of multiple redesigns in the final stages of design, during manufacturing, and even after the product has been sent to the customer. Furthermore, complex engineering systems often fail, “not because of exotic, poorly understood problems, but because of simple flaws that could not be identified in isolation from the operation of the full system”. In many modifications of design concepts, the changes are conceived and made without thinking much beyond how it improves the one aspect observed to be lacking in the original design.

Nicolai noted that “our universities are turning out great scientists but mediocre engineers”. He went on “the engineering graduates’ knowledge of engineering science, mathematics and analytical techniques was very good, but they were poorly equipped to use the knowledge.” Furthermore “the new theoretical engineering curriculum was fine preparation for graduate school. However, the missing practical background delayed their ability to contribute to laboratory settings in industry.” The need for the application of this knowledge did not go away as technology advanced. Nicolai further observed, “In the 1940s and 50s American engineering programs were very applications oriented and design received a great deal of attention in the curriculum. … Almost overnight (following Grinter and Sputnik) the engineering programs went from an application and design emphasis to research and analysis. …In the 60’s design disappeared from most engineering curriculum as the faculties became predominately analytical oriented and preoccupied with research. …They (the researched trained faculty) were
more attuned to the needs of university research programs rather than to developing engineering that met the needs of American business.”

The inescapable fact was that the applications facet was as important to a successful design as the mathematical modeling. “The design shortfall required changes…in how we viewed the relationship between engineering and engineering science technology.”

Engineering Technology at a Similar Crossroads

Based on first hand exposure to discussions within Purdue’s College of Technology, and based on first-hand exposure to discussions taking place within groups such as ASEE, engineering technology programs today are asking many of the same questions and are responding to many of the same societal, economic, and professional pressures as were being experienced by engineering programs in the early 1900s-1920s. Today engineering technology is seen to be under pressure from the same two sources as early engineering. The first is the pressure to be seen as professional because of, or in spite of the responsibility to be able to “do” something. The second is the academic pressure to demonstrate the value of the technology program in a time when institutes of higher education are reevaluating programs in term of value to society, to the industry they serve and to the academicians employed by the institutes. What should engineering technology programs be doing as they attempt to move to the next level? How does an ET program stand up to or compare to an engineering program at the same institution? How do ET program administrators and educators reconcile their roles as educators and builders with the pressures as researchers and to be perceived as professional?

Professionalism

One of the most frequently discussed concerns of technologists and technology educators at internal academic meetings and within specialized groups within the ASEE heard first hand by the three authors, is the concept of having graduates considered professionals. In the 1940s and 1950s two separate roles were created, science theory and application technology. At the time the two distinct roles evolved, the training and background of the graduates from the two programs were considered by industry to be essentially equivalent and therefore the perception of professionalism was essentially equivalent as well. As the emphasis on engineering research science grew, the applied content was frequently moved to technology institutes and programs. This did not diminish the relevance of the applied skills. The applied technology skills were valued by industry as being important to the design success.

It is important for technology administrators and educators to understand the negative impact of engineering education’s inability to reconcile their roles and desires. By pursuing a perception of professionalism, engineering programs removed the education of many of the skills which made engineering graduates successful in industrial careers. These “sub-professional skills” were instead what provided engineers with the potential to be successful professionals.

Academic Acceptance

From the 1960s through today the question of the value of technology and application-based education in the university setting has been raised. Grinter suggested that the application-based content belonged in the Technical Institutes as opposed to the traditional four-year university program. It has been suggested that engineering is intrinsically better than
engineering technology due in part to the mathematics and theory content. This has arguably led to an observable academic snobbery and a view that engineering technology is subordinate to engineering as opposed to complimentary.

In presentations regarding the role of engineering technology, educators have questioned the value versus expense of technology programs, especially where engineering programs already exist. There has been anecdotal evidence that even engineering technology professors question the “vocational” content of an engineering technology program and that perhaps such content is better suited for community colleges and “Tech” schools not offering traditional college degrees. This self-deprecating view suggests that the content of traditional engineering technology programs is intrinsically of less value, a view not supported by research.

The value and need of applications-based education should be compared to the impacts of engineering departments removing the application technology from the programs. It has been suggested this loss of practical knowledge has had a negative impact not only on the ability of the engineering graduate to perform successfully in an industrial environment, but also on engineering graduate education in that students are not well prepared to participate in successful or useful research endeavors.

Another academic consideration is the necessity for and the responsibility to provide engineering technology graduate and post graduate programs. It has been suggested that it is necessary to have technology graduate programs which provide opportunities for engineers with application-based interests. As part of the considerations for the content of technology graduate programs, the impacts of pursuing engineering science at the expense of application technology need to be carefully reviewed. In engineering, the need to train PhD’s that in turn taught and administered graduate programs resulted in a cycle of training researchers who did not understand the world and then taught others in their paradigm. These professors also taught the undergraduates who in turn became the graduate researchers.

Evolution and change are inevitable characteristics for most academic programs. Just as engineering has evolved to where it is today, technology programs also have experienced a period of evolution and change. In the early sixties, most engineering technology programs began as two-year associate degree programs. Over the past four decades these associate degree programs have evolved to include baccalaureate level degrees and some have evolved to offer graduate level degrees.

Today, some technology faculty members and administrators believe the future of technology and engineering technology disciplines may be greatly influenced by the development of appropriate graduate programs for their disciplines, see for example the efforts taking place by committees within the Conference for Industry and Education Collaboration (CIEC). There are many issues surrounding the need for this development, which include the need for faculty and students to function successfully within large research focused universities, providing funding to support the teaching and scholarship of the faculty, professional development for industry practitioners, and developing the future professorate for technology and engineering technology programs.
Successfully functioning in a large university today requires a faculty member to make contributions in the area of learning, discovery, and engagement. While the relative importance of these three activities may vary from institution to institution, faculty contributions in these three activities are usually the primary factors when considering promotion and tenure.\textsuperscript{18}

Also, at many research focused universities, faculty members are expected to be engaged in some form of research endeavor. For some in technology and engineering technology, this research activity is often described as applied research. Sometimes the research may take on a learning or pedagogical focus, while other forms of applied research may be more focused on the solution of a technical problem in industry. Sometimes the applied research activity may take on a developmental role in support of basic research or advancing the development of intellectual property. Regardless of one’s definition of applied research, there is clearly a need to establish and support an appropriate research mission in technology and engineering technology, if faculty members are to experience appropriate recognition and rewards at research driven universities.

While many metrics are used in measuring a faculty member’s contribution and performance in learning, discovery, and engagement at universities, the scholarship component is considered a very important metric. In today’s environment, for technology and engineering technology faculty to be recognized and rewarded through the promotion process at a major university, contributions to the scholarship of their discipline is considered one essential element for measuring success.

In addition to the scholarship metric, extramural funding is another important measure of faculty accomplishment and success. Another critical issue facing technology and engineering technology professionals today will be the need to find financial resources to support their work and the work of their graduate students. As state support continues to diminish in the future, identifying sources of financial support outside the institution will be necessary in continuing the development of excellence in undergraduate and graduate education most universities.

This support may come in the form of industry support for professional graduate education through tuition and fees, as well as support to faculty and students involved in solving technical problems facing industry trying to maintain a competitive edge in a world marketplace. Other sources of financial support for faculty and students will need to come from state and federal levels. An appropriate level of financial support will be required to continue developing innovative curricula, faculty development, and support for graduate students, who will become the future academic leaders and professionals in technology at the university level and in industry.\textsuperscript{18}

While these are considerations and concerns of academic administrators, actual data as well as anecdotal evidence are needed to make educated decisions. The research done in preparation of this paper provides the academic administrator with foundational data with which to begin to make these evaluations.

From the Results of Research on Engineering Education

As a result of the perceived deficiencies in engineering design abilities, research was undertaken to identify the skills necessary for successful participation in complex design activities.\textsuperscript{19} It was
determined that application skills were viewed as important to design success. The survey of industry practitioners indicated that the most important skills for graduating engineers and technologists were an understanding of how things worked, how to apply theory to something useful, and how to leverage what was already know. Furthermore, supporting data were identified for the belief that the removal of applications exposure measurably reduced the opportunities for students to learn and practice skills deemed necessary for successful participation in design activities.

Observations of students in senior engineering design courses suggested that the students were not well prepared to put to use the knowledge provided during their academic career. While the students could perform mathematical and computational tasks, they were limited in their ability to apply the knowledge in a useful way. Furthermore, the students were not observed to leave the knowledge garnering paradigm to demonstrate design skills.

The educators, on the other hand, were expecting demonstration of abilities in performing engineering design tasks. A review of the literature as well as observations of instructors showed endeavors to identify the abilities which made an engineer successful at design but did not demonstrate the instructors had a good grasp of how to assess the abilities or an understanding of what skills were necessary to apply the engineering knowledge the students possessed.

The final conclusion was that industry practitioners could identify specific, measurable skills which were necessary for successful design activities, the majority of which were rooted in application skills. The students could demonstrate understanding of formulaic knowledge but lacked the opportunity to practice applying the skills that utilized the knowledge. The educators were expending effort to identify and evaluate the perceived abilities believed to be desired by industry practitioners but were limited in their ability to assess the success in demonstrating the abilities. This was due primarily to a lack of identifying the skills that connected the knowledge to the application by the students.

The Impact of the Research to Technology and Engineering Technology Programs

Research shows that applications technology content is valued by industry practitioners. Practitioners agreed in over 70% of the responses that it was necessary to understand how the world works in order to be able to see how a design worked together as a system and as a product. The respondents also indicated that by having a basic understanding of how things worked, the other attributes perceived as important, i.e. teamwork, communication, using design tools, would occur as a result of the application skills not as a cause.

Based on the research, application technology is not “sub-professional” and “vocational” has been imbued with a subordinate meaning that is unwarranted. Technology education is the other half of a successful design engineer. Technology programs are complimentary to engineering programs, not subordinate.

The removal of the core competencies in engineering education resulted in a loss of success in the workplace. Because of engineering education’s inability to reconcile the engineer’s role as someone who did things and made things with the desired perception of “professional” engineering educators removed the core competencies that made engineers, engineers from their
programs. This is one of the causes of the perceived deficiencies in graduating engineers expressed by industrial and educational representatives.

The greatest perceived difference between engineers and technologists is in the ability to run formulaic (mathematical) analyses and to perform complex modeling. In reality computers can do most of the mathematics. Furthermore, research suggests that contemporary engineers may not always fully understand the impact of the formulaic and mathematical modeling output on the final product. The result is the output is of limited value in the production of actual artifacts and systems.

Considerations Facing Technology Programs

It is the view of the authors of this paper that technology and engineering technology educators will have to deal with several important issues in order to exist and thrive at the university. Developing a national forum to support a positive discussion and debate concerning the future development of technology programs and their role in fulfilling the university’s mission should be a national priority. Clearly, a major dichotomy is the appropriate balance and focus in the areas of teaching and research. Clearly, good classroom and laboratory instruction is expected at all major universities, especially those that are state supported.

Some would also argue that good teaching is not possible without good research and scholarship, and that the scholarship should be grounded in the creation and development of new knowledge. This new knowledge could come in the form of new curriculum or pedagogy, or the application and development of new science and technology. So finding an appropriate balance between appreciating and teaching the core competencies, and performing externally supported research, will be an important issue in the future.

Technology and engineering technology programs, especially at the undergraduate level, have enjoyed success because of the practical hands-on approach to curriculum development and student learning. While the development of practical laboratory-based education is a hallmark of most technology programs, there is some risk in losing this important component as we look to the future.

Historically, graduates from technology programs have enjoyed great success in the area of job placement. The skills they bring to the technical workforce are viewed as essential to sustainable economic development. If technology and engineering technology leaders are considering a new vision for their disciplines and moving forward in a positive way, they would be wise to learn a very valuable lesson from the results of following the Grinter model. Identifying strong core competencies and new signature areas with some level of balance will be essential.

As technology educators look to the future, understanding the role of engineering education and how it has evolved over the past five decades provides a good historical lesson from which to reflect and learn. Contemporary engineering’s role in learning, discovery, and engagement is essential to the economic and social development of our national economy and way of life. The social and economic value engineering education has added to our nation is invaluable. Likewise, technology programs also continue to add great value to our national economy and are fulfilling an important role in the academy.
While the “Grinter Model” has provided an opportunity for engineering to play a valuable role in our economic development, it has also provided an opportunity for the development of technology programs, which are better suited for talented individuals with an applied aptitude and interest. Clearly our economy and society will need high quality engineering and technology programs working together at universities to educate future generations and providing solutions for some of the greatest technological problems facing our world today.


5 *Study of technical Institutes, A Collateral project to the investigation of engineering education* (1931). Pittsburgh, PA: Society for the Promotion of Engineering Education


7 *Study of technical Institutes, A Collateral project to the investigation of engineering education* (1931). Pittsburgh, PA: Society for the Promotion of Engineering Education.


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