



MANUFACTURING ENGINEERING EDUCATION IN TRINIDAD AND TOBAGO: REVIEW AND FUTURE RESEARCH AGENDA

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Abstract: Manufacturing has long served as the main engine that drives a country's economic growth and development. Manufacturing engineering (MfgE) education should thus support and help drive advances in the manufacturing sector. In Trinidad and Tobago, there has been much talk about diversifying the economy by strengthening sectors such as manufacturing. However, the bolstering of MfgE education to drive this diversification has largely been ignored. This paper provides an overview of the present structure of manufacturing engineering education in Trinidad and Tobago with an aim of briefly benchmarking its current state. A new concept of science, technology, engineering, mathematics, manufacturing and entrepreneurship (STEMME) education is introduced to draw as much focus on manufacturing and entrepreneurial education as the traditional science, technology, engineering, mathematics (STEM) subjects. A research agenda is then outlined which proposes the future research direction of the authors towards the development of MfgE education to support the sustainable diversification of the economy, specifically the manufacturing sector.

Keywords: *Curriculum, Diversification, Manufacturing Engineering, STEMME, Trinidad and Tobago*

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1. Introduction

Manufacturing is globally regarded as a wealth creation industry which has developed at a rapid pace with new innovations, especially those behind the 4th Industrial Revolution. However, this pace has significantly overtaken the advancement of teaching and learning methods and curricula content utilised by universities and other higher education institutions. Moreover, traditional teaching and learning approaches are becoming less effective, as students rely less on educators in a classroom setting and more on accessing knowledge through technological means [1]. Consequently, new pedagogical approaches, content and frameworks are necessary. There is thus a need for manufacturing engineering (MfgE) educators in higher institutions to innovate the curricula to meet the requirements of industry.

Having recently experienced a recession, Trinidad and Tobago (TT) is currently faced with the task of diversifying its economy to prevent further negative growth. The manufacturing sector currently contributes 18.3% of gross domestic product (GDP), compared to the 33.7% contribution



of the energy sector [2]. In order to diversify the economy to reduce the effects of oil price fluctuations, innovation of the manufacturing sector needs to be the main focus which will serve to increase the GDP contribution potential and stabilise the economy. However, there is a lack of skilled personnel in the manufacturing sector and most organisations cannot afford to send their employees abroad for training. At the launch of the Trinidad and Tobago Manufacturers' Association's (TTMA) TTMA Careers platform in 2016, the Minister of Trade and Industry, indicated that 72% of the manufacturing sector vacancies require skilled and graduate/professional workers and that collaboration between industry partners is needed to build better workforce and improve global competitiveness by innovation and research and development [3].

The science, technology, engineering and mathematics (STEM) approach is a curriculum based on the idea of teaching these four specific disciplines in an interdisciplinary applied manner [4]. It has been recognised around the world as a critical component for economic prosperity and security, both in developed and developing countries [5]. Other variations of STEM have been proposed throughout the years, namely STEAM - science, technology, engineering, arts and mathematics; STEMM- science, technology, engineering, mathematics and medicine; STREAM - science, technology, robotics, engineering, arts and mathematics and STEMIE - science, technology, engineering, mathematics, innovation and entrepreneurship. However, none of these variations specifically include manufacturing. Furthermore, entrepreneurship has been receiving increased attention in the engineering education community due to its considerable role in innovation [6] [7]. Entrepreneurship can positively aid MfgE as it promotes business creation and globalisation.

The current state of manufacturing engineering (MfgE) education in Trinidad and Tobago (TT) needs to be reviewed as we need to know where we are before deciding on where we should proceed. This paper provides an overview of MfgE education in TT by discussing the programmes offered by the two primary higher learning institutions in TT, The University of the West Indies (UWI) and the University of Trinidad and Tobago (UTT). It then reviews local and regional higher education policies and introduces a new concept of STEMME education where manufacturing and entrepreneurship education are given the same focus as the traditional science, technology, engineering and mathematics topics. A research agenda is then proposed to provide the groundwork for the redesign of MfgE education for economic diversification.

2. Overview of Manufacturing Engineering in Higher Education

2.1 Undergraduate Studies

The UTT offers a B.A.Sc. in Manufacturing and Design Engineering that spans three (3) years and requires successful completion of 108 credits. It features content such as manufacturing processes and materials, product design and development, production management, sustainability, innovation and mechatronics. The UWI does not offer an undergraduate degree in MfgE specifically but includes MfgE in its BSc. Mechanical Engineering programme. Students can choose to specialise in MfgE in their third year of study, with courses such as product design and development, production management, materials technology and computer-aided design and manufacture. This programme also spans three (3) years and requires 99/103 credits to complete, depending upon the specialisation chosen by the student. The courses combine face to face lectures with tutorials, laboratories and in-course projects where appropriate. However, there has been criticism that graduates from these programmes, especially those from the UWI BSc programme, are not properly equipped to enter industry and solve the present challenges.



Admission into these undergraduate programmes are based on the minimum entry grades of the student as well as the average grade. The subjects studied at Secondary level are also important as the programmes have a heavy focus on science and mathematics. The UWI offers a one-year pre-engineering programme, through its Open Campus, for those not meeting the minimum entry requirements. The UTT offers a similar Pre-University Programme (PUP).

Registering with the Board of Registered Engineers of Trinidad and Tobago (BORETT) is encouraged but not required to be a practicing engineer. Consequently, many graduates do not work towards meeting the specific criteria of academic qualifications, work experience and continuous professional development, as it is perceived as unnecessary for career advancement. The bachelor's degrees offered by both universities are institutionally accredited by the Accreditation Council of Trinidad and Tobago (ACTT) and evaluated periodically to ensure the required standards are met. The BSc. Mechanical Engineering programme is internationally accredited by the Institution of Mechanical Engineers (IMechE) for Chartered Engineer (CEng) registration whilst the B.A.Sc. Manufacturing and Design Engineering programme is accredited by the Institution of Engineering and Technology (IET) for CEng registration. Graduates from both degrees are obliged to undertake an appropriate accredited master's degree to fully complete the academic requirements for Chartered Engineer status.

2.2 Graduate Programmes

The UWI currently offers an MSc. Manufacturing Engineering and Management (MEM) programme that spans approximately 18 months full-time, with 9 months allocated to the taught courses and 9 months for the individual project. It includes core topics such as computer integrated manufacture, advanced computer-aided design and manufacture, research methods, technology and product development, and production planning and control. Elective or optional courses focus on management, robotics and system simulation. The UTT offers two (2) postgraduate programmes that are designed to provide graduates with the personal and technical skills, and industrial experience needed to be successful in their respective career paths. The two (2) programmes, the MSc. Innovation, Manufacturing Management and Entrepreneurship (IMME) and the MSc. Innovative Design and Entrepreneurship (IDE), encompass such themes as strategy, marketing, entrepreneurship, human resource management, operations management and product and process design. Moreover, these programmes are also 18 months in duration but are only offered part-time.

2.3 Teaching and Research Staff

The categories of teaching staff in TT higher education institutions are largely varied. The categories of long term teaching staff include Lecturer, Senior Lecturer and Professor. These posts all require a doctorate and several research publications in reputable peer-reviewed journals. Other categories of teaching staff include Teaching Assistant, Instructor and Part-time Lecturer. These posts do not require a doctorate, although most staff in these positions are graduate research students. Research Assistants are also commonly required to assist in teaching courses that are in line with their area of research. Demonstrators assist with the conducting of laboratory and practical work and are normally industry professionals or graduate students. Moreover, the UWI employs Development Engineers to assist with both the teaching of courses and industry outreach.



2.4 Industrial Collaboration

Currently, most undergraduate and graduate degree programmes do not include obligatory industrial internships, though it is encouraged to allow students to gain work experience and a better understanding of their field. Obligatory internships should be a formal part of MfgE education though, as MfgE programmes ought to be generally practical and not merely involve university based learning.

Most of the funding provided to universities and other post-secondary institutions is mainly government funding, as industry and charitable support is severely lacking. The UWI has established the Mechanical and Manufacturing Enterprise Research Centre (MMERC) to provide research and consultation services to the industry, in an effort to increase collaboration [8]. Similarly, the UTT is home to the Design and Innovation group that aims to work closely with industry in various design and manufacturing sectors. However, unlike developed countries with significant manufacturing research resources, there is no local or regional research council to provide funding and support. For example, in the United Kingdom, manufacturing research is supervised by the Engineering and Physical Sciences Research Council (EPSRC) which in turn is a part of UK Research and Innovation, a governing body that works in partnership with universities, research organisations, businesses, charities, and government to generate an engaging environment for research and innovation to thrive [9]. The EPSRC manages research centres and hubs, and centres for doctoral training. Trinidad and Tobago would do well to adopt a simplified version of this research model to support collaboration and innovation.

2.5 Educational Policies

According to Hackett [10] our local education system could become stagnant if educational policies are not driven by research and the assessment of local economic needs. The author goes on to state that policy makers need to make teaching and learning requirements the centre of policy creation, recognise that changes must be supported by appropriate curriculum structures and organisation, demonstrate that policy outcomes are attainable through effective strategy creation and understand that development strategies should encompass not only educational achievement but also the maintenance of sustainable management practices within educational institutions. Moreover, in a review of educational plans and policies in the Eastern Caribbean [11], the United Nations Children's Fund (UNICEF) reports that although Trinidad and Tobago had a comprehensive educational plan at the time, it lacked a monitoring and evaluation framework for the assessment of the planned strategies.

A Regional Policy Framework for Science, Technology and Innovation (STI) was created by the Caribbean Council for Science and Technology (CCST) in 2007 for national and regional advancement of STI for the attainment of social and economic goals, and global competitiveness [12]. Although this policy framework was a step in the right direction for the promotion of innovation, it may have been introduced too soon, as recent checks for the current standing of CCST reveals their latest activities were in 2016.

In the most recent education policy document titled 'Draft Education Policy Paper 2017-2022', the Ministry of Education of TT recommends policies and initiatives for the achievement of Vision 2030 [13]. The collection and analysis of labour market data is stated as an urgent requirement for the 2025 agenda as such data is recognised as critical to the relevance and responsiveness of the



current higher education curricula. Strategies to produce a highly skilled workforce that match the needs of the local economy include blended learning, entrepreneurial training, work-based programme components, linkages with industry partners, and labour market data collection for policy development. Another issue identified is the inadequacy of our research efforts, with the policy envisioning a higher education sector that fuels the national research and innovation to turn knowledge into economic gain. Collaborative arrangements and research facilities are some strategies proposed.

3. Towards a STEMME Research Agenda

3.1 Manufacturing and Entrepreneurship education

Locally, STEM has been promoted by organisations such as the National Institute of Higher Education, Research, Science and Technology (NIHERST) and the Ministry of Education to create a foundation in knowledge, understanding and problem solving. However, these STEM skillsets have not had much of an economic impact as students merely enter STEM fields to add to the annual cycle of replacement of workers from large commercial organisations or educational institutions, which does little to drive true economic growth [14]. By the promotion of manufacturing and entrepreneurship in secondary and higher education, novel solutions can be created and brought to market, thus establishing new small and micro businesses and research centres to directly support industry. This in turn will drive GDP growth and strengthen the local manufacturing sector towards genuine diversification.

3.2 Research Agenda

The main economic growth strategy of small island nations is the establishment of knowledge-based manufacturing and services industries that seek to enhance the skills of their citizens, thereby strengthening the technological innovation through R&D and retaining highly skilled personnel for the public sector. In TT a great deal of government funds is used to assist nationals with tertiary level training. However, there is much need for the determination of industry needs and the redevelopment of the education curricula, throughout all levels, to meet these needs. Moreover, the public sector needs to do more to retain highly skilled graduates to develop policies and drive the diversification efforts. More specifically, the challenges faced by local higher education institutions in developing the MfgE curriculum need to be presently addressed in order for TT to truly diversify its economy through manufacturing innovation. In light of this, the following research agenda is proposed.

The proposed research is aimed at providing a foundation framework for the development of MfgE education, inclusive of entrepreneurship, in TT in line with industry and economic needs and global standards. The objectives of the proposed research are to (1) review up to date literature on the recent trends in the global manufacturing industry and the engineering educational approaches; (2) determine the current and future needs of the local manufacturing sector in terms of the skills, manpower and technologies required; (3) determine the structure and effectiveness of current pedagogical practices in local manufacturing education; and (4) draw from the review of literature, views of stakeholders and current local pedagogical practices in designing and validating policy



guidelines and assessment frameworks for the development of manufacturing education inclusive of entrepreneurship.

A mixed research method approach is proposed, i.e. a range of qualitative and quantitative data collection methods, to achieve each of the objectives using literature reviews, surveys, focus groups and case studies. Figure 1 shows the basic research methodology that will be applied, whilst Fig. 2 shows the research population that will be of interest in the study. Firstly, an in-depth review of relevant literature and the implications for our local industry will be undertaken using sources such as books, journal articles, case studies, industry reports, governmental reports, related dissertations and internet articles. Then, surveys and workshops involving the sample population will be used to gather information and insight from various stakeholders to gain industry feedback on the current and future needs, student feedback on the content and delivery of courses and educator feedback on the teaching techniques utilised. This will be useful in determining the state of the local manufacturing sector and MfgE education from different viewpoints. It will also enable dialogue between stakeholders, thus serving as a starting point for further discussions. The benefits of MfgE and entrepreneurship education on the wider community i.e. pre tertiary education and non-manufacturing industries will also be discussed to determine the impact that STEMME can have on the country as a whole. Next, based on these findings, policy guidelines and frameworks will be developed to guide the MfgE curriculum design and delivery. Finally, these guidelines and frameworks will then be applied to selected courses/educational programmes in the form of case studies to validate its practicality.

Similar approaches for improving the manufacturing education curriculum have been noted in the literature. Chryssolouris [15] formulated knowledge areas to serve as a framework for boosting Europe's manufacturing education by undertaking major surveys of industry requirements and the manufacturing curricula from leading universities. Moreover, Jack [16] undertook annual evaluations of the state of manufacturing education in the United States of America by surveying educators, professionals and students on their perceptions of the current manufacturing engineering curriculum with an aim of providing a basis for improvement of these programmes. These authors, however, only scratch the surface by performing stakeholder surveys without applying the findings to actual courses and programmes and determining the outcomes. The agenda proposed in this paper will seek to use its stakeholder findings to develop a framework applicable to TT which will be applied to actual manufacturing courses to determine feasibility.

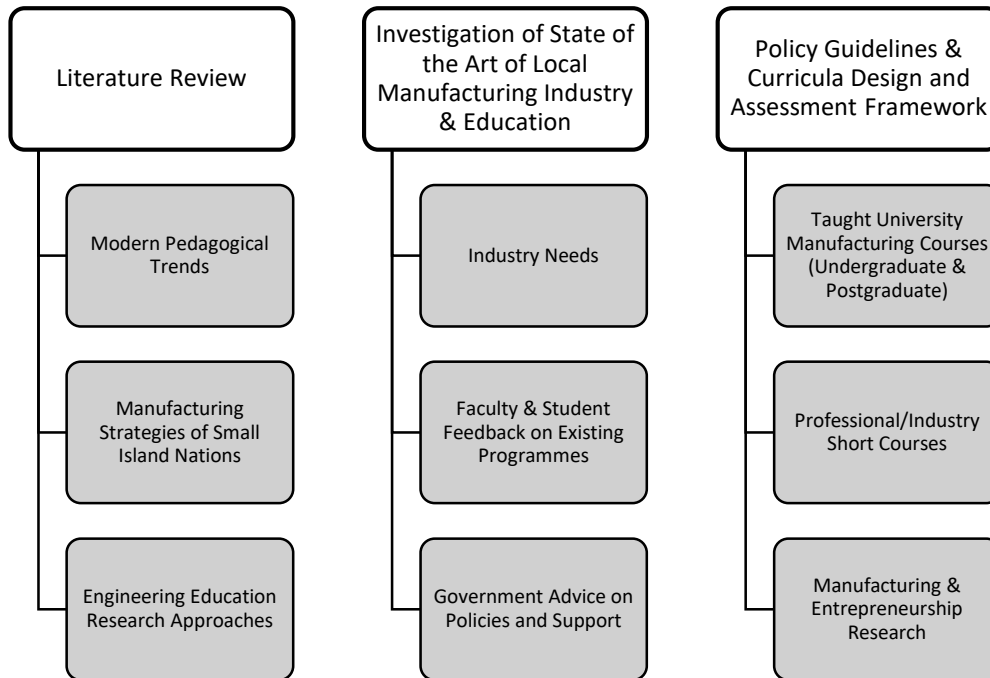


Figure 1: Research Methodology

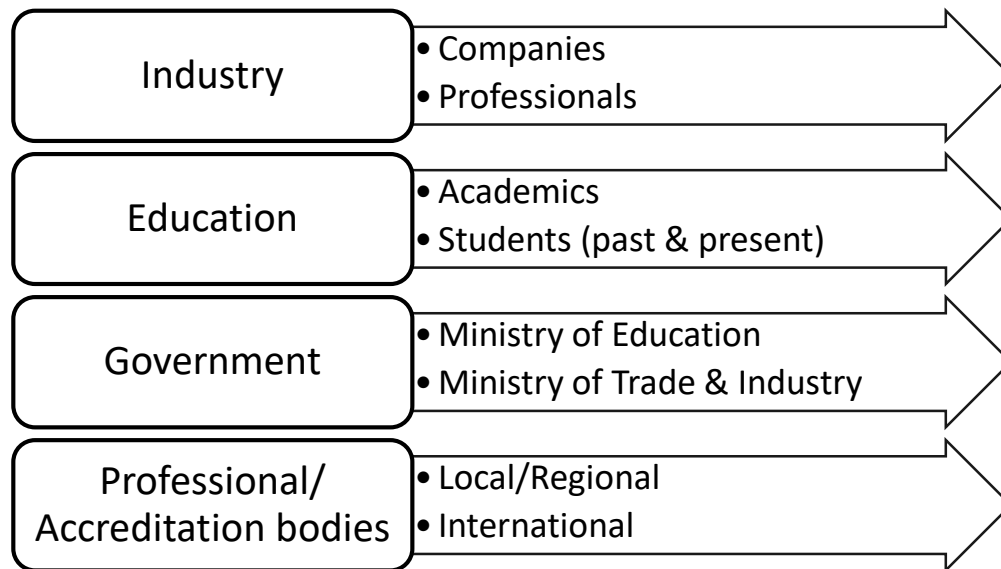


Figure 2: Research Population



4. Concluding Remarks

The aim of this article was to provide a brief overview of MfgE education in higher education institutions in Trinidad and Tobago, and to establish a basis and strategy for future research. It has been demonstrated that there is a need to investigate the needs of the local economy in order to redevelop the curriculum and produce a highly skilled workforce, as well as drive research and innovation. Diversifying the economy by strengthening and expanding our manufacturing sector could only be supported by a remodelled MfgE curricula design and structure which includes entrepreneurship education to drive the creation of small and micro enterprises. Gathering data from the stakeholders involved in MfgE education for the development of policy guidelines and assessment frameworks should be of significant benefit to higher education institutions in enabling them to respond to local industry needs and keep up with global research trends.

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