

Handbook of Research on

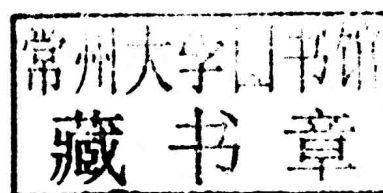
Recent Developments in Materials Science and Corrosion Engineering Education



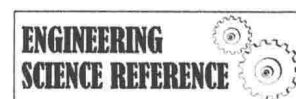
Hwee Ling Lim

Handbook of Research on Recent Developments in Materials Science and Corrosion Engineering Education

Hwee Ling Lim
The Petroleum Institute, UAE



A volume in the Advances in Chemical and
Materials Engineering (ACME) Book Series



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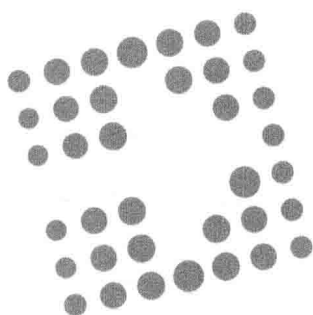
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Preface

Three major technologies form the driving forces for global economic growth: information technology, biotechnology, and materials science and engineering. However, materials science and engineering plays a more significant role as it enables the other two technologies; lowers cost and improves the performance of manufactured goods; leads to the development of new materials; and provides the means for materials protection, corrosion management, and environmental remediation (Flemings & Cahn, 2000).

The discipline of Materials Science and Engineering (MSE) is the “generation and application of knowledge relating to the composition, structure, and processing of materials to their properties and uses” (Claassen & Chynoweth, 1979, p.43). Within MSE, Corrosion Science examines mechanisms behind materials degradation while Corrosion Engineering applies corrosion science principles to minimize corrosion in design and practice (Ahmad, 2006). The synergistic relationship between MSE, Corrosion Science, and Corrosion Engineering is reflected in the outcomes of MSE educational degree programs. In other words, a MSE education builds a technical workforce with sound understanding of material fundamentals that improves materials performance and leads to effective materials degradation management. This in turn reduces costs and safety problems, contributes significantly to the sustained growth of critical industries such as energy, national defense, communication, construction and manufacturing.

The economic impact of materials degradation is well documented. Global annual cost of corrosion is estimated at US\$ 2.2 trillion (2010) which is about 3% of the world’s gross domestic product (GDP) of US\$ 73.3 trillion (Al Hashem, 2011). Materials degradation also results in structural failures, leaks and discharge of flammable fluids and gases that are health, safety and environmental (HSE) risks. One of the main limitations to the growth of many industries and technologies is the availability of materials with appropriate properties and performance characteristics. This implies a continuing need for materials scientists and materials engineers for the foreseeable future (National Science Foundation, 2008). A technical workforce, which is well educated and trained in Materials Science and Engineering, is needed to conduct research and development work in materials as well as manage the ageing infrastructure in countries worldwide. In particular, energy industries are in critical need of expert materials engineers to manage the challenges in refining the more corrosive petroleum products extracted from an increasing number of lower quality reservoirs. The key to ensuring a constant supply of such a skilled workforce lies in the availability of robust MSE educational programs.

The MSE discipline is highly dynamic and has undergone many changes in response to revolutionary inventions and improved technologies (polymers, ceramics, nanomaterials, metamaterials, etc.) that are extensively documented in engineering reference, technical textbooks and other publications available in the market (Ahmad, 2006; Ashby, Shercliff, & Cebon 2009; Bradford, 2002; Callister & Rethwisch, 2010; 2012). These changes in the discipline have invariably filtered down to impact the structure and

content of MSE educational and training programs. Yet there are no significant publications that encapsulate the recent developments and trends in MSE education. This edited book fills this gap and satisfies a long-felt need among academics and practitioners for such a pedagogical resource, and creates a sustained interest in the future of MSE education.

The purpose of this edited book is to disseminate the challenges and successes in the development of innovative, effective instructional approaches for Materials Science and Engineering education and training that can produce the next generation of skilled engineering professionals to solve global materials problems. The book is divided into four sections with 21 chapters; with each section reflecting a main theme as shown below. Each chapter offers suggestions for future work that can be carried out by academics, researchers, practitioners, and industry partners in the fields of materials science and corrosion engineering, engineering education, and higher education.

Section 1: Innovations in Materials Science and Engineering Degree Course Curricula.

Section 2: Incorporating Information Technology into Materials Science, Engineering, and Corrosion Education.

Section 3: Materials Science, Engineering, and Corrosion Education: Interdisciplinary Approaches in Teaching and Training.

Section 4: Engineers at Work: Professional Skills and Career Development.

The first section contains seven chapters that cover the theme of *Innovations in Materials Science and Engineering Degree Course Curricula*.

Chapter 1, *Bridging Product Design with Materials Properties and Processing: An Innovative Capstone Course* by Andrew M. Bodratti, Chong Cheng, and Paschalis Alexandridis, presents a product design capstone course, for chemical engineering seniors, which was implemented at the University at Buffalo – The State University of New York (USA). The course structure is based on two themes: a framework for product design and development; and (nano)structure-property relations that guide the search for materials with particular properties. The course material is supplemented by case studies of successful products and integrated into nanostructured product design projects that are drawn from real-world problems. The authors provide detailed descriptions of course organization, learning outcomes, teaching techniques, assignments, assessment, and student feedback that would be invaluable to teaching professionals. Since innovative products improve the quality of our life and are important for the prosperity of the chemical and materials industries, the course would enable university students to receive significant exposure to real-life materials development problems and strategies in their engineering education.

Chapter 2, *Teaching “Design-for-Corrosion” to Engineering Undergraduates: A Case Study of Novel Ni-B Coatings for High Wear and Corrosive Applications* by Ramazan Kahraman and R. A. Shakoor, shows the innovative application of research in corrosion that was conducted at Qatar University (Qatar) to the teaching of Materials Science. The authors provide an introduction to corrosion that explains the different forms of corrosion, the damage arising from corrosion and hence the importance of its prevention. Research on novel Ni-B coatings is presented as a case study for designing effective approaches to the instruction of corrosion management. The authors also describe how modern characterization tools such as Atomic Force Microscopy (AFM) and Transmission Electron Microscopy (TEM) can be powerful tools used in class or training sessions to build deeper student knowledge on materials. Overall, the chapter is a useful guide to developing engineering students’ understanding of the fundamentals of materials selection, coating design, and their characterization in order to combat corrosion.

Chapter 3, *Linking Materials Science and Engineering Curriculum to Design and Manufacturing Challenges of the Automotive Industry* by Fugen Daver and Roger Hadgraft, describes the design and development of an Automotive Materials postgraduate course in an international automotive engineering program at RMIT University (Melbourne, Australia). Engineering education at undergraduate level usually focuses on building students' knowledge of fundamental principles and linking the principles to practice through capstone design projects. However, engineering education at postgraduate level is more challenging as instructors need to impart graduates with the required technical background and at the same time ensure that the curriculum is constantly updated to keep up with advances in the industry. In the context of postgraduate education of automotive engineers, the authors present an interesting approach to teaching Materials Engineering that overcomes the inherent weakness of the traditional teaching methods by enabling students to make the connection between the underlying physical science of a material and its performance in real-life engineering applications. The authors provide details of the Automotive Materials course, including an example module, a case study, a group project on Materials and Process Selection, and the assessment methods used in the course. The authors argue that in a world of constant change, there is a need to develop the right graduate capabilities in engineering students, hence the chapter includes a wider discussion on several key issues facing educators in designing engineering curriculum such as the development of graduate attributes, adopting a systems thinking approach to materials education, and the importance of inculcating sustainability considerations in the design and selection of engineering materials.

Chapter 4, *The Interdisciplinary, Project-Based Infrastructure Degradation Curriculum at Worcester Polytechnic Institute* by Aaron Sakulich, Tahar El-Korchi, and Richard D. Sisson Jr., describes a new graduate-level project-based course on infrastructure degradation offered jointly by the Materials Science and Engineering; and Civil and Environmental Engineering departments at Worcester Polytechnic Institute (USA). The unique feature of the course lies in the interdisciplinary nature of the instruction and team projects. Professors from different departments offered lectures on their areas of expertise and the course incorporated a multidisciplinary project where student teams work on degradation methods that impact different infrastructure systems. A key aspect of the course is the support of engineering students' professional development in the form of student conference presentations at the first Worcester Polytechnic Institute Degradation Symposium. The authors' explanations of the motivation behind, experience with, and lessons learned from this course, can serve as a model in corrosion education as infrastructure degradation becomes more important with the continuing decay of man-made environments.

Chapter 5, *Applying a Coherent Academy Training Structure to Vertically Integrate Learning, Teaching and Personal Development in Material Science and Engineering* by Ian Mabbett, describes an innovative model used in the design of Materials Education in Swansea University (UK). The author describes the Materials Academy model, the driving force behind it, and explains the features of each stage and interaction of the various levels. The model shows possible paths for students as they progress from undergraduate to doctoral studies as well as to work based learning, with particular emphasis on the wide range of student backgrounds and experiences that must be catered for in the learning environment. At a higher level, the model reflects the necessary relationship between academia and the wider society through basic outreach and public engagement activities. The author promotes the adoption of the Materials Academy model in order to fill existing skills gaps so as to create an employable workforce for the materials science and engineering industry and contribute positively to economic growth.

Chapter 6, *Innovative Instructional Strategies for Teaching Materials Science in Engineering* by Fahrettin Ozturk, Tanju Deveci, Ebru Gunister, and Rodney J. Simmons, highlights the shortcomings of traditionally structured Materials Science education and describes the development of a Materials Science course by the Mechanical Engineering Department in the Petroleum Institute (Abu Dhabi, United Arab Emirates). The quality of materials education is of concern to the Petroleum Institute given its role in producing engineering graduates who work in the oil-gas industry where knowledge of materials is essential in process-product designs and ensuring the integrity of petroleum production facilities. The chapter describes the challenges faced in designing pedagogical approaches that would be effective for undergraduates with a weak educational background in STEM. It traces the evolution of the Materials Science course curriculum (lectures and laboratory) since 2005 to its present form that emphasizes the importance of designs which consider costs in economic, social, and environmental terms. The authors propose several new directions in materials engineering education that include adopting a *HSE Through Design* approach in the curriculum and integrating sustainable development considerations in engineering design decisions.

Chapter 7, *Developing Deeper Understanding of Green Inhibitors for Corrosion of Reinforcing Steel in Concrete* by Mohammad Ismail, Pandian Bothi Raja, and Abdulrahman Asipita Salawu, concludes this section on *Innovations in Materials Science and Engineering Degree Course Curricula*. The chapter focuses on the corrosion of reinforcing steel which is a significant problem particularly in the construction industry worldwide. The authors provide a background to the causes of corrosion as well as the materials and methods applied in monitoring corrosion. The use of corrosion inhibitors are subject to restrictive environmental regulations hence the latest trend in research is the development of cheap, non-toxic, environmentally benign, natural, or green corrosion inhibitors. Based on their research in this area, the authors propose a comprehensive course on green corrosion inhibitors for undergraduate and postgraduate engineering students that would help develop awareness that natural resources provide enormous choices to isolate corrosion inhibitors which can serve as “green solutions” for corrosion prevention. Academics, researchers and practitioners would benefit from the authors’ detailed descriptions of the proposed course objectives, content, assessments, laboratory experiments, and possible avenues for university-industry collaboration in designing high quality corrosion education.

The second section contains three chapters on the theme of *Incorporating Information Technology into Materials Science, Engineering, and Corrosion Education*.

Chapter 8, *Virtual Environments in Materials Science and Engineering: The Students’ Opinion* by D. Vergara, M. Lorenzo, and M. P. Rubio, highlights students’ views on the use of virtual environments as learning resources in Materials Science and Engineering courses offered by the Mechanical and Civil Engineering departments in seven universities from Spain and Portugal. As the increasing rate of undergraduate enrollment outstrips the number and size of physical classrooms and engineering laboratories that are available, universities tend to encourage the use of virtual teaching tools to accommodate the increasing student numbers. While virtual laboratories can be beneficial in teaching Materials Science and Engineering, the authors posit that the use of virtual tools must be framed within an appropriate methodological framework so that the educative objectives can be attained. From a survey of engineering students from the seven European universities, the findings show that students considered virtual resources (such as interactive virtual platforms; interactive multimedia applications and didactic videos) to be important in supporting learning provided the tools are able to engage their attention and interest.

However, students considered the most useful activity for learning as the instructor-led master class, followed closely by the problem solving class. In this sense, the physical presence of the teacher in the classroom is still an essential element in engineering education.

Chapter 9, *Artificial Intelligence Methods and Their Applications in Civil Engineering* by Gonzalo Martinez-Barrera, Osman Gencel, Ahmet Beycioglu, Serkan Subasi, and Nelly González-Rivas, explains that in Materials Science and Engineering, the simulation of material properties conventionally requires the development of a mathematical model derived from experimental data. In structural mechanics and construction materials contexts, research has reported that artificial intelligence (AI) methods such as fuzzy logic (FL), artificial neural networks (ANNs), genetic algorithm (GA), and fuzzy genetic (FG) may be promising alternatives. The chapter discusses the application of Mamdani type in concrete technology and highlights key studies related to the usability of FL in concrete technology. The authors provide a detailed description of the instructional application of AI methods in a postgraduate course titled *Applications of Artificial Intelligence in Engineering* at Düzce University (Turkey). The principles of FL methods that can be taught to engineering students through a MATLAB graphical user interface are described. Details are provided on the course structure, teaching activities, student feedback on the course, and instructors' reflections on the teaching experience that can be used to guide future course improvements. The authors emphasize that since experimental studies in civil engineering and particularly concrete technology can be difficult to conduct and usually involves the costs of time and materials, teaching the use of AI in modelling materials behavior will become increasingly important in Materials Engineering education.

Chapter 10, *Role of Digital Libraries in Teaching Materials Science and Engineering* by Arlindo Silva and Virginia Infante, explains that printed books and other forms of printed texts that provide technical engineering information can become outdated very fast and unmanageable in terms of physical storage space. Hence, the authors suggest adopting the use of digital libraries that can bring many advantages particularly in teaching Materials Science and Engineering (MSE). For instance, information on materials in digital databases of material properties can elaborate on the science and engineering fundamentals explained in textbooks with real data about current materials. The chapter provides a review of a range of materials databases available commercially. To support their thesis, the authors compare two experiences of teaching Materials Engineering at the Instituto Superior Tecnico (IST), (University of Lisbon, Portugal). One experience was drawn from a Materials Science course that uses the traditional textbooks and a bottom-up instructional approach, the other was a Materials in Engineering course using the CES EduPack database to support a design-led approach. Results from student surveys over three academic years showed that the instructional approach that uses materials digital libraries was well received by students.

The third section contains seven chapters on the theme of *Materials Science, Engineering, and Corrosion Education: Interdisciplinary Approaches in Teaching and Training*.

Chapter 11, *Interdisciplinary Course Development in Nanostructured Materials Science and Engineering*, by Kenneth L. Roberts, explains that advances in industrial processes are moving towards the use of multiscale production techniques where consumer products can be made at the mesoscale and also approaching the nanoscale level. However, engineering graduates who had undergone conventional Science, Technology, Engineering and Mathematics (STEM) education are typically not exposed to nanoscale science and engineering topics in their technical courses. Drawing from the author's research

in nanostructured catalytic materials, he describes the development of interdisciplinary undergraduate and postgraduate courses in nanoengineering and nanoscience at North Carolina A&T State University (USA) and King Faisal University (Kingdom of Saudi Arabia). The author posits that expanding the reach of current nanoscience and nanoengineering education would ensure a future engineering workforce that is prepared to contribute innovative industrial applications and products.

Chapter 12, *Materials and Mechanics: A Multidisciplinary Course Incorporating Experiential, Project/Problem-Based and Work-Integrated Learning Approaches for Undergraduates* by Kyle G. Gipson and Robert J. Prins, provides a background to Madison Engineering – an innovative undergraduate engineering program established at James Madison University (USA) – that is dedicated to the development of engineering versatilists who are capable of integrating knowledge from historically different fields of engineering. The authors explain in detail, *ENGR 314: Materials & Mechanics*, a course that integrates concepts from traditional several stand-alone courses (Materials Science and Mechanics of Materials) via a semester long design project in which students incorporate knowledge from both engineering fields. Positive student feedback to the integrated approach adopted by the new course suggests that there is significant value to this instructional method. The authors acknowledge the challenges encountered with this instructional approach that include needing the expertise of a teaching team and overcoming institutional barriers to the logistics of cross-disciplinary instruction. However, as Materials Science and Engineering is one of the few engineering fields that emphasizes understanding the interrelationships of elements, the exploitation of these interrelationships should be regarded as a priority in engineering education pedagogy.

Chapter 13, *Integrating Industry Research in Pedagogical Practice: A Case of Teaching Microbial Corrosion in Wet Tropics* by Krishnan Kannoorpatti and Daria Surovtseva, explains that Microbiologically Influenced Corrosion (MIC) is a major problem for industries operating in tropical environments as it accelerates corrosion rate dramatically. Based on the authors' research in MIC at Charles Darwin University (Australia), they propose to integrate the analytical and experimental investigations of MIC processes into the Materials Engineering curriculum. The authors describe a Project-Based instructional approach where students undertake an inter-disciplinary project to produce a database that outlines the relationship between the material type and bacterial environment through the relationship between corrosion rate and factors such as types of bacteria, functional genes, types of alloys, and welding procedures. Such a project would integrate learning in multiple fields of biochemical, chemical, materials and corrosion engineering, microbiology and thermodynamics, as well as offer authentic learning environments at both undergraduate and postgraduate levels. The authors provide insights on the instructional and management strategies for implementing this approach in online courses to cater to distance students and meet the up-skilling needs of practicing engineers.

Chapter 14, *Integrating Sustainable Engineering Principles in Material Science Engineering Education* by Bandita Mainali, Joe Petrolito, John Russell, Daniela Ionescu and Haider Al Abadi, argues that the proper selection of materials and production technologies is essential in face of increasing use and consumption of materials worldwide. Hence, the teaching of sustainable engineering should be given greater priority in undergraduate and graduate engineering courses. The chapter describes how sustainable engineering principles can be introduced into Material Science education. It introduces the curriculum for a new course on *Sustainable Infrastructure* offered at La Trobe University (Victoria, Australia) for senior Civil Engineering students. The authors provide details on course learning outcomes, individual/group learning activities, assessments that facilitate student engagement and deep learning. The authors

propose that by integrating sustainability principles, the scope of Materials Science and Engineering as a discipline may need to be redefined to enable greater interactions with multidisciplinary subjects and reflect its broader role in benefiting society, promoting economic growth and preserving the environment.

Chapter 15, *Materials as a Bridge between Science, Engineering, and Design* by Arlindo Silva, argues that while materials are used by user groups such as product designers, engineers and materials scientists, the teaching of materials tend to be isolated according to disciplines, and proposes that materials be used as a subject area to bridge the multiple engineering disciplines of Materials Science, Mechanical Engineering, and Product Design. A new model is proposed that connects the three common materials user groups, highlighting their differences and similarities in terms of materials knowledge and education. The author posits that the teaching of materials can become a precursor of future interdisciplinary discussion amongst these user groups. Moreover, having a common teaching support platform across these three disciplines, within a design context, can enable interdisciplinary collaboration in higher education and motivate future professional and industry collaborations.

Chapter 16, *Successes in the Development of an Arabian Gulf Materials Program* by Bruce R. Palmer, Dana Abdeen, Walid Khalfaoui, Nasser Al Jassem, Brajendra Mishra, Eunkyung Lee, and David Olson, provides an overview of the latest educational and training initiatives in the Arabian Gulf for developing corrosion engineering professionals to address the critical materials issues in the region. Since the future of Middle Eastern oil-gas business is greatly dependent on the availability of highly trained materials engineers, universities in the Arabian Gulf are regarded as vital sources of such professionals. Stemming from their research on corrosion resistant stainless steel alloys for the oil-gas industry conducted by Texas A&M University at Qatar (TAMUQ), the authors describe the challenges in establishing new materials research and education capabilities at the university that feature the development of unique laboratory facilities for investigating sour oil-gas production. These facilities are effective resources that enable students and researchers to examine critical, region-specific fundamental and applied corrosion issues. Inter-university collaborations between TAMUQ, the Colorado School of Mines (USA), and The Pennsylvania State University (USA) led to the introduction of new materials and corrosion courses at undergraduate and postgraduate levels at TAMUQ. A main goal of these efforts is to produce materials professionals who will remain in the Arabian Gulf and contribute to the region's growth with their engineering knowledge and skills.

Chapter 17, *Setting up a Learning Environment in an Interdisciplinary Professional Collaboration* by Elin Legland, discusses the contributions to the learning environment from collaboration between education, research and industry, and their impact on the professional growth of engineering graduates in Material Science. Through self-reflection on experience, author argues that by combining theoretical knowledge from university education and research with practical skills and experience gained from the industry, students can develop individual empowerment and bring future business advantages to the industries where they would later work. Moreover, collaborations between universities, industries and other professional societies can enable students to experience interdisciplinary learning environments through joint research. Additionally, stakeholders can attain their objectives through such collaboration and a range of competitive advantages in own business sectors. Hence, from an educational perspective, this three party collaboration provides opportunities for situated learning that link theoretical studies with practical research work.

The final section contains four chapters on the theme of *Engineers at Work: Professional Skills and Career Development*.

Chapter 18, *Cultural Heritage Career Paths for Materials Scientists and Corrosion Engineers* by Stavroula Golfomitou, Myrto Georgakopoulou, and Thilo Rehren, bring a new perspective to the conventional expectation that engineering graduates establish careers within their own disciplinary fields. The authors posit that cultural heritage is a multidisciplinary field where Materials Science and Corrosion Science have a significant role to play. They explain that materials engineering knowledge can be applied to the treatment of cultural materials, such as the reverse engineering necessary to reconstruct ancient technologies used for materials production, the examination and condition assessment of complex artefacts, and the development of innovative treatment methods for their protection and conservation. The authors describe the educational/training programs in the field of Archaeological and Conservation Sciences that are available internationally, with specific focus on the MSc in Conservation Studies program offered by the University College London Qatar (Qatar). The authors urge engineering graduates to consider career paths beyond the mainstream options and seize the opportunity to work with unique artefacts using state of the art technologies to unravel their secrets and ensure their long-term preservation.

Chapter 19, *Teaching MSE Students to Teach: A Design-Based Research Model for Introducing Professional Skills into the Technical Curriculum* by Catherine Berdaniel, Tasha Zephirin, Monica F. Cox, and Suely M. Black, provides a brief background to the US federally-funded Integrative Graduate Education Research Traineeship (IGERT) program that aims to reduce the gap between expectations of technical employers and non-technical competencies of graduates. Based on the authors' work with IGERT in a Magnetic and Nanostructured Materials (MNM) project that involved Norfolk State University, Purdue University and Cornell University, they explain how design-based research (DBR) methodologies can be implemented in Materials Science and Materials Engineering courses. The authors present a new flexible model for DBR that can be used to integrate professional non-technical skills development into the technical curricula. They offer strategies for faculty, department heads and graduate students to conduct the iterative process needed for developing courses to suit the needs of their departments.

Chapter 20, *Development of Non-Technical Skills Required by Future Global Practitioners in MSE and Corrosion Engineering* by John Robertson-Begg, argues since engineering students are usually taught a narrow subject specific curriculum, a broader educational base is needed to prepare them for work in the global environment. Based on the author's self-reflections on professional experience at the University of Derby (UK), he proposes the concept of a 'global engineer' who is knowledgeable about sustainability, ethics, human rights, social justice, and cares about life-long learning as part of career development. He describes the pedagogical designs of several undergraduate and postgraduate Materials Engineering courses that integrate the teaching of technical and essential non-technical competencies that would equip students to meet the changing needs of industry.

Chapter 21, *What Makes Them Stay and Go? Best Practices for Engaging Gen Y Female Professionals in the Critical Arabian Gulf Petroleum Industry* by Hwee Ling Lim, concludes both the section and the edited book. As earlier chapters in this section dealt with issues pertaining to equipping future engineers with technical and non-technical skills in the course of their engineering education, this chapter covers the career perspectives of young engineers in terms of the factors affecting their decisions to join and stay with a company. The author explains that in United Arab Emirates (UAE), the petroleum industrial sector plays a key role in ensuring the nation's continued economic growth. Towards that goal, petroleum companies need technical professionals knowledgeable in Materials Science and Engineering to maintain the integrity of production facilities and corrosion management. Non-technical personnel are also needed to support production and business activities. The companies' recruitment efforts transpire in a multi-generational labour market complicated by under-utilization of Generation/Gen Y females.

The author presents findings from a recent study that investigated gender differences in life priorities and work preferences of Gen Y in UAE petroleum industry. The survey findings from 150 young professionals showed that *Conservation* and *Self-transcendence* were the most important life dimensions with *intrinsic* and *extrinsic* work motivators most valued. There were also changes in the importance of specific motivators in recruitment, by each gender, compared with retention. The author offers recommendations for recruitment and retention that would guide personnel managers develop initiatives that cater to the specific requirements of each gender and promote understanding of the needs of the technical workforce.

In summary, the individual chapters in this book capture and consolidate recent international advances in course content and curriculum design of MSE degree programs, critically reflect on their implications for engineering pedagogy, identify what works and what does not; and outline future research and actions relevant to academia and industry. Collectively, the chapters in the edited book showcase empirical studies where the application of instructional strategies in MSE degree courses is grounded in pedagogical frameworks; highlight action research on innovative MSE curriculum development (at undergraduate and postgraduate levels) that present compelling implications for learning theories, educational practice, and best-practices in non-academic stakeholder collaborations, particularly in the integration of curriculum design with industry needs. The collection of chapters also includes international studies on the design of MSE courses in e-learning contexts with implications for online pedagogy, use of technology in teaching and training. Finally, the edited book includes chapters that present lessons learnt from successful engineering programs that incorporate career preparation in the form of developing job skills essential to engineering professionals; and highlight issues surrounding the recruitment and retention of young engineering and non-technical professionals employed in the critical energy industry.

This book can certainly be differentiated from other publications available on MSE education. For instance, the National Science Foundation published a report on *The Future of Materials Science and Materials Engineering Education* based on findings from a workshop on the future of MSE education (National Science Foundation, 2008). It was attended by representatives from the industry, academia, federal agencies, national laboratories, and professional societies. The report summarized key issues and recommendations from the discussion on the state and future of the materials education. However, the report is limited to the US educational system and to the context in 2008. This edited book showcases research on MSE programs from a wider range of countries and provides actual examples of instructional innovations. The chapters in this book extend the scope of the report and to some degree, reflect the extent to which the recommendations were followed up in practice.

The National Research Council was commissioned by the US Department of Defense to assess the state of corrosion engineering education. A Committee on Assessing Corrosion Education was formed to study the situation and reported its findings in 2009. The *Assessment of Corrosion Education* report presented findings and recommendations from a survey of 31 universities on the availability of materials and corrosion engineering related courses in the universities (National Research Council, 2009). Similar to the first title, this report is limited to the US educational system and focuses specifically on corrosion education rather than on the broader MSE discipline. This edited book is broader in scope with the inclusion of studies on corrosion as well as materials science education from more countries. Hence, the edited book also provides an international perspective on the developments and trends in MSE education and training.

Finally, presentations from a 2000 Materials Research Society meeting held in California (US) was published as a book of proceedings titled *Materials Science and Engineering Education in the New Millennium* (Materials Research Society, 2000). The proceedings covered 25 presentations on MSE courses

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at undergraduate and postgraduate levels. The contributions were predominantly from US university faculty and researchers with only three chapters from authors in UK, Germany, and Estonia. The edited book is broader in treatment of MSE education as it included more international authors and chapters that extend beyond the classroom to examine career development for young engineers.

The contributions in this edited book represent the current state of pedagogical research in MSE education and provide a rich picture of the international developments and future trends in MSE education. The book will appeal to the needs of a wide audience of academics, researchers, and industry practitioners. The authors, editorial advisory board members and I hope that this publication will inspire educators and researchers to push the boundaries in the fields of MSE and Corrosion Engineering education.

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REFERENCES

- Ahmad, Z. (2006). *Principles of Corrosion Engineering and Corrosion Control*. Oxford: Butterworth-Heinemann.
- Al Hashem, A. (2011). *Corrosion in the Gulf Cooperation Council (GCC) states: Statistics and figures*. Paper presented at the Corrosion UAE.
- Ashby, M. F., Shercliff, H., & Cebon, D. (2009). *Materials: Engineering, science, processing and design* (North American Edition). Oxford, UK: Butterworth-Heinemann.
- Bradford, S. (2002). *Corrosion Control* (2nd ed.). Edmonton, Ohio: ASM International.
- Callister, W. D. Jr, & Rethwisch, D. G. (2010). *Materials Science and Engineering: An Introduction*. Hoboken, NJ: John Wiley and Sons, Inc.
- Callister, W. D. Jr, & Rethwisch, D. G. (2012). *Fundamentals of Materials Science and Engineering: An Integrated Approach* (4th ed.). Hoboken, NJ: John Wiley and Sons, Inc.
- Claassen, R. S., & Chynoweth, A. G. (1979). Part II: Materials science and engineering as a multidiscipline. In M. Cohen (Ed.), *Materials Science and Engineering: Its Evolution, Practice and Prospects* (1st ed., pp. 41–102). Sequoia, SA: Elsevier. doi:10.1016/0025-5416(79)90183-6
- Flemings, M. C., & Cahn, R. W. (2000). Organization and trends in Materials Science and Engineering education in the US and Europe. *Acta Materialia*, 48(1), 371–383. doi:10.1016/S1359-6454(99)00305-5
- Materials Research Society. (2000). *Materials Science and Engineering Education in the New Millennium* (Vol. 632). Red Hook, NY: Curran Associates, Inc.
- National Research Council. (2009). *Assessment of Corrosion Education*. Washington, DC: The National Academy of Sciences.
- National Science Foundation. (2008). *The Future of Materials Science and Materials Engineering Education*. Arlington, VA: National Science Foundation.

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