

# Commercialization of products and licensing of technologies from academic researches

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## Abstract

*Engineering education is facing an ever-increased challenge, i.e. the balance of teaching values and commercial interests. It has four social measures to be closely investigated; they are knowledge transfer, the output of qualified engineers, excellent research, and industrial impact. When an engineering institute executes its integrated approach for improving the social measures, a clear strategy is required. The authors would suggest an industrial research oriented education system that can effectively associate the above-mentioned measures together with an explicit and integrated model. The commercialization of products and the licensing of technologies from researches are the means to realize the values. This paper will also discuss the current international trends in engineering education, the challenges, and how the proposed approach can address them in Singapore as well as other countries.*

## 1. Introduction

Revolutionary changes, technological challenges, and economic opportunities have changed our priorities dramatically. Engineering education has to address the requirements of targeting industries for our graduating students. In the past, most efforts to reform engineering education have been developed predominantly from a university prospective, hence they were reactive to perceived shortcomings in the training of future manpower to meet the needs of extant engineering industry units that vary in size, and business nature. The frequently changing and contradictory messages from the industries are largely uncoordinated or aimed at near-term issues of the immediate concern. Generally, universities have to strategize three aspects, teaching, research and services. Most universities have realized that the design of engineering education must be industry led. On the other hand, engineering education is required to balance teaching values and commercial interests. Many constraints must be considered by universities to promote close relationships with industry partners.

This paper is aimed to address an industrial research-oriented approach, which can better integrate the efforts in the above-mentioned three aspects. In our proposed system model, there are four social measures to be closely investigated; they are knowledge transfer, qualified engineers, excellent research, and industrial impact. The effectiveness of these measures is discussed in Singapore context of social and technological expectations. The author would present our strategies that, we believe, can effectively improve the above-mentioned measures with an explicit and integrated approach.

This paper also covers our views of the current international trends and the challenges in engineering education. Examples of industrial-research projects are presented to explain the proposed approach that could be useful reference cases for Singapore as well as other countries.

## 2. Trends and challenges for engineering education

Engineering education must evolve to keep pace with mighty changes occurring today in business, industry, and society. "We live at a time when man believes himself fabulously capable of creation, but he does not know what to create [1]." The core values for Kansas State University are: teaching and learning, research, and service to the community [2]. These values are also shared in different ways by many other universities around the world. Nanyang Technological University aims at

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becoming a university with general academic excellence and niches of international eminence. Its mission is to train leaders, professionals and entrepreneurs for Singapore and the region and to advance research and development in both the academic and professional disciplines [3]. To address the new trends, four aspects are discussed in the following subsections.

## 2.1 Industry-oriented engineering teaching and research

In commercial technological enterprises, there is a value triangle among customer needs, technologies and product attributes in their management principles. Most of the successful technological leaders give the sequence as “customer needs-technologies-product attributes” [4]. For engineering education, certainly, the industries at large are our customers. Mapping from their value triangle elements, if we consider our students as products; the service to the community (or industries) as our customer needs; while teaching and learning, and research as the technologies; then, we can derive a value triangle for engineering education as shown in Figure 1. We would highlight an embedded priority sequence. Traditionally, tertiary education followed a sequence of 3-2-1, as shown in the dashed arrows, i.e. university teaching and learning, and research, determined students’ abilities, knowledge, and skills. They were then sent to their employers without systematic consolidation for their feedback. The employers had to conduct in-house training to address their specific manpower requirements.

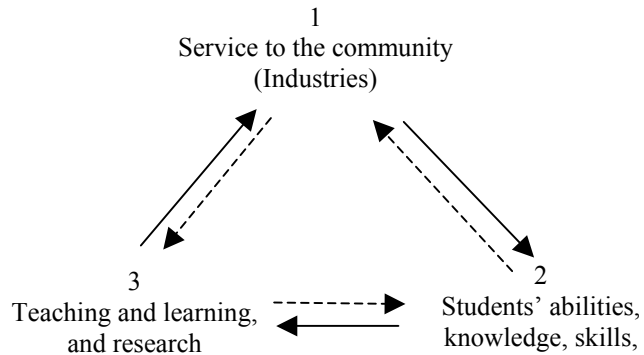


Figure 1. The value triangle for engineering education

In this paper, we propose that the sequence nowadays has to be 1-2-3, i.e. giving the top priority of consideration to the industrial requirements, emphasizing students’ capabilities, knowledge and skills with clear specifications, and finally managing teaching, learning and research activities to satisfy all the requirements. That is the reason why industrial orientation is emphasized in this paper.

In the last quarter century, technology and society exhibited two defining characteristics: 1) increasing rates of change and 2) increasing complexity as suggested by Kash and Rycroft [2, 5]. They examined the 30% most valuable exports in the global market and found that the most successful technologies have become more complex. In the 1970s, 60% of the world top exports were simple products that could be designed and manufactured through relatively simple processes and methods. However, since 1994, over 60% of the top exports has required complex design and manufacturing methods. It is these exports that generate the most wealth for a country or region in this globalization era [5]. The future economies in all countries will be based on its ability to create new and innovative technologies, and applied science. Hence, moving up along the positioning ladder from pure “teaching-oriented” to “teaching- and research-oriented” model will continue to be trendy for most of the engineering education institutions. On the other hand, engineering education has to be practice-oriented, firmly rooted in fundamentals, learning-based and integrative.

Meaningful research programmes generate new technologies and innovation ideas. Such results can only be qualified and measured by the industrial relevance and their values created through knowledge or technology transfer, enrichment of teaching curriculum and student projects developed. Directly and indirectly, students’ 11 abilities listed in ABET “Criteria 2000” [6] are enhanced. However, we, in the academy, sometimes, have focused on engineering science to the extent that we have created a profession largely taught by non-practitioners [2].

Industrial research is critical to align a university's research effort with the industrial requirements where the purposes as well as the resources are justifiable. Through industrial research, staff members and students are involved with real projects where teamwork across multi-disciplines is expected. The knowledge and experiences gained through research projects and consultancy services are then brought into the classroom where students of the university benefit as these experiences are incorporated into their courses.

## 2.2 Emphasizing on graduates' employment rate and commercial viability

It becomes common that universities must compete for resources allocated from governments and industries, and for student intakes. Generally speaking, the basic measurement of a good university is the graduates' employment rate. This situation will be increasingly alarming with the economic transition from labor-intensive model to knowledge-intensive model. From the student point of view, as mentioned in the previous section, the business products and processes are more and more complex and demanding, yet less and less job opportunities available to fresh graduates. Which university can offer a higher employment rate, the better and more students they could recruit. From the angle of government and funding sources, the better quality a university has, the more resources it may obtain. Of course, the measurement for engineering education quality can be many folds, but employment rate is too bold to be ignored.

Then, it would be interesting to discuss about the commercial viability problem that is going to be faced by majority of the universities except for a few "Big brothers". The government grants are not going to be increased if not significantly reduced. If those less developed universities do not improve the candidate's perception, they may not get enough intakes, and hence becomes difficult to operate, not even sufficiently funded for maintaining the necessary staff strength. Other sources of financial support can be social donations and industrial contributions. However, these funding sources equally look into the excellence of university quality.

The solution that could coherently add values to different aspects of engineering education is industrial research. The essential mechanism that enables such research is the close interactions between the university and industrial partners. Through such interactions, 1) student employment requirements can be anticipated; 2) research funding can be attracted, and in turn, research projects/consortiums can be formed; 3) research results can be applied; 4) university student internships can be sourced with companies' management support; 5) graduates are well accepted due to their tailored project involvement and close engagement; 6) staff members are exposed to industrial environment with insight understanding about the knowledge scope, the professional conduct, and essential skills, hence they can improve teaching development. Ideally, dedicated research institutes, which serve as the incubation centers and connection windows, are very useful.

## 2.3 Intellectual property generation and transfer

Universities must generate intellectual properties. They should be the natural outcome from their technological research and innovations. Intellectual property generation and transfer have strategic importance to manage a university because they are the counter realizing the value of intellectual efforts within the university and reflecting the levels of research strength and industrial relevance for teaching and learning. Intellectual property transfer provides a channel to apply new knowledge and engineering methods to the industry beyond the campus, and establishes vital links between faculties and those who can effectively use the results of their efforts. It is also the powerhouse for research funding generation through industrial projects.

## 2.4 Mass customization of teaching curricula

As the industry becomes more and more high-tech intensive, training with a common syllabus from a university is not sufficient for most of the new job positions. Yet the company may not have the

resources to train their novice staff via in-house training. Hence, customized education with flexible configurations will increase; let's name this model as tailored-education. The key challenge is to design the flexible configuration of teaching and learning elements such that they collectively satisfy the specific company's requirements and yet intellectually well structure without learning barriers. Since this aspect needs much more effort to elaborate, due to the space limit, it will be discussed in another separate effort in future.

### **3. Elements and relations of an industrial research oriented education system**

We believe that the key factor to success in engineering education is to enable a coherent and integrated approach, which prioritizes industrial relevance. It is important to note that it is not the university alone that must shoulder the responsibility of the applied research. Industry must also shift its role from being a customer only to being a partner in meaningful research collaborations. Industrial research projects serve as the connection channels to exchange insight views on engineering requirements and to develop rigorous problem-solving study culture.

Industrial research is interactive, non-linear and concurrent. Its practice includes basic science, engineering science or fundamentals, technologies, as well as social, economic, and political interactions. A common and yet critical process in both teaching and industrial research is scientific inquiry, an analytic, reductionism process that involves delving knowledge. Those universities, which excel at this paradigm, sustain and nurture the world's rich intellectual infrastructure. The following elements are important to establish an industry-research oriented engineering education system.

#### **3.1 Government infrastructure and support**

To enhance industrial research in a university, working closely with the government, including ministries, departments, status boards and agencies is essential, because these government bodies have the necessary infrastructure, i.e. systems, resources, and connections to kick off industrial initiatives, to spread information, and to get enterprises work together collectively. Then specific research programmes, research grants, and technological upgrading funds can be established.

Industrial associations play important roles as well. Their endorsements indicate the research alignment to the common interests and requirements of member companies. Their support is also a strong signal to member companies to follow the trendy practice. They are also very helpful to solicit the matching funds that are usually required for the government to sponsor any major research or development programme.

Continuing on the government role, agencies administrate the funds for technology upgrading, workforce skill upgrading, and research grants. The early participation of a university in the initiation phase of a funding programme means the early preparation in technological research and manpower, and in turn, it translates into an advantageous position to obtain the grants. On the other hand, matching different intellectual commercialization portfolios with the government programmes can achieve enormous impact to the industry and the maximization of the potential intellectual vales.

#### **3.2 The framework of connections among universities, research institutes and industries**

As a teaching and learning institution, directly working with industries on project basis is difficult. This is because the high demand from the industries on the complexity, time frame and practical teaming. The most successful approach is through research institutes, which have been established in several countries in the past 15 years, one of them is the Center for Engineering Education and Practice at the University of Michigan-Dearborn [7].

An industry-oriented research approach was also taken in Singapore. Under the umbrella of A\*STAR (Agency for Science, Technology and Research) [8], formerly known as the National Science and Technology Board (NSTB), there are two clusters of 12 research institutes (RIs). These RIs are sizable

with 100-300 full-time research staff members each; and over 50% of them are PhD holders. One of these RIs is SIMTech [9], the research institute in manufacturing technology. RIs in Singapore are committed to enhancing the competitiveness of Singapore's industries through the generation and application of advanced technologies. More specifically, SIMTech's role is to create intellectual capital through the generation, application and commercialization of advanced manufacturing science and technology, to train people by providing opportunities for scientists and engineers to do use-inspired research for industry. It also contributes to Singapore's industrial capital by collaborating in projects and sharing research expertise and infrastructure with the industry. Its areas of research focus include production and logistics, advanced forming and joining technology, machining technology, mechatronics, precision measurement, advanced automation and product design and development.

The connections with research institutes as well as industries are beneficial to university education in the following five folds [7]: (1) industrial relevance; (2) active collaboration with practitioners; (3) long-term technical merits; (4) impact on the curriculum; and (5) funding from external sources.

### 3.3 Flexible manpower management system

The university must have a flexible timing system for staff to perform industrial research. We have experienced conflicts of time clocking when a rigid system was in place. The top management should recognize the contributions made by industrial projects and waive the requirement of office hours in this connection. On the other hand, staff members should avoid over-committing themselves. By estimation, a ratio of 50/50 between teaching and industrial research is a good measure although many universities cannot afford so much research time for key teaching members. The system should also allow staff members take up regular time-base consultancy projects even though well-defined turnkey projects are more common.

### 3.4 Effective engagement with the industry

Conducting meetings may not be the effective way to engage the industry in the sense of intellectual exchange. Joint project team is usually necessary and industrial practitioners must be significantly involved. Typical input for industrial projects is usually not well documented and needs a lot of streamlining and analysis. Shared project documents, drawings, software codes are a few sharable formats. Teaching staff and students are beneficial to learn professional communication skills, such as producing clear and brief reports, project schedule diagrams, flow charts, software object class diagrams, etc.

### 3.5 Interdisciplinary collaboration and teamwork

Most small research projects do not need interdisciplinary work. However, in a serious project, such as software product development, or the feasibility study of a major investment, interdisciplinary collaboration becomes a must and it gives rear opportunities for teaching staff, researchers, and students to be exposed to and involved in different paradigms of thinking. Understanding the financial concerns, business feasibility measures, core competencies, as well as the technological gaps makes team members well rounded in future project planning.

### 3.6 Development of entrepreneurial culture and leadership in research and development

It was our experience that training a project leader is a quite different process from developing a researcher or a teacher. He must have a sense of over-all judgment on the team capability, the risks, the difficulties, workflow, milestones, quality and the amount of effort. It has always been more difficult to identify a project leader candidate than to recruit a researcher or teacher. He or she has to be outstanding with the right character that can be trusted by the industry, and with the right approach to lead the team. Making the team to deliver and satisfying the customer requirements within a given constraint matrix of time and budget, are similar to running an enterprise. Inevitably, the project leader has to manage manpower cost, combination of member disciplines in training, and customer relations. Further more, the methodology applied in the research project and the processes at every stage are

challenging factors for any success. The useful experience, such as consolidation of customer requirements, negotiation with customers, and the decision making for project management, provides valuable training for a future entrepreneur or a leader of an R & D organization.

### 3.7 Relations of the essential elements in industrial research

Figure 2 shows the relations among the essential elements in industrial research. A well defined project has to include the goal of research, viability of technology, time frame and industrial support, estimated cost, project team members, execution and management of project plan, and the intellectual property agreement between the parties involved based on the win-win principle. These elements are aligned with the deliverables listed by customers, i.e. industrial partners.

The expectations from different levels of an enterprise can be different. For example, the employer would like to see the feasibility of an investment, which covers technical difficulties, financial risks, supply chain support and government regulations. Such projects are usually specified as a feasibility study; and the university faculty is involved for certain specific areas, such as technical or financial feasibilities. When we look into such projects, the consultants, i.e. professors, have to be well experienced in both academic standing and industrial practices. Other than such qualifications, they are also influential to certain industry sectors due to their achievements and characters. They must be experts in presentation and human connections.

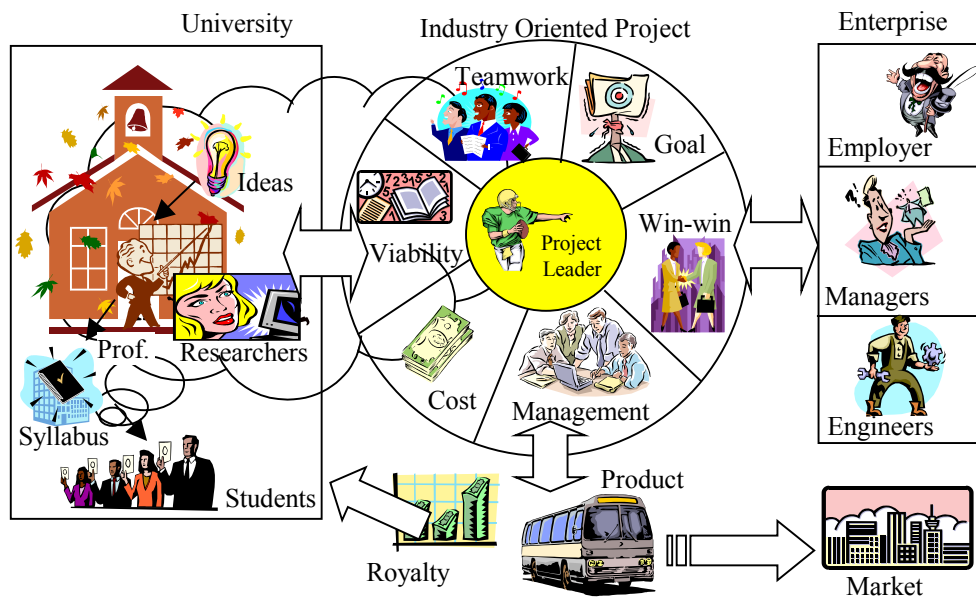


Figure 2 Relations among elements in an industry-oriented project

At the level of managers, a turnkey project is more preferred than some ideas or pieces of solutions. The nature of middle-management responsibility requires the timely completion of the project with high reliability as well as the conformation to the minimum of technical requirements. Such projects are very demanding in implementation and are not suitable for typical university professors. Instead, research institutes are well positioned to do so. They require competitive project teams. From a commercial point of view, the first a few such projects are not attractive because the technical uncertainty and possible high risks and costs involved for both manpower and other tangible resources. However, for a particular research focus, hopefully, through a few projects, the research team can generate some common methods and tools, and even a product. These results could then be condensed and wrapped up as some intellectual properties transferable in a certain period of time. Out of such intellectual properties, even though only a few will be successfully transferred, but they will make

sufficient returns, directly or indirectly, for the university to justify its input to those early stage projects.

At the level of engineers in an enterprise, the most appreciated results from collaboration with a university are processing solutions, which can either make impossible processes possible, or enhance the productivity, or improve the quality significantly. Such projects are very good for professors and usually generate good results. However, such projects are conditioned to a certain specific setup in a specific environment, and are protected by the enterprises as their know-hows. The intellectual results generated are not transferable. The best scenario for a university is to create a joint venture with the collaborator from the industry as a spin-off small business. In this way, entrepreneurship is the required quality for the project leader at the commercialization stage.

#### 4. Characteristics of research projects

Within a university, research projects create the driving momentum to renew its faculty knowledge and experience, generate new disciplines and technologies, and attract students and funding. The types of research projects can be categorized into four groups, theoretical research, application research, industrial projects and product development. A diagram is shown in Figure 3 to illustrate the characteristics of these groups in terms of three measures: manpower knowledge and intelligence, skills and experience, and cost/risk/return.

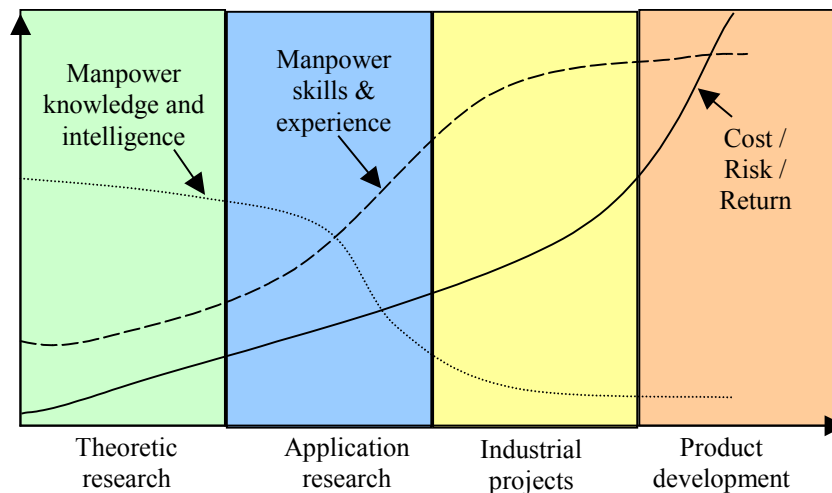


Figure 3 Types of research projects and their related characteristics

##### 4.1 Theoretic research

Traditionally, within a university, the most common motivation for research was for publications. The number of publications has been usually used as a staff performance measure. Hence, industry-oriented research was actually not emphasized. The reason can be analyzed by using the diagram shown in Figure 3.

Theoretical research can create many ideas and academic papers. The process is also well established in most universities. Professors are trained when they completed their PhD research (most professors are PhD degree holders). Such research projects have low requirements for experience and skills. They also involve less costs and risks. The key success factor is the creativeness and the intelligence of students, if not only those professors involved. However, such research projects have no immediate industrial impacts and are difficult to create transferable intellectual properties. Such research may be useful to establishing teaching excellence, and can contribute to academic society in the long run. Top

universities in advanced countries are usually comfortable to keep up theoretical research because they have been financially well-supported one way or another, and the 2nd tier universities can support their industries more closely. However, many universities in developing countries may find such research irrelevant to immediate industry needs.

## 4.2 Application research

From left to right in Figure 3, the next category of research projects are application research. Most of the universities should encourage professors to carry out research in this domain because they are essential for industrial development and for the training of R&D manpower in a country. To provide the necessary support, many governments have existing funds and specific organizations to attract projects initially for many economically critical areas, such as the biomedical research in Singapore in the past 3-4 years and the 863 high-tech research plan in China. In contrast, many developing countries do not have the resources to support such research plans. Since the projects in this category are usually well managed by governments, and are relatively traditional, this paper is not intended to address them in details.

This paper focuses on the innovative mechanism for the third and fourth categories as shown in Figure 3, i.e. industrial research projects and product development.

## 5. Nature of industrial projects and their impacts

As mentioned earlier, different industrial projects can be formulated, and we are sharing some of our experience.

### 5.1 Time-based consultancy

From time to time, enterprises go through certain re-engineering processes to upgrade their technologies and management. Professors who have the knowledge and energy to coach a company can find him demanded by small and medium enterprises because they do not have the well-trained personnel. The first author of this paper had acted as a time-based consultant for Rayco Technologies



Figure 4. Some of the precision rubber products of Rayco Technologies (courtesy to Rayco Technologies)

[10] from 1993 to 1997. The scope of work includes setting up a tool room for rubber mould manufacturing, which involved application of advanced CNC and CAD/CAM technologies, and coordinating the re-engineering processes. After the successful implementation of the tool room, the author had also been engaged to conduct workshops for company culture building and strategic planning. Even after he joined SIMTech [9], he had been given an industrial project to enhance their CAD/CAM technologies.

The experience achieved through such exposure to a real company is fully rounded. It has in fact trained the author with the in-depth understanding about industrial systems, processes, services and management. Such experience has been translated into his teaching material, such as slides and examples. Yet, the company was very happy to see their staff were coached throughout the phases of development and educated with best technical practices.

### 5.2 Turnkey consultancy projects

A typical turnkey project is started with an industrial enquiry. Then, an “on-site” visit is followed to understand more about the feasibility and the scope. Very often, the company does not know what a professor can do, hence a good technical proposal in layman’s terms is important to bid the project. Usually, the project cost is based on the estimated effort with a standard timely rate. The material and equipment costs are usually absorbed fully by the company. The challenges of such projects include:



(1) Appropriate description of technical specifications and their measurements for commission; (2) Communication and management of the design and the schedule; (3) Unexpected difficulties and consequences; (4) Exiting from the projects. The professors involved should avoid any over-statement of the expected performance or quality, and have to give sufficient margin of resources for unexpected difficulties (and such things always happen).

As to the intellectual properties, the company usually require sole-ownership of the deliverables, such as software source codes, for their specific business. However, the generic technologies, such as the methodology, or embedded tool kits, or processes developed, can be owned by the professors for future research. Usually a non-disclosure agreement for the project material is required upfront.

The first author and his colleague from Ngee Ann Polytechnic in Singapore had done a grating CAD system for ShangJing Dahe Industries, which is based in Singapore with several branches overseas. Grating is a process that builds up decks for supporting structures, such as those on a ship or a refinery facility as shown in Figure 5. Traditionally, the grating projects were carried out on-site with a rough estimation about the layout on paper. Then the design is carried out by cutting the area into layers, and panels. The design work was very tedious and error-prone considering the size of a deck and the number of panels. They couldn't consider the pipelines and other obstacles because there was no information about the overall panel layout. Hence the openings were cut on-site on standard panels.

Our CAD based design system considers obstacles when the on-site inspection is carried-out, the detailed layout and openings are planned accurately on a plane. Then grating panels are automatically generated with the consideration of obstacles, alignment, standard sizes and bundles for transport. This system has significantly reduced the on-site cutting of grating panels, hence the project period has been reduced from 3 months to 3 weeks. Other than that, the accurate design of panels has increased the efficiency of project design and management, and reduced the in-house logistic load. The company sales was boosted because of its increased competitiveness in the field, hence their market share in Singapore has gone up. The company had also used this system as its key technology investment and created several joint ventures in overseas markets. Because the company was very satisfied with the first project, they engaged our research team to carry out another phase to further develop a new version of the system. In this new phase, since the research work had been done in the first phase, only development were involved. Hence it became a easy project without any risk.



Figure 5. Grating project sites (courtesy to Shangjing Dahe Industries Pte. Ltd)

Another turnkey project that the first author supervised was to develop a scaffolding design system for refinery facilities. The industrial partner of this project was Hai Leck Engineering Pte. Ltd [11]. The team was engaged to generate 3D scaffolding structures as well as the bill of material with details of the raw material list and transport bundles.

Figure 6 shows some of the site projects designed with our software tool. Again, the project involved a team with 4 other lecturers from Ngee Ann Polytechnic in Singapore. Here, a point that can be observed is that, every generic technology excelled in an education institution, can be applied again and again for different turnkey projects. On the other hand, the idea or the generic technological solution can only be fully investigated, and in turn, excelled by the experiences of different industrial projects with a similar nature. One aspect that needs attention is that the professors who are involved to deliver turnkey projects must be supported by some contracting engineers or researchers instead of

carrying out the projects themselves. Firstly, they are too busy and too expensive to be fully employed for the projects. Secondly, they would be quickly worn out in day-to-day practical problems and hence no energy for further research. This situation can be unhealthy for an academic member in his career development. By making use a team of industrial engineers, the new technologies can be better tested in the hands of practioners and propogated into the industry.



Figure 6. Some projects carried out with a scaffolding design system developed in a turnkey project (Courtesy to Hei Leck Engineering Pte Ltd)

### 5.3 Software Commercialization

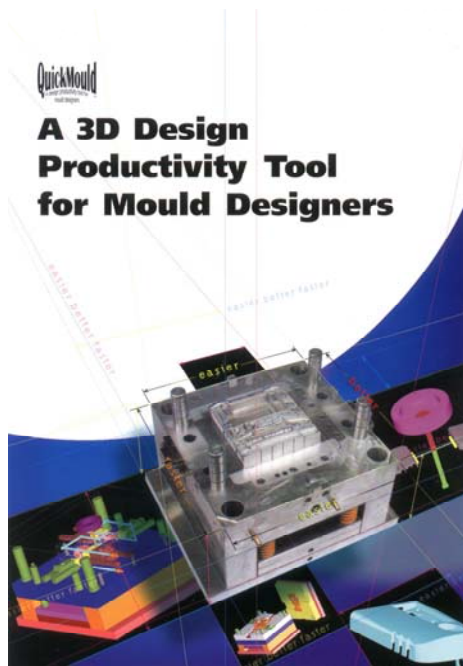


Figure 7. The QuickMould product brochure cover page (Courtesy to SIMTech and NTU)

It should be appreciated that the commercialization of intellectual properties is embedded through different forms of projects with different expected outcomes as shown in Figure 3. Among them, software product commercialization can be rather more challenging. The following aspects must be considered even at the stage of project initiation:

- Identification of industrial needs;
- Demanding project requirements;
- Transition from research to industrial development;
- Multidisciplinary team work;
- Commercial relevance evaluation;
- Business collaboration and knowledge transfer;
- Impacts to the university and the industry;
- Manpower training at different levels of the university and the industry;
- Roles to be played by professors researchers, students, and engineers;
- Industry technological upgrading – increased competitiveness;
- Monetary costs and direct returns;
- Research foundations; and
- Potential investments that can be attracted.

The authors would like to share our QuickMould project experience. The initial project idea was generated out of a final year student project supervised by Professors Tor and Britton. The student applied object-oriented technology to generate mould-base structures automatically by calling CAD Application Programming Interface (API) functions. The project was very interesting. Impressed by the outcome, Professors Tor and Britton worked out an applied research project proposal together with SIMTech, and in 1996, got funded from Singapore Inforcomm Development Authority (IDA, formerly known as the National Computer Board). With the S\$1 million funding, a development team was established in SIMTech (formerly known as Gintic [9]) with Professors Tor and Britton as the advisors [12]. Initially, the project was not running smoothly due to the poor architecture design and the team's lack of development experience. The first author was one of a team member. Then SIMTech management restructured the development team after much of the learning curve; the team was put under the first author's charge. With the new leadership, soon the team delivered the first version of prototype. Encouraged by the functions and the total strategies, SIMTech continued its support to this project and launched the product into the market, which was in November 1998 [13, 14]. Figure 7 shows the product brochure cover page for QuickMould. Figure 8 shows the report on QuickMould in Cutting Edge [14], a corporate publication by SIMTech.

Figure 8. Report on QuickMould in Cutting Edge (Courtesy to SIMTech)

Immediately after the launch, the team swiftly moved into technical support for beta testing in some companies, such as L & W Mould Pte Ltd [15] and Kojin Mould Manufacturing Pte Ltd. Positive results were obtained from the practical use of QuickMould; and enhancements were carried out. The object-oriented approach was well recognized by the software engineering profession [16] and the research institute [17]. Figure 9 show the article written on the first author [17].

The success factors reflected in this project are: (1) Core competency in new technologies; (2) Strong team bonding and leadership; (3) Effective system design and methodology; (4) Sound project management; (5) In-depth research to solve new problems; (6) Conformity to a sound methodology; and (7) A systematic quality assurance scheme.

Clearly, this project has been a big industrial project effort for a university. By estimation, the total cost for this project was about S\$4 million. The processes that the authors were involved are valuable lessons that can be referred in future projects. It is our observation that currently, a university's global standing is significantly influenced by its industrial

impact, which in turn, is measured with the successful implementation of large projects like QuickMould. It demonstrated three aspects of excellences: research and education, industrial relevance, and services to the society. More significantly, the sustainability of the momentum for industrial projects is a high standard of measure for a world-class engineering university.

## 5.4 Value realization

In the commercial world, very few universities are matching competitors to large international companies; neither are we. Soon after the launch of QuickMould, we found our deadly weak point, because QuickMould was developed on top of a commercial CAD software kernel. It means from the intellectual property point view, QuickMould is dependent to the CAD vendor, and naturally not a

viable commercial product. That was a crisis when this issue was brought up to the management of SIMTech for the first time. To salvage this product, the team negotiated with the “big brother” and finally got a “win-win” deal. The CAD vendor merged QuickMould with their new product, and team further developed the merged product in the form of a subcontract deal. Other than that, through negotiation, Singapore industry had got upgraded with the most advanced CAD solutions from the vendor in a very good price. In different ways, the potential value of QuickMould was realized partially.



Figure 9. Report by the Cutting Edge [17] (Courtesy to SIMTech)

The experience taught us the following points: before developing a commercial product, evaluate the intellectual property rights and your position, because the position will directly affect whether the potential product is viable or not. If it could be foreseen that QuickMould was not viable, the NTU-SIMTech team would have just used it as a tool kit and focus on different industrial turnkey projects. It was also nerve striking when the intellectual property issue surfaced and the business decision was not clear. Even though QuickMould product was compensated in several ways, but compared with its potential market value, the compensation was still just a fraction. One good thing was that the team had quickly developed the commercial product for the CAD vendor and earned some more revenue and reputation [18]. The conclusion is, such software product development projects are very risky; and the intellectual property rights involved have to be managed upfront.

On the other hand, there is a sub-topic to explore on the ways of compensation when an intellectual property is to be negotiated. Of course, the first

form, i.e. cash component, is the favorite. The second form can be the market share for the sales of certain products in certain territories and within a certain period. The third form is promising contracts that can generate future revenues or opportunities. The fourth component can be beneficial packages for other indirect associated business entities, such as industrial partners or an industrial cluster in a country. The compensation package for QuickMould had all these components. Seeking compensation with such multiple components requires creativeness. It would always be the last choice to go for litigations.

Finally, it has to be emphasized that upon the commercialization of a technology, the intellectual property development has reached the end of a cycle. Another cycle should be started instead of dragging further with the existing technology, because it would be a waste of resources for further improvements or redevelopment. Considering the high cost involved at the development stage, universities should be decisive to step on the brake of the “vehicle” in order to avoid further resource consumption.

## 6. Conclusions and discussion

This paper presented some findings for the necessity and approaches of industrial research in engineering education institutions and the formats for commercialization of intellectual properties generated. The characteristics of industrial projects and the challenges to deal with intellectual properties have been discussed. Together with several real cases of industrial projects, a major industrial research effort, QuickMould project, was reviewed. The overall educational, industrial and

social impacts of this project were evaluated. Finally, some discussions are presented to highlight some outstanding issues within the scope of management strategies, policies and technical aspects.

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