2012 International Conference on Education and Management Innovation
IPEDR vol.30 (2012) © (2012) IACSIT Press, Singapore

Analyzing the Trends of Engineering Education Using TRIZ

Issac Lim Sing Sheng [1], Satesh N. Namasivayam[2], Kenny Tan Boon Thong [1]

[1] Monash University Sunway Campus

[2] KDU University College

Abstract. The field of engineering has been the main workforce behind economic development. Stemming from the industrial revolution ages, engineering has now branched into different areas of application. From the more traditional area of mechanical, engineering has evolved to meet the current demands of this generation. Current and future demands require engineers that are able to solve problems innovatively. The old methods of problem solving rely heavily on the knowledge within the area of specialty. However, problems are getting more complex as they interrelate with various fields. In catering to these changes, universities are offering engineering courses that are varying. This research is conducted to relate the trends of engineering courses together with TRIZ which stands for Theory of Inventive Problem Solving. TRIZ is an internationally recognised powerful problem solving method. Current general trends of engineering courses were correlated with one of the main tool of TRIZ called 'Trends of Evolution of Engineering Systems'. These evolution trends stem from the discovery that engineering systems evolve over time following eight distinctive trends. From this research,it is shown that the changes of engineering courses over time have been following the these eight trends. Therefore the future trends of engineering courses can also be charted using this TRIZ tool.

Keywords: Engineering Education, TRIZ, Innovation, Education Trend

1. Introduction

Economic development depends heavily on development and the major workforce behind development is the engineering industry. The modern engineers are involved in global problems that are interdependent and interconnected[1]. As the problems that arise are more complex than ever, engineers would be required to produce innovative solutions. Solving usual technical problems require training and years of experience from that specific area of work. As most problems faced by engineers have not been anticipated before, problem solving skills are essential and not just knowledge gained from experience.

However, studies reveal that an increasing number of fresh engineering graduates lack problem solving skills[2]. Furthermore, the number of students choosing to study engineering in university has reduced with the increasing variety of other courses. On top of that, not all engineering graduates choose to embark their career in the same field. These mean that the new crop of engineers which is dwindling in number would carry heavier workload to drive development. To achieve that, they would need to have an increased level of problem solving skills. The university play a major role in solving this problem. It is the responsibility of the university to attract more engineering students and to equip them for a fulfilling engineering career.

This research involves the method of observing the general trends of engineering courses in recent times. These trends are correlated with one of the tools of TRIZ called the 'Trends of Evolution of Engineering Systems'. Upon proving the correlation between these two sets of trends, the future trend of engineering courses can then be charted.

2. Research Methodology

2.1. TRIZ

TRIZ is a Russian acronym which translates to the meaning of 'Theory of Inventive Problem Solving'. It is a structured approach towards inventive and innovative problem solving. TRIZ was first developed by a Russian engineer named Genrich Altshuller. His job was to study and approve patent applications. From the analysis of over 200,000 patents, Altshuller observed several distinct patterns and from there he made three key discoveries[3].

- Not all inventions and solutions are of equal level. There are five different levels of innovation.
- All possible technical solutions have been discovered and can be found either within or outside an industry.
- Every engineering system tends to evolve over time according to a set of trends.

Fortune 500 listed companies such as Intel, Samsung, Siemens, Procter & Gamble, Boeing, and General Electric have been using TRIZ since the 1990s to as a tool in developing more innovative products. TRIZ consists of all possible inventive solutions that are distilled and indexed into a handful of general principles. By referring and applying TRIZ, these companies managed to achieve combined revenue and cost savings of hundreds of millions of dollars if not billions.

With the success in industrial application, the introduction to engineering undergraduates in universities around the world is gaining ground. Most of these universities are from Malaysia, China, Taiwan, Japan, South Korea, and United Kingdom. In Malaysia, over 500 university lecturers from local and private universities have been trained in the area of TRIZ by Intel engineers through the government's initiative.

This research focus is not about the implementation of TRIZ in engineering courses. Rather this research is about using TRIZ to improve the overall course structure of engineering courses. As the third key discovery of Altshuller states that all systems tend to evolve according to a set of trends, this research will use it to correlate and improve the system of interest which is the engineering courses in universities.

2.2. Trends of Evolution of Engineering Systems

Altshuller has observed that overtime engineering systems will continue to improve and develop following certain patterns. Regardless of which industry, inventor or time, these patterns hold true. Subsequently these patterns are termed as evolution trends. There are in total eight different evolution trends that engineering systems evolve into. The eight trends are as follow[4].

- Increase in ideality
- Follows the S-curve
- Increase of controllability, flexibility, and dynamism
- Uneven development of parts
- Alternate simplification and increase of complexity
- Increase of segmentation
- Matching and mismatching parts
- Lesser human involvement

These eight trends are listed in no particular order. A system can be following either one or a combination of these trends. These trends are termed generally so that it can be used in any type of application.

Even though these trends were initially developed based on physical products, these trends are interpreted in this research to be applied in the area of engineering education. Specific technical jargons will cause a mental block in terms of psychological inertia which limits the ability of conceptualising new solutions. The advantage of having the trends in general terms is the avoidance of psychological inertia.

Upon receiving a specific problem, a specific solution is not often found immediately. TRIZ provides a systematic approach towards developing the desired solutions. The flow chart in Figure 1 depicts the ability of TRIZ to generalise a specific problem and recommended tried and tested general solutions for the implementation of specific solutions in whichever field of interest. Similarly this is how these trends of evolution will work in providing general guidelines for the future trends of engineering courses.

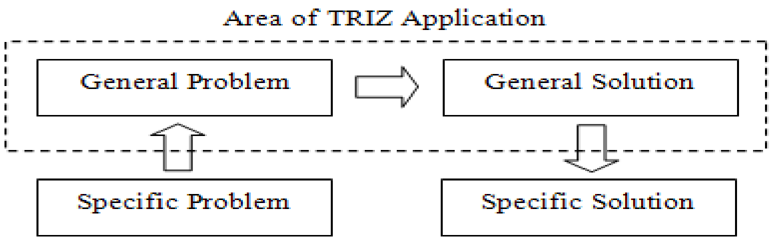

Fig. 1: Framework of TRIZ

3. Correlation of Trends

Over the past decades, engineering courses have been changing following certain trends. Through this research, it is determined whether these trends correlate with TRIZ's eight Trends of Evolution of Engineering Systems.

3.1. Increase in Ideality

Ideality is a concept in TRIZ which formulates an ideal solution is the ratio of the benefits of the solution over the costs and harmful side effects that occur alongside the solution. A bigger ratio value means that a more ideal and better solution has been generated.

$$\text{Ideality} = \frac{\Sigma \text{Benefit}}{\Sigma \text{Cost} + \Sigma \text{Harmful Effect}}$$

Eq. 1: Ideality Formula

Like any product, engineering courses are getting better over the years. The table below tabulates the benefits, costs, and harmful effects of existing engineering courses.

Table 1: Benefits, Costs, and Harmful Effects

Benefits	Costs	Harmful Effects
• Specialised and experienced academicians • Latest lab facilities and syllabus • International accreditation • Award and recognition • Comprehensive syllabus covering economics, marketing and management • International culture exposure • Exchange program with other universities for students and academicians • Practical experience through industrial collaboration	• Research fund • Scholarship allocation • High salary • Purchasing and maintenance cost of facilities • Incentives for students and academicians	• Overcrowded class • Quality control • Students fail from more demanding syllabus • Time constraint in covering wide syllabus • Time to assimilate cultural differences • Graduates not ready for industry • Frequent switching of engineering major • Experienced academicians attracts better incentives elsewhere • Students transfer to other collaborating universities

Universities are constantly tweaking their existing courses to meet have more benefits. However not every change increases the ideality of their course as there are costs and harmful effects that comes with these changes. There are three ways to increase ideality. The first is to reduce or eliminate some of the existing costs and harmful effects. Next, is to introduce more benefits at the same or slightly higher cost. Finally is to remove or find a replacement for the benefits that cost the most.

3.2. Follows the S-Curve

S-curve analysis is about the lifecycle of a system. The study originated first from the observation of the population growth of microbateria on a paltry dish. Initially the growth happens slowly as the population size is small. This is called the first stage. On the second stage, there is an accelerated rate of growth as the population increases. After that, as food source and space are limited on the paltry dish, the population stops increasing and maintains its size. Finally as the food finishes, the entire population slowly die.

Similar to this biological pattern, engineering systems would face a similar trend during its lifecycle. Each engineering university represents a microbe. The student population is like the source of food. The only way the microbe could survive is either through the decrease of other microbes or the increase of more food source. The current challenge is that there are more universities offering engineering courses and there is a lesser amount of students interested in engineering. This indicates that engineering courses are at the final stage in the S-curve. A jump to the next S-curve is needed. This can be achieved by increasing the ideality of engineering courses as discussed.

The S-curve is also applicable for any new courses introduced into engineering education. It will take time to gain ground. If it is a right approach, it will survive for the next round of accelerated growth. As it matures, preparation for the next new course should be done because the current one will eventually face a decline.

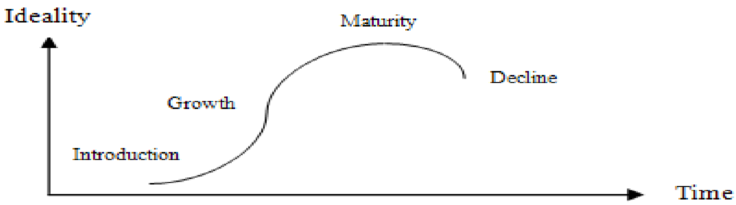

Fig. 2: S-Curve Analysis

3.3. Increase of Controllability, Flexibility, and Dynamism

Controllability is defined as the ability to change, manoeuvre, guide, or control a system. Flexibility is about the ease to make changes to the system. Finally, dynamism is about the mobility of a system. Under the context of engineering education, there are three possible systems. These systems are the students, the universities, and the governing body of education and engineering. The table below is a summary of the observation of these increasing trends.

Table 2: Increasing Controllability, Flexibility, and Dynamism Trend

System / Trend	Student	University	Governing Body
Controllability	• Decides which engineering major	• Ability to handle more diverse students, academicians, and engineering majors	• Accredit only approved universities and courses • Governs the quality of the students and syllabus
Flexibility	• Able to mix and match different subjects • Transfer credit across majors	• Cater different engineering majors • Periodically alter syllabus content	• Recognise and accredit new engineering majors
Dynamism	• Travel for overseas study	• International campus exchange programs	• Provide guidelines for universities within the country, region, and globally.

Among these three systems, the governing bodies are the least to have flexibility and dynamism. Although accreditation is important to maintain the credibility of the engineering courses, the rigidity of the process overly bureaucratic and time consuming. This may lead to the impedance of creativity among academicians and students[5]. However based on these trends, engineering education would improve and achieve ideality when the governing bodies become more flexible and dynamic.

3.4. Uneven Development of Parts

A system usually consists of a few subsystems. For engineering education, the subsystems would be the various syllabus, the academicians, students, and administrators. To progress, these subsystems are interdependent of each other.

Courses that need new and well developed lab equipments and software might not be practical for all universities. At times it is not the matter of course but rather the question of social and cultural preferences. An example would be around the ethical issues surrounding potentially sensitive researches carried out in biomedical engineering such as cloning. Besides that, nuclear energy is another engineering study that is ethically and politically sensitive.

This trend highlights the frequent presence of under developed parts of a system. A suggestion will be to integrate the undeveloped parts with a more established system. For instance, collaborations amongst universities and industries are in trend. The industry has the right infrastructure and funds which universities often lack. On the other hand, universities have highly specialised engineers and researchers that industries lack. Through the merger of more developed parts with lesser developed one, both sides will develop further together.

3.5. Alternate Simplification and Increase of Complexity

It is normal to have a complex system becoming simplified and a simple system becoming more complex. In fact according to TRIZ, simplification and increase of complexity will occur alternately to a system. This indicates that it is not wrong to simplify or to complicate an engineering course.

Engineering is always at the frontier of the latest technologies. As technologies develop rapidly, engineering education system has to be updated too[6]. Therefore new subjects related to these technologies ought to be taught at universities.

Upon introduction of new subjects alongside existing subjects, the course becomes more complex. It is complex because there will be mismatch and non coherence of subjects. Furthermore it is more demanding for the students as well as teachers to cope. Over time, the older subjects will phase out and hence simplifying the syllabus. This process will repeat again when newer subjects replace the current ones. An iterative process of simplification and complication of the engineering education is a good indication of further development.

3.6. Increase of Segmentation

Segmentation is the continuous division of system into multiple parts. There is an increasing decentralisation of the way engineering education is being run.

On a higher level, even universities are setting up more campuses within a region, country, regionally, and globally. This is termed as the internalisation of higher education learning[1]. Other than that, even engineering courses are being offered for distant learning. This is taking trend especially in developing countries. In rural areas in China, distant education is of great education and economic value[7].

Within the school of engineering in universities, each engineering majors are being managed independently in separate departments. Even within the classrooms, students are segmented into groups during problem based learning. The skills learnt from problem solving within a small group will be beneficial as engineering workplace in the future will be smaller. Even multinational companies have become smaller in size as they believe that innovation and creativity thrive best under incentives of smaller groups[8]. Further segmentation of the engineering education system will continue to increase.

3.7. Matching and Mismatching Parts

Engineering education revolves heavily if not solely on technical subjects. A survey that has been conducted among engineering undergraduates in Europe revealed that a third of the students want more non-technical subjects in their courses[9].

As modern engineers perform many management activities, mismatching subjects such as project management, economics, and law are not uncommonly found in engineering courses. This continuous matching of non engineering related subjects is a trend that is already happening. Even more mismatching subjects will be introduced into engineering education in the near future.

3.8. Lesser Human Involvement

The trend of less human involvement describes the lesser amount of human interaction within the system. It is also known as automation. There is a widespread trend of the replacement or supplementation of human educators with the use of multimedia computer technology[10].

Students could access entire body of knowledge and information from the internet and from online databases. Lecture classes conducted over live cameras has made distant learning possible. Learning has also been more interactive with the use of software with pre-programmed solutions for practice classes. This trend indicates that the delivery of engineering education would be more automated.

Problem based learning also requires lesser contribution from the teacher. Instead of spoon feeding the students with closed problems with known solutions through a series of lectures, teachers pick up the role as facilitators. They facilitate and encourage students to work in groups to solve open ended problems. Hence, the activity related to the acquisition of knowledge is mostly carried out by the students themselves instead of the teachers.

4. Conclusion

Through this research, it has been proven that the current trends of engineering education correlates with TRIZ's Trends of Evolution of Engineering System. In developing a more ideal engineering education course, universities could apply these evolution trends as a guide. From these trends, it has been proven that the engineering education system will continue to be more ideal, following the S-curve, more controlled, flexible and dynamic, consisting developed and non-developed parts, having continued simplification and complication, integrating matching with mismatching parts, and involving lesser human interaction.

Future works would be in the area of correlating the evolution trends with specific engineering majors. Besides that a database of current engineering education trends will be established in order to develop a more detailed prediction of future trends.

5. References

[1] Rajaratnam R., Emerging Trends in Engineering Education- Indian Perpectives. *Proc. of the 16th Australian International Education Conference*. Hobart. 2002

[2] Maul G.P., Teaching Problem Solving Skills. *Computers and Industrial Engineering*. 31: 17-20, 1996

[3] Yeoh T.S., *TRIZ-Systematic Innovation in Manufacturing*. Kuala Lumpur. First Fruits. 2009

[4] Gadd K., *TRIZ for Engineers*. London. John Wiley. 2011

[5] Ibrahim A.M., A Critical View of Current Trends in Engineering Education. *Proc. of IEEE International Symposium on Industrial Electronics*, 4: 3207-3209, 2006

[6] Sobol H. Future Directions in Engineering Education: A View From Industry and Academia. IEEE Communications Magazine. 28: 25-29, 1990

[7] Wu Y., He W., Tan J. Status, Function and Development Trend of Distance Education in the Rural Areas of China. *Proc. of International Conference on E-learning, E-Business, Enterprise Information Systems, and E-Government,* p 181-184, 2009

[8] Ernst E.W., Workplace Changes and Education Reform. *Proc. of Frontiers in Education Conference*, 1996, 2: 882-885

[9] Freitag D., Intervention Models Towards More Diversity in Engineering Education. *Proc of IEEE Global Engineering Education Conference*, 2011, p518-522

[10] Storto C.L., Engineering Management Education: Trends, Concerns, and Open Questions. Proc. of *IEEE International Engineering Management Conference, Europe: Managing Engineering, Technology and Innovation for Growth*, 2008