

# Development of Training Method and New Materials for Novice Designers (Aiming at development of design ideas)

**Shigeo HIRANO\*<sup>1,2</sup>, Susumu KISE\*<sup>2</sup>, Sozo SEKIGUCHI\*<sup>2</sup>  
Kazuya OKUSAKA\*<sup>2</sup> and Tsutomu ARAKI\*<sup>3</sup>**

- \*1 Professor emeritus, Tokyo City University  
3-44-5 Isobe, Mihama-ku, Chiba-city 261-0012, JAPAN  
rs4775hirano@ybb.ne.jp
- \*2 Artner Co. Ltd, JAPAN  
2F Sumitomonakanoshimabiru,3-2-18 Nakanosima, Kita-ku  
Osaka-city 530-0005, JAPAN  
kise@artner.co.jp
- \*3 Professor emeritus, Tsukuba University of Technology  
5-444-26 Aioi, Kiryu-city, Gunma, 376-0011, JAPAN  
tutaraki@yahoo.co.jp

## Abstract

The following were revealed through technical education for young designers and new employees. (1) They have a broad range of engineering knowledge but lack true fundamental knowledge. (2) They are unable to construct mechanisms. Knowledge on element design alone is insufficient for creating effective designs. To increase the degree of perfection of designs created by novice designers, technical textbooks in each specialized area are used. For the purpose of developing training methods and new materials for novice designers, we produced training materials based on a book entitled “*Mechanism no Jiten*” (Encyclopedia of Mechanisms), which is a fundamental textbook on mechanics. The original 2D drawings in the textbook were mainly replaced with 3D drawings so that trainee designers can easily understand how mechanisms work and the relationship between constituent parts. In this article, the following are explained. (1) The improvement of technical skills through the acquisition of three-dimensional modeling skills (design = determination of shape = reduction of ambiguity and shape formation). (2) The development of training materials used to clarify the relationship between two- and three-dimensional shapes in mechanics. (3) The external evaluation of the feasibility of our training materials by people in charge of providing technical training to new employees of 20 external companies.

**Keywords:** drawing reading comprehension, technological folklore, design technique and know-how, technical skills, human skills, encyclopedia of mechanisms

## 1. INTRODUCTION

The following were revealed through technical education for young designers and new employees. (1) They have a broad range of engineering knowledge but lack true fundamental knowledge. (2) They are unable to construct mechanisms. Knowledge on element design alone is insufficient for creating effective designs.

Regardless of the product, its structure becomes increasingly complex as the number of functions increases. Technologies from different fields are combined in many aspects of a product, and the integration of such factors raises the complexity of the entire product. The difficulty of design increases exponentially with the complexity of the structure, resulting in a low probability of success. Under such circumstances, the ability to comprehend design contents is required. This ability includes, for example, skills for determining whether (1) the overall composition is appropriate and (2) the integrity of components is ensured. Designers should be able to comprehend design contents

from various perspectives. Otherwise, high-quality design cannot be maintained. To this end, we should improve creativity and design skills. To increase the degree of perfection of designs created by novice designers, technical textbooks in each specialized area are used.

For the purpose of developing training methods and new materials for novice designers, we produced training materials based on a book entitled “*Mechanism no Jiten*” (Encyclopedia of Mechanisms), which is a fundamental textbook on mechanics. The original 2D drawings in the textbook were mainly replaced with 3D drawings so that trainee designers can easily understand how mechanisms work and the relationship between constituent parts.

In this article, the following are explained.

- (1) The improvement of technical skills through the acquisition of three-dimensional modeling skills (design = determination of shape = reduction of ambiguity and shape formation).
- (2) The development of training materials used to clarify the relationship between two- and three-dimensional shapes in mechanics.
- (3) The external evaluation of the feasibility of our training materials by people in charge of providing technical training to new employees of 20 external companies.

## 2. TECHNICAL SKILLS & HUMAN SKILLS

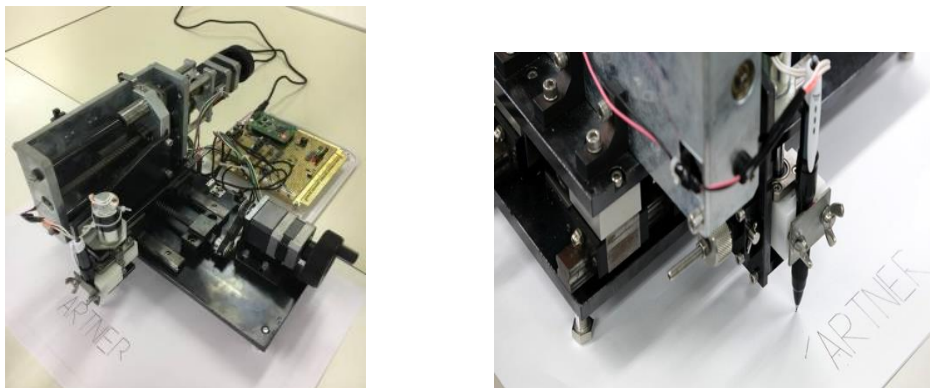
### 2.1 Technical skills[1]

While providing technical training to new employees, we found that, for example, young machine designers have little experience in reading, writing, drawing, and comprehending drawings. To come up with an answer, they first run a computer search, then retrieve and copy and paste the information. As a result, their answer is correct but some of them are not able to explain the reason for their answer.

It is said that in the near future, optimal design will be achieved simply by inputting design conditions and parameters to a designing system. Although this may be the trend of technology today, if unlimited wisdom of people can be brought forth through thinking and struggling, then creating ideas and visualizing them in rough sketches are the essence of the design process. Without taking these steps, machine design skills will not be improved.

It requires some ingenuity to turn a knowledge-oriented mindset, which has the above characteristics, into a hands-on mindset. To this end, we developed training materials to make new employees experience an ordinary workflow of observing, thinking, deciding, and yielding output on their own responsibility.

One of the training materials is a practical exercise used for mechanical education, called the “disassembly” of a calligraphy machine named Fude-R (Fig. 1). The structure of this machine has three axes, X, Y, and Z. The X- and Y-axes are equipped with a stepping motor and a ball screw driving device, while the Z-axis is equipped with a push-pull solenoid. The task for new employees is to create freehand drawings of parts from the assembly drawings of the calligraphy machine and the machine itself.



**Fig. 1 Calligraphy machine named Fude-R**

This is a common task in mechanical courses, and “comprehending and creating drawings” is one of the fundamental design skills. Namely, new employees must recognize the shape from the drawings and convert the information received through the eyes into freehand drawings.

To create drawings, it is necessary to fully understand the mechanism. A vague understanding is not sufficient. If one knows mechanical drawing techniques but is not able to comprehend and create drawings, it is like knowing the structure of a bicycle but not being able to ride it. The knowledge obtained through memory-based learning alone is insufficient to find solutions..

People gain a feeling of accomplishment when they find a reasonable solution to a problem on their own, which gives them some confidence and a sense of fulfillment. It serves as a stepping stone to the next step. This is what we aim to achieve in this training.

The lecture method has also been well considered. New employees are given documents in which some parts, marked in red, have been modified to be incorrect. They are also informed of the type and number of such modifications. They are given only hints, not the exact answers, to encourage them to solve the problems by themselves.

This style of education requires persistence on the part of both the instructors and the new employees.

## **2.2 Human skills[1]**

Our company carries out a character evaluation of new employees on the basis of documents after they join our company so that we can offer training programs suited to the characteristics of each employee. The human skills classified by various traits are quantified, and the trend of the human skills of each new employee is examined on the basis of the results of character evaluation over the last five years. The traits of new employees are analyzed by our original method through (1) a digital analysis carried out before they joined our company, using an equation representing the trend and (2) an analog analysis through interview after they joined our company. The data obtained will be useful for encouraging them to develop a sense of being an integral member of society as they transition from a free-living student to a productive adult.

The training of new employees is carried out under the premise of an employment relationship. Under the employment relationship, there is a certain coercive force applied by the instructors and there is a risk that they may give advice to new employees on the basis of their personal views and likes and dislikes. Viewing new employees as people who will come to play leading roles in the company with a sense of coexistence will create a relationship of mutual trust. Therefore, it is no exaggeration to say that the most important factor in the growth of the skills of new employees is the way instructors interact with new employees.

As we interact with many new employees, we find that there are factors that may inhibit the growth of their skills. We need to motivate them to overcome these factors while preserving their self-esteem and nurturing their self-awareness. The instructors should be conscious of encouraging new employees while giving them technical advice.

One of the traits of new employees is that they worry about how they are evaluated by others. This may be because they have been told by people around them “do not do this because it is dangerous” since they were children. We call this type of education “do not do this” education. No parents allow their children to play until they get hurt. I feel this is one of the negative effects of a risk society.

Fundamentally, people are active and interested in things around them and learn new techniques while confirming their effectiveness. Although they may meet with occasional failures, such incidents serve as valuable growth experiences. In other words, experiences obtained through autonomous venture and activities are required. I feel that recent new employees have few such experiences.

The basic skills required for members of society are “the strength to take initiative (action)”, “the ability to think (thinking)”, and “the ability to work in a team (teamwork)” as defined by the Ministry of Economy, Trade and Industry. These are also the fundamental skills required when people work cooperatively with others in a local community and

one's workplace. In more detail, these skills are the abilities to (1) step forward and make steady efforts even after failures, (2) pose questions and think things through, and (3) cooperate with various people to achieve goals.

The reason behind the proposal of these three skills by the Ministry is simply that young members of society lack them. When their tendency is expressed by the opposite of the above abilities, they do not make judgements or act by themselves for fear of failure, are not interested in various phenomena, rely on others, and act only within their personal. Although this is an extreme expression, new employees have this tendency.

Instructors in our company have long considered that new employees should be educated by company staff because they can give appropriate advice to new employees on the basis of their long experience working as engineers, the failures they have encountered, and the methods they adopted to overcome these failures. The effects of training are quantified in the form of an evaluation of new employees by customers several months after training. The quantified effects are also used as feedback to improve the contents of training. Our abilities to evaluate the traits of new employees and train them properly have evolved as a result of continuous feedback.

To improve the human skills of new employees, we have developed the following tools and methods through the training carried out over the last ten years: (1) human skills evaluation table, (2) recognize → plan → do → check → act (RPDCA) table, (3) table for simulation of a meeting with customers, and (4) group discussion.

The RPDCA table used to improve human skills is explained here. The basic concept behind this is to continuously improve business processes by repeating the cycle of plan → do → check → act (PDCA). We add R for recognition at the beginning of PDCA. The point of the RPDCA table is to identify one's shortcomings that should be improved through self-analysis and write down these shortcomings. Next, one should plan the improvement method, act voluntarily, and manage the progress of improvement, hence achieving self-reform by drawing out the inner power to overcome these weaknesses. However, people generally do not want to recognize one's flaws or cannot find the clues for improvement even when they recognize the flaws. Therefore, the RPDCA table can be used as a tool for self-reform using an appropriate combination of a change in consciousness and the desire for improvement in their daily activities.

At heart, people want to recognize their weak points and overcome them, even though they grapple with the difficulty of doing so.

### 3. "Encyclopedia of Mechanisms" ("*Mechanism no Jiten*")

A book entitled *Mechanism no Jiten* ("Encyclopedia of Mechanisms", edited by Shigeru Ito) was revised and published as a compact edition, *Shinpen: Kikaino Moto* ("New Edition: Element of Machines"), published by Rikogakusya Publishing Co., Ltd., in 1983.

The preface from the book is cited here. "Recent development of machine industry in Japan has been remarkable; in particular, the advancement of robots in Japan has been attracting the attention of many countries. Robots are assembled by combining several mechanisms. In this sense, the mechanism of robots is closely related to the contents of this book. Many demanding tasks, such as long-term continuous work requiring high precision and work that may cause harm to human bodies, are frequently carried out by robots these days. We hope that this "Encyclopedia of Mechanisms" will serve as the bible for students in the mechanical engineering department and for engineers, as well as for those who want to be inventors".

The book is a great book read by many engineers and students and is currently published by Ohmsha, Ltd [2].

We have developed training materials that help young designers understand how mechanisms work. The training materials are based on a book entitled "*Mechanism no Jiten* (Encyclopedia of Mechanisms)" with all the original 2D drawings in the book having been replaced with 3D drawings. Figures 2–8 show some of them [3].

The evaluation of drawings is based on whether a product that meets the requirements can be manufactured from the drawings. Drawings are considered to be acceptable if young designers or new employees have defined the tolerance, surface texture, and surface treatment on the basis of their own reasoning. The key is whether their

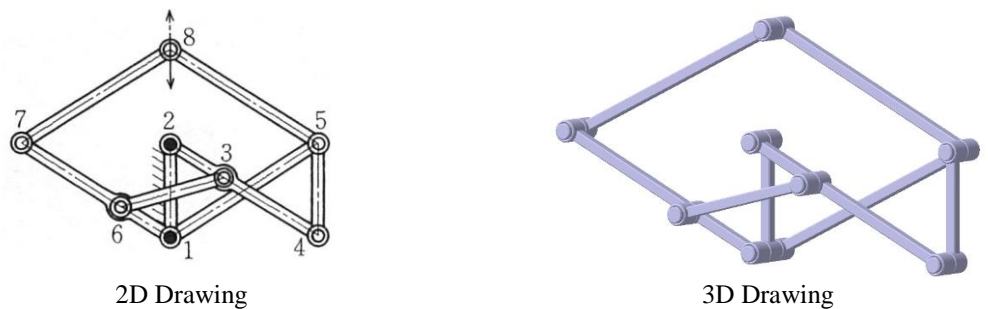
intention is conveyed in the drawings. When they give an answer but are unable to explain the reasoning behind their answer, their understanding is insufficient.

The outcomes of using the training materials are as follows.

- 1) Young designers understand design procedures (total flowchart).
- 2) They experience the problem resolution process (concept design and rough sketches) keeping in mind that their design directly affects the manufacturing process (design = manufacturing).
- 3) They understand mechanisms on their own (solids and projection drawings).
- 4) They become able to choose appropriate materials (examples of application of new materials).
- 5) They become able to devise machining methods (how to manufacture products).
- 6) They become able to design existing instruments.

We are still at the trial stage and have achieved no noteworthy outcomes. However, the questionnaire survey conducted after the training indicates positive changes in how young designers approach a design process and a design object.

For example, the following comment was given in the opinion column on the submitted answer sheet: “All manufacturing processes or some of them, such as the examination of structure, the determination of shape and dimensions, the analysis for functional verification, the realization of a shape by controlling the machine tools, and the evaluation of the deliverable, can be reflected in the model. Now I clearly see the connection between the processes through a 3D environment, although they previously showed little correlation.”



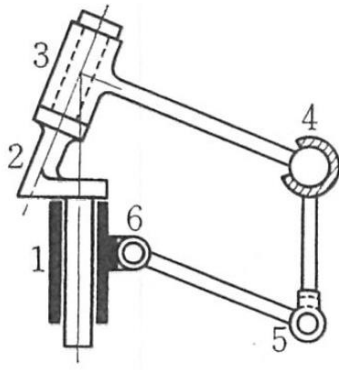
**Figure 2: Ito's parallel movement**



**Figure 3: Transformation of four clause organization**



**Figure 4: Sou return organization**

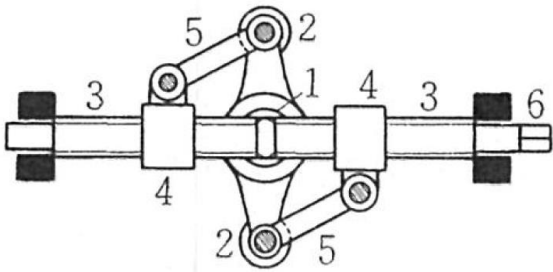


2D Drawing

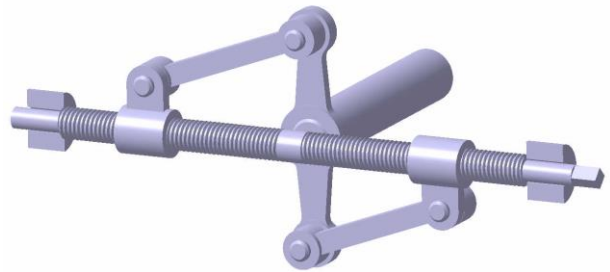


3D Drawing

**Figure 5: Solid mechanism of a crank**

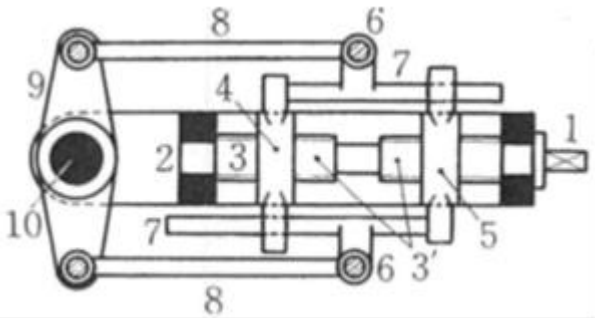


2D Drawing

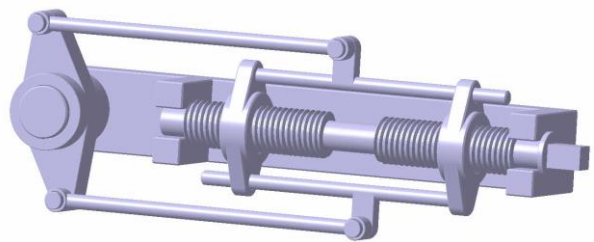


3D Drawing

**Figure 6: Steering equipment**

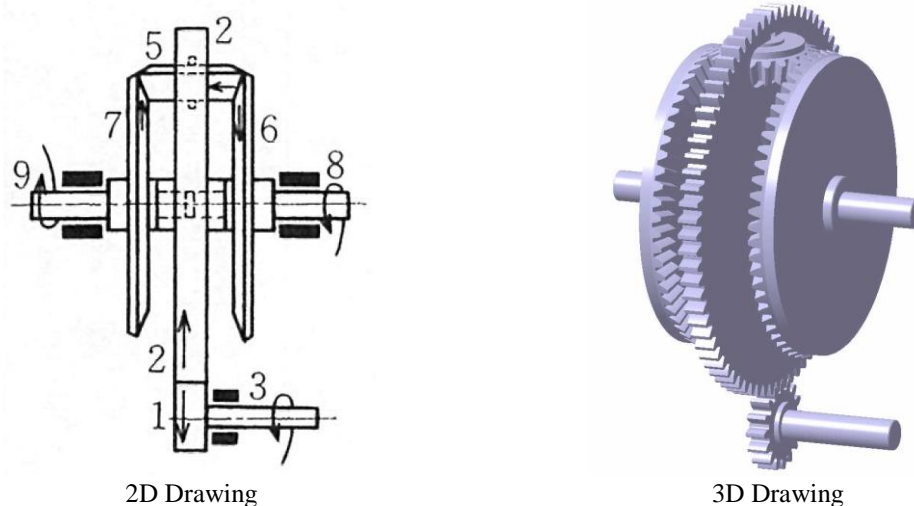


2D Drawing



3D Drawing

**Figure 7: Hitchcock coupler**



**Figure 8: Differential gearing**

#### **4. Design mind and cultivation of human resources**

Children these days tend to have little interest or knowledge in science and technology, and more and more students are turning to studies other than the sciences. As a result, the number of students who wish to study design development has been decreasing. Talking to students, my impression is that the number of students who show interest in the word “design” is decreasing.

Drawing on my long experience with designing, I take every opportunity to convey, from the aspects of the joy, spirit, and required training of designing, how interesting designing is to new employees as follows.

○ Designing is interesting

1. There is joy in realizing something for the first time
2. There is joy in expressing one’s own knowledge, experience, and idea as a concrete shape
3. There is joy in contributing to society using manufacturing technology

○ Abilities required for designing

1. Rich observation skills to understand the shape and mechanism of products on the basis of interest in the products
2. Power to generate new ideas to create shapes limited only by sensibility and imagination
3. Ability to decide the shape of products as a designer on the basis of a wealth of experience and theoretical background data

○ Designing needs training

1. Training through learning by mimicking what exists in nature
2. Training by putting ideas to paper
3. Training by actively incorporating culture and the knowledge of different fields

There is no definitive method of cultivating human resources. We believe that training methods should be continuously improved. People grow up in various environments and are educated differently. Therefore, each new employee has different abilities and characteristics. In the actual workplace, sudden changes to adapt to the dynamic environment may be needed. What is important here is to establish a strong relationship of trust between new employees and instructors, provide advice to new employees without exercising coercive force, remove obstacles that may inhibit their growth, and provide an environment in which new employees can voluntarily carry out training to acquire lifelong abilities through continuous self-reform.

The essence of training is character formation. Particularly in the field of designing, we must train people so that they are independent and possess boundless imagination and creativity. Therefore, not only new employees, but also the instructors themselves should continuously evolve through applied effort and training.

## 5. External evaluation of the training materials under development

We have asked instructors in charge of providing technical training to new employees of 20 external companies to evaluate the feasibility of part of our training materials (30 drawings of two- and three-dimensional shapes with explanations of their mechanisms). The development work of the training materials is still in progress. We have received the following comments, although the details have been omitted.

- ◇The drawings of two- and three-dimensional shapes are precise. We agree with the concept of the training materials and would like to use them in our training of new employees (5 companies).
- ◇We think the training materials are good for the training of young designers (4 companies).
- ◇We really agree with the contents of the training materials and would like to tell younger staff and colleagues about them.
- ◇We will use the training materials in the training of new employees (4 companies).
- ◇We consider that the training materials are effective in improving the skills of young staff and will convey the technique to younger staff (2 companies).
- ◇We think the training materials will serve as a model of technical training. We will refer to the training materials.
- ◇We believe that new employees must be trained to acquire a wide range of basic knowledge, method of thinking, and ability to handle problems as early as possible, whereas they can learn techniques and abilities that are unique to designing through on-the-job training (OJT). In this sense, the training materials are useful. We would like to use the training materials in the future(4 companies).
- ◇Along with the diversification of major subjects in universities, the skill level and technical knowledge of young engineers have become biased; this is a source of concern for instructors. The way of thinking of basic mechanics required for young engineers is clearly explained in these training materials. We will refer to the training materials (5 companies).

## 6. CONCLUSIONS

A common source of concern for designers at the beginning of their careers is the factors that need to be determined on the basis of experience and the lack of a sense of balance as designers. Such factors are no obstacle to experienced designers. However, no matter how much young designers think about those factors, they cannot arrive at a solution and they can only pose very simple questions about such factors. In designing, young designers often encounter factors that cannot be determined from standards or logical calculation. We endeavor to give simple answers to their simple questions by using analogies.

The use of training materials with an abundance of examples with the purpose of conveying techniques is effective for the training of young designers.

## References

- [1] Susumu Kise and Shigeo Hirano: A Case of New Employee Training in Business (About Technical Skills and Human Skills), *Journal of JSDE*, 54, 3 (2019),163-169..
- [2] Shigeo Hirano, Susumu Kise, Sozo Sekiguchi, Kazuya Okusaka and Tsutomu Araki: Development of training method and materials for young designers in three-dimensional mechanical design.12th Asian Forum on Graphic Science (AFGS 2019).
- [3] Shigeru Ito: *Encyclopedia of Mechanisms*, Ohmsha,Ltd (2012).