Preface

Research is the food for an inquiring mind. Research opens up new avenues in the world of curiosity and has paved the way for novel information and findings. Research provides the investigator with the freedom to delve into untested territory. Therefore, it is logical to accept the importance of the introduction of research in schools and colleges/universities in the early years. Current difficulties to introduce research in schools is mainly due to the challenges in finding sufficient numbers of qualified faculty, time, and syllabi that accommodate research as a part and parcel of curricula. Rectification of this situation would need a policy change at a national/state level that will make it compulsory for research to be taught in schools as a subject with other core school subjects. The core subjects are considered as the main language of the country (e.g. English language), social studies, mathematics, and science. The solving of this problem in colleges and universities is not as challenging as schools, although community colleges and the first two years of universities in the USA tend to focus the least on research in their attempt to foster students to learn the core subjects, which is a main requirement in the USA style of education. It is my personal opinion that the situation needs to be changed by holding high schools more responsible in teaching the core subjects thoroughly and then let students at community colleges and the first two years of universities spend more time strengthening the knowledge in their respective chosen fields. This will deliver a group of students who are better equipped to take on real-life challenges with advanced knowledge, since more time could be then spent at colleges/universities in mastering the skills necessary in their chosen careers. If schools, colleges, and universities can introduce multidisciplinary research in combination with core subjects, then the students would benefit more in experiencing the real-life challenges rather than learning the core subjects mainly from textbook-based classroom activities and limited laboratory scale settings. In the British educational system, high school students, after their General Certificate in Education at Ordinary Level (G.C. E. O/L), select only the subjects relevant to their chosen fields. Yet, the lack of an in-depth knowledge in core subjects due to time constraints in high schools makes it difficult for science students to make an easy transition to the work force
after graduation from universities since they lack the skills and knowledge required by employers. The introduction of multidisciplinary research should provide the answer; yet this would be possible only if a strong policy change is made to accommodate the inclusion of multidisciplinary research that would expose students to real challenges in their chosen and allied fields while strengthening their knowledge on core subjects. In addition to students not possessing the necessary knowledge or skills when they leave education and enter the workforce, in science education the lack of interest and understanding of the importance of science among students further exacerbate the situation.

Science has been the foundation of the progress of mankind. The 21st century technology, which we have proudly embraced, the distances we have travelled in space, the software development that has made the “world in my pocket” possible, and the longevity that has been promised in humans and animals have been the result of the realization of capabilities of science and its allied fields. Most of the predictions made by great futurists such as Jules Verne, H. G. Wells, Hugo Gernsback, and also my mentor for a brief period, the late Sir Arthur C. Clarke, have now become realities because of the consensus of the great writers and great scientists. Science teaches a systematic approach to solving problems. It is a compass that leads us to wisdom. It is a tool that verifies concepts. It is a subject that empowers the learners and strengthens the practitioners. The scientific method, the singularly utmost and unique concept, conveyed to learners through scientific experiments, laboratory work, and research projects, is an unrestricted application in any field of study. Whilst in the study of science and its allied subjects, one hones the art of the application of scientific method; young learners do not realize the potential of this method in any non-scientific fields and also in their own future lives. As educators, our failure to enlighten our students of the efficacy of the scientific method perhaps is mostly because of our own failure to recognize its uses in our daily activities. Socrates, Plato, Aristotle, Galileo, Newton, Maxwell, and Einstein, to name a few of the giants of scientific discovery upon whose shoulders we attempt to stand, always combined science with other fields of research.

The method of elenchus introduced to us by Socrates is used as a form of pedagogy and in discussions in subjects in science, arts, and commerce. Socrates was a soldier in the Athenian army. His teaching practice of pedagogy where a teacher questions a student that ultimately leads to the correct answer is a unique contribution to the world of philosophy.

Plato was instrumental in establishing the Academy of Athens dedicated to higher learning, which was the first academy of this nature in the Western world. He was a philosopher who was also a competent mathematician. To date, his dialogues are used to teach subjects such as logic, ethics, religion, philosophy, and mathematics.
Aristotle was a philosopher who wrote on subjects such as physics, poetry, politics, music, logic, biology, etc. His writing was not limited purely to one field of study. He was also responsible for classifying knowledge into different subjects, which is important for in-depth studying at higher levels. Yet, at lower levels such as high schools and the first two years of college studies, science should embrace other disciplines and be delivered as an integrated, multidisciplinary subject.

Galileo combined physics, mathematics, and astronomy in his philosophical thoughts and was inspired by the renaissance artists such as Cigoli. Galileo combined his science knowledge with fine art as evident in his designing of instruments that are useful in the scientific field. His work also inspires us to understand the importance of supporting and fostering analytical, critical thought processes in science by combining and connecting with other subjects.

Newton, with his famous discoveries in science and mathematics that changed our lives tremendously, was also interested in religion, politics, and business ventures. The application of Newton’s laws is not limited to physics principles; they can be seen in everyday activities. In sports, martial arts, and dancing, one can easily display the instances where the three laws of motion are practiced.

Maxwell, who made the second great unification in physics after Newton, was also talented in English and poetry. His curiosity from a very young age helped in delving into many different subjects. His explorations during school years went beyond the syllabi, and he was not concerned by examination performances. The true test of his abilities was the publication of scientific papers at the age of 14.

Einstein was not just interested in physics and mathematics. He was also an avid player of violin and was interested in classical music. Yet, in his early years as a student, he found it difficult to follow the standard, rigid teaching model in school and was considered a failure by some in the academic and professional fields, until his theories became acceptable, and now his name is synonymous with genius.

It is evident that most of the great scientists of the past were competent in more than one subject, struggled or disliked the standardized teaching and assessments in education, and were always the thinkers who went beyond the limitations and boundaries set up by traditional system. Therefore, the teaching of science and mathematics should always display relevance to the world around us, to our daily activities, and should link to other subjects. The standard examinations alone would not always display the abilities or the limitations of every student. The vast, varying nature of learning styles and the range of abilities among students make it difficult to truly measure the limitations or the promising future expansion of young students. Therefore, our approach to teaching needs to be changed to accommodate the needs of the students and to recognize the varying abilities of learners.

Nevertheless, the teaching of science and mathematics in our classrooms in schools and lecture halls in colleges and universities mostly tend to promote sci-
Science and mathematics educators tend to stay away from business studies, marketing, arts, philosophy, literature, music, theater, films, etc. Over the years, there have been attempts to get students interested in science and mathematics through different methods based on pedagogical connotations and theories. The effectiveness of these methods has been little to nothing as evident from the scores released from the 2012 Program for International Student Assessment (PISA). The US results for mathematics were below the average and for science and reading the results just met the average standards lagging behind Shanghai-China, Hong Kong, Singapore, Japan, Korea, Finland, Canada, Poland, Netherlands, and Switzerland. These results were not much different from the 2009 PISA results. This comparison clearly indicates that our attempts to improve standards have not been as effective as we had expected.

In spite of sincere efforts by the science and mathematics educators, educational policymakers, and the administrators, the students still tend to look at science as a disconnected subject delivering abstract knowledge. This belief adds to the alienation of science from other popular subjects. As science educators, our beliefs in the efficacy of science need to be reflected through our approaches to solving problems, our assessment of worldly occurrences, and in general our philosophy about life and nature. We need to deliver our material and impart our knowledge with commitment, conviction, and a clear set of objectives that go beyond classrooms.

According to the National Math and Science Initiative (n.d.) (NMS), the latest data show that only 36% of the high schools students were ready for science in 2013. Further analysis showed that 38% of students who took STEM did not graduate with one. The NMS initiative also stated that in 2007, about a third of middle school science teachers either did not major in the subject in college and/or were certified to teach it. Another two important aspects to note are that in 2009 only 29% of research papers were published in the most influential journals, when compared to the 40% published in 1981, and that over half of the US patents were awarded to non-US companies. These are the results of failing standards in the US science education and its policies. If we attempt to correct the mistakes and improve the effectiveness, in about two decades we should be able to reap the benefits, since we need a cultural change within our society to produce a generation of science-loving, scientifically analyzing, and problem-solving men and women.

This book, written by experts in the field of science and mathematics education, brings together a plethora of information, methods, ideas, and activities that have produced results in improving the standards of science and mathematics education. The cases on research-based teaching in science education deliver a collection of successful results that can be used by any school, college, or university to improve the standards of science and mathematics education. This book also echoes the call for a policy change at a national/state level.
This book has been divided into four sections for better understanding of the efforts of the experts, the effectiveness of the work, and the extension of the research in the future of science education.

The science curricula written for students should focus on actual, measurable learning. A mere delivery of material to satisfy the institutional objectives will not be an effective path to delivering the knowledge.

The first chapter, “Making Sense of Science: A Review in Scottish Further Education,” presents the readers with strategies for teaching chemistry to non-majors. This chapter delves into the ways in which attitudes to learning chemistry can be improved. The chapter further attempts to answer why chemistry is perceived as a difficult subject. This chapter provides a good overview of the problems faced in schools and colleges not only in chemistry but also in science in general. Changing the perception of science among students is paramount to tackling the difficulties faced in science education. The author provides a variety of recommended principles in the designing and delivery of curriculum, assessment formats, peer and material interaction, and that support project-based learning.

The second chapter, “Developing Scientific Literacy: Introducing Primary-Aged Children to Atomic-Molecular Theory,” proposes the introduction of a spiral curriculum to teach macroscopic and microscopic properties of matter. Supported by successful research data and strong evidence, the authors of this chapter challenge the schools to introduce atomic-molecular structure in the years 3 and 4. The lack of progressive and persuasive teaching of science to students in elementary schools and middle schools later creates difficulties in learning science and appreciating it as a useful subject far beyond the classroom. The confidence in students to continue to study science is also tested during the years in elementary and primary schools. This chapter provides the solution to teaching atomic-molecular theory but could easily be adapted to teaching other concepts within science.

In developing an effective curriculum in any field, it is important to consider the possibility to deliver the material effectively to students. It is also imperative that teachers thoroughly understand the objectives stated in the syllabus and be competent and qualified in their chosen fields. The third chapter, “Implementing the Understanding by Design Framework in Higher Education,” provides an insight to an organizational initiative undertaken to develop and implement curriculum-planning framework. The developed curriculum has focused on knowledge, skills, and dispositions related to science teaching. The chapter places emphasis on the importance of effective design of curricula by science teachers to proficiently deliver the subject to students. The failure of professionally competent science teachers in schools/colleges to design and deliver an effective curriculum causes science students to become confused, which then leads to disaffection. Therefore, the points given in this chapter can be easily extended to produce a learner-centered and objectives-focused curriculum.
The effectiveness of hands-on experience in learning is a valid method established in the arena of education. One of the ways to achieve success through this approach is to introduce popular, novel, and engaging activities. The fourth chapter, “Martial Arts and Physics: A Multidisciplinary Approach to Increase Student Engagement and Interest in the Sciences,” delivers a new syllabus to teach physics through martial arts and presents results over several years of students’ attitudes after taking part in annual physics day programs. The delivery of physics syllabi through martial arts and hands-on experience in understanding physics topics mainly using a qualitative, conceptual approach is described with supporting evidence.

In order to direct students from non-science majors to science studies, it is necessary to make science appealing to a wider audience. This could be achieved through highlighting the importance of science in multidisciplinary fields. The fifth chapter, “The Inclusion of Multidisciplinary Research in Science Teaching: A Novel Teaching Method,” introduces a new model to be used in science teaching that reaches to other disciplines. The chapter, which is built up on previously conducted research leading up to the model, supports the efficacy of the model through past results and places emphasis on the importance of providing students with opportunities to understand the use of science in other non-science fields. This model is further presented as a way to generate interest among students who are least likely to select science as their majors.

The STEM (Science, Technology, Education, and Mathematics) initiatives in education have focused largely on improving the standards in schools and colleges. The collective work of these initiatives have paved the way for collaborative projects to aid in developing and delivering tested, effective modules in science subjects that have been perfected through research-based knowledge. The sixth chapter, “Developing a Research-Informed Teaching Module for Learning about Electrical Circuits at Lower Secondary School Level: Supporting Personal Learning about Science and the Nature of Science,” describes the importance of social mediation of learning and the inclusion of learning through dialogue. This project, implemented as a part of “Effecting Principled Improvement in STEM Education” is informed by the constructivist perspective and also connects previous research conducted on student learning and thinking of science subjects, their relevance in the developed module, and the factors affecting learning.

Our delivery of subjects must improve the creativity among students and encourage their curiosity. The curiosity to investigate, research, and learn more on concepts allows the students to develop a set of important skills in their future careers as scientists. The seventh chapter, “Presenting Physics Content and Fostering Creativity in Physics among Less-Academically Inclined Students through a Simple Design-Based Toy Project,” offers a pathway to teaching physics through a hands-on approach. The authors explain how the content was taught while enhancing the
creativity among technical students, thereby providing an opportunity for students to generate a desire for learning. The chapter relates directly to kinesthetic learners and the advantage of introducing design-based toy projects to such learners. An elaboration of the principles of physics taught through the project provides an interesting insight to how a simple project can be utilized to deliver an effective lesson.

The focus on multidisciplinary research should improve the number of learners of science and mathematics and support non-science majors and weak science majors to improve their learning and application of knowledge. The eighth chapter, “Using Multidisciplinary Research Experiences to Enhance STEM Learning through Undergraduate, Team-Based, Summer Research Projects for At-Risk Students,” describes a project focused on at-risk undergraduate students with weak mathematics backgrounds. This chapter delivers the results of Summer Immersion Projects from 2011 – 2013. The success of this program is further ascertained through survey responses and Depth of Science Experience (DOSE) results. The importance in the integration of multiple disciplines in research is further stressed in this project.

As previously stated, STEM initiatives have opened doors for sharing information and knowledge. Therefore, it is unwise to not use collaboration as a tool to improve the delivery of material. The ninth chapter, “Collaborative Teams as a Means of Constructing Knowledge in the Life Sciences: Theory and Practice,” details the importance of collaborative learning in STEM classes in post-secondary settings. Combined with previous research work in this context, the chapter describes the advantages of team-based work even in classes with high numbers of students. The work also includes a discussion of the application of the system in a large-enrollment, non-major biology classroom. Enhanced peer-learning, improved communication, increased student retention, and higher-order thinking are just some of the advantages offered in this proposed collaborative learning.

When combined with other disciplines, the learning can provide the learner with several opportunities to find answers and improve the understanding of the subject. The tenth chapter, “Interdisciplinary Problem-Based Learning Practices in Higher Education,” delivers the results of a research project conducted to bring together two groups of students from different disciplines. Using IPBL as a way to eliminate ad hoc learning of skills and study students’ actual learning, this project takes a case study approach. The end results of the research display students’ satisfaction in working on interdisciplinary tasks.

Similar to the previous chapter, the eleventh chapter, “Transdisciplinary Research in Sustainable Scientific Education in the Field of Urbanism and Architecture,” highlights the importance of transdisciplinary research in higher education. The importance of sustainable scientific education in answering complex issues is stressed through the practices in the fields of architecture and urbanism. This work further elaborates how transdisciplinary studies can improve the educational process at universities.
The educators who deliver science subjects need to be trained in the most effective teaching methods using the latest available technology. It is also imperative that they deliver the material with greater confidence and understanding using appropriate methodology. The twelfth chapter, “Pre-Service Teachers’ Self-Efficacy and Attitudes toward Learning and Teaching Science in a Content Course,” elaborates on the introduction of active and interactive teaching techniques in the preparation of teachers of pre K-8 level. This chapter brings in the perspective from the point of view of science teachers. When teachers continue to follow the now outdated methods introduced to them during their training in teaching children and when teachers are not exposed to novel teaching techniques or are not provided with an opportunity to learn new ways to improve their teaching, the educational system fails. Based on this concept, this research work introduces interactive teaching methods to improve the attitudes and self-efficacy of pre-service teachers.

The advent of online teaching has provided learners with ample opportunities to embark on programs with the least interruptions to their daily commitments. Yet, it has also brought new challenges in the delivery of material, which is limited as a result of the online environment. The thirteenth chapter, “Traditional Teaching and its Effect on Research-Based Teaching: Science via Online Instruction,” delivers the types of on-ground educational methods that can be used to teach online science subjects. The chapter further discusses various technologies that can be used to produce classroom setting that are conducive to effective learning.

There are obvious challenges faced by those who deliver research through online teaching. The solutions to these challenges are provided through advanced technology. The fourteenth chapter, “Research Institutions: Research-Based Teaching through Technology,” addresses the challenges faced in delivering online instructions and some barriers to teaching some skills to students via online institutions. The chapter further provides solutions to managing these challenges and suggestions to improve the systems, including the preparation necessary for students when they embark on research-based studies.

Finally, the fifteenth chapter, “Application of Information and Communication Technology to Create E-Learning Environments for Mathematics Knowledge Learning to Prepare for Engineering Education,” discusses the effective ways to include ICT applications and create e-learning environments to prepare students in engineering education. This chapter further explains how the use of mathematical models supports education in interdisciplinary fields and the ways to include mathematical models in classrooms through the use of technology.

Most of the work presented here is a collection of continuous research work moving and improving from previous established methods. If the trend to improve science and mathematics among high schools, colleges, and universities continues with this momentum, then it is possible that in about two generations the world
would witness a sea change in attitudes, perceptions, and applications not only among future school children but also among the parents. If the mind-set of a child can be changed at a very young age to appreciate and enjoy the power of science, then this is possible not only by the efforts of teachers, but also because of the parents. It is important to understand the ways to generate this interest. It should be a fun and exciting process. If a child who yearns for a bicycle is first given a lesson on circular and rotational motions, center of mass, and velocity, would that ever create interest in the riding of the bicycle? Should we deliver a lesson of software programming to a kid who asks parents for an iPad? If in the process of cycling and using the iPad, the child is guided through the principles behind the use of the bicycle, iPad, or for that matter any toy, the child is more likely to remember the information. This knowledge could be coupled to show how the child can reap the maximum benefits by possessing that scientific and technological knowledge. Can calculus be used to understand the stock market or the economy? If so, why shouldn’t we teach these subjects using more real-life applications where students can actually relate to them, instead of seeking examples purely related to science? Why should physics and chemistry be taught as abstract knowledge when ample opportunities are available to produce easy-to-understand curricula using most popular subjects such as sports, martial arts, magic, and children’s toys?

Why couldn’t we use real-life problems in the classrooms to find solutions with students to improve their critical thinking, logical approach, and understanding problems? We can use a multi-faceted, multi-pronged approach to find answers to day-to-day challenges through science and mathematics and make that the starting point of learning. We do not have to stick to the same style of teaching in which we have been conditioned. Our objectives should not be to generate a group of students who think, apply, and solve problems in the exact way we do. We need to promote multi-dimensional approaches to solving problems. We need to encourage students to challenge us, test us, disagree with us, and ultimately find themselves under our guidance if their pathways to finding solutions are the most effective ways or not. We need to not resist the diversion from norm of our students as long as their goal also is to successfully learn the subjects. We need to provide our students with all the opportunities for them to build their own success. We can guide, advise, and walk with them, but we must give them the freedom to explore and research. This can come only through the introduction of research-based teaching in multidisciplinary fields. We need to collaborate with non-science disciplines to promote science and mathematics among our future students. The best minds in businesses, creative arts, law, etc. could have been great scientists, too! Similarly, great scientists can be great businessmen, lawyers, and politicians! In promoting education, we should not separate science from arts, arts from business, or business from science. Our answers to problems should cover all aspects, and this is only possible through a multidisciplinary approach.
I hope that the work presented here and other similar work all over the world will continue to grow and generate students who are qualified in science and mathematics whilst simultaneously appreciating other subjects and using that appreciation and understanding as the supporting force to do well in the fields of science and mathematics. I am confident that the current trend in science and mathematics studies can be changed through the use of multidisciplinary research approach in future education.

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**REFERENCE**