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The Empowering Innovative Mathematics Curriculum and Industry Collaboration in Gearing Malaysia for IR4.0 Era

C. D. Hoo[1*], S. H. Yeak[2]

[1]*BDP International Inc. 510 Walnut Street Philadelphia, PA 19106 United States*

[2]*Department of Mathematical Sciences, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

This paper aims to illustrate the global megatrend of IR4.0 and points out their impacts and gaps faced by today's industries and mathematics applications. Meanwhile, in responding to the MoHE Education Framework 4.0 plan and direction, this paper adopts the qualitative approach to review and investigate the needs of transformation in mathematics curriculum, gears up to the change of industry requirements and adapts to the shift of market demands and operations landscape. Therefore, the outcome of study urges to form a closer tie or partnership between industries and mathematics collaboration in industrial research and problem-solving. With this, the role of industrial mathematics has to become part of the necessity for Malaysia's leading mission to achieve the status of a developed nation. In conclusion, based on the missing links between mathematics and industries, the paper recommends the realignment and rebranding of existing university mathematics curriculum and formation of the National Industries and Mathematics Community (NIMC). It expects industrial mathematics will be one of the key boosters besides engineering and technologies fields, to produce the industries talents and expertise, which will contribute to Malaysia's mission in IR4.0, the migration of industries into high-value services and technological intelligence-based productions era.

Keywords: IR 4.0 megatrend; Education 4.0; Innovative Transformation; Mathematics Curriculum; National Industries & Mathematics Community (NIMC)

I. INTRODUCTION

In line with the global megatrend of the IR4.0 revolution, Malaysia is also preparing for this transformation and wants to be part of the beneficiary toward this global shift. During the 2018 Budget presentation, the former Prime Minister of Malaysia reported, IR4.0 has become an important reference and focus of the country (Mohamad, 2018). This statement has shown to us that Malaysia accepts and understands that IR4.0 is now happening across the world and that it presents modern challenges to every sector of the country. Thus, the shift in the country must reflect the changes in the digital transformation so Malaysia can remain competitive and relevant in the 21st century.

Nine pillars of IR 4.0 are clearly illustrated in Figure 1 below:

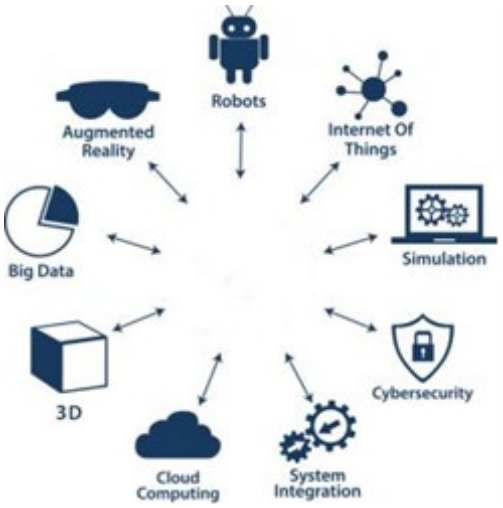

Figure 1. Illustration the Nine Pillars of IR 4.0 [2]

*Corresponding author's e-mail: chingdew.hoo@bdpint.com

Where else of IR4.0 cover the following key principles as stated in (Al-Madinah International University, 2019) as below:

- Interoperability: the ability of cyber-physical systems, humans and smart factories to connect and communicate with each other via the Internet of Things and the Internet of Services.
- Virtualisation: a virtual copy of the smart factory which is created by linking sensor data with virtual plant models and simulation models.
- Decentralisation: the ability of cyber-physical systems within smart factories to make decisions on their own.
- Real-time capability: the capability to collect and analyse data and provide the insights immediately.
- Service orientation: offering of services of cyber-physical systems, human and smart factories via the internet of services.
- Modularity: flexible adaptation of smart factories for changing requirements of individual modules.

Since 2018, Ministry of Higher Education Malaysia had set a clear direction to progress towards Industry Revolution 4.0 (IR4.0). The ministry has set the direction for institutions to attain as well as maintain its institutional sustainability. The continuous improvement of education delivery system is key to produce quality manpower that ready for the workplace which in line with the Malaysian Higher Education framework 4.0 as follows:

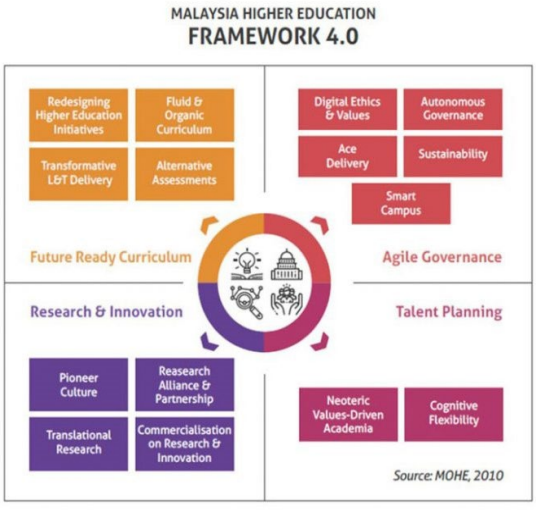

Figure 2. Malaysia Higher Education Framework 4.0 (MoHE, 2010)

Out of 4 core frameworks, three of them emphasised on curriculum, research & innovation and talent planning, which is paramount to redesign of quality curriculum, supposed to be more collaborative with industries.

Couple with the unprecedented outbreak of the COVID-19 pandemic has contributed to the rise of online learning. As emphasised by Professor Dr. Abdul Karim Alias, Director of the Centre for Development of Academic Excellence (CDAE) from the Universiti Sains Malaysia (USM): "The online learning and online education are no longer an option – it's a must." Because of this, it pushes people move out from comfort zone and routine traditional classroom learning quickly, adapt to the new e-learning environment. As a result, the application IR4.0 in modern IT era, information control as well as modern communication apart from increasing use of smart devices have become a reality (MIDA, 2021).

II. ADAPTING TO THE NEW REALITIES CHANGE DRIVEN BY IR4.0

World Bank Report (2017) titled "Building a World-Class Higher Education System" concluded that there is often an increase in the rates of unemployment in Malaysia because there is a clear gap between the specific skills required in the job market and the quality of education and training offered at higher learning institutions. The mismatch is due to the supply-demand gaps between the fields of study, and imbalance between technical and generic skills and between theories and practices in education and training received by a graduate. This report concludes that the main contributing factor for this situation is the disparity between fields of study with the needs of the working world.

IR4.0 is transforming the world at a rapid pace and it also changes the requirements of the workforce. Therefore, education must be carefully planned, which will enable the universities to provide clear job prospects especially to the mathematics graduates. According to the World Economic Forum's Future of Jobs Report, 50% of all employees will need reskilling by 2025 (Kate, 2021).

Penprase (2018) conducted a study on the title: "The impact on higher education in United States and around the global". According to Penprase (2018), the objective of the study is based on the impact in higher education in the United States and the globe due to the industrial revolutions which took

place earlier. The researcher found that the societal changes in the IR4.0 will definitely necessitate higher education. Another paper entitled 'Industrial Revolution 4.0 and Education', discussed the similar issue. It was published by Shahroom and Hussin (2018). They discussed the future happenings of the education system in the IR 4.0 era. The researchers suggested instructing the graduated students to learn with IR4.0 assisted work. It focuses on educational advancement and skills development which makes future learning easier. It also provides more information, produces virtual innovation and spreads worldwide quickly. The IR4.0 with the disruptive technologies such as digital technology has shown the potential to significantly transform the economic landscape around the world. Therefore, Malaysia Digital Economy Blueprint 2021 highlighted that "the digital economy will become the foundation of the modern economy" (MDEB, 2021). This blueprint can be a guide for universities to prepare graduates with the required skilled manpower to fulfil the national mandate.

Malaysia universities produce thousands of graduates each year for the job market, recognising the high-demand jobs which are instrumental to jumpstart the college planning process. "Referring to Malaysia's Top In-Demand Jobs for 2020, engineering, computer science and business are list of top 3 Malaysia's most sought-after jobs in 2020 based on the annual Critical Occupations List 2019/2020", as stated by TalentCorp Malaysia and the Institute of Labour Market Information and Analysis (ILMIA) (The Star, 2021).

The main question is, where is the home of a new career for mathematics graduates? Actuarial science graduates are in high demand especially in banking and insurance industries for their skills in statistics and data analysis. Especially banks are looking for qualified actuaries who are master in niche skills such as OLAP (online analytical processing) design and data modelling (Markarow & Gyllenberg, 2010). In addition, manufacturing and logistics industries are also in high need of applied mathematics in areas of production optimisation, materials planning, predictive supply chain analysis, just to name a few here. On the other hand, oil and gas industry is also in search for experience candidates in big data and AI. With reference to the nine pillars of IR4.0, future career landscape related to the mathematics arena will be data scientist, data mining analyst, pricing actuary, big data engineer, valuation actuary, statistician and mathematician.

A. The Strategic Missing Link between Mathematics & Industries

Markarow and Gyllenberg (2010) has rightly pointed out: "*The lack of recognition of industrial mathematics by the mathematical community. The attitude of the mathematical community with respect to collaboration with industry is far from homogeneous: sometimes one finds a simplistic supercilious attitude that denies industrial mathematics the citizenship in the ethereal world of science, under the unproved postulate that it consists only in the application of standard results and methods without any creativity. The other extreme position would assert that the only justification of mathematics lies in its usefulness.*"

Similarly, Malaysia universities mathematics curriculum and industry collaboration will also facing with two phenomena of facts namely, (i) urges for Malaysia universities mathematics curriculum to direct tie and collaboration with industries, (ii) involvement of industry public in Mathematics Societies activities which relevant to the industries. This statement is supported by the subsequent facts.

Not only Malaysia universities have this challenge to have closer collaboration and engagement of mathematics with industries. Look at the International Mathematical Union (IMU) is an international NGO, functions as international cooperation in the field of mathematics across the world. It is a member of the International Science Council (ISC) and supports the International Congress of Mathematicians. Its members are national mathematics organisations from more than 80 countries including Malaysia (Wikipedia, IMU).

The IMU objectives still very much remain at the level of promoting international cooperation in mathematics, International Congress of Mathematicians (ICM) and other international scientific meetings/conferences, which supporting other international mathematical activities, and acknowledging outstanding research contributions to mathematics through the awarding of scientific prizes, and very much still at the educational level, with very little representation of industries leaders.

Between, Malaysia became IMU full membership in 2016 (Ibrahim, 2016). Malaysia's main objective is to become a centre for excellent mathematics education, but still lack industry leaders' participation as well as joint project engagement between industry and university. In Mathematical Societies in Malaysia, the majority members are academia, mathematics researchers or student. Very little member participation from industries. Furthermore, the societies are also relatively small in representation, PERSAMA is one the largest mathematics societies, with a membership of less than a thousand. The following are the list of few major and active societies and number of memberships:

List of few cores Mathematical Societies in Malaysia (Source: Malaysia Academy of Mathematical Scientist (AISMM), 2016):

a. Malaysian Mathematical Sciences Society (PERSAMA) (680 members)
b. Malaysian Society for Cryptology Research (MSCR) (70 members)
c. Malaysia Institute of Statistics (ISM) (100 members)
d. Management Sciences and Operations Research Society (MSORM) (100 members)
e. Malaysian Academy of Mathematical Scientists (AISMM) (30 members)

The following session will discuss the new opportunities from the increasing demands due to the shift of industries emerging IR4.0. On the other hand, some existing practices and careers may be obsolete or replaced by AI automation. Therefore, it's crucial for universities to review and adjust the existing mathematics curriculum as well as further expand the industry's collaboration initiatives more rapidly.

This is in echoing to Prof. Dr. Sharidan Shafie, Director of Mathematical Sciences Department, UTM stressed that Mathematicians are not only involved in academics but mathematicians need to also interact with society and industry players (INSPEM, 2021). He serves as a Director in the Department of Mathematical Sciences, UTM explains the activities and programs that have been implemented by the Department of Mathematical Sciences in bringing the community closer to Mathematicians. He stressed that Mathematics plays a very important role in society and it is key in the strategy of human development. This was reported by INSPEM organised activities of World Mathematics Day Celebration themed "Mathematics for a Better World" by IMU (Noorizzati, 2021). Since 2019, UNESCO has declared International Day of Mathematics as a day celebrated on March 14 every year starting in 2020. The date of March 14 was chosen based on the date writing format that is the month/day written as 3/14 which represents Greek letter π.

In addition, the research paper has also taken Institute Chemical Engineer (IChemE) of Malaysia Chapter and Institut Kimia Malaysia as the benchmark of this study. Despite the field of chemistry and chemical engineering have diverse differences in comparison to mathematics, but, the purpose of this study is referring to their activities or curriculum, and to learn how they successfully foster collaboration with the industries. The findings show many of these can be applied to mathematics curriculum and in return can potentially expand the Mathematical Societies connectivity to the industries.

III. MISSING LINKS AND OPPORTUNITIES FOR MATHEMATIC IN COLLABORATING WITH INDUSTRIES IN IR4.0 ERA

With recognising of above mentioned strategic missing links between mathematics and industries, we come out with the recommendations in two main expects with path forward as follows:

Missing Link 1: Innovative Mathematics Curriculum

I. Many mathematics associations and societies, their mission and objectives stated in the website still remain in the 90's, not up to date to current global trend and disconnect industries IR4.0 revolution.
II. Mathematics curriculum and its society focuses still on academia, researchers and students. Partly it is due to most curriculum activities being mainly confined to education and R&D.
III. Lack of industry public involvement. One of the main reasons is due to the lack of industry-related topics or activities engaged in the mathematics curriculum.
IV. Lack of promotion and publicity of mathematics initiatives and its application to industries especially in areas of practical industrial modelling and problem-solving.

V. Lack of mathematics recognition by industries and vice versa, also lack of academia recognition of industry leader contribution to mathematics application and promotion.

Recommendation 1:

I. Foster industries participation and collaboration in mathematics application.

II. In addition to academic & research focus curriculum, the society should also periodically review and adjust the objectives and curriculum. With this, the society can upgrade the objectives to be in line with the global trends and transformation. For instance, the MoHE Education Framework 4.0 plan and direction, to increase the emphasis on curriculum, research & innovation and talent planning, which is paramount to redesign of quality curriculum, is supposed to be more collaborative with industries. As such, the society curriculum will certainly attract and widen its membership participation from industry mathematical practitioners. One of the suggestions is to widen the curriculum activities to include mathematics innovation and application in IR4.0 core pillars.

III. To change perception of mathematics recognition by industries and vice versa. Good reference is IChemE, specifically the Malaysia Chapter. The institute is led by industry leaders & entrepreneurs, in collaborating with academia. They often conduct seminars or conferences to promote chemical engineer initiatives and research outcomes for industries. At the same time, present industry awards to recognise leaders who are major contributors to the chemical industries (IChemE, 2019). Likewise, Institut Kimia Malaysia is another good success reference (Institut Kimia Malaysia official website). Both associations have clear missions and objectives which are related to the current industry's needs and its applications. Both Institute Kimia and Institute Chemical Engineer (IChemE) Malaysia Chapter have over 5000 and close to 4000 members respectively. Thus, Mathematics societies could also consider adopting some of their good practices and will be able to attract a higher number of industry practitioners' membership participation too.

IV. Conduct joint collaborative Industries Mathematics conferences and forums, promote more industries participation, one of reasons are research study and theoretical focus. Industries are expecting real study on industry problem modelling and issue solving. In addition, to promote more mathematics applications through more joint-driven applied mathematics activities between industries and academia to the public in order to create greater industry visibility and recognition of mathematics as a core mainstream requirement to industries.

V. Furthermore, Malaysia is in an internet high-speed era now, many mathematics activities can be organised online, relevant to industries and aligned to IR4.0 core thrust such as imaging & digitisation application mathematics, simulation, big data analysis, etc.

Missing Link 2: IR4.0 New Emerging Opportunities for Mathematics

No prominent industry-leading sector, for example, IT or Chemical Engineer that required mathematics as a main job description. We find mathematics in almost everything of our daily life but always being viewed as supplement or support fields, but not mandatory job requirements or leading job description being called out by the industries. Perhaps just with very few job exceptions like actuarial science.

Recommendation 2:

I. To promote mathematics as one of industries leading sectors in ir4.0, in line to the emerging industries 4.0 trends. The near future demand of applied mathematics will be in high demand in the areas of:

- Actuarial science
- Big data mining
- Business modelling/problem solving
- Production planning
- Operational optimisation
- Predictive analysis
- Industries risk forecasting

With this, it's important that universities and colleges need to equip the students with all these basic skills and knowledge application in Applied Mathematics subjects, systems and computing tools, starting with curriculum, project work, etc.

Bond (2018) highlighted that:

"*Mathematics is increasingly leveraged by economies intending to compete by enabling digital, biomedical and environmental innovation to generate greater social and economic benefits. The UK increasingly relies on innovation to provide a significant proportion of the productivity gains required to support rising standards of living. In consequence, the mathematical sciences are playing an ever-expanding role in generating innovation and impact and, via knowledge exchange, are adding substantial social and economic value to the UK.*"

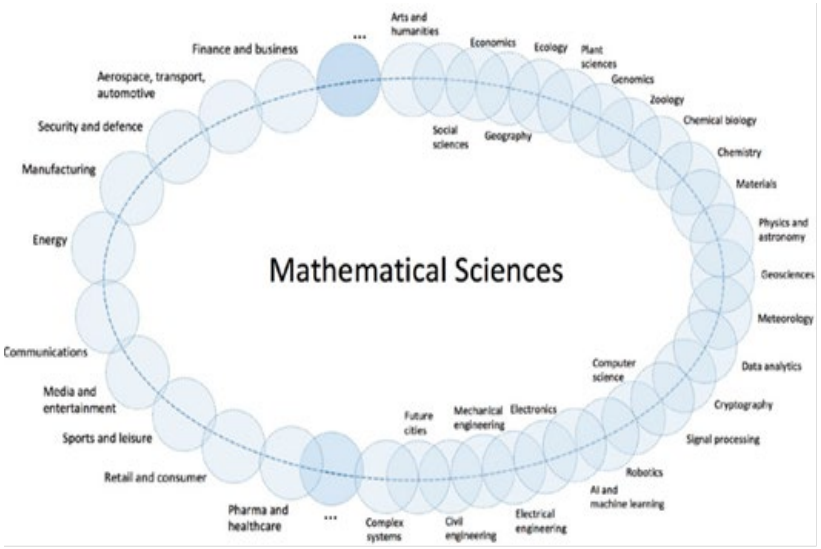

Figure 3. Some linkages of the mathematical sciences to other academic fields and industry sectors (Bond, 2018)

II. Industries transformation causing emerging needs in mathematical thinking. Industries accelerated the pace of research, development and innovation. In that process, an increasing need is seen for mathematical solutions to complex problems such as computation, optimisation and other industrial challenges. The all-rounded mathematicians are nearly impossible in this new era. Therefore, cooperation and information flow are increasingly necessary, not just across disciplines, but also across borders. Just name few applied mathematics potential contribution to industries as follows:

- Predictive multiscale materials modelling
- Algorithmic trading: perspectives from mathematical modelling.
- Mathematical and statistical challenges in landscape decision-making.
- Understanding multi-modal data for social and human behaviour.
- Challenges in dynamic imaging data.

Bernama (2021) reported that "MIDA also initiated a structured MIDA-Academia-Industry collaboration framework to address investors' human capital needs." Engineering, Science and Technology are main selected industries in this Public-Private collaboration initiatives. There are six key technology clusters being identified as key focus areas namely the Embedded Systems, IoT and IR 4.0. In addition, the Government has allocated RM9 million to Collaborative Research in Engineering, Science and Technology Centre (CREST) to undertake R&D activities and related programs under Budget 2021.

With this, we need to promote industries to get them to realise that mathematics is part of the mainstream sciences.

IV. FINAL RECOMMENDATIONS AND CONCLUSIONS

In conclusion, in order to achieve the goals of greater recognition of mathematics application outstanding impacts to human life & closing the gaps faced by today's industries on wrong perception about mathematics contribution to the industries, the paper strongly proposes all Malaysia universities and its mathematics societies form a National Industries and Mathematics Community (NIMC), in a join collaboration to promote the following:

a) Review, readjust and rebrand the universities mathematics curriculum and final-year project work.
b) Enlighten mathematics and industries collaboration in various application fields, especially on AI, machine learning and big data mining.
c) Promote to industries that mathematics is the main job description in the new emerging job such as data analyst, risk manager, business analyst, logistics, inventory/material/production planners, etc.

In order to achieve the above goals, we need to promote transformation of Mathematics Societies in Malaysia, build a stronger tie with industries membership. NIMC play the role by joint lead and collaboration by academia and industries leaders or entrepreneurs. In addition, we need to make mathematics a meaningful and useful lifelong learning subject for school leavers or working adults due to its demand and application to the industries. Today these groups of people learn mathematics mainly for education and research purposes, either as a tutor, teacher or researcher. Lastly, we need to promote the contribution and impact of mathematics application to IR4.0, to include Maths be part of core thrust to achieve Malaysia Master Plan goal in IR4.0.

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