




STEM
for Sustainable Development

Andrew Ragai Henry Rigit



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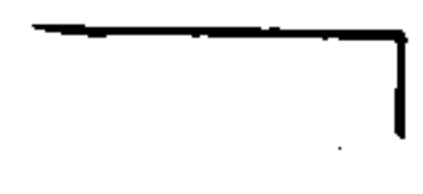
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Andrew Ragai Anak Henry Rigit

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Foreword

It is my great pleasure to pen down a foreword for this book entitled STEM for Sustainable Development, which highlights Professor Ir. Dr Andrew Ragai Anak Henry Rigit over twenty years of research contributions. He is a Professor of Mechanical Engineering with major emphasis and expertise in fluid mechanics. His journey in research started with his endeavors in bringing improvements into the combustion processes, of which he has applied the electrohydrodynamics of the charge injection through electrostatic atomizers, attaining bulk convection. He not only evaluated the electrical performance of the atomizers by using increasingly smaller orifices, but he also investigated thoroughly the spray characteristics for improvement in mixing of fuel and air that contributed in the efficiency of combustion process. Another area that has recently caught the attention of Professor Andrew is the application of charged plasma to achieve various industrial benefits. The viability of the charged plasma to achieve complete combustion in the engines and its applications for the removal of heat from MEMs, has attracted substantial interest in view of the fundamental aspects of plasma research.

Having multifarious and multi-dimensional approach in research, Professor Andrew has not confined himself to academic research only. Instead, he played a cordial role in consulting some of the organizations in Sarawak on issues such as how to deal with greenhouse gases (GHGs) emitted from landfill, how to design an efficient and hygiene solar dryer for pepper farmers, and how to conduct material characterization for overhead high voltage power conductors used for transmitting electricity over the

state grid system. He used both qualitative and quantitative techniques to help a local IPP to maintain their high voltage cables for a longer life span without experiencing any severe damage. He also designed a black pepper berries solar dryer and has successfully developed an efficient solar dryer by conducting a detailed study on transport processes inside the dryer. The use of this efficient solar dryer has proved to accelerate the drying process, and maintain the quality of the pepper berries. Finally, he worked on the landfill gas (LFG) piping system where he has helped the client in using the LFG as a supplement to Diesel oil, reducing the cost of incinerating hazardous wastes, and promoting sustainable development the by reducing GHGs emission.

Professor Ir. Dr Al-Khalid Bin Othman

Dean, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS)

Preface

“

*Science, Technology, Engineering and Mathematics (STEM),
are vital disciplines to our future, the future of our country, the
future of our region and the future of our children*

Daniel Suchenski

When I was invited to deliver an inaugural lecture as a professor in UNIMAS, I took the liberty to position my research of more than twenty years into the importance of STEM and how they are fundamental disciplines required for sustainable development. STEM comprises of Physics, Chemistry, Mathematics and Biological sciences: providing the complete knowledge and understanding of the Nature and the Universe.

Physics deals with the knowledge of nature, study of matter, its motion and behavior through space and time, along with concepts related to energy and force. Its main theme is to understand how the universe behaves and sustains. Whereas Chemistry is the scientific discipline involved with the atoms, molecules and compounds that undergoes changes when they interact with each other to form new useful materials. Mathematics attains the status of the mother of sciences because it is the language that demonstrates the scientific description of physical or chemical nature, related to any phenomenon or process prevailed within the nature or industry. Biological sciences deal with the knowledge of living things. All these four branches of learning are introduced at the school level and have been taught with increased level of breadth and depth till the highest

level of study, i.e. PhD. The essence and beauty of these subjects lies in the fact that their roots go deep into the transformation of a society from an aboriginal society to the technological advanced society. The transformation of knowledge of science to some practical embodiment always brings great benefits to the society. Now let us consider the flow of a fluid, which depicts energy and when it is guided on to the turbine machinery that revolves under the effect of this fluid flow, is causing a magnetic coil to revolve inside a magnetic field to produce electricity. This is one prime example of transfer of science to technology. The generation of electricity at economical capacity (e.g. in MW) as well as distribution of electricity through a grid system to the households and the industrial units is the transformation of technology to the engineering scale.

I have observed and contributed in many such transformations through my academic and research experience of which I hope I have presented them into this book. My aspiration is that through the reading of this book, you will appreciate how sustainable development is connected to the importance of STEM.

Andrew Ragai Anak Henry Rigit (PhD, PEng)

Professor, Department of Mechanical and Manufacturing Engineering, UNIMAS

Acknowledgments

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The hardest arithmetic to master is that which enables us to count our blessings.

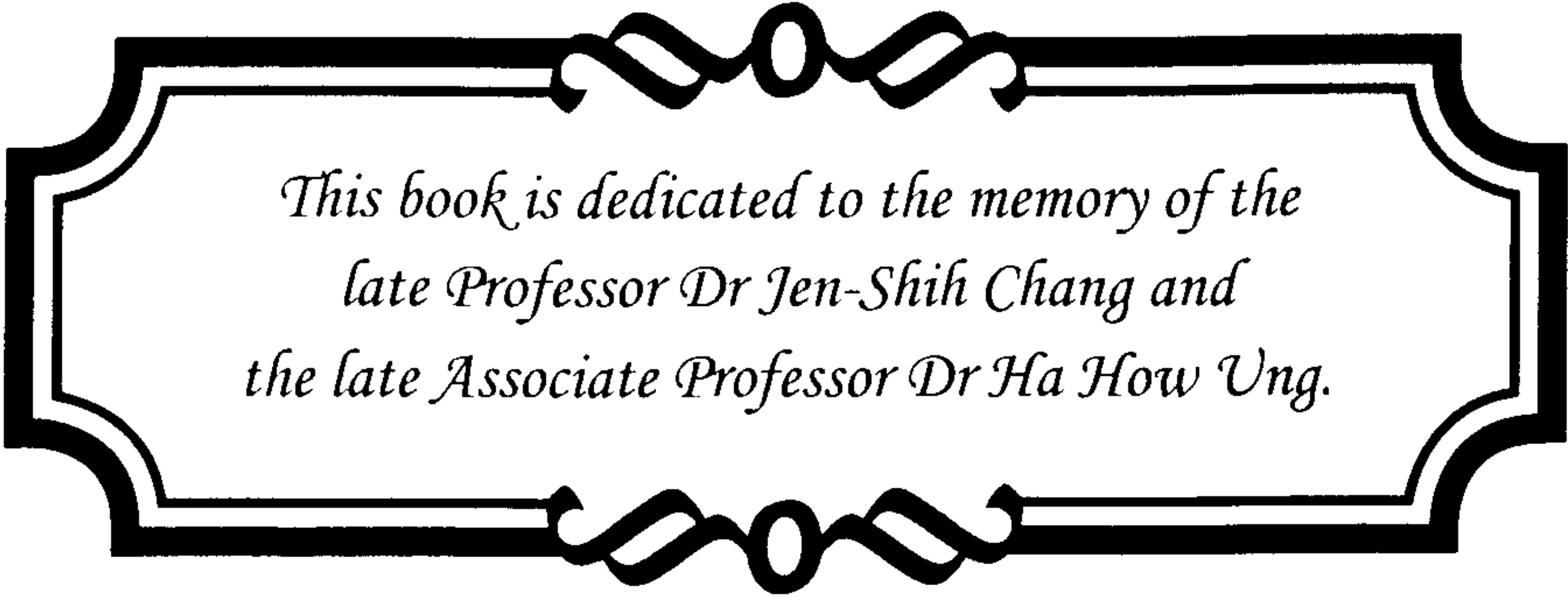
Eric Hoffer

Indeed God has blessed me with the wonderful people especially those who have assisted me directly or indirectly in producing this book. I am indebted to my parents, Henry Rigit anak Rambah and Rita Tina anak Simod for their unconditional love and their enormous support. I thank my loving wife, Associate Professor Dr Jane Labadin, for standing beside me throughout my career and for her continuous encouragement. I also thank my children: Amber, Amelie, Angelina, Anatalia and Jonah, my source of inspiration. These beautiful people have kept me going and this book would not have been possible without them.

I would like to thank my supervisors, Professor Dr Sarim Al-Zubaidy and Professor Dr John Shrimpton for guiding me academically and professionally with patience whilst under their supervision. I would also like to acknowledge my colleagues, especially Professor Dr Mohammad Omar bin Abdullah, Professor Dr Amir Azam Khan, Associate Professor Dr Khairuddin Sanaullah and Ir. Dr David Bong, my postdoctoral, postgraduate and undergraduate students, mentors and friends who have never stop challenging me, and helping me in developing my ideas.

A special word of gratitude is due to the Inaugural Lecture Committee chaired by Professor Dr Wan Hashim bin Wan Ibrahim for this opportunity

to deliver this lecture, and my Engineering Dean, Professor Ir. Dr Al-Khalid bin Othman and Department Head, Dr Shahrol bin Mohamaddan for showing confidence in my work. My eternal grateful also goes to UNIMAS Publisher for their patience and help in the production of this book. Last but not least, my deep appreciation to Associate Professor Dr Siti Noor Linda bt Taib for keeping the working committee well motivated till the end. The front cover picture is courtesy of Ir. Dr Mohd Danial bin Ibrahim showing Bakun Dam, Sarawak.



*This book is dedicated to the memory of the
late Professor Dr Jen-Shih Chang and
the late Associate Professor Dr Ha How Ung.*

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Chapter 1

Introduction

1.1 The Importance of STEM

Science is all about figuring out how things work. It comprises fundamental knowledge or old ideas, which requires scientific understanding and mathematical analysis. Technology is the invention of new designs by using old ideas. It is the thrill of discovery by curiosity leading to the feeling of being a pioneer, which is the motivation for technological discoveries. It is the role of engineers to turn technological discoveries into marketable products. Engineering is therefore a discipline that enriches the quality of human life. It is an instrument of civilization or development that destined to serve mankind. Sustainability, on the other hand, is the property of any entity, system or mechanics to be remain productive infinitely.

Malaysia would do well in developing its economy in a sustainable manner with talent in Science, Technology, Engineering and Mathematics (STEM) to contribute to an increasing share of the country's economic output. STEM play a big role not only in enhancing people's well-being but also in propelling our nation's progress. Science is indeed indispensable and the emphasis on the need for Malaysians to excel in STEM is increasing in order to develop and create quality human capital to remain competitive globally. Nurturing talent in STEM is therefore very important especially among our youth.

It is important to nurture interest in STEM education and career. The need to have adequate supply of future scientists, mathematicians, engineers, medical professionals and innovators is greater than ever if the country wished to be on par with other developed countries. The government and the non-governmental organizations should play their roles well in engaging and nurturing youth with knowledge and skill in STEM and developing their interests in pursuing a career in STEM.

Therefore, the main objective of this book is to introduce the different ways knowledge in STEM could be transformed into producing solutions to the present and future technological challenges associated with environment, social and economy in a sustainable manner. It will spark the ways on how to inculcate interest into its reader by developing a sound understanding in mind about this transformation.

1.2 Sustainable Development

STEM is essential to meet the challenges for sustainable development. It is essential in the sense that it embodiment the basic foundation stone for the new technologies, approaches, and solutions that human needs to tackle present and future challenges. In order to understand the role of STEM for sustainable development, broad understanding of the whole range of disciplines is required, from natural and biological sciences to engineering, as well as social sciences and economics. STEM based knowledge will never straight away gives practical application based solutions. The basic knowledge shared by STEM is all about thinking out of the box in order to understand the ways that lead to new thinking and approaches.

Based on these new approaches, practical solutions can be devised which are actually the transformation of the STEM based knowledge to device sustainable solutions. These solutions, when practiced on engineering scale

helped to bring in sustainable development. This whole transformation process for sustainable development needs a lot of time and patience. It is a long term human capital investments which ultimately brought the realization of development to society as a whole. This transformation is the fuel for further progress and is essential for sustainable development.

1.3 Structure of this Book

This book shed light on the knowledge transformation from basic sciences to technology and then to engineering. It comprised of four chapters with this first chapter gives an introduction to STEM and sustainable development. Chapter 2 demonstrates how knowledge in STEM is applied to Research and Development (R&D) work in designing and developing an electrostatic atomizer for application in combustion system. The atomizer's electrical performance and the characteristics of the resultant sprays were analyzed, and the the mathematical model of the droplets charge distribution were presented.

Chapter 3 provides an insight into consultancy work based on knowledge in STEM where it gives detailed account on how to deal with greenhouse gases, designing a solar dryer, and failure analyses of high voltage power cables. Chapter 4 concludes the book by giving suggestion on how to promote STEM education and career in schools and proposing a new R&D work in fuel cell technology.

Chapter 2
STEM for R&D Work

2.1 Introduction

This chapter demonstrates how knowledge in STEM is applied to R&D work in designing and developing an electrostatic atomizer for application in combustion system. The motivation for this R&D work is to develop an energy-efficient method for atomizing insulating hydrocarbon liquids, for application in spray combustion systems. In order to reduce the environmental pollution, emission regulations such as Kyoto Protocol, 1997, and green-house gases (GHG) consensus at the Conference of Parties 15 (COP15) in Copenhagen, 2009 and COP21 in Paris, 2015 are becoming more stringent and an added motivation is to investigate a spray combustion system that has the possibility of much reduced emissions of nitrogen oxides, NO_x and sulphur oxides, SO_x.

Electrostatic spraying of hydrocarbon liquids for practical combustion systems still lacks of basic research, and it is important to carry out this task with increased efficiency and reduced pollutants in mind. This R&D work seeks to provide a contribution to the fundamental knowledge that is required for future utilization of electrically charged sprays of electrically insulating liquids. A combustible spray plume requires a spray with droplet Sauter mean diameter of $D_{32} < 100 \mu\text{m}$, and smaller orifice diameters and