

Polymer Engineering Education in Indonesia

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ABSTRACT

The polymer industry, which plays an important role in Indonesian manufacturing, requires a more-skilled workforce to sustain its competitiveness. Despite its importance today and the potential for future economic growth, there is no adequate information for polymer education in Indonesia. This present article provides an overview of the education in the field of polymer engineering related to the current profile of the industry. Literature research on plastics-industry-related statistics has been developed in order to give an indication of what polymer education will need to meet the future challenges in the Indonesian plastics industry. It then discusses the current practices of polymer-related curricula implemented not only at university but at vocational and training institutions. A gap analysis was performed to identify the mismatch between the current education practices and demands of the labour market. It is expected that this paper will provide an opportunity to consider expanding current courses to include programmes relevant to the polymer industry.

Keywords: Curriculum, plastics industry, polymer education, vocational education

INTRODUCTION

As a synthetic polymer, plastic materials are used in a variety of applications in nearly every aspect of human lives, from food and beverages to spaceship components. The

plastics industry is one of the most dynamic and vibrant growth sectors within the global manufacturing sector. The statistics report that, with an average of 109 kilograms of plastics being consumed by each person in a year in the USA, global plastics production was around 311 million metric tons in 2014 (PlasticsEurope, 2015). Indonesia also offers plenty of potentials to the plastics industry as personal income continue to rise in its consumption-led economy. The domestic industry is able to supply

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around 3.6 million tons of plastic a year out of 4.3 million tons of total demand. Most of the domestic industry's products are used as inputs to components of other manufacturing sectors as they supply several products to the packaging, building and construction, agriculture, automotive, and pharmaceutical industries.

The ability of the industry to adopt new approaches to manufacturing, successfully implement emerging technologies and develop the capability of its workforce will determine its ability to remain competitive in the global economy. The development and maintenance of a highly skilled workforce is crucial for boosting innovation and maintaining global competitiveness. The International Labour Organisation (Organization, 2012) emphasises the importance of skills development for enhancing employability in Indonesia. It is reported that several countries, including Indonesia, are facing difficulty in responding to the skills needs of their workforce in the manufacturing sector due to increasing globalisation and new technology. This highlights the importance of investing in education and training. In order to meet the human resources requirement in the plastics industry, the skills of the workforce should be developed either by a higher education institute, or a vocational- and skills-training institute. Polymer science and engineering is an instructional pathway that prepares people for employment, or continued education in plastics and polymer materials manufacturing. This field includes multiple disciplines in Chemistry, Physics and

Engineering, which have emerged to meet the growth of commercial polymer industry (Pannell, 2007).

The extent of polymer education in some countries has been presented in previous studies (Amornsakchai & North, 2015; Chan & Ho, 2015; Edmonds, McKee, & Plimmer, 2015; Fellows, 2015; Nakano, 2015; Salamone, Deonin, Young, & Pearce, 1973; Santos, Dias, & Canevarolo, 2015; Stein, 1997; Theato, 2015; Thu, Khoi, & Tung, 2015), which mostly focused on higher education degrees. In light of the recent economic developments in the Indonesian plastics industry, it is important to identify current educational and training elements that are relevant to the skills required in the plastics industry. The learning outcomes of those education and training institutes should be assessed in conjunction with the Indonesian Qualifications Framework (IQF) for manufacturing plastic products, which is established in IQF number 2014-90 (Iskandar, 2014a). This paper will review the Indonesian education system with respect to the education for polymer engineering, not only in higher education but also in vocational schools and colleges. It will be developed through literature research on the statistics for Indonesian plastics industries and the curricula offered by the main universities, polytechnics, academics and the directorate of vocational secondary schools.

METHODS

This work provides an overview of the education in the field of polymer

engineering that is related to the current profile of the industry in Indonesia. The first part of the article focuses on the current trends in the Indonesian plastics industry. The contribution of this industry to the economy is indicated from the statistics data for some economic indicators. The profile of employment in the plastics and rubber industry is also presented. The second part of this article deals with the situation of polymer engineering education in Indonesia by reviewing the polymer-related curricula offered in higher education and vocational training institutions. To quantify the breadth of polymer education traditions in Indonesia, it uses a similar approach to the one suggested by Fellows (2015), which covers a number of research projects in the field of polymers. It is an indication of the extent to which polymer research is embedded in polymer education in academia. Lastly, the analysis is focused on identifying the gap between the demands of the polymer-related industry and the workforce supplied by the education and training institutes.

RESULTS AND DISCUSSION

Current Trends in the Indonesian Plastics Industry

The plastics industry is a diverse manufacturing sector that plays an important role in Indonesian manufacturing. According to the statistics data from the Indonesian Central Bureau of Statistics (Statistic, 2013), the industry consists of 1,729 plastics and rubber companies among 23,941 manufacturers in Indonesia. In 2013, the

Indonesian plastics industry generated a value of 88,844 billion rupiahs for the economy, which is a share of around 6% of the total manufacturing industry. A total export value for plastic products of US\$ 2.77 billion was reported in 2014. Even though this accounts for less than 2.5% of the total exports of manufactured goods, the statistics show growth in the Indonesian plastics industry. For the local market, the plastics market grew by 22.47% in 2011 in spite of the global economic slowdown and continue growing by 7.75% to 3.48 million MET in 2012 (Federation, 2015).

The Indonesian plastic industries produce a diverse range of output, from the raw materials to commercial products such as packaging and automobile components. The industry supplies 60% of the total packaging demand, which accounted for US\$5.3 billion in 2013, mostly to the food and beverages industry. The superior flexibility and durability offered by plastic packaging are the key advantages over other packaging materials. In the construction industry, plastic materials are used to provide efficient insulation, flexible pipes and durable surfaces. Moulded plastics are increasingly being used for automobile components and consumer goods (kitchenware, household articles, etc.).

The current profile of the workforce in Indonesia gives an indication of what polymer education will need to meet future challenges in the plastics industry. In 2013, the industries employed over 360,000 people nationally, which gradually increased from around 329,000 in 2009, as can be seen

in Figure 1 (Statistics, 2014). This represents more than 8% of Indonesia's manufacturing workforce; a larger proportion than in the USA (5.5%) (Rogalski, 2006). This closely

follows a recent general trend towards increasing employment being observed in the total manufacturing employment in Indonesia.

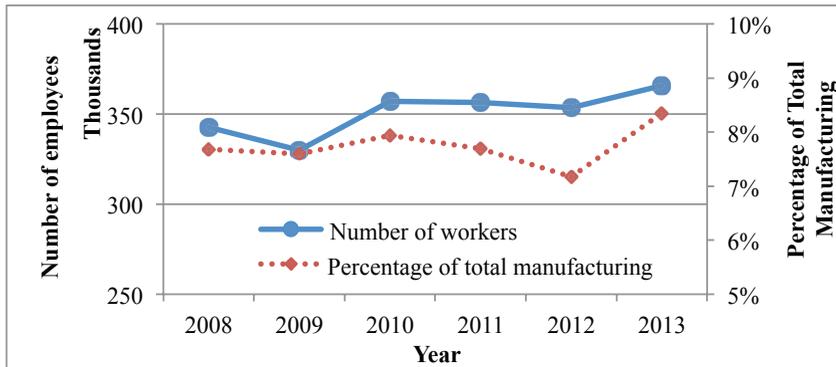


Figure 1. The number of employed persons in the plastics and rubber industry as a percentage of total manufacturing (Statistics, 2014)

Education and skills training is one of the supportive factors used to gain high productivity and competitiveness. Attainment of education is a structural issue, and it takes a considerable time to transform the educational profile of a nation. It can be seen from Figure 2 that majority of the workforce in the Indonesian manufacturing sector (48.6%) has only attained a low level of education (primary education and below)

(Statistics, 2014). This reflects the fact that the manufacturing industry employs more low-skilled workers compared to the service sector. It might be one of the reasons for the low labour productivity in Indonesian manufacturing since innovative production technology that provides a competitive advantage requires a more-educated workforce.

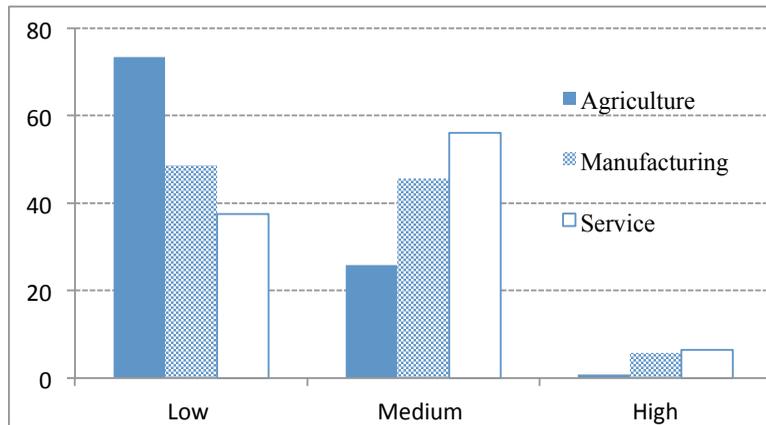


Figure 2. Workforce by education in the Indonesian manufacturing industry in comparison with the agriculture and service sectors (Statistics, 2014)

Low education: primary school graduates and below; medium education: secondary school graduates; high education: academy and university graduates

In 2014, a total of 816,505 vacancies were reported with the placement of 625,187 positions. However, more than 1,295,000 job seekers were also reported in that year. This highlights the simultaneous existence of both a shortage of required workers and a labour surplus in Indonesia. The Ministry of Manpower's Employment Service Centres indicates that unemployment in Indonesia is in part caused by the skills mismatch that is observed between registered job seekers and registered job vacancies (Organisation, 2015) as a mere fraction of the vacancies were filled up due to an insufficient supply of manpower and skilled personnel. In general, only 37% of workers are indicated to be well-matched between their occupation and educational attainment, with more than 55% being considered underqualified, especially in the manufacturing-related area.

Polymer Education at Undergraduate Level and in Vocational Schools

The educational system in Indonesia is set out in its Act on National Education System Law No. 20/2003 (D. o. I. H. Education, 2003), which is divided into several stages. According to this law, basic education is general education with duration of nine years, including six years in primary school and three years in lower secondary school. Secondary education, which covers the broad fields of general and vocational education, aims to increase the ability of students, such that they become contributing members of society, through developing a mutual relationship with their social, cultural and natural surroundings. Higher education in Indonesia offers not only theoretical degrees but also vocational degrees, provided by different types of institution such as academies, polytechnics, institutes and universities.

The extent to which polymer research is embedded in polymer education in academia is quantified from a number of research projects in the field of polymers. Compared to other Southeast Asian countries, Indonesia has a considerably lower research profile in

polymers (Figure 3), which accounts for around 2,200 documents (Scopus, 2016). This number is far lower than China and the USA, which currently produce more than 370,000 and 480,000 publications, respectively.

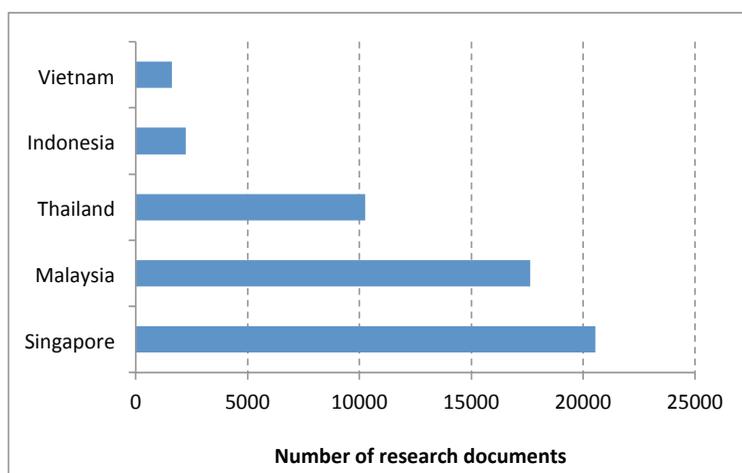


Figure 3. Number of published research documents (research articles, conference papers, review articles and book chapters) reported in Scopus database that include the keyword “polymer” (Scopus, 2016)

Unlike the USA and Malaysia (Chan & Ho, 2015; Stein, 1997), universities in Indonesia do not offer undergraduate degrees exclusively in polymer chemistry or polymer/plastics engineering. Courses in the polymer-related subjects are usually incorporated into chemistry, chemical engineering, materials engineering and mechanical engineering. The syllabi of some universities that offer courses that include the word “polymer” were considered in this analysis. Out of 1,668 engineering undergraduate degree programmes offered by Indonesian public and private institutions, only 7.5% of the programmes

are in chemical-related subjects. This number also includes degree programmes in Chemistry under the faculties of Science. Materials engineering degrees are offered by only three institutions, and account for less than 0.2% of the total number of engineering degree programmes, compared to mechanical engineering degrees, which account for 12% of the total (I. A. B. o. H. Education, 2016).

Literature research was performed to determine some different polymer-related courses identified in the syllabi. Tables 1 and 2 list some of the different polymer-related courses identified in the syllabi analysed.

There are four institutions listed that offer free access to their syllabi (Anwar, 2011; ITS, 2014, 2015; Rochmadi, 2010; UGM, 2011), which are Gadjah Mada University (UGM), Indonesian Education University (UPI), Indonesian Islamic University (UII) and Sepuluh Nopember Institute of Technology (ITS). This shows that the courses on polymers are usually offered as elective courses within the chemical-related undergraduate programme, which carry two to three credit hours. The elective courses

are taught in the third or fourth year of a four-year bachelor degree programme. The courses provide students with an overview of the methods for polymer synthesis and its characterisation. On the other hand, the polymer-related courses offered in materials engineering are mostly in the core curriculum as compulsory courses. The courses, which are equal to three credit hours, are mainly related to polymer properties and polymer processing.

Table 1
Polymer syllabi for chemistry and chemical engineering courses in selected universities

University Name	UGM	UPI	UII	ITS	ITS
Program Name	Chemistry (Science)	Chemistry (Science)	Chemical Engineering	Chemistry (Science)	Chemical Engineering
Course Name	Polymer Chemistry	Polymer Chemistry	Polymer Technology	Polymer	Polymer Technology
Compulsory/ Elective	Elective	Compulsory	Elective	Elective	Elective
Credit	2	2	2	2	3
Content	Molecular weight, polymerization, copolymerization	Polymerisation, molecular weight, copolymerization, processing	Polymerisation, molecular weight, chemical and physical properties	Characteristics, synthesis, molecular weight, physical properties and structure	Characteristics, polymerisation, copolymerisation, processing

Table 2
Polymer syllabi for materials-engineering-related courses in selected universities

University Name	ITS	UI	ITB		
Program Name	Materials and Metallurgy Engineering	Metallurgy and Materials Engineering	Materials Engineering		
Course Name	Polymeric Materials and Composites	Polymer Technology	Polymer Chemistry	Polymeric Materials	Polymer Processing
Compulsory/ Elective	Compulsory	Elective	Compulsory	Compulsory	Compulsory
Credit	3	3	3	3	3
Content	Chemical bonding, structure, types of polymers, synthesis, processing, physical properties	Morphology, rheology, mechanical & thermal properties, blending and copolymerisation, processing	Polymerization, molecular weight, morphology, structure and properties, effect of temperature	Types of polymers, additives, natural polymers, polymers with special properties	Fundamentals of polymer processing, rheology and blending

Some institutions are equipped with standard apparatus for qualitative and quantitative analytical chemistry, as well as equipment for material characterization analysis such as differential scanning calorimetric, thermal gravimetric analysis, atomic absorption spectrometry, differential thermal analysis and thermo-mechanical analysis to support research and teaching in the relevant areas of polymer science and engineering (UI, 2016). The practical works performed in this area usually cover material characterisation and mechanical testing, which are carried on for four to five laboratory work hours.

The Indonesian government, through its Ministry of National Education, is investing more in improving the vocational education and training (VET) system in order to close the skills gaps in line with the demands of the labour market. The ministry has made

VET expansion a priority, and set a goal to shift the ratio of students enrolled in general senior secondary education to those in a vocational senior education school to 40:60 by 2015 (UNESCO-UNEVOC, 2013). The government believes that vocational education is obviously required to respond to the needs of the current global market.

Among 18 skills courses offered by the vocational senior education schools in technology and engineering fields, there is no course exclusively on a polymer-related subject (School, 2008). There is only a study programme for industrial chemistry, which aims to provide the knowledge and skills students need to be capable of working in the general chemical industry. Politeknik ATK Yogyakarta (2016) is the only higher education institute offering vocational education in plastics processing. However,

a vocational institution is reported to offer a course in the design of plastic casting moulds (ATMI, 2016).

The law on the National Education System of 2003 recognises the existence of non-formal education to replace, complement and/or supplement formal education to support lifelong education (UNESCO-UNEVOC, 2013). Several institutions offer short-term, non-formal, vocational training which focuses on preparing workers and trainees to enter the job market with specifically upgraded skills. Currently, the centre for Indonesia's polymer research, Sentra Polimer, offers training programmes in plastics technology, polymer composites, polymer testing and plastics processing. The participants for this training are mostly practitioners currently working in the polymer industry.

Gap Analysis

To support the smooth running of the manufacturing plants in polymer processing, it is necessary to have highly trained personnel with manufacturing skills (Tillery, 1993). The industries dealing with rubber and plastics require skilled, trained manpower such as chemists, physicists and engineers in polymer-related science to maintain its competitiveness. Those industries also require support in designing and synthesising new materials, as well as characterising, testing and evaluating these materials to find new uses for them (Chan & Ho, 2015).

Since 1968, the Society of Plastic Engineers has stated the necessity of

educational programmes to train skilled technical and engineering personnel for the plastics industry. Polymer education has been widely taught around the world, which can be in a specific degree programme, or part of a science or engineering degree programme. As one of the Association of Southeast Asian Nations' (ASEAN's) top exporters of plastic products, Malaysia offers several bachelor's degree courses specialising in polymer engineering, and covering polymer rubber and latex processing (Chan & Ho, 2015), as do the USA and the UK (Stein, 1997). Besides the degree courses, some short courses providing comprehensive coverage of the main aspects of plastics technology are also available (ILPMRG, 2015; PRIM, 2015; SHRDC, 2015). Meanwhile, with more than 4,000 plastics manufacturers, instruction in polymer science and technology has been widely spread across all levels in the Thailand educational system, from technical vocation schools to a doctoral degree programme (Amornsakchai & North, 2015). Short courses in polymer processing that are provided by a Thai institution have also been found in the literature (PPC, 2017). In Vietnam, a university is found in the literature providing a bachelor's degree course in polymeric materials technology (Hotcoursesabroad, 2017), and several others have incorporated polymer-related subjects as part of a Science or Engineering programme (Thu et al., 2015).

Even though they do not offer undergraduate degrees exclusively in polymers, some countries such as Brazil

(Santos et al., 2015) and Australia (Fellows, 2015) have a strong emphasis on preparing skilled manpower for the plastics industry through various vocational training courses. These range from mould production and polymer processing to polymer composites technology. Designed to deliver workplace-specific skills and knowledge, the VET in Australia is presented in tiered levels based on the qualifications required. For example, the Certificate II in polymer processing is intended for operators who directly control production equipment, while the Certificate IV in polymer technology is intended for senior operators who are capable of working in situations that require autonomy and judgment (Australian Government: Department of Education, 2017). Higher learning institutes at university level in Indonesia offer courses in Chemistry, Chemical Engineering and Materials Engineering that are relevant to the plastics industry. However, by looking at the examples of the benchmark countries, it is hoped that there will be more vocational schools and training institutions in Indonesia that are relevant to the plastics industry. Those institutions will not only be for educating freshmen but also for retraining the staff and technical employees who are currently working in the industry. It is required that working professionals need to be aligned with skills training and certification from intensive, short courses (Malaysia, 2013).

Indonesian plastics manufacturing is expected to rapidly grow since plastics has become the material of choice in

various types of applications. With the requisite use of advanced manufacturing technology in plastics processing, the industry requires more skilled labours capable of using the new generation of equipment. As revealed from the facts presented in Figure 2 for manufacturing industries, a skills mismatch may also exist in the plastics industry. To strengthen competitiveness and productivity, it is necessary to reduce the mismatch between supply and demand in the labour market by developing a responsive education and training system with a tight collaboration among the government, industry players, learning institutions and research centres. As reported by the Indonesian Packaging Association, food packaging accounts for more than 60% of plastic consumption sales in Indonesia, with around 892 manufacturers producing both rigid and flexible packaging. The National Occupational Skills Standards (NOSS) for the plastics packaging industry developed by the Indonesian Ministry of Labour (Iskandar, 2014b) has formulated the knowledge and skills required to perform a specified job in this sector. Such training courses that offer comprehensive coverage of the main aspects of plastic packaging processing technology would be considered to be beneficial by the industry.

According to NOSS (Iskandar, 2014b), a total of 27 competency units have been identified comprising of three main areas, namely operations management, process engineering and technical maintenance. The operations management consists of functions related to inventory management

and material requirements planning. The process engineering covers the scope of the work required when dealing with the different process of plastics manufacturing such as injection moulding, blow moulding, extrusion, thermo forming and vacuum forming. Finally, the technical maintenance area deals with maintaining the quality of the plastics manufactured. For a vocational schools curriculum, Potter (1971) suggests the following learning outcomes should be accomplished:

- Developing the fundamental skills associated with the production of plastic commodities.
- Understanding and exercising safe methods of performing work.
- Demonstrating knowledge of the importance of accuracy and the use of standards in production.
- Understanding the use and care of equipment and materials through demonstration and practice.

CONCLUSION

It is crucial for the Indonesian plastics industry to strengthen its competitiveness through the continued acquisition of the appropriate technologies, as well as enhancing marketing capabilities and skills training. The development of responsive education and training is one of the keys to addressing the issue of workforce skills enhancement. Currently, several higher learning institutes offer courses in chemical and process engineering, mechanical and

manufacturing engineering, materials engineering, and other subjects relevant to the industry. However, it is hoped that there will be more training and education centres under the skills and the vocational umbrella that expand their courses to include programmes relevant to the plastics industry. The number of skilled personnel in this industry can be encouraged to meet the growing requirements of the industrial sector. It is expected that technically competent polymer scientists and technologists would form the main core support for the sustainability of the polymer industry in Indonesia.

Further research should include identifying and verifying a list of job duties and tasks for the industrial polymer technicians to use in developing a polymer education and training programme that fully meets the needs of the Indonesian plastics industry.

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