Motorsports Engineering: Bridging the Divide between Engineering and Engineering Technology with an Industry-Focused Curriculum

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Abstract
Traditionally, engineering baccalaureate programs have emphasized theory and design, including a rigorous background in the basic sciences and mathematics in the curriculum. Alternatively, engineering technology baccalaureate programs have required less theoretical and mathematical rigor, focusing more on application and the implementation of existing state-of-the-art technology. As leaders of both engineering and engineering technology curricula guide the continuous improvement of existing programs and consider the creation of new programs, they must strengthen their relationship with industry to ensure that their respective programs reflect the needs of the industries that their graduates will enter. As industries change and advance their technologies and processes, new programs may need development by academia to meet the evolving demands of new industrial specialties. Plans of study for these new programs should be guided by advice from industry to ensure that graduates acquire the most appropriate knowledge and abilities upon graduation. Addressing these concerns will help shape engineering and engineering technology programs to meet the future needs of industry while supplying a well-rounded educational experience that will serve as a foundation for graduates to succeed in life. This paper examines some specific ways that these issues have been addressed in the Bachelor of Science in motorsports engineering (B.S.MSTE) program within the Purdue School of Engineering and Technology (E&T) at Indiana University-Purdue University Indianapolis (IUPUI).

2. Coordination with Industry
The B.S.MSTE program at IUPUI serves the needs of students seeking careers in the motorsports industry as well as their employers (Hylton 2007a). The motorsports program also places a strong emphasis on activities that support the recruitment of pre-engineering students through K-12 outreach programs that increase prospective students’ interest in STEM through motorsports (Hylton 2010a; Otoupal and Hylton 2011). The B.S.MSTE program was created in recognition of the recent trend within the motorsports industry to incorporate more advanced technologies and more highly specialized individuals into the design and development of components and systems specifically for racing vehicles (Ul-Haq 2013; Bloye 2010; Sriman et al. 2013; De Winter and De Groot 2012; Hylton 2008). Academic program leaders must keep attuned to evolving trends in industry to adapt or create new objectives of a program is to prepare students with the knowledge and abilities necessary to find, and sustain, careers in industry that closely match their field of study upon receiving a baccalaureate degree. The following, therefore, become apparent. First, as industry changes and advances, programs will need to be revised or new programs developed to meet the hiring needs of new specialties. Second, academic curricula, developed especially for these new specialties, should be guided by advice from industry experts in these fields so that the graduates acquire the most appropriate knowledge and abilities to serve industry upon graduation. Addressing these concerns will help shape engineering and engineering technology programs to meet the future needs of industry while supplying a well-rounded educational experience that will serve as a foundation for graduates to succeed in life. This paper examines some specific ways that these issues have been addressed in the Bachelor of Science in motorsports engineering (B.S.MSTE) program within the Purdue School of Engineering and Technology (E&T) at Indiana University-Purdue University Indianapolis (IUPUI).

1. Introduction
It can be assumed that one of the most important
programs to meet changing needs of the workplace, for the United States to continue to successfully compete at the highest levels.

Industry advice and assistance has been solicited throughout the development of the new B.S.MSTE program consistent with the criteria of both the Engineering Accreditation Commission (EAC) and the Engineering Technology Accreditation Commission (ETAC) of ABET for program educational objectives to reflect the needs of constituents (ABET 2014a; ABET 2014b). A certificate in Motorsports Technology was initiated in 2006 at IUPUI as a predecessor to the B.S.MSTE program. When the certificate was created, the director of the program polled associates from the motorsports industry regarding what knowledge and abilities would aid graduates in finding jobs associated with the motorsports field. The leading answers were knowledge of two key attributes of a racecar: vehicle dynamics and power-train development, as well as data acquisition, which is one of the fastest growing areas of expertise needed in motorsports. The industrial advisors also made it clear that the students needed hands-on skills refined through experiential learning, since, on a race team, the engineers must often work alongside the mechanics and technicians to implement new ideas or repair a vehicle. Such feedback was a strong influence in the extension of the Motorsports Technology program to the B.S.MSTE program.

The requirement to develop applied mechanical skills is consistent with recent educational trends that indicate experiential learning opportunities support student success (Groves et al. 2013; Manolis et al. 2013; Joo Hyoung et al. 2008; Regev 2009). Additionally, the requirements for enhanced mechanical skills reflect an issue recently brought to light regarding the shortage of individuals in the workplace who have the ability to perform hands-on skills (Weber 2014). By creating practicum courses requiring students to implement their designs, their traditional classroom learning was coupled with project-based learning to fulfill all aspects of a conceptualize-design-implement-test sequence. Thus, the B.S.MSTE program was created to include courses and projects that taught students how to implement their designs, including a project to design and build a complete racecar. The results of these efforts were deemed successful in three ways by the program founders. First, the classes achieved solid enrollment of highly motivated and energetic students. Second, the project car, shown in Figure 1, was completed and has subsequently gone on to compete with a student team and driver in amateur level competition. The team has won both a regional autocross championship and a divisional racing championship with the Sports Car Club of America (Hylton 2007b). The team was also invited to the 2009 SCCA National Championships, the first student team ever to accomplish this feat ("Student" 2010).

With the initial success of the technology program, it was decided to create a new four-year Bachelor of Science (B.S.) degree in motorsports engineering. The program utilizes the same mathematics, science, and engineering fundamentals courses as the school’s long-standing mechanical engineering program. However, given that this was the first motorsports engineering B.S. program to be created in the United States, the program director felt that it was imperative to acquire from members of the motorsports industry their perspective on the additional specialized knowledge and abilities necessary to create an optimum engineering graduate for the industry. The program then synthesized this advice from industry with best practices for teaching derived from the school’s existing and successful engineering programs to develop specialized courses applicable to this new degree.

Since the advice from members of the motorsports industry had given the technology program such a strong start and since ABET emphasizes the involvement of program constituents, especially in the establishment and review of program educational objectives, it was natural that a formal Industry Advisory Board (IAB) was created. By partnering with the Indiana Motorsports Association (Fiorini 2012), the founders of the new B.S. program sent the proposal for the new degree to nine race teams (three in IndyCar racing, three in NASCAR racing, and three in NHRA drag racing) and nine supporting businesses within the motorsports industry. To gain the full support of these industry partners, the program founders explained that the mission of the program was to provide a specialty engineering program to reflect the needs of teams and businesses in the motorsports industry. Furthermore, if the graduates of this new program were to optimally serve those teams and businesses, it would be best for these organizations, as potential employers, to participate in designing the program and sharing responsibility for its success. Subsequently, IAB members actively participated in the curriculum selection. Their feedback was synthesized into a list of required classes that reflected the knowledge and abilities expressed by the IAB. These classes included the following:

- Motorsports Industry Overview
- Vehicle Dynamics
- Internal Combustion Engines
- Motorsports Modeling
- Analysis of Motorsports Designs
- Motorsports Design (2 classes)
- Data Acquisition (2 classes)
• Motorsports Aerodynamics
• Business and Management in Motorsports
• Internship
• Practicum (3 classes)

Subsequently, the program has received regular review by both faculty members and the IAB to ensure appropriate program educational objectives and student outcomes were in place to reflect the needs of the program’s constituents (Hylton et al. 2012). These advisors, with their familiarity with the program, became some of the first to offer internships and graduate placement. As the students and graduates took their place in these organizations and word spread, soon other teams and businesses were also seeking to participate in internships and hiring graduates.

Some of the program’s courses were added specifically at the behest of industry advisors. For example, the business classes were included because the advisors indicated that motorsports companies operate in a world much different from virtually all other industries, with timelines that are significantly compressed and with extreme demands (Young 2012). For this reason, the IAB wanted a business class unique to the B.S. MSTE program rather than utilizing a more generic and traditional class from the School of Business. IAB advisors were adamant that any graduate of the program needed to be comfortable with a competition vehicle in both theory and practice. The required internship (Talbert-Hatch et al. 2007; “Racing” 2010) and the practicum courses (Hylton and Otoupal 2014) were included to meet this directive.

During the formative stages of the program, significant discussions occurred within the School of Engineering and Technology as to whether the blossoming motorsports program should organizationally reside in the engineering or the technology side. According to a definition once used by ABET, engineering is “the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind” (ABET, 2010). By contrast, the Engineering Technology Leadership Council (ETLC) of ASEE defines technology as “the profession in which a knowledge of mathematics and natural sciences gained by higher education, experience, and practice is devoted primarily to the implementation and extension of existing technology for the benefit of mankind” (ETLC, 1992). Based upon these definitions, the two fields seem closely aligned, both requiring a strong mathematics and science foundation although engineering programs typically specify more depth in those areas. The engineering definition clearly indicates that “practice” is included as a criterion, whereas the technology definition focuses more strongly on “implementation,” implying more hands-on activity. Industrial specialties, such as motorsports engineering, which require both the depth of theoretical knowledge and the ability to physically implement projects, require a blending of the two perspectives and may be considered as applied engineering.

The ultimate decision at IUPUI was that while graduates of the motorsports engineering program needed to have the strong theoretical aspects common to the other engineering programs, students in the program also had to acquire the knowledge and abilities that were often considered to be more aligned with the engineering technology programs. Oner Yurtseven, the former dean of the School of Engineering and Technology, elected to maintain motorsports engineering within an engineering technology department, which also housed five other engineering technology programs, to ensure that the program retained its strong emphasis on applications, consistent with the IAB’s feedback. Moreover, the motorsports engineering program leveraged its technology roots, including the engineering technology laboratories and supporting infrastructure for student-led projects, while still constructing curriculum to satisfy the EAC of ABET general criteria. That is, the curriculum content and student outcomes of the motorsports engineering program are consistent with the mathematics and basic sciences requirements, as well as the other pertinent student outcomes and curriculum reflected in the EAC general criteria.

David Russomanno, who succeeded Oner Yurtseven as dean of the school in 2010, has agreed that, in retrospect, it was a good decision to maintain the motorsports engineering program organizationally within the engineering technology department for two key reasons. First, the organizational framework within the engineering technology department ensures the traditional hands-on component will remain prominent in the program as emphasized by the highly active IAB. Second, the program capitalizes on its geographic location in Indianapolis in that numerous racing engineers are available with extensive experience. Some of these racing engineering practitioners are interested in a career transition to academia after success at the highest levels of motorsports, including IndyCar and Formula One. These engineers, although with strong traditional academic preparation in engineering, have extensive experience and accomplishments in the highly specialized field of motorsports engineering. Such experience more readily translates to an appointment as a lecturer or professor of practice. Moreover, such prospective faculty members are more likely to successfully progress through the academic
ranks via the engineering technology department’s promotion and tenure (P&T) guidelines, which provide ample flexibility to pursue industry engagement and applied projects in the demonstration of excellence in the scholarship of teaching and learning, as compared to the traditional research excellence track more common in the P&T guidelines among the IUPUI engineering programs.

In an effort to assess whether the path taken at IUPUI for motorsports engineering has led to success, let us review some key outcomes. The B.S.MSTE degree was approved in 2008 and graduated its first cohort in 2012. During those four years, accomplished race engineers from Formula One and IndyCar racing joined the faculty, attracted by the fact that the program had been designed to reflect the needs of industry, it had incorporated the relevant hands-on aspects of motorsports, and that a path for their advancement existed within the faculty ranks. These faculty hires complemented the program director, who served as the glue for the program, as he had both traditional academic experience as well as extensive experience in the motorsports and aerospace industries. Student projects have involved the previously mentioned SCCA racecar, rebuilding another damaged racecar, shown completed in Figure 2, while simultaneously producing a new electronic technical manual for the original manufacturer of that car. Three racing go-karts have been designed, as shown in Figure 3. Two are gasoline-powered and have won the Purdue Grand Prix for three of the last six years, in Lafayette, Indiana. The Purdue Grand Prix is the best known collegiate go-kart competition in the United States. The third go-kart competed and won the first annual Electric Vehicle Grand

Figure 1. IUPUI’s winning SCCA racecar. (P. Hylton photo)

Figure 2. Racecar rebuilt by IUPUI students. (P. Hylton photo)

Figure 3. IUPUI’s winning go-kart team. (P. Hylton photo)

Figure 4. IUPUI’s FSAE racecar. (P. Hylton photo)
Prix at the Indianapolis Motor Speedway in 2011. Additionally, the students have designed and built the car shown in Figure 4, which was the top rookie entry in the Society of Automotive Engineers (SAE) annual Formula SAE intercollegiate competition in 2011.

Besides the B.S.MSTE program achievements, the faculty and students have made additional contributions to the racing industry. Examples include advancing the areas of motorsports safety (Hankins 2014; Borme 2012) involving the analysis and re-design of roll cage structures for sprint and midget race cars using finite element modeling of race car structures as shown in Figure 5. Other research has advanced race car vehicle performance (Borme 2011; Barkman 2014), including the development of a new chassis, as shown in Figure 6, for a Top Fuel dragster that set a new world record (Burgess 2010). Most recently, the program has received a $1.15 million grant to aid the development and application of the world’s most advanced automotive simulator in collaboration with Dallara, the designer and manufacturer of the IndyCar chassis (Kimberly 2014).

Moreover, all graduates to date who have sought positions have been offered jobs with teams or businesses. Several graduates have also sought and found placement in prestigious graduate programs. Additionally, teams and businesses in the motorsports industry are continually seeking interns and graduates from the B.S.MSTE program for open positions. Based on these results, the B.S.MSTE program has been judged a success by the university, members of the IAB, and other program constituents, establishing a significant legacy in its brief history.

Additionally, the B.S.MSTE program has drawn the two sides of the School of Engineering and Technology closer together and renewed the collaboration among engineering and engineering technology faculty members and students. Much of the debate over the years concerning the defining features and strengths of the various engineering and engineering technology programs has centered around perspectives regarding the emphasis of theory over application, or vice versa, in the respective curricula.

The B.S.MSTE program offered the opportunity to integrate and amplify the advantages that are often cited for engineering and engineering technology programs, respectively. As stated in a recent speech by Dean Russomanno at a celebration event for a Siemens in-kind gift of product lifecycle management (PLM) software to IUPUI valued at $538 million (“IUPUI” 2014): “Given our School’s comprehensive academic portfolio in the E and T of STEM, motorsports engineering and PLM software provide an ongoing mechanism to make our engineering and engineering technology programs more connected and mutually dependent, that is, more reflective of the organizational fabric found within companies known for their innovation.” It is noteworthy that an additional speaker at the event included a representative of Andretti Autosport, a motorsports company that uses PLM and hires motorsports engineering students from IUPUI.

Dean Russomanno has reinforced on multiple occasions the merits of the approach taken to design the B.S.MSTE program, including remarks given as part of the 2013 ASEE ETI panel on “Should Industry Co-Own the Education of Engineers?” (Russomanno 2013): “Motorsports engineering leverages...
the core of our B.S. in mechanical engineering program in its curriculum, while integrating the application-oriented approach emphasized in our engineering technology programs for its motorsports-specific courses and experiential learning opportunities for our students. Therefore, the motorsports engineering program ensures our graduates unite theory and practice such that things work and they know why."

The IAB has continued to meet twice a year with faculty members to ensure that the program continues to improve and reflect the needs of industry. Additionally, as the B.S.MSTE program drew to the close of its fourth year, the program director spent a semester-long sabbatical in the motorsports industry, reviewing the needs of graduates, their employers, and feedback from the students who had interned in industry. The sabbatical leave has resulted in improvements to the program, including the reorganization of some of the classes so that students are better prepared for internships earlier in the four-year program.

The motorsports program continues to be the quintessential example of a program that leverages the unique opportunities offered by its city and region, while making a national and international impact on the industry it serves. The B.S.MSTE program continues to serve as a best practice for utilizing industry recommendations to formulate a new program, or revise an existing one, to enhance the viability of the program for both graduates and employers. The B.S.MSTE program provides a direction for others in the development of new programs that connect most effectively with the industries that will employ the programs’ graduates.

3. Using Industry Assessments in the Classroom

Another aspect of the program is the method by which industry-based assessments have been integrated into some classes. EAC and ETAC of ABET criteria state that program educational objectives should reflect the needs of constituents, and industry is a typical constituent. Therefore, integrating industry-style assessment of selected student outcomes into some classes may better prepare graduates to attain program educational objectives. Classroom assessments, such as exam problem scores and project rubrics, are typically designed to measure the learning that students gain from their lectures, labs, assignments, and projects. These metrics measure the knowledge and abilities attained during the course of a semester.

A traditional quantitative classroom assessment might be points awarded to measure a student’s ability to apply knowledge of mathematics and science in the solution of an engineering problem. A traditional qualitative classroom assessment might be a letter grade awarded as part of an overall assessment of an essay to measure the student’s ability to communicate via writing. Ramlo (2006) has examined how traditional science classroom lectures could be enhanced by establishing a connection between real-life events and problems and the concepts of science. Michko et al. (2012) have also looked at improving traditional classroom teaching techniques using updated tools and paradigms. Davidson (2014) similarly looked at ways to develop critical thinking skills in higher education by using new methods of instruction. These researchers maintain mostly traditional assessment approaches for ranking student performance while enhancing the learning experience via modern presentations and approaches.

However, Schejbal (2012) indicates that paradigms for some educational programs are shifting to adopt industrial models. Fuh et al. (2010) recognized that there is a need to develop the ability to execute more than traditional design skills. There is also a need for students to be able to balance a project’s technical and non-technical requirements. Such competencies require dealing with non-technical issues including time management, scheduling, costing, coordination, team dynamics, formal presentation, informal communication, and professional ethics. Conrad and Sireli (2005) indicated that many graduates are faced with management responsibilities in which they need to have program management skills to administer various aspects of a project-driven technological organization. Their roles combine managing engineering problems, human factors, time and resource constraints, and financial issues on a cross-functional team. The IAB for the B.S.MSTE indicated that inclusion of more of these topics into the curriculum would enhance the ability of graduates to advance their industry careers.

As an example, faculty members of the School of Engineering and Technology with years of experience in the aerospace industry have begun using assessment approaches in the classroom that are drawn from those used in their industrial experience (Workman and Hylton 2006). One of the ways this industry-style integration has been accomplished is to introduce the topic of technical risk management (Hylton 2009) and utilize it as a mechanism for measuring semester-long progress on a senior design project (Hylton 2006). Risk management (Branscomb et al. 2006) is an area that has been given short shrift in engineering and technology programs despite industry recognition of its importance (Jarrett 2000). Instructors have integrated more aspects of project management into the MSTE students’ studies since this topic was pushed by the IAB. Topics such as work breakdown structure (WBS), budgeting, scheduling, resource allocation, team building, conflict management, etc., have been
integrated into the major design experience; faculty have even tried utilizing some unique class formats, which have proven successful (Hylton 2010b; Hylton 2007c).

Student design teams are required to take a design project from the initial concept phase through a preliminary design review to a final design configuration and report. Risk management plans and integrated program schedules must be created and continually updated through the course of the semester. Budgets, schedules, and resource allocations are driven by the project’s WBS. Teams are not scored on how well they follow their original schedule. Instead, assessment is based on how well they modify their plans as the project evolves and requirements change. Additionally, guests from industry participate in the reviews and fill out Request for Action (RFA) forms similar to those used in government contract reviews in industry. The student teams are not scored on how many RFAs their presentation generates. Rather, they are monitored on how well they address, and close, each of the action items that were raised before the end of the semester. Additionally, intra-team peer reviews and participation reviews by the instructor are utilized to assess the level of effort that various team members put into the group project. Less than half of the senior project course grade is based on traditional assessment approaches; the majority is based on these industry-based assessment styles. This concept of aligning academic assessments with assessment styles used in industry in some classes has satisfied the IAB’s requirement for preparing graduates for industry evaluations.

4. Conclusions

The B.S. in motorsports engineering program was founded based on an innovative use of industry advisors and the integration of industry-specified knowledge and abilities into a curriculum that has incorporated those attributes traditionally touted as strengths of the engineering and engineering technology curricula. The approach yields courses and student projects and experiences more closely aligned with industry needs. Feedback from both students and industry has indicated that program graduates have a much better perspective on the solutions to the challenges they will face when working in the rapidly evolving and demanding motorsports industry. Since industry is ultimately the career destination for most students in engineering programs, it is imperative to maintain a close relationship with industry representatives when determining curriculum, program educational objectives, and desired student outcomes.

The following are specific recommendations for engineering and engineering technology programs:

• Recognize changing needs of industry and align programs and classes to those needs.
• Acknowledge and address unique aspects of specific industries.
• Use an industry advisory board from the earliest stages of new program development.
• Tailor new programs to reflect the needs of industry in terms of specific or unique knowledge and abilities for the particular industry.
• Incorporate industry-style assessment techniques into selected courses to better prepare graduates for their chosen industry.
• Remember that applied engineering programs can bridge the engineering-engineering technology gap to the mutual benefit of both programs and the students.

References


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