



The development of the global automotive engineer, a case study from the Clemson University International Center for Automotive Research

Prof. Mohammed A Omar, Clemson University

Dr. Omar is an Associate Professor of Mechanical and Automotive Engineering at Clemson University, and the Director of Graduate studies. Dr. Omar also served as a visiting scholar at the Toyota Motor Corporation, Research and Development Headquarters in Japan in 2005; Dr. Omar's research has been recognized by the Society of Manufacturing Engineers SME through its Richard L. Kegg award, the Society of Mobility Engineers SAE through its Foundation Leadership in Manufacturing award, and through the Murray Stokeley excellence in engineering education award. Currently, Dr. Omar serves as Editor-in-Chief for the Journal of Material Science Research. His work is published in 5 book manuscripts, 4 US and Japanese Patents, and more than 90 refereed journal publications, conference proceedings

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Abstract

The presented study discusses a multifaceted, four step approach conceived and implemented by the Clemson University, to compose a graduate-level curricula for global engineering education, with focus on automotive engineering. The study presents both the preparation and the implementation levels, at the Clemson University International Center for Automotive Research CU-ICAR. The work will be purposefully presented in terms of four steps; first, conceiving the curricula to balance between the global issues related to the sustainability of the transportation systems, and the strategic national issues related to job creation and advanced manufacturing. Secondly, assembling an interdisciplinary character through unique educational and research structures. The third step discusses the students' recruiting mechanisms and the orientation process. Lastly, the fourth step is presented via the tools, collaborations, and initiatives implemented to foster the global nature of the program and ensure its relevance. In addition to partnering with international research centers and governmental agencies via flagship projects and competence centers.

Key words: Automotive Engineering, Global Engineer, Organizational learning, Curricula development

1- Introduction:

Engineering education has been going through a phase of continuous shifts in response to changes in its operating environment; specifically due to changes in the societal and economic conditions. To illustrate with examples, the Accreditation Board of Engineering and Technology ABET have proposed several changes to its accreditation criteria over the past few years in an accelerated fashion to cope with the aforementioned issues, Cheever¹ indicated five different proposed changes to the ABET criteria from 2003 to 2008. These proposed changes highlight the accelerated pace of change in engineering education in recent years, which come after the ABET comprehensive studies that led to the approval of the milestone Engineering Criteria 2000 in 1996. Ernst² indicated that since the founding of the ASEE in 1893 every decade had a milestone study that changed the engineering education focus from course content to the development of students as emerging professionals. Another example is the shift in engineering education focus between the pre and post-World War II; specifically following the 1955 Grinter³ 3 year study.

The current ABET criteria reaffirm a set of core engineering skills coupled with a second set of professional skills. The professional skills focus on communication skills, teamwork, ethics and

professionalism; in addition to “awareness skills” as coined by Shuman⁴ et al, which translates into engineering within the global and the societal contexts coupled with life-long learning and the knowledge of contemporary issues. Moreover, there is a recent trend of what can be called “Add-on” skills that come to complement the core engineering and science content; such as the innovation and entrepreneurship skills in addition to the system level thinking. Similarly, the spread of dual engineering-business degrees can be considered part of this trend.

Moreover, more and more engineering firms and industries are recognizing cultural-awareness as an important attribute of successful engineer. Such companies even try to train their engineering workforce to be more globally ready so that they yield a flexible workforce that can be deployed in and collaborate with the company’s different locations and teams. Such in-house training is typically offered through foreign language courses and overseas deployment. This trend is most evident in the automotive industry. Thusly, the current manuscript presents and discusses the multi-faceted approach applied by the Clemson University when developing its automotive engineering program. The presented study will first discuss the special attributes of the automotive industry that render it the most aware and sensitive to the global context. Subsequent sections will introduce the curricula development while highlighting its global aspects and the operational plan set in place to ensure the delivery of such curriculum.

2- The Global nature of the automotive industry

Inspecting the automotive industry and its operating environment; specifically its customer base, governing bodies, and competition style, demonstrates following unique attributes that make such industry most globally aware:

- *Market dynamics*, this refers not to the changes in one market but to the emerging of new markets with different buying trends. Currently, the automotive industry classify their markets into; established markets, mainly North American and West European markets, and Emerging markets that include the BRICS countries; in more words; Brazil, Russia, India, China and South Africa. Inspecting the geographical locations and cultural attributes of these markets reveal the global identity of the automotive industry, since each market is composed of different customer expectations and different perception of value. To provide an example, the Chinese market is made up of customers who are looking to own their “very first” vehicle, which shift their focus from the quality and reliability of the product onto the quality and cost of after-sale services [according to a study by the China Association of Quality CAQ in 2002]. Additionally, each of the mature markets have established their own National Standards Setting Bodies or NSBs to coordinate the automotive industry level standards and their reconciliation into the international standards, however some of these NSBs have been “aggressively and successfully promoting its technology practices to other nations around the world through its own standard process and through its national representation” American National Standards Institute⁵, which include specific regulations to that market for example the CEN environmental legislation. This means that the automotive engineer should be aware of such standards in addition to the national standards of each market.

- *The Global Nature of the Competitors* even in the same market. Since the 1980's the Asian-pacific Original Equipment Manufacturer OEMs have not only penetrated into the established markets but have also dominated it with their different production styles and suppliers' strategies. This have motivated the automotive engineers of North America and Europe to practice the Just-In-Time JIT delivery of goods and services and apply the Japanese Kanban and Andon systems to synchronize their production lines, while understanding that some of these concepts such as the Poke-Yoke are context-sensitive (specific to the labor force).

- *The automotive industry has pioneered the development and the usage of advanced engineering communication tools* through the Information Technology IT offerings. Such tools include a full suite of Computer Aided Engineering; Computer Aided Drafting and Design CAD, Computer Aided Manufacturing CAM, etc. Such tools have facilitated new modes of remote collaborative engineering work.

- *The automotive industry recognized the need to develop organizational learning systems* with global focus. An example of such learning systems is the Rover Group Learning Business or RLB, initiated in 1990, and the Volvo partnership with Renault in 1993 and with Mitsubishi in 1996 to establish cross-industry learning initiatives; more detailed studies on the organizational learning in the automotive industry see Omar⁶ et al.

3- The Clemson University Approach

In 2006, the Clemson University established the International Center for Automotive Research or CUICAR on 250 acres of land to host the automotive engineering Masters and PhD programs. This program is established based on comprehensive market studies that highlighted the need for an automotive research and educational presence in the South Eastern region of the United States, to help deliver a unique engineering workforce that the automotive industry demands. The program is structured to provide two offerings; a Masters degree designed to provide the technical skill-set that an automotive company requires for its operational activities such as running the production system, process and product control, and working with suppliers. The second offering is a PhD degree that delivers the research workforce that can develop and innovate new technologies and products.

3-1 Curricula Development and Design

Recognizing the fact that engineering curricula have been traditionally slow when responding to industrial demands, and typically lack the "real-world" preparations demanded by industry as highlighted by Miller⁷. So there is a need to develop a curricula design-structure that utilizes an objective methodology and uses the industry input to yield a set of educational offerings that cater to the professional and awareness skills required to develop the global automotive engineer. Beasley⁸ of Clemson University created and applied a design optimization approach for undergraduate curriculum development, which aimed at optimizing the course offerings subject to accreditation constraints, facilities, advisory board feedback, and faculty time. In addition to more expanded work by Beasley and Elzinga⁹ in 1996 that complemented the aforementioned

approach with quality-related continuous improvement concepts. Shea and West¹⁰ also developed a structured methodology using design tools for curriculum development.

The automotive engineering program designed its curricula through a two step process; the first included the core-engineering skill-set identification through industry surveys that asked the automotive OEMs and suppliers about the specific core-engineering skills that are vital for the automotive engineering, still not delivered through current mechanical, electrical, chemical engineering disciplines, in addition to the professional type skills they require. The survey results are then analyzed and implemented into a Quality Function Deployment matrix to match the voice of customer and the proposed course offerings in terms of content and scope. Several faculty workshops inspected the QFD results and tried to balance the depth and breadth of the proposed courses. A sample of the QFD is displayed in figure 1, showing the OEM capabilities and its translation into specific concepts and how it relates to the curricula structure in terms of core course, minor courses, and technical electives. Another of QFDs are developed to address the automotive suppliers' needs and sought technical and professional skills; the OEMs focused on process related skills while the suppliers requested product specific specialties, more details are found in Mears and Omar¹¹.

OEM Capabilities	OEM Concepts	Core				System Stem Required					Minor		Tracks					
		AuE 880	AuE 881	AuE 882	AuE 883	AuE 831	AuE 832	AuE 833	AuE 834	AuE 835	M1	M2	T1	T2	T3	T4	T5	T6
Vehicle Development: Process and Integration Tools and Methods (C1)	Vehicle Architecture		X				X											885
	Development Process and Tools			X			X											875 876 884 885
	Vehicle Testing						X							825 826				887
	Problem Solving Methods and Tools			X			X											
	Quality Methods	X		X	X		X								826			867 868
	Cost Structures	X					X					X						
Manufacturing : Process, Tools and Development: Focus on OEM and NOT Component Manufacturing (C2)	Supplier Integration	X						X										867 868
	Flexibility in Manufacturing							X			X				876			867 868
	Quality Methods in Manufacturing	X						X										867 868

Figure 1; QFD sample for the manufacturing related courses within the automotive engineering program

The second step, which is more relevant to the present study topic, is the professional skills identification. The results from this step indicated a consensus on following items; the curricula should provide the students with: opportunities to work and interact with teams of different expertise and nationalities, explicit instruction and courses on communication skills, understanding of the system level thinking (organization level), and explicit teaching on skills related to engineering projects such as problem solving, resolving conflicts, time management, idea creation and presentation to different audience levels.

Thusly, the automotive engineering curriculum established its course offerings in three levels, as depicted in figure 2; level 1 covers the core-engineering courses mandatory for all the students in the program, the next level addresses specific specialties in automotive manufacturing, vehicular electronics, vehicle performance, in addition to a certificate program. The third level covers the professional skills and include the cultural immersion, foreign language courses, in addition to courses in policy, and management. The third level courses are also mandatory to all students in the program. Designing the curriculum in this fashion is meant to integrate the engineering competency within a cultural, global context. In other words, the student going through this program will have to communicate his/her engineering knowledge through practical experience within a global environment. Additionally, the sequence of the course offerings ensured the students are exposed to all three levels every semester of their study.

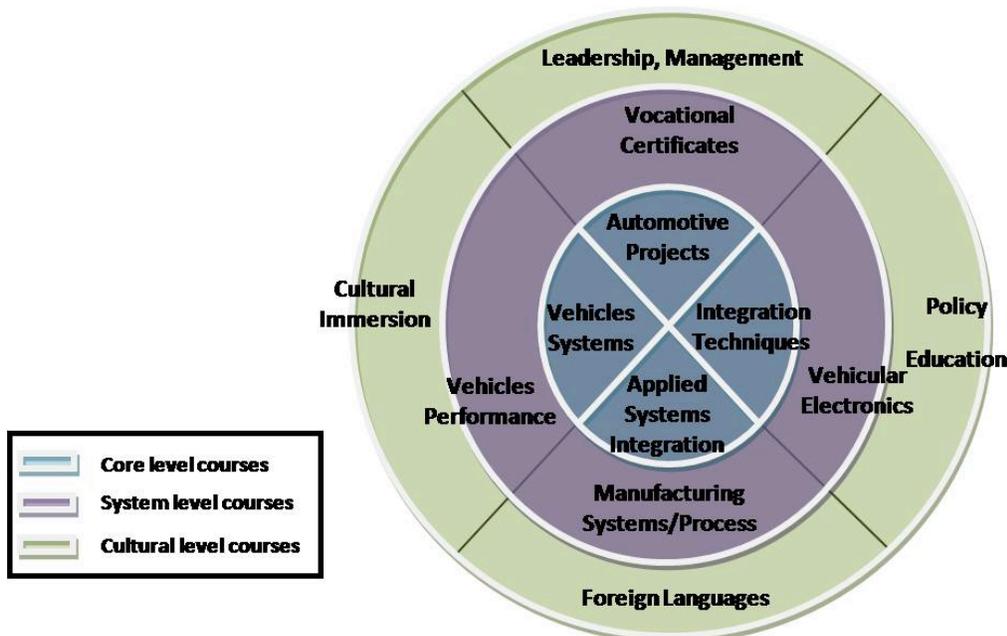


Figure 2, the automotive engineering curriculum development structure, Omar⁶

The cultural immersion courses included an international internship program, where each student will have to spend 6 months working for an automotive OEM or supplier overseas. The internship program is further structured to bear academic credit worth 6 hours, and graded across two semesters by an internship faculty advisor who monitors the student performance and record the employer feedback through a structured questionnaire that covers the student understanding and implementation of the core-engineering tools; in addition to the cultural immersion and communication aspects. The second part of the cultural immersion experience is the participation in the seminar series program at CUICAR, which is designed to host international expert speakers. The third cultural immersion component is achieved through a mandatory foreign language education, where each student should demonstrate competency in a foreign language as a graduation requirement. The automotive engineering program delivered concentrated language classes, in addition the automotive engineering program library had full suite of foreign language education software packages.

3-2 Interdisciplinary Character

One of the guiding principles of the automotive engineering program at Clemson University is the program interdisciplinary character. To ensure that the interdisciplinary character is integrated into the program and through the student educational experience, the hiring of the program faculty targeted faculty expertise in computer science, mechanical, electrical engineering, business and management, in addition to psychology. Additionally, the program faculty are recruited with industrial experience and with academic backgrounds, coming from 11 different countries. This diverse faculty composition ensured the interdisciplinary global character; through the faculty teaching styles and methods in addition to their research topics and methodologies, which created a balanced educational experience that exposes the students to the research and innovation opportunities that exist at the boundaries of disciplines and to the different teaching styles that exist internationally.

To further exploit the interdisciplinary character in educating global engineering, the students are continuously asked to solve multifaceted engineering problems that are context sensitive. Such problems included the design of sustainable mobility solutions for different markets, to help the students recognize the resource availability per region, and the legislative and societal structures that exist in that region before designing or selecting specific technologies.

3-3 Student recruiting, and cultural initiatives

The process of student recruiting is designed to selectively attract a diverse student body nationally and internationally. The admission efforts recognized the need to attract students from different regions within the United States, and from different countries. The current student cohort represents around 14 different countries coming from 6 different engineering disciplines in addition to mathematics. The recruiting mechanisms focused on students with BS degrees in any engineering discipline, mathematics or applied science; additionally the recruiting targeted students with different levels of expertise; even though the program have several newly BS graduates; the average post-BS working experience of the current students is around 2.5 years. Students with post-BS industrial experience had higher appreciation of global interactions and have been very active in advising new international students. This recruiting effort is meant to create not only a diverse student body but also an in-homogenous student population to incite more dynamics in student academic life; hence more cultural awareness.

To further enrich the student cultural experiences; upon admission each student is asked to post his/her picture along with a one-page description about him/herself in the student common area to help introduce and assimilate him/her into the student body; additionally a student organization (called the CUICAR student association) invites the incoming students into variety of cultural events that include; the German lunch, which is an event for automotive engineering students studying German to have lunch together while speaking only German during the lunch period.

4- Conclusion:

The presented study discussed the different tools and mechanisms deployed by the Clemson University newly created Automotive Engineering Department to help develop the global automotive engineering skill set. The manuscript discussed the objective approach assisted with decision-making tools, namely QFD, in developing the automotive engineering programs curricula. Additionally, the study highlighted the unique aspects that make the automotive industry the most proactive in terms of the global engineering education. Furthermore, the text discussed methods used to reinforce the cultural immersion aspect of the student learning experience through international internship program and foreign language competency. Moreover, the role of the interdisciplinary research and education in addition to diverse student body is discussed.

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