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A Study of Disruptive Technology Impacts on Industrial Engineering Professionals under the Context of Thailand 4.0

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Abstract: The purpose of this study is to examine the impact of disruptive technologies on the industrial engineering profession and learn how to deal with such disruptions. The study uses questionnaires to collect data from 8,149 individuals practicing industrial engineering at the Associate Engineering level and Senior Professional Engineering levels. After that, the sample is calculated using the Taro Yamane method with a confidence level of 95 percent. Then, the main reasons for the impact of disruptive technology on industrial engineers were analyzed using the Affinity Diagram, and the problem structure was clarified using the Relations Diagram. The main cause was analyzed to find a solution with the help of a Tree Diagram. Finally, the matrix diagram was used to find the correlation of solutions by comparing 11 technologies that will affect global change, according to research by McKinsey Global Institute. The result of this research shows that disruptive technology directly impacts the work of the sample, affecting Decision Making and investment in industry and technology rather than replacing people. Therefore, industrial engineers should further explore technology and engineering such as Big Data, the Internet of Things (IoT), and maintenance engineering. This also includes improving one's language skills and ability to collaborate with others.

Keywords: Disruptive technology; industrial engineering; Thailand 4.0

1. Introduction

Industrial engineering emerged simultaneously with the Industrial Revolution when production systems required mass production at a lower cost [1]. Frederick W. Taylor, the father of Industrial Engineering, invented an approach to study guidelines and applied it successfully at Bethlehem Steel Co. to increase productivity. He also created scientific management principles that have been continuously applied and developed [2].

However, the challenges of a changing world mean a constant struggle for the profession of industrial engineering. In the 21st century, these challenges may be more pressing than ever. This is especially true considering the impact of disruptive technologies and innovations [3-4] that will fundamentally change manufacturing and the service sector. In addition, the Thai government has embraced change by encouraging everyone to escape the middle-income trap by producing and providing high-value, high-technology products to prevent the country from becoming a low-performing country and to support the country's target industries [5]. Thailand's Industry 4.0 policy proposes a new technological development and manufacturing paradigm with profound economic, environmental, and safety implications. It is believed that the exploration of Industry 4.0 is a viable way to create sustainable manufacturing [6]. The division between the S-Curve and New S-Curve groups has raised concerns about the adaptability and competence of the industrial engineering profession.

This study aims to answer the question of what the industrial engineering profession will look like in the future. Adapting to the situation and the impact of disruptive technology under the accelerator of Industry 4.0. This is a survey to test hypotheses and draw conclusions based on the interest of interested groups regarding the profession of industrial engineering.

2. Methodology

This study is exploratory and based on data collected through a stakeholder questionnaire. The specific characteristics of the population, sample and analytical instruments are listed below:

2.1 Population and sampling

This study considered a population of the Council of Engineers working in industrial engineering, divided into two levels: 8,002 people with Associate Engineering levels and 147 people with Senior Professional Engineering levels (2019 data). Then, as indicated in equation (1), the Taro Yamane method is used to determine the number of samples with a 95% confidence level [7].

$$n = \frac{N}{1+N(e)^2} \tag{1}$$

Where: N = number of people in the population

n = sample size requires

e = allowable error

After calculating the sample size by substituting the numbers into the Yamane formula, $N_1 = 8{,}002$ persons, $N_2 = 147$ persons, and $e = 0.05$, the number of samples is $n_1 = 381$ persons (Associate Engineering levels) and $n_2 = 108$ persons (Senior Professional Engineering levels).

2.2 Tools for research

This study used surveys and interviews to collect data, feedback, and recommendations. The data is analyzed using four new high-quality tools to find answers to the question: Affinity Diagram, Relationship Diagram, Tree Diagram, and Matrix Diagram, which are as follows:

2.1.1 Questionnaires and interviews

The questionnaire consists of four parts: personal information and comments on specific industrial engineering topics suitable for the era of Industry 4.0. Comments on the impact of disruptive technologies on the industrial engineering profession and other recommendations. The interviews assessed industrial engineering stakeholders to obtain the most accurate and relevant preliminary information possible.

In this study, the validity of the questionnaires and interview forms was assessed by three qualified individuals to determine the quality of the questionnaires. Then, the IOC approach was used to check the content and language concordance index values.

2.1.2 The New QC tools in research

The review revealed secondary data, which are qualitative data that cannot be quantitatively calculated mathematically. Therefore, these data were analyzed using contemporary qualitative tools to ensure the data's viability and reliability [8]. The analysis tools are described below:

1) Affinity diagrams organize secondary data combining citations and opinions on technical subjects for industrial engineering disciplines.
2) Relationship diagrams identify cause-effect relationships for primary and secondary data with various correlations. It shows the appropriateness of the quotes from the interview and the characteristics of the others.
3) Tree diagrams evaluate solutions from multiple key sources at different levels to understand the potential cause-and-effect relationships.
4) Matrix diagrams are used to compare 11 solutions and technologies impacting global change [8]. This has sudden implications for the industrial engineering profession.

3. Results

3.1 Findings from the analysis of the research tool

The three experts will read all questionnaires to assess validity. The evaluation criteria for the questions are as follows:

1 means that they are convinced that the questions meet the objectives.

0 means they are unsure whether the question meets the purpose.

-1 means that it is certain that the question does not meet the purpose.

Then, the experts evaluated the questionnaire for its content and index of consistency (IOC). The results were used to evaluate the average value of 12 questions using the IOC. All questions had a concordance index greater than 0.60, indicating that the questionnaire was appropriate for the subject. The results of this survey were valid because respondents consistently understood the questions.

3.2 Results of questionnaire analysis

According to a survey of industrial engineering stakeholders, 36.4% of respondents had worked in industry and education for over 20 years. This level of experience helps to understand better how the industrial engineering profession has changed over time and helps to shed light on the true impact of disruptive technology adoption on labor market demands. Therefore, the data collected in this study are acceptable and reliable. In addition, the respondents have a working duration of 16-20 years (24.2%), 11-15 years (22.2%), and others (17.2%), respectively. According to the above findings, the respondents have high industry knowledge and expertise. Therefore, it is very likely that the questionnaires used in this research will provide actual data for an in-depth study when evaluating the hypothetical results of the research.

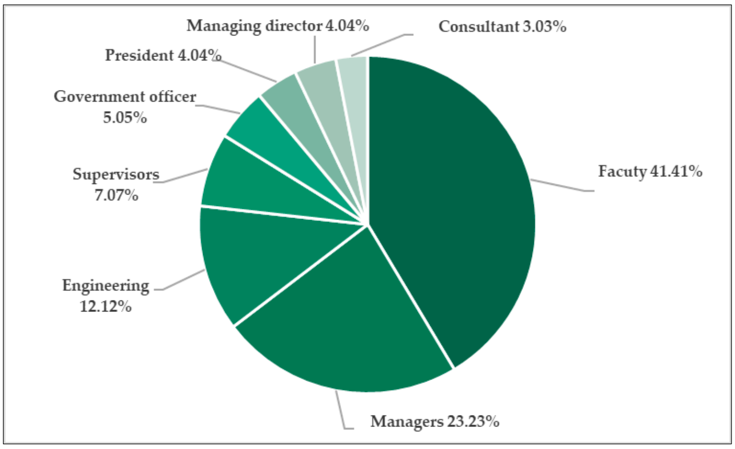

Figure 1. The proportion of respondents' positions

Regarding the categorization of the operating group, the respondents included individuals working in industrial engineering: Associate Engineering (78%) and Senior Professional Engineering (22%), both of which are stakeholder groups directly related to the industrial engineering career field. Explain in detail how technology has evolved and how much the field of industrial engineering has changed. Faculty respondents made up most respondents at 41.41%. They were followed by managers (23.23%), engineers (12.12%), supervisors (7.07%), government officials (5.05%), presidents (4.04%), general managers (MD.) (4.04%), and consultants (3.03%), as shown in Figure 1.

Respondents' responsibilities are divided into two categories: 1) 229 industry professionals divided among Electronics (24%), Automotive (19%), Food (19%), Consumer Products (8%), and Other (30%); and 2) 152 faculty members in Industrial Engineering who currently have teaching loads, divided among Work Study (15.6%), Plant Design (15.6%), Maintenance Engineering (13.3%), Production Planning and Control (11%), Safety Engineering (6.7%), Engineering Economic (6.7%), and Other (31.1%), as shown in Figure 2.

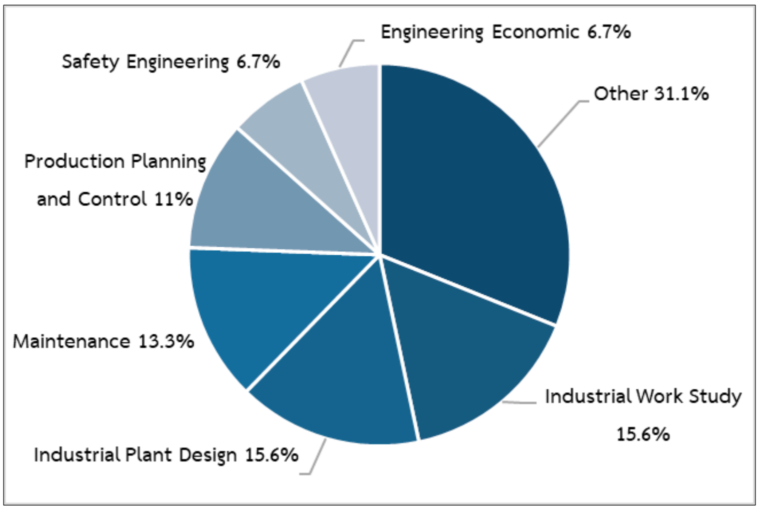

Figure 2. Faculty proportions

The importance of engineering-specific subjects for industrial engineering meets Industry 4.0 with a matrix diagram of eight fundamental subjects in the Council of Engineers industrial engineering certification exam. Respondents prioritize the application of knowledge to their work areas and tasks. The subjects in the rankings are as follows: 1) Safety Engineering, 2) Industrial work study, 3) Production Planning and Control, 4) Quality Control, 5) Industrial Plant Design, 6) Operations Research, 7) Engineering Economics, and 8) Maintenance Engineering, as shown in Table 1.

Table 1. Prioritization of subjects

Subjects		Prioritization of subjects							
		1	2	3	4	5	6	7	8
1	Safety Engineering	**76**	53	50	38	34	30	50	50
2	Industrial Plant Design	53	38	72	42	**57**	46	34	38
3	Production Planning and Control	57	61	**88**	50	38	50	19	19
4	Quality Control	69	72	57	**50**	46	30	27	30
5	Industrial Work Study	69	**88**	34	27	57	50	23	34
6	Operation Research	53	46	46	38	53	**72**	30	42
7	Engineering Economics	53	65	53	30	38	46	**61**	34
8	Maintenance Engineering	57	46	30	34	46	27	53	**88**

Table 1 shows respondents with first-hand knowledge of industrial engineering ranked safety engineering as the most important. Therefore, it should be taught in this degree program. The subjects of secondary importance are Industrial Work Study and Production Planning and Control. To prioritize 8 basic subjects, all of which are basic subjects of the profession and taught in the current curriculum. It is based on the actual application in the respondents' industry. The survey shows that the subjects taught are still important and applicable in the industry. However, to train industrial engineers capable enough to meet the market's demands, education must still adapt to the changes brought about by disruptive technology.

3.3 Analysis of disruptive technology affecting industrial engineering

Based on interviews with stakeholders in the industrial engineering profession: the Associate Engineering level and the Senior Professional Engineering level, to examine the impact of disruptive technology on the industrial engineering profession. It was found that these issues can be divided into three groups: 1) technology, 2) investment and decision-making, and 3) labor. We analyzed all the collected data with four new quality tools to find the exact correlation and cause, which led to the following results:

3.3.1 Affinity diagram

After collecting the stakeholder interviews, the data is organized into groups to work together on any issues that arise. This makes it easy to see and understand. Figure 3 shows how the comments are grouped.

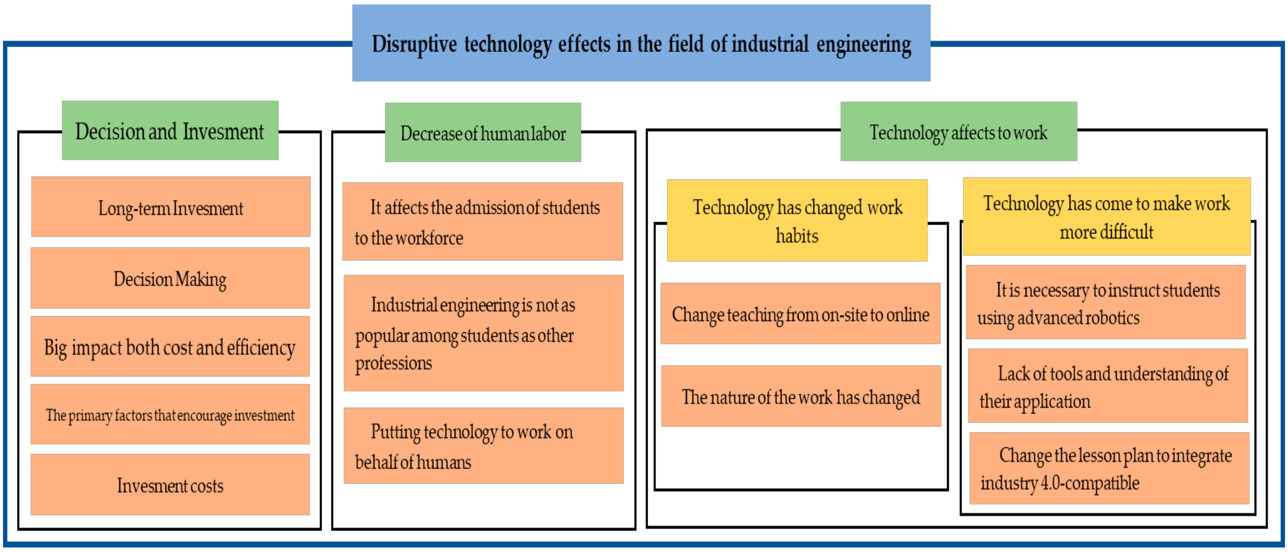

Figure 3. Affinity diagram

3.3.2 Relations diagram

The problem was classified using the affinity diagram. We defined the relationships between the three groups of problems to understand the results better. As shown in Figure 4, the field of industrial engineering is highly affected by disruptive technology, which can be divided into problem groups as follows:

1) Technological problems are changing our work, making it more difficult and complex. On the other hand, the technology we use at work is very useful, especially in supporting humans. Humans must try to adapt to life with technology. Therefore, the semester should familiarize students with technological learning opportunities to cope with rapid technological changes and constantly prepare them to pursue knowledge.

2) Due to disruptive technology and expensive investment, investment and decision-making problems affect executives and entrepreneurs. For this reason, the company is exposed to relatively high risks when deciding to invest in technology. Therefore, executives and entrepreneurs must consider usability and cost-effectiveness when making investment decisions.

3) The workforce problem is becoming more serious as technology replaces personnel in areas that do not require critical thinking or problem-solving skills. Therefore, using technology to increase production and efficiency while reducing costs is wise for businesses.

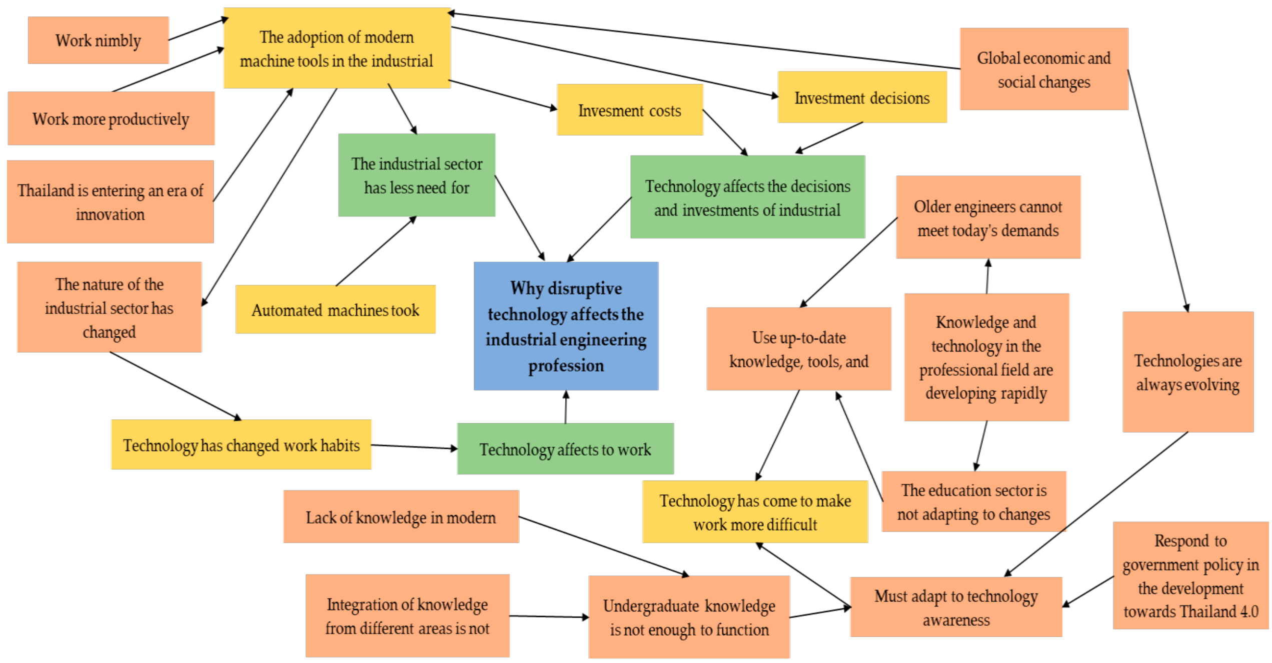

Figure 4. Relations diagram

3.3.3 Tree diagram

We analyze the solutions and improvements using the tree diagram. As shown in Figure 5, it is necessary to understand the causes of disruptive technology and adaptation approaches. Data were obtained from questionnaires and interviews with industrial engineering stakeholders.

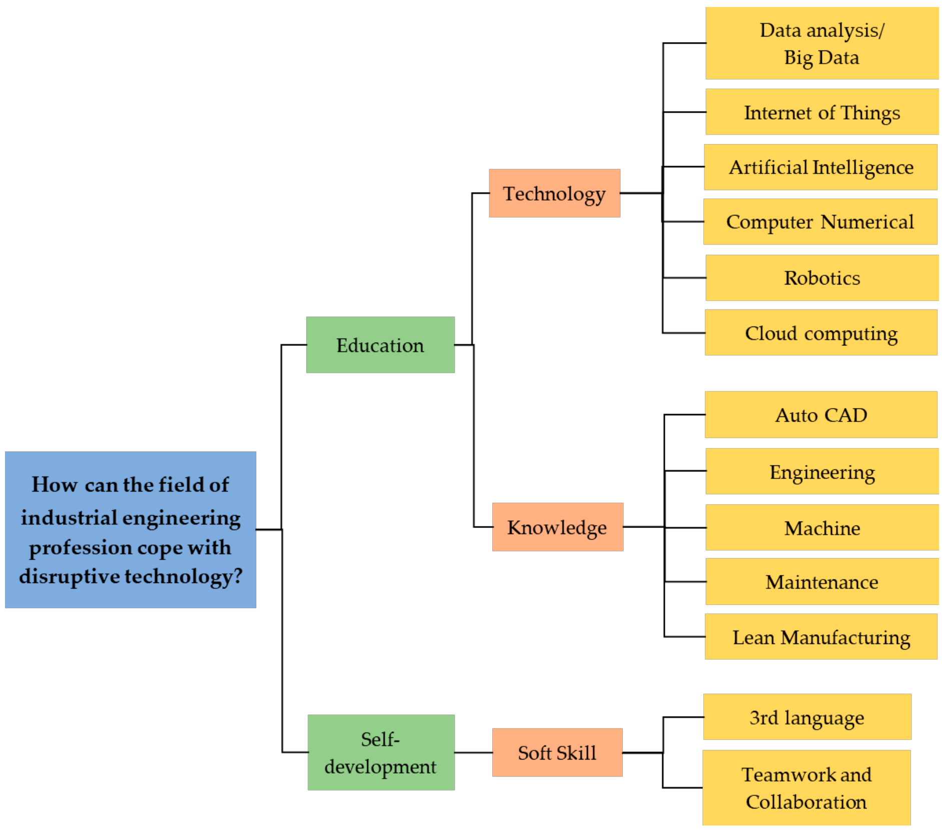

Figure 5. Tree diagram

From the analysis, solutions and improvements to address the impact of disruptive technologies consist of two approaches:

1) Industrial engineering stakeholders should educate themselves in the areas of technology and engineering. Technology knowledge focuses on learning more about Big Data, Computer Numerical Control (CNC), the Internet of Things (IoT), Artificial Intelligence (AI), Robotics, and Cloud technology. The details are as follows:
    1.1 Big Data: There is a large amount of structured and unstructured data. Understanding how to analyze and manage data to use it effectively is important. Knowledge of Big Data is an essential tool for direct data management.
    1.2 CNC: It significantly reduces errors in the production process.
    1.3 IoT: The IoT is indispensable today as it enables all forms of communication, including the operation of devices that collect data and search for data quickly. Undoubtedly, this technology is already part of our daily lives.
    1.4 AI: One of the factors that are critical to the performance of industrial engineering is AI. For example, AI can quickly determine the best solutions for engineers and is often used in cost-conscious planning of production processes.
    1.5 Robotics: robotics is a popular technology used in various industries where humans cannot perform all tasks themselves due to their limited cognitive abilities in certain tasks.
    1.6 Cloud technology: Cloud technology is also important for the knowledge that enables the industrial engineering profession to deal with disruptive technologies.

Engineering fundamentals assume that engineers should already have these skills. Still, learning more about software such as computer-aided design (CAD), engineering statistics, machine learning, maintenance engineering, and lean manufacturing is a good idea. This is important knowledge that is used in most tasks and is specific to the field of industrial engineering [10]. According to the survey, 36.4% of the industrial engineers surveyed have more than 20 years of professional experience. Twenty years ago, Computer Numerical Control (CNC) was not widely used in the Thai industry, so such content did not cover teaching in industrial engineering.

It was found that there is an imbalance between the number of students who have graduated in this field and the number of students applying for engineering licenses. As a result, there are few recent engineering graduates in this research population. This suggests that few industrial engineers know disruptive technology's real impact. Stakeholder in the field of industrial engineering must strengthen their soft skills. According to interviews, the abilities required for today's industrial engineering career include communication and interpersonal skills. Engineers need to continue to grow to develop hard skills and their hard specialty to keep up with the changes occurring. Therefore, knowing many aspects of coping with change in every way is very helpful.

3.3.4 Matrix diagram

We will use the solutions and improvements the tree diagram offers to guide our response to 11 technologies that will affect global change. According to research by the McKinsey Global Institute, USA [9]. Figure 6 shows that Big Data/Data Analytics studies received the highest with 11 points, followed by IoT (7 points), AI (6 points), machine learning (6 points), robotics (5 points), maintenance engineering (5 points), lean manufacturing (5 points), CNC (5 points), AutoCAD (4 points), and cloud technology (3 points).

● Consistent
(empty) Inconsistent

	Mobile Internet	Automation of knowledge	Internet of Things	Cloud Technology	Advanced Robotics	Autonomous and near-autonomous	Next-generation	3D printing	Advanced materials	Advanced oil and gas exploration and	Renewable energy	Score
Learn more: Big Data	●	●	●	●	●	●	●	●	●	●	●	11
Learn more: Internet of Things	●	●	●	●	●	●		●				7
Learn more: Artificial Intelligence	●	●	●		●	●		●				6
Learn more: Computer Numerical Control		●	●		●	●		●				5
Learn more: Robotics	●	●			●	●		●				5
Learn more: Cloud Technology	●		●	●								3
Learn more: AUTO CAD	●	●			●			●				4
Learn more: Engineering Statistics												-
Learn more: Machine Learning	●	●	●		●	●		●				6
Learn more: Maintenance Engineering	●	●			●	●		●				5
Learn more: Lean Manufacturing	●	●			●	●		●				5

Figure 6. Matrix diagram

4. Conclusion

This research is an application of new quality tools to study the impact of disruptive technologies on the engineering profession. This includes examining how sudden technological changes prepare people in educational systems to become industrial engineering practitioners. The findings of the research can be summarized as follows:

1) Three effects of disruptive technology in industrial engineering:

1.1 Increased labor productivity due to technology reduces the need for human labor in the industrial sector.

1.2 Technology affects business and investment decisions. The cost-effectiveness of long-term technology investment decisions will have a direct impact.

1.3 Technologies that change the nature of the job and the aptitude of the engineer by making it more demanding.

In addition, it was noted that the curriculum used in classrooms to train graduates is not in line with the twenty-first century, forcing stakeholders to adapt to new modern technologies.

2) The approach to addressing disruptive technology in the industrial engineering profession is as follows:

All continents worldwide have increasingly accepted the Internet in the industrial sector in the twenty-first century. As a result, technological advancements have occurred rapidly to keep pace with the demands of the entire supply chain. The industrial sector is changing rapidly technologically, but the education sector has not adapted. Therefore, it is time for collaboration between industry and the education sector. The industrial sector is seen as an important variable, indicating that the industrial engineering curriculum and instruction in the education sector need to change. There is a need to ensure graduates can meet the sector's demands and find employment. Curriculum adjustments must consider the future for 3-10 years. In the past, technology and innovation did not play a major role in industrial engineering, so the curriculum did not deal much with the application of technology. Today, technology and innovation are becoming increasingly important in the industrial sector. Those in the industrial engineering profession need to learn more about their areas of expertise, such as engineering statistics, maintenance engineering, and lean manufacturing, and learn more about technology to apply that knowledge to the emerging technology and innovation groups that are coming into play in the industry. This will help to improve the skills of the entire Thai industrial engineering profession in the future.

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