Implications of a Multi-Disciplinary Educational and Research Environment: Perspectives of Future Business, Law, Science, and Engineering Professionals

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Functioning well in a global, technology-driven, multi-disciplinary environment necessitates a more robust educational paradigm in science and engineering. For a technical education to be complete, it is no longer enough to train scientists and engineers solely in technical areas. There are clear shortcomings in academic curricula that need to be addressed in order to bring about this required paradigm shift. Much the same is true for students of law and business, who will have to understand many of the technological underpinnings and corresponding implications to impart their perspectives. While it is true that multi-disciplinary education and innovation programs are starting to surface, the question of "how the participants' experiences will influence future career plans and personal goals' is largely unanswered.

Our focus in this paper is the importance of understanding social, economic, and legal aspects of science and engineering within the context of graduate-level education. Specifically, the authors take a closer look at the TI:GER®(Technological Innovation: Generating Economic Results) program from the participants' perspective. TI:GER® is a multi-disciplinary program between Georgia Institute of Technology and Emory University, focused on integrating science, engineering, business, and law for the commercialization of innovations in the global marketplace. Based on their experiences, the authors present their learning and insight on multi-disciplinary education in a mixed technical and professional degree setting.

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1. Introduction

Traditional lines that used to divide the different disciplines are becoming less pronounced in the global marketplace. While the need for specialized education, focused on a single-discipline, is important in providing insight to essential skills, it is no secret that most employers desire their potential employees to be knowledgeable in a variety of topics outside of their domain. Given that an average employee will spend a significant time of his/her time managing information in the 21st century, it is essential that this employee be aware of how his/her role fits within the overall goal of the work environment. It should therefore be the goal of educational institutions to provide the right set of skills for future employees in the marketplace [1].

In the case of engineering and science students this translates to easing the transition from an environment focused on mostly disciplinary research to one centered on market-driven research. In the case of professional degree students, such as those in pursuit of a Master of Business Administration (MBA) or a Doctor of Jurisprudence (JD) degree, the fundamental shortcoming is one of lacking experience with applied research and development and the associated interactions. A more robust educational paradigm will thus be needed to enrich the curricula of technical and professional students to properly prepare them for the true challenges they are likely to encounter in a global marketplace. With this in mind, it is becoming a requirement to provide graduate students not only with fundamental skills, but also with contextual perspective in order to instill in them an appreciation for the multi-disciplinary nature of innovation related careers.

It is our belief that mere preparation of scientists and engineers in technical areas is no longer sufficient. Traditionally students in the technical fields have received intensive training in their respective skill sets. A student in engineering has to take several classes in design, mathematics, mechanics of materials, and physics. As part of the engineering curriculum, the student will not be required to synthesize many of these skills until working on a capstone design project with other engineering students. In some cases, these projects will involve the development of a new technology. However, usually the social, environmental, commercial, legal, and public policy implications of a technology are usually overlooked, mainly because of the time constraints put on the educational curricula.

The same is true for students of law, business, and public policy who will have to understand technological innovation as part of their work in selective information management. Typically students in these fields do not get adequate exposure to technological innovation in their training, and their experiences are limited to popular case studies [2]. It is thus not until their debut in the workplace that they are confronted with applying the knowledge gained in the course of their education to address the fundamental challenges of their respective professions.

In this paper, a graduate-level program aimed at addressing multi-disciplinary issues in technological innovation is discussed. In particular, we focus on Technological Innovation: Generating Economic Results (TI:GER®), a joint program between Georgia Institute of Technology and Emory University. A detailed description of the program and its core activities is presented, followed by insights regarding participants' experiences from MBA, JD, and science and engineering Ph.D. students' perspectives, emphasizing the latter. While it may be too early to assess the long-term implications of the TI:GER® program, benefits of the program for engineering Ph.D. students in the context of both research activities and future career objectives are discussed. As part of their experience, the authors suggest future improvements on technical education curricula that may produce more well-rounded individuals.

2. Multi-Disciplinary Education and Research

Multi-disciplinary education efforts have been developed in a large number of universities to address the need for college graduates to be aware of issues in a number of domains. There are different types of multi-disciplinary programs, ranging from group projects in a single-course setting to multi-year research initiatives. Multi-disciplinary education programs usually involve grouping a number of students to work on specific projects, involving a number of multi-disciplinary considerations. These single-course projects are typically capstone projects designed to bring together a number of students from different science and engineering disciplines. Usually, such a project constitutes a student's first exposure to a multi-disciplinary work environment in his/her undergraduate education. Though invaluable in helping students improve communication and time management skills, such projects are still confined to the comfort of a single goal- namely that of technical feasibility - without a lot of concern for economic viability, environmental impact, legal implications, and the like.

Even though most programs were originally developed for undergraduate students to work in teams, other programs are tailored specifically for graduate students to gain a deeper knowledge of and experience with different domains. In certain graduate-level courses, market analysis of existing technologies is conducted. In addition, comparison of similar technologies may be undertaken to document the evolution of a market. Usually, such programs study existing case studies in the relevant subject and/or take an existing technology in the marketplace and develop a business plan around it.

Similarly, there are a growing number of joint degree programs in business and law, such as Jurisprudence Doctor / Master of Business Administration programs at several universities including Emory University, Harvard, and the University of Miami. Syracuse University offers a joint M.B.A. and Master's of Science degree program, designed to provide a more evenly balanced education in engineering and management at the graduate level [3]. There are also "high technology law" clinics at Syracuse University and the University of California at Berkeley, focusing on the study of legal aspects of existing technologies. A number of other institutions offer specialization in technology commercialization as part of a Master's degree program.

On the other hand, multi-disciplinary research programs, where actual university-level research is the subject of the study, are rare. Multi-disciplinary research is usually focused on bringing together professional and advanced degree candidates in research activities. An example of such programs is the Innovation Realization Laboratory at Purdue University [4], where the research of science and engineering Ph.D. students is evaluated with respect to commercial potential. This 2-year program pairs Ph.D. students with M.B.A. students in order to study the potential marketability of the Ph.D. students' research. This program has been successful in identifying technologies with commercialization potential. However, analyzing the marketability of a technology is only one aspect of the overall impact of technology on society. There are many other aspects that need to be considered, including legal and public policy implications. What is needed is a long-term multi-disciplinary *research* effort that will characterize the overall spectrum of implication of academic research on society. This is the underlying principle that has guided the establishment of the joint TI:GER® program between Georgia Tech and Emory University [2].

3. TI:GER® Program

The Technological Innovation: Generating Economic Results (TI:GER®) program was launched in 2002 with the goal of bringing together Georgia Tech Science and Engineering Ph.D. students, Georgia Tech M.B.A. students and Emory University Law School Jurisprudence Doctor (J.D.) students. Central to TI:GER® are the research topics of the science and engineering Ph.D. students, which is also the aspect of the program that makes it unique: TI:GER® is the only program that brings together science and engineering Ph.D., M.B.A. and J.D. students with the goal of studying commercialization, technology transfer, legal, and marketing issues in students' ongoing research for a duration of 2 years (4 academic semesters). It should be pointed out that the primary goal of the program is to immerse Ph.D., M.B.A., and J.D. candidates in subjects immediately relevant to technological innovation in an academic setting. The secondary goal, which can be seen as a bonus, is the identification and commercialization of research technologies developed at the Georgia Institute of Technology.

Commercial application of academic research has a longstanding tradition in US universities through a variety of mechanisms [5]. In the United States, there has been an increasing trend for transfer of university research to industrial users through licensing since the passage of the Bayh-Dole Act of 1980 [6]. The Act allows nonprofit institutions to take ownership and exclusively license inventions from federally funded research for the purpose of further development and commercialization [7], thereby giving universities more freedom in the commercialization of research. On the whole, the Bayh-Dole Act appears to have increased the flow of innovative technologies into the marketplace, but also expedited the process of commercialization of new technologies. However, even with accelerated technology transfer, a number of issues remain unanswered: How can potential technologies be identified? How can the development of these technologies be managed? How can researchers in academia be made more aware of commercial potential? How can researchers become knowledgeable in technology transfer? In order to address these questions, a comprehensive program with the participation of not only different academic disciplines but also different *professional* disciplines is required.

To address this need, the TI:GER® program was established with funding from a National Science Foundation Integrative Graduate Education and Research Traineeship (IGERT) grant [8]. In its first year, a total of 21 students, with equivalent participation from the Ph.D., M.B.A. and J.D. programs, were selected. It was recognized early on that the success of this program would rely on the selection of suitable candidates.

Since the Ph.D. students' research areas lie at the core of TI:GER®, their selection can be considered to be the most crucial element to the program's success. A number of science and engineering Ph.D. students, who (1) had identified their research areas, (2) had met the prerequisites of their respective programs, and (3) were interested in learning about innovation and commercialization, were selected to participate in TI:GER®. The research areas of these students represented a wide variety of disciplines including

Biology and Bioengineering, Chemistry, Electrical and Computer Engineering, Industrial and Systems Engineering, and Mechanical Engineering.

Even though the M.B.A. and J.D. students could be viewed as participants in a program centered on the Ph.D. students' research work, the selection process used to identify them is equally as rigorous. Incoming M.B.A. students, interested in commercialization, marketing, and managing high-tech companies were selected to participate in TI:GER®, based mostly on their academic credentials. Emory University J.D. students were selected at the end of their first year of study in the Law School[2] based on their academic credentials, background and interest in intellectual property, technological innovation, and business associations.

TI:GER® is a two-year program during which students of all three disciplines take seminar-type courses on topics ranging from creativity, technological innovation, commercialization, intellectual property, business associations, and marketing, to entrepreneurial finance, technology licensing/venturing, and technology transfer. The outline of classes and different topics covered in TI:GER® are shown in Figure 1.

As indicated in Figure 1, the science and engineering Ph.D. students typically participate in TI:GER® during their third and fourth years of graduate study. The J.D. students take part in the program during their final two years of Law School. The M.B.A. students participate in TI:GER® during their entire two-year tenure. The topics shown in Figure 1 span a wide range of issues related to commercialization of technology and are presented in seminar format during the first three semesters of the TI:GER® program. In the last semester of the program, the students take an optional class of their choice, related to innovation, intellectual property, and entrepreneurship.

During the course of their tenure, the students apply the topics shown in Figure 1 to their research areas by working in groups. It is expected that each student actively participate in his/her group, composed of one or more members from each of the three disciplines, throughout the duration of this 2-year program. Even though the science and engineering Ph.D. students' research area is taken as the focal point, active participation from all three disciplines is necessary to successively generate the four end-of-semester milestone deliverables:

1. *Intellectual Property Survey*
   A comprehensive survey of intellectual property is conducted by all members of a group in addition to developing an invention disclosure for the Ph.D. student's research area. Intellectual property consists not only of patents but also more academically oriented literature. After the Ph.D. student's research is defined, the team does an intellectual property survey during which the goal is to identify existing prior art pertaining to the student's technology. This survey is invaluable in identifying possible competing technologies or prior work in the area so that Ph.D. work can be better framed. The results of this survey are reported by the students at the end of their first semester of TI:GER® participation in an intellectual property survey report and an invention disclosure. Each document can later be submitted to the Office of Technology Licensing at Georgia Tech for intellectual property protection. This deliverable contributes to bringing the non-

[2] Law School J.D. degree is obtained in 3 years

technical group members up to speed and serves to familiarize them with the product they will focus on for the remainder of their tenure.

2. *Commercialization Plan*
   A commercialization plan is a precursor to a business plan. In the commercialization plan, the specifics of a technology are identified and some possible applications and/or potential markets for that technology are selected. In order to achieve this goal, students perform marketing research and identify competing technologies and companies. The goal of the commercialization plan is to assess not only commercial applications for a technology but also the value of generating a business plan in the future. This commercialization plan is developed at the end of the second semester of participation in TI:GER®.

3. *Business Plan*
   The development of a comprehensive business plan is dependent on the commercial viability of the technology. In essence, the commercialization plan dictates whether there is any merit in developing a business plan. The comprehensive business plan is a combination of the Intellectual Property Strategy and the Commercialization Plan developed during the first year of the TI:GER® program. In addition, the business plan outlines specific target industries and products, and is more specific with regard to financial projections. For Ph.D. research areas that have promising commercialization plans, the business plans are developed further and refined at the end of the third semester of participation in the program. If a business plan is well-written and has the potential for attracting venture capital, the student teams may be encouraged to enter several of the business plan competitions held throughout the world.

4. *TI:GER® Case Study*
   Reflecting on their experiences as a group, participants are expected to write a case study on an aspect of the TI:GER® program. This case study is similar in nature to other case studies such as those published by the Harvard Business School, but the emphasis is not necessarily on the evolution of a particular technology. Instead, the students are given the choice of writing on a topic which they deem useful to future participants of TI:GER®. Topics may range from writing on group dynamics in multi-disciplinary research programs to management of intellectual property in academic research. These case study documents are completed at the end of the third or fourth semester of participation in the TI:GER® program.

By the end of the 2-year TI:GER® program, the students are expected to have gained an appreciation for and understanding of each of the fields they were previously not familiar with. More specifically, Ph.D. students are expected to learn about intellectual property protection, issues in commercialization, and management of innovation. The M.B.A. students are expected to gain insight on the process of technological innovation , valuation of early-level research technologies, and management of high-technology companies. The J.D. students are expected to understand the underlying principles behind becoming a patent attorney, establishment of business associations, and process of technology development. While these expectations, as aforementioned, would differ for each group, our focus in this paper is to present the experience from the technical perspective. In the next section, several of the benefits gained by the authors (themselves engineering Ph.D. students in the program) will be presented.

4. TI:GER® Program Impact on Participants

The main benefits of the TI:GER® program can be attributed to the manner in which it is structured. Organized around the concept of a multi-professional educational experience, the focus throughout the two-year tenure of its participants is on the integration of the knowledge and expertise pertaining to various disciplines within the professions of Engineering/Science, Business, and Law involved. In our case, some of these benefits were direct, others more indirect.

4.1 MBA Students

The most immediate benefit of participating in TI:GER® for MBA students was the practical experience provided by the program through entrepreneurial focus of the PhD technologies. Even though each PhD student's research was at different (early) stages of development, which proved to be a challenge for most MBA students, formulation of commercialization plans remained nonetheless quite a realistic and practical exercise. The market analysis insight gained by the market research conducted throughout the development of the various commercialization plans also proved quite useful to most participants. Moreover, being able to experience the challenges of applied research firsthand from a PhD student's point of view on one hand and the challenges of securing protection of the inherent intellectual property from the JD students' perspective on the other provided a well-balanced environment within which MBA students could realize their roles and grow from information providers to business promoters.

4.2 JD Students

A majority of JD students participated in the TI:GER® program as a result of a strong interest in practicing patent law, others felt that acceptance into the program would serve to further distinguish them, even other used the opportunity to explore the field in order to judge their suitability. Faced with the difficulties inherent in conducting extensive patent searches for early-stage research technologies proved to be an invaluable experience, especially for those JD students entering the work force as either patent attorneys or reviewers. Exposure to this practical application of intellectual property law enriched the experience of participants in the program beyond that typically encountered in law school curricula. It is important to note, however, that the wide range of different motivations for joining the program also made the experience more challenging in a multi-disciplinary environment.

4.3 PhD Students

For a majority of PhD students, including the authors, there were a number of more immediate benefits to participating in the TI:GER® program. By applying some of the lessons learned throughout the curriculum, they were better able to evaluate the potential impact of their research, both in the short and long terms. One of the fundamental challenges in this regard, facing any Ph.D. student in the United States, is the inability to simultaneously match the expectations of both academia and industry. While the former focuses on fundamental contributions, the latter is usually concerned with addressing more immediate needs. Although the size of this chasm, separating academic research and industrial problem solving is usually research area dependent, participation in the TI:GER® Program resulted in improved levels of understanding on how to evaluate and bridge this gap. Long-term applicability of PhD research to industry also became more apparent after participating in the program and aided many in seeking industrial employment.

Many of the exercises were aimed at identifying potential applications of research in arenas outside of their respective fields of origin. Realizing that there was an actual interest from the Office of Technology Licensing (OTL) to commercialize technologies at similar stages of development served as additional encouragement to most PhD students in venturing outside their traditional comfort zones. Much the same was true for writing a commercialization plan and participating in business plan competitions with the goal of leveraging PhD research work to either start a company or license the resulting technology. In fact, additional research in intellectual property, conducted while producing the required invention disclosures, often confirmed a more immediate industrial need that had not previously been suspected in most cases. This in turn opened the door for new research directions and caused additional research issues to surface, improving the overall quality of the PhD students' research.

Before entering the TI:GER® program, many PhD students, including the authors, viewed their research merely as a means to an end. The goal or product was not the research itself, but the Ph.D. dissertation that would serve as the basis being awarded the degree. Becoming involved in the TI:GER® program resulted in increased awareness of the underlying value that many of the research projects held. The realization that years of dedication were not just a means to an end, but perhaps a means of their own, increased the overall confidence of the students in their accomplishments and laid the foundation for a future in entrepreneurship for some. The explicit question the PhD students were forced to ask themselves was – What is the value proposition of technical research – why is it conducted and to whom else does it have value? Although this question may seem simple and self-evident, it is a question few would have ever asked themselves had they not been explicitly prompted during the course of the program.

Understanding the relevance of one's work also made the PhD students realize that research relevance is dependent on marketing. Being able to sell an idea, be it as a future professor in academia, a research director/thought leader in industrial R&D, or a manager in a company, is very important. As a result of their experience, insights on how to sell research to either industry or academia and effectively solicit funds by highlighting aspects relevant to the interests of a particular audience were gained by all. Since salesmanship is required of all of us at some point in our lives, whether selling ourselves or a product, this is an essential skill to have.

Additionally, there were a number of indirect benefits derived from participation in the TI:GER® program. A crucial skill for Ph.D. students was learning how to communicate the value proposition of their respective technologies successfully to more non-technical audiences. Each group of students gained an appreciation for working in multi-professional settings and became experienced at effectively addressing different audiences by tailoring presentations to suit different interests.

Discovering how to pose and answer questions effectively in multi-professional settings was another significant benefit. Typically fellow researchers in academia are aware of the context of the problem being investigated. This was not true for non technical audiences: questions posed by both M.B.A. and J.D. students tended to delve into issues usually only covered on a superficial level or ignored entirely. Often, such questions were quite difficult to answer. The result was that Ph.D. students were often forced to consider their research in a new, and often more critical, light by answering more fundamental questions.

The TI:GER® program instilled a basic appreciation for the intricate interplay that the roles of research and technological innovation possess within society in all of the PhD students. Specifically, the roles that marketing and business play in commercializing research came to be respected and each of the future scientists and engineers became wary of the legal concerns that pervade virtually every issue involved in this process. Technological innovation does not occur in isolation. It is critical to assess its impact on society by considering evolving marketing, environmental, legal, and commercial implications. Participation in the TI:GER® program shed light onto this bigger picture and allowed for a better understanding of how to assess pertinent aspects in a structured manner. Thus, even honed critical thinking, analysis, and decision-making skills can be greatly improved as a result of acquiring a “big-picture consciousness”.

5. TI:GER® Program Assessment and Improvements

The TI:GER® program has been in existence for only two years and has thus far only benefited a small group of students from science, engineering, business, and law. Because of this fact, it is not yet possible to thoroughly evaluate the implications of the program on its participants in a systematic manner. As the program and the data gathered from its participants grows, it will become possible to conduct more quantitative analysis on both short-term and long-term implications of the program and more aptly assess the value of a truly multi-professional education.

We believe that TI:GER® is a conceptually sound program that is experiencing growing pains in its infant stage. One of the challenges of the program has been synthesizing and presenting relevant information to all three groups of students that will keep them interested while not over-saturating the lecture material. As more students go through the program, it will become possible to have TI:GER® alumni return and share their perspectives on the program in retrospect with current participants. This will help current students deal with potential challenges of the program and guide the provision of more relevant subject matter. Increasing the level of interaction between the various groups of students as well as among the project teams has also been a consistent challenge. In the future we hope to increase exchanges by organizing more outside-of-classroom activities for all of the participants.

6. Closure

In the last few decades, the lines separating professional disciplines have been successfully blurred. Roles are no longer defined by professional training; instead, people are forced to venture outside of their comfort zone. Interactions among multiprofessionals require adaptation, dynamic thought, facility of expression, and open mindedness. Until now, such skills could have been learned while on the job. Considering their prevalence, however, these proficiencies may be worth including in one's education.

In this paper, we provide an overview of the manner in which some of these emerging concerns are addressed in the TI:GER® program, jointly offered between Georgia Tech and Emory University. Throughout the paper, we offer some of our own insights into both direct and indirect benefits obtained from participation in this unique educational venture. Our own experience has been eye-opening, and our participation in the multi-disciplinary TI:GER® research program has allowed us to broaden our learning perspectives in both short term research goals and long term career objectives.

Although the views expressed are focused primarily on engineering Ph.D. students' perspective, we feel that they are quite representative of the impact of multi-professionalism in a graduate degree setting. Based on our experiences we feel that both technical and non-technical professional degrees can greatly benefit from encompassing broader perspectives, and making future generations more aware of overall impact of technological innovation on the society.

Due to the fundamental role of science and engineering in the evolution of society, this awareness may be of special importance that needs to be addressed in science and engineering curricula. TI:GER® is a first-step towards bridging this gap in education, but the overall impact of the program is too early to assess. In particular, future work will incorporate the perspectives of J.D. and M.B.A. students with the hope of shedding some light on which technical aspects may enrich those respective curricula.

Acknowledgements

The authors gratefully acknowledge the financial support of the National Science Foundation IGERT Program (NSF IGERT-0221600) and the Georgia Tech Rapid Prototyping and Manufacturing Institute (RPMI). The authors would also like to recognize the support they have received from their thesis advisors Drs. David Rosen and Farrokh Mistree, as well as other members of the Systems Realization Laboratory.

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Figures and Tables

S&E Ph.D.

		TI:GER® Participation (Year in Degree Program)		
1	2	3	4	5
Science& Engineering Courses Regular Research /Teaching Assistant	Science& Engineering Courses Regular Research /Teaching Assistant	Principles of Management Innovation Fundamentals TI:GER® Teams & Workshop	Innovation Electives[3] TI:GER® Case Course TI:GER® Teams & Workshop	

M.B.A.

1	2
M.B.A. Core Innovation Fundamentals TI:GER® Teams & Workshop	Innovation Electives[3] TI:GER® Case Course TI:GER® Teams & Workshop

J.D.

1	2	3
Law Core	Business Associations Patent, Copyright, & Trademark Law Innovation Fundamentals TI:GER® Teams & Workshop	Corporate Finance Courses for IP/ Business Law/Tax Concentrations[3] TI:GER® Case Course TI:GER® Teams & Workshop

Figure 1. - TI:GER® Seminar Topics [2]

[3] Optional Class