Design of Educational Program for Management of Market, Procurement, and Production
—Case Study of Educational Program for Factory Management in University—

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Abstract. The current production environment promotes the development of new products and the rapid production of a variety of product types by diversification of customers' needs. These phenomena lead to a production environment in which it is difficult to prevent late completion of products, reduce work in progress, and reduce finished product inventory. Given these characteristics, an education system is required for administrators of product lifecycles to flexibly manage production through a wide range of production activities: creation of product concepts, planning, work design, in-factory production control, and so on. This paper discusses the educational program for administrators of product lifecycles by focusing on the management of factories. The program is developed and applied in curriculums for undergraduate and graduate students at the Nagoya Institute of Technology. In addition, it forms part of an educational program provided to workers for administration of factories. This is part of a case study of an improvement activity (KAIZEN activity) in actual factories with foreign students. In this paper, the educational program is described, and the case study is used to evaluate the effectiveness of the program.

Keywords: Educational system, Administrator of production, Product Lifecycle management, Production management, KAIZEN activity

1. INTRODUCTION

In the current production environment, global production—that is driven by combining manufacture automation and the internet—is spreading. In global production, real time production is tried in distributed factories based on robots, internet, automatic machines, and so on (Porter et al., 2016). The production system, which includes a network of automatic machines, is mainly introduced in large enterprises with large budgets. However, it is difficult to introduce medium and small enterprises to the production system because of inadequate budgets. Ordinarily, since many medium and small enterprises are suppliers to large enterprises, we consider that a production system based on quick response and a global network is difficult to construct as part of the whole supply chain.

Although work automation systems can manufacture products based on quality (depending on the accuracy of the machines), commoditization of products would be promoted if the same automatic machines were introduced in factories globally. Since companies continuously develop, manufacture, and merchandise new products, they require the specialist who can manage the lifecycle of products in a specific product family. The specialist requires skill to investigate the requirements in the marketplace, to propose adaptive manufacturing systems, and to evaluate the cost of long-term investment.

On the other hand, medium and small enterprises require a system to manufacture high-quality parts and modules with a short lead-time to prevent the commodity values of their own products from decreasing. If the finished products are commoditized, we consider that the companies could profit from manufacturing parts and modules with high quality. Many medium and small enterprises have an advantage over other enterprises based on the high quality and unique technology of skilled workers. We therefore consider that enterprises are effective in constructing the system for additional valuable products by combining the technology of skilled workers with automatic machines. Therefore, medium and small enterprises require education from the specialist who can develop core technologies and manage production in factories based on plan, analysis, and improvement in order to continuously enhance the commodity value of own products.

Furthermore, when the specialist manages the lifecycle of products in a product family that has the same enterprises as the supplier, the commodity value of the products could be maintained in the long run, even if commoditization of finished products is enhanced.

However, since many countries face a declining birthrate, there is a shortage of skilled engineers and workers in these countries. Furthermore, companies become wary of exchanging information among different departments related to product plan, development, design, and manufacturing for the large item small volume production in future. We consider that it would be difficult for companies to develop new products, including additional commodity values in the short time.

From these discussions, we intend that companies should educate technological managers to continuously manage the lifecycle of entire products in product families in order to develop the products that include high commodity values in the long run. Since the managers require knowledge of various types of technologies, companies find it difficult to educate human resources within a short period. On the other hand, in Japanese universities, there is a large gap between real problems and theory in the current educational curriculums related to production management and quality control.

Therefore, we construct the educational program based on practical experiments using simple actual products and actual factories in order to fill a gap between the theory in the classroom and the real problems.

This educational program is composed of practical experiments for undergraduate students and the case study in the actual factories for graduate students. The practical experiments include process design, work design, layout planning, and product design using actual products. The case study is an improvement activity (KAIZEN activity) in the actual factories.

In this paper, we focus on the educational program for the KAIZEN activity. We explain the contents of the practical experiments of process design, work design, and layout planning, and show the case study of KAIZEN activities in actual factories. In addition, we discuss the effectiveness of the educational program.

2. THE REQUIREMENTS FOR PRODUCT LIFECYCLE MANAGEMENT

As shown in the previous chapter, we consider that companies require management of the entire product lifecycle in product families in order to enhance commodity values of its own products in the long run. Furthermore, in order to continuously manage new product development activities, companies should prepare the specialists who manage strategic technology development and marketing analysis from a long-term perspective. Hereafter, we call the specialist "Product Lifecycle Manager."

In the process of continuous development of new products in product families, companies should enhance the diversification of products and continuously develop core technology to enhance the commodity value of new products under the condition of diversification of marketplace requirements (Arakawa, 2014). Figure 1 shows the concept of commodity value enhancement of new products. Figure 2 shows the schematic diagram of strategic treatments of new product parts and modules.

The commodity value of product parts and modules is mainly evaluated by its technology. Parts and modules that have high commodity value and are difficult to imitate should be developed continuously to enhance the commodity value based on the core technology (see Figure 1).

On the other hand, parts and modules that are manufactured by common technology and that are easy to imitate can effectively be exchanged with common and low price parts and modules in order to reduce the finished product manufacturing cost (see Figure 2).

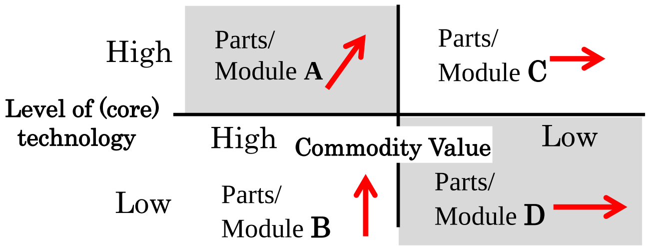

Figure 1: The concept to enhance commodity value of new products in the long run

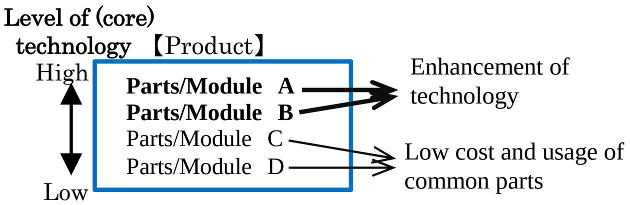

Figure 2: Schematic diagram of relationship of parts and modules in the proposed strategy

If new products are designed by combining their own high technology parts and modules with common parts and modules in the product design process, diversification of products could be adapted to the characteristics of different market segmentations. We expect that this product strategy can easily promote design and manufacturing processes for the development of global products. Therefore, the following skills and abilities are required to manage this product strategy in the long run:

> Skill to analyze marketplace requirements,

> Ability to predict effective technology in future,

> Ability to modify the manufacturing activity

Figure 3 is a schematic diagram of the relationship of the structure of products and manufacture/process design for global products; parts and modules manufactured by different levels of technology are indicated. In order to learn, the Product Lifecycle manager requires knowledge of product design technology as well as knowledge to manage manufacturing.

In our university, although the educational program of management of manufacturing enterprises is prepared for undergraduate students, an overview of management is explained in many classes. However, these classes are not sufficiently practical. On the other hand, since management methods are company-specific, many companies tend to consider that students could develop their product manager skills after they start to work. The importance of managing the product lifecycle is inadequately discussed in the academic area in Japan.

In order to resolve the problem, we introduce the educational program for process design and work design using actual products for undergraduate students in the Department of Industrial Management in our university (Nagoya Institute of Technology: NIT). In addition, in the curriculum for master degree candidates in the graduate school, graduate students participate in the case study for the KAIZEN activity in the actual factories. This case study is provided in the educational program to educate factory administrator candidates in actual factories. Through this continuous educational program, students are expected to fill a gap between the theory and the actual problems of product design and construction of process. Fifty undergraduate students participate in this curriculum; however, the number of graduate students is limited to approximately 10.

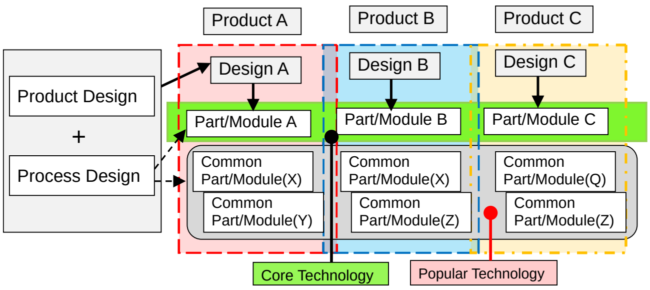

Figure 3: Strategy for development of parts and modules in the development of various types of products

2. PRACTICE EXPERIMENT

3. 3.1 The problems of the class in which the practice experiment is introduced

We supply practical experiments of process design and work design in a production management class in the undergraduate curriculum at NIT. On the other hand, in a production management class, the following theory is mainly explained: production control, production planning, inventory management, and so on.

Although the students watch videos of actual factories to study the theory of production management in this class, they find it difficult to understand the activity in actual factories. In fact, many students find it difficult to construct the correct mathematical model of the actual problems. Therefore, we introduce the practical experiment using actual products for undergraduate students to fill a gap between the problem treated in the theory and the problem in the actual factories.

3.2 Educational design of the practical experiment

The practical experiment related to process design and work design is included in the curriculum for second year students. This class is held for 1.5 hours per week over a ten-week period.

In this class, we expect that students would understand usage of the theory and apply the skill to resolve the real problem through the following activities, using the actual products:
(a) Group discussion to resolve the problem,
(b) Competition among groups for motivation to tackle the practice experiment,
(c) Analysis of the results and generation of ideas to resolve the problem,
(d) Presentation to show conclusion of the result.

Table 1 shows the contents of the experiment for each week. The experiment consists of Phase 1 and Phase 2.

In Phase 1, five or six students form a group for the first six-week period; process design and work design related to the work of multiple manipulations are performed by each group. The student's skill with respect to reduction of completion time of products is enhanced. In this phase, work operation time is predetermined by using the Methods-Time Measurement (MTM) method (Sellie, 1991), and the Bill of Materials (BOM) (Ostwald, 1991) is constructed from the parts of the product.

In Phase 2, approximately 20 students form a group for the following seven weeks; the process design of work manipulation assuming mass production is performed by each group.

In both phases, the groups compete to reduce the completion time of multiple products. Here, they discuss ideas to reduce time by modifying assembly methods, parts locations, and the process line. Each group assembles four and 12 products in the competitions of Phases 1 and 2, respectively.

The product used in the practice experiment is Mindstorm (9797, LEGO Ltd.), shown in Figure 4. There are 46 different part types and 94 parts in total. The total number of work elements is 110 when the assembly process of a single part is regarded as a single work element.

Table 1: The curriculum of the practical experiment for undergraduate students

Week	Contents
Phase 1：Process design and work design related to multiple manipulations	
1	(1) Explanation of BOM (2) Construction of BOM of the finished product
2	(1) Explanation of work representation and estimation of operation time by using MTM (2) Practice of work representation and estimation of operation time by using MTM (3) Practice of work design
3	(1) Explanation of conventional process design (2) Practice of process design and measurement of assembly time (3) Practice of assembly process (Determination of operation order and comparison of the measured operation time)
4	Practice of assembly process for competition among groups
5	【Competition】Practice of assembly process
6	【Presentation】Summary, evaluation, and proposal of improvement of process line
Phase 2：Process design of work manipulation assuming mass production	
7	Practice of process design including work design and estimation of operation time by using data obtained in Phase 1
8	Construction of process line and improvement of work assigned to the students to enhance productivity
9	Practice of assembly process for competition among groups and improvement of the work
10	【Competition】Practice of assembly process

In the first three weeks, the students generate the BOM, analyze works by MTM method, and predetermine the operation time of the work elements by the same method. Then, they generate line balancing by assigning works to workers. In this experiment, the students compare the predetermined operation time with the measured operation time, and they discuss the problem included in the actual assembly process as well as the accuracy of the predetermined operation time. In addition, the students assign the work elements to the appropriate students from the measured operation time. The competition is performed after training of the assembly process. Finally, the presentation on the explanation of the structure of the BOM, the motion analysis by MTM, and the analysis of the experiment results is given by each group.

In Phase 2, the production line resembling mass production is constructed by many students. The students modify the process design for reduction of cycle time. In addition, a number of the students estimate the productivity of the process line and the total cost required for various types of management by using simulation software.

Figure 4: The finished product used in the experiment

3.3 The result of the practice experiment

Figure 5 shows a picture of the competition performed under the mass production assumed in Phase 2. This group constructs a parallel process line composed of two linear process lines.

Figures 6, 7, and 8 show the structure of the parts of the product using pictures, e-BOM (engineering-BOM), and m-BOM (manufacturing-BOM), and the Gantt chart of the designed process line including operation time estimated by the MTM method in the report submitted by this group. These figures show the results obtained from the actual operations. In addition, they discussed the improvement plan from the results of the competition and presented ideas to enhance the productivity of their process line.

Samples of process designs and work designs obtained in the competitions in Phase 1 and 2 are as follows:

(1) Continuous works and similar works are located nearby each other in order to reduce the idle time of each student. In this layout of works, when the operation of a student is delayed, different students can support the delayed student. Here, all students are trained to handle more than two different works.

(2) In the final work center, the small number of work elements are gathered and assigned to multiple students. The gathered works are easy for students to do by gathering the small number of work elements. Furthermore, the students are assigned to the work centers for the pre-process move at the final work center after they have finished their own works.

(3) The adhesive tape, the adhesive surface of which is upward, is attached on the desk. The parts are vertically located on the tapes to easily pick up the parts shown in Figure 9.

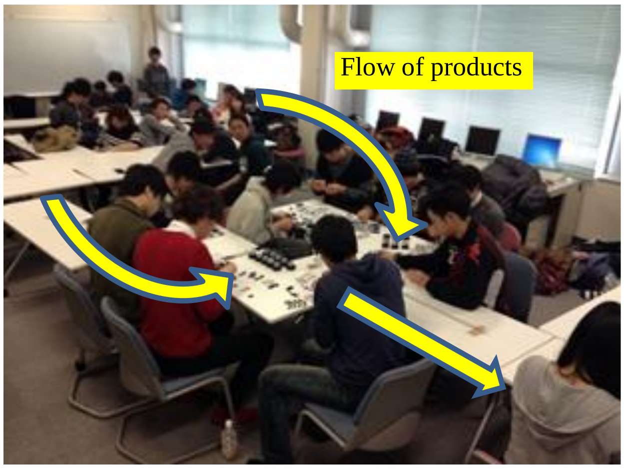

Figure 5: A picture of the competition performed under the mass production process assumed in Phase 2 (flow layout of the production line)

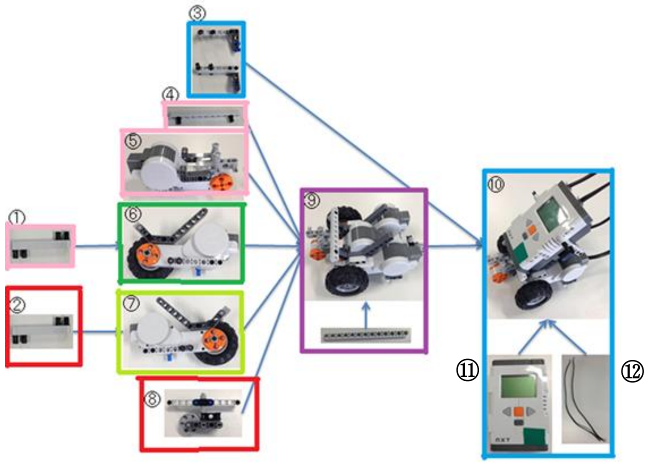

Figure 6: Construction of parts of the finished product shown in the submitted report

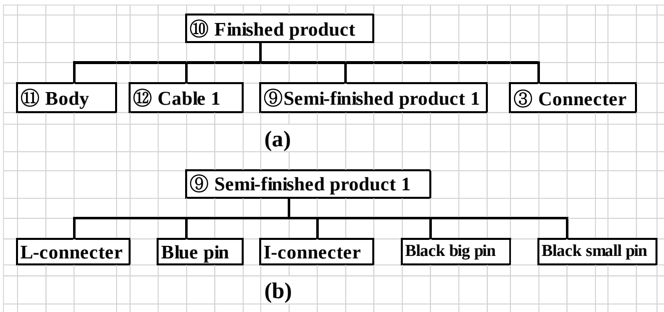

Figure 7: A section of the BOM structure drawn in the submitted report (A part of BOM structure)

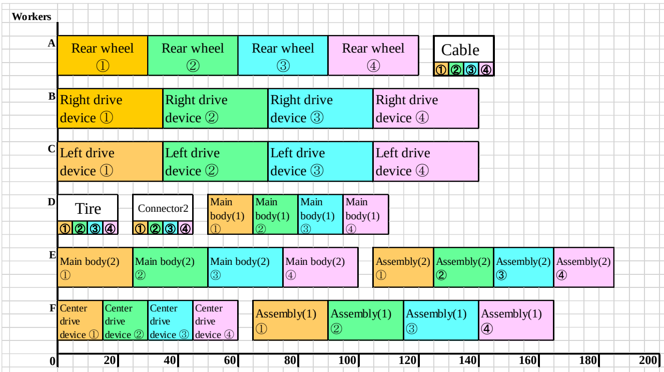

Figure 8: Gantt chart related to workers using the pre-determined operation time in the submitted report

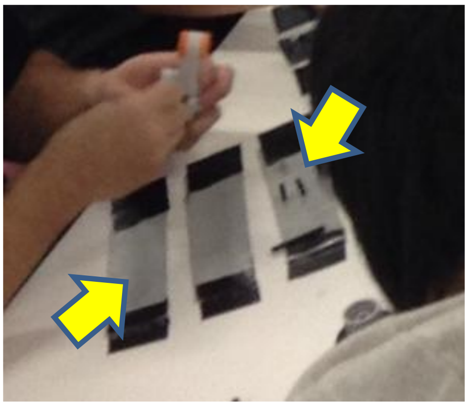

Figure 9: A picture of a sample of specific work design (The parts are vertically located on the adhesive surface of the tapes to easily insert the parts.)

3.4 The questionnaire survey

We distributed the survey questionnaire to all undergraduate students after they have finished the practical experiment in 2015; it was answered by 40 students. Each question is evaluated against five levels by the students. Here, five is the best evaluation and one is the worst evaluation. The questionnaire consists of five questions, as follows:

Questions

Q1: I came to be interested in process design and work design from the experiment.

Q2: I got knowledge of process design and work design from the experiment.

Q3: I understood the process line requirement of the KAIZEN activity from the experiment.

Q4: the group work is more useful to resolve the problem than the work done by oneself.

Q5: I came to be interested in the actual problem in the manufacturing industry from the experiment.

Figure 10 shows the results of the questionnaire survey. The bars denote the average of the evaluated levels obtained from all students. The error bars denote the standard deviation of all evaluated levels. This figure denotes that almost all students have favorable opinions at Q1, Q2, Q3, and Q4. Especially, the value of the bar is high at Q3. We consider that it is valuable that students are conscious of the requirement of the KAIZEN activity in process line.

However, we consider that the result of Q5 denotes that the students are not motivated to work in the factories, since the students find it difficult to imagine the activity in actual factories from lack of their experience. Although the educational program requires improvement to resolve the problem of Q5, we think that this educational system could be constructed so that the students easily understand the various activities in actual factories and fill a gap between the theory and the actual problems.

In the practice experiment, we did not impose the students the paper test. We are difficult to evaluate the level of knowledge which the students obtained in the experiment. However, the purpose of the experiments is a training of practical and technical operations for process design, work design, allocation of works to workers, and so on. In the reports they have submitted, the original facilities layout, the original assignments of works to workers, and the original ideas to resolve issues appeared in the process line were described. Therefore, we could evaluate that the practice experiment is effective for students to obtain technical knowledge for these designs from the reports.

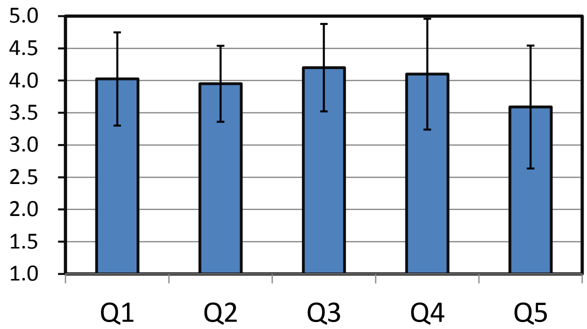

Figure 10: The result of the questionnaire survey

4. CASE STUDY FOR KAIZEN ACTIVITY

4.1 Educational system for graduate students

During the spring educational period of the master candidate curriculum in the graduate school, we teach the methods for improvement of the process line and the development method of the information system. The class consists of the lecture and the practical experiment related to contents (1) and (2) below. We explain the special and practical knowledge related to production management in this class.

(1) A lecture on the analysis method and the improvement method of the process line,

(2) Development of the database system based on e-BOM and m-BOM.

In content (1), the following methods are taught by using samples:

> 5S and reduction of useless works and motions,

> Construction and management of the Push-Pull production line,

> Control method of inventory using Kanban,

> Control of the process line based on the Theory of Constraints.

In content (2), the BOM database is designed and implemented for the management of production information. The graduate students learn the relationship between the parts structures of products and the manufacturing information from the design and implementation of the BOM database. Then, they develop the database information system based on the Object Oriented Development method.

The students can learn the basic knowledge to design and implement information from this curriculum.

4.2 Case study for education of factory administrator

The graduate students participate in the case study of analysis and improvement of the process line in the actual factories during the autumn educational period in the same year. NIT supplies the curriculum to educate the candidates for the factory director of small and medium-sized enterprises in the Tokai area in Japan (Nagoya Institute of Technology, 2016). This curriculum is supported by the professors of NIT and veteran persons with experience in Denso Corporation or Toyota Industries Corporation. This case study forms part of the curriculum. Therefore, the graduate students have the opportunity to tackle the actual problems in the factories with the candidates in the case study.

Figure 11 shows the relationship between the curriculum for the students and the case study. Figure 12 shows the relationship between different types of participants in the case study.

In the case study, a group is constructed of four candidates, a student, and a foreign student. They perform the KAIZEN activity in the actual factory of each company. A single veteran person participates as a tutor in the group and educates them through the discussion.

Although a method of improvement of the factories depends on the tutor, he performs in the order of the process of analysis of the factory, proposition of improvement ideas, analysis of the improvement ideas, and determination of priority of the ideas, realization of the selected ideas, and evaluation of the results of the ideas.

By this process, the students can develop the skill to analyze the problems and knowledge to improve the process line in the actual factories. Especially, we consider that it is significant experience for the students to propose ideas for improvement and to realize the idea through group discussion.

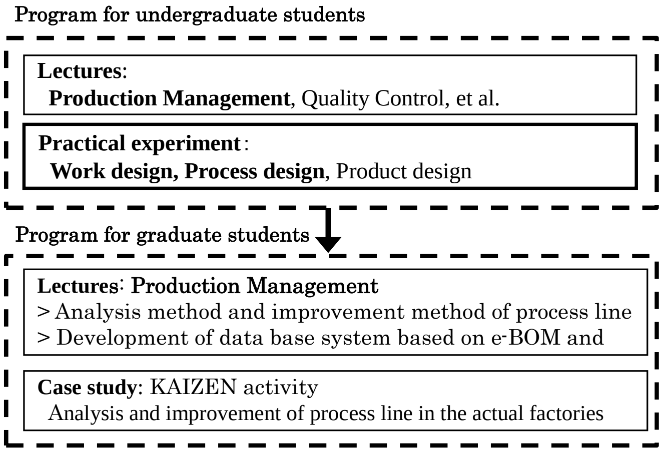

Figure 11: Educational program to study knowledge of production management and product lifecycle by using the theory and the actual problems

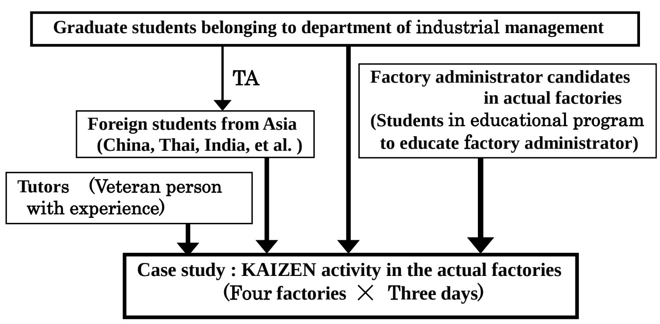

Figure 12: Relationship of participants of the case study in the actual factories

5. CONCLUSION

The current production environment promotes the development of new products and the production of various types of products in short periods by diversification of customers' needs. Companies should educate technological managers to continuously manage the lifecycle of entire products in the product family in order to develop the products in the long run, including high commodity values. In Japanese universities, since there is a large gap between the real problems and the theory in the current educational curriculums related to production management, it is difficult for the students to train technological managers to continuously manage the lifecycle of products.

Therefore, we construct the educational program based on practical experiments using simple actual products and actual factories in order to fill the gap. This educational program is composed of practical experiments for undergraduate students and a case study in the actual factories for graduate students.

This paper explains the contents of the educational program and analyzes the effectiveness of education from the result of a questionnaire survey.

In future, this educational program is developed by including product design. A method to easily perform decision making for product design is developed, to effectively and efficiently design new products from the views of Goods Dominant Logic and Service Dominant Logic. Methods could be incorporated into the education program, and the developed program could be performed for the students to educate Product Lifecycle manager.

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REFERENCES

Arakawa, M. (2014) A Framework of Integrated PLM System for International Production Strategy and Production Development, 1*st East Asia Workshop on Industrial Engineering (EAWIE), Hiroshima, Japan*, SU22-3 (USB).

Nagoya Institute of Technology (2016), Plant Manager Training School, *http://kojocho-juku.web.nitech.ac.jp/*, (Accessed 2016/06/27) (in Japanese).

Ostwald, P.F. (1991), Cost Estimating, *Handbook of Industrial Engineering (2nd Ed.) Salvendy, G. (Ed.)*, Wiley Interscience, 1263-1288.

Porter, M.E., Heppelmann, J.E., Ariga, Y. (Trans.) (2016) How Smart, Connected Products Are Transforming Companies, Diamond Harvard Business Review, 2-27, (in Japanese).

Sellie, C.N. (1991), Predetermined motion—Time Systems and the Development and Use of Standard Data, *Handbook of Industrial Engineering (2nd Ed.) Salvendy, G. (Ed.)*, Wiley Interscience, 1639-1698.