Essay

Setting out to Become a Professional Engineer, Japan

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1. Introduction

Have you ever heard of the qualification known as "professional engineer, Japan (P.E.Jp : *gijutsu-shi*)"? I'm sure there are many people who have not heard of or are not familiar with this qualification. Generally, the word "*shi*" comes from meanings, such as "samurai" and "person who excels at academics and morals who should be respected", and it is often used as a suffix for occupations, etc. with specialized characteristics. "P.E.Jp" is also one of the special qualifications that are true to this meaning.

That being said, I also had not even heard of this qualification immediately before deciding to take the examination. Opportunities enabled me to acquire the qualification a few years ago, so I would like to introduce the contents of the qualification and the background before I obtained the qualification through this report.

2. Professional Engineer, Japan

The professional engineer qualification is for "workers who have expert knowledge, skills or experience", such as certified public accountants and physicians, according to Article 14 of the Labor Standards Act (Table 1). Furthermore, "professional engineer" is defined as "a person who conducts business on matters, which require advanced and adaptive expertise in science and technology using the name of professional engineer" according to the Professional Engineer Act. Due to the fact that only those who have passed the professional engineer examinations, which are national examinations, and have completed the registration can call themselves "professional engineers", we can say the title of "professional engineer, Japan" is for highly-skilled engineers whose capabilities have been certified by the government. Since doctors formulate theories and professional engineers apply them to industry, doctors and professional engineers are often expressed as two wheels of technology. Knowing this relationship would probably help you to understand the positioning of professional engineers.

It was 1958, when the high economic growth period was starting, that the certification system for professional engineers started. Since engineering skills have always been specialized skills, it has never been easy for those who aren't involved with technology to assess the skills. Japan had not had a system to demonstrate the practical skills of engineers until then. Due to this, selection of business operators to perform practical tasks came with risks for the side which wished to utilize science and technology. This was holding the national economy back. Due to such a background, they launched a certification system for professional engineers as a structure to appoint engineers with experience and practical skills to important posts. This significance still remains today, and it seems as though many companies provide incentives or payment amounting to that of Ph. D holders when they obtain the qualification [1] as the engineer qualification of the highest authority [2].

Table 1 Qualifications for workers who have expert knowledge, skills or experience according to Article 14 of the Labor Standards Act

	Qualification name	Difficulty		Qualification name	Difficulty
A	Certified public accountant	Extremely difficult	G	Certified tax accountant	Difficult
B	Physician	Extremely difficult	H	Pharmacist	Difficult
C	Dentist	Difficult	I	Certified social insurance consultant	Difficult
D	Veterinarian	Difficult	J	Real estate appraiser	Difficult
E	Attorney at law	Extremely difficult	K	Professional Engineer, Japan	Extremely difficult
F	Class-1 architect	Difficult	L	Patent attorney	Extremely difficult

3. Professional Engineer Examinations

As Fig. 1 indicates, there are several ways to become a professional engineer. While the first stage examination is said to be a difficult examination, it is sometimes exempt, depending on the curriculum. On the other hand, the second stage examination cannot be avoided. This examination is said to be extremely difficult to pass, with both difficult eligibility requirements and difficult

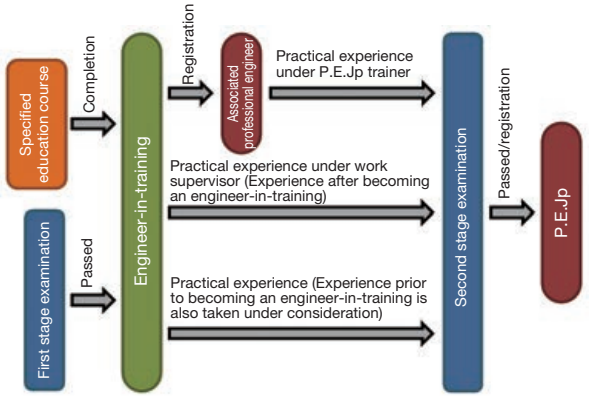

Fig. 1 Structure of professional engineer, Japan examinations

examination contents. For reference, I have included the difficulty level of each qualification, which is taken from the material [1], in Table 1. If you are familiar with some of these qualifications, you can probably easily imagine the difficulty level of the second stage examination.

First of all, the second stage examination for professional engineers normally requires that you have at least 7 years of specialized work experience to take the examination. This alone greatly reduces the number of qualified people for the examination.

Examinees select the preferred categories from the total of 21 technical categories (Table 2), and they further select the subjects according to their own specialty to prepare for the written examination. For example, the list of subjects to select from is shown in Table 3 for the mechanical engineering category, which I took. Among these, I selected mechanical dynamics/control.

The written examination tests your specialized knowledge regarding the overall engineering in the selected category, in addition to questions in which you have to discuss engineering for as long as 4 hours. You are tested on your advanced technical knowledge, capabilities to identify issues, capabilities to adjust contradicting elements, capabilities to formulate theories, capabilities to explain, etc.

Table 2 Elective categories for professional engineer, Japan

1	Mechanical Engineering	8	Mining	15	Industrial Engineering
2	Marine & Ocean	9	Civil Engineering	16	Information Engineering
3	Aerospace	10	Water Supply & Sewerage	17	Applied Science
4	Electrical & Electronics Engineering	11	Environmental Engineering	18	Biotechnology & Bioengineering
5	Chemistry	12	Agriculture	19	Environment
6	Textiles	13	Forest	20	Nuclear & Radiation
7	Metals	14	Fisheries	21	Comprehensive Technical Management

Table 3 Elective subjects in the mechanical engineering category

Engineering category/ elective subject		Elective subject description
1 Mechanical engineering category		
1-1	Mechanical design	Machine element, tribology, design engineering, study of design information, and other mechanical design-related matters
1-2	Material mechanics	Structural analysis/design, fracture mechanics, mechanical materials, and other material mechanics-related matters
1-3	Mechanical dynamics/control	Motion/vibration, measurement/control, structural dynamic analysis/control, and other mechanical dynamics/control-related matters
1-4	Power energy	Internal-combustion engine, hydraulic turbine, boiler, generator, steam turbine, gas turbine, wind power generation, photovoltaic power generation, fuel cell, and other power energy-related matters
1-5	Thermal engineering	Heating/cooling, thermal transfer (including electric heat, convection current, and reproduction), combustion, heat exchanger, freezer, heating and cooling equipment, thermal storage machinery, and other thermal engineering-related matters
1-6	Fluid engineering	Fluid engineering, fluid machinery (including air blowers), chemical machinery, hydraulic equipment, and other fluid engineering-related matters
1-7	Process/factory automation and construction machinery	Process approach, processors, production systems (factory automation, etc.), their components, factory facility plans, industrial machinery, and other process/factory automation and industrial machinery-related matters
1-8	Transportation/hoisting and conveying machinery and construction machinery	Rolling stock, automobile, hoisting and conveying machinery, construction machinery, systems related to the above, other transportation/hoisting and conveying machinery, construction machinery, and matters related to their relevant systems
1-9	Robot	Industrial robot, locomotive robot, construction robot, robot-related equipment, and other robot-related matters
1-10	Information/ precision equipment	Information/precision equipment, optical instruments, electronic application equipment, operation monitoring control devices, other information/precision equipment, and matters regarding relevant systems

Furthermore, when you pass the written examination, you must take the oral examination, which is the final examination. The interviewers, who are expert professional engineers, determine your competence as an engineer.

In the second stage examination in 2015, the number of examinees was 24,878, the average age of examinees was 43.3 years old, and the passing rate was 14.7% [3]. This is considered to be the most difficult national examination among engineering-related examinations.

4. Motivation behind Taking the Examination

So far, I have briefly explained the professional engineer qualification and its examination system based on general theories. From here, I would like to resume the story from the aspect of why I aimed to obtain this qualification by going back to my personal perspective.

When I decided to take the examination, my oldest son was starting to learn word after word. Children grow so quickly, and they copy their parents' words and learn new things one after another. One day, seeing my son's growth like this made me think of something. It was that "My son is learning about the world from every move I make, but I'm living my life without much growth". I thought that this attitude was unfavorable as a parent, who should be a role model for their children.

Encountering the unknown and learning from failures are key factors in enriching one's life. I want my children to have many such experiences. In order to do so, it is important to voluntarily be interested in many things and have the habit of voluntarily taking action. It would be difficult to teach a child to obtain this habit, but I thought it might become a natural lifestyle for my children if I, as a parent, naturally practice this on a daily basis.

So, I decided that I would like to always be hungry for challenges and pursuits. I always try to be rid of adult-like hesitance and follow my curiosity. Whether it's something serious or something silly, I always try it if I'm interested, no matter what. And one day, I thought about obtaining a qualification. And I thought it would be more fun to aim for something difficult, if I'm going to obtain a qualification anyway. And the "professional engineer" qualification caught my attention for being reputably extremely difficult.

5. Examination Preparation

Once I decided to take the examination, I first took the first stage examination. This requires university-level engineering knowledge, but I will omit the details because I passed this by skimming through the textbook.

The main examination starts with the second stage examination, which I took in the following year. I submitted my application, and I decided to start studying approximately 1 month before the test. I began researching on the internet.

According to my research, the average experience for most people seemed to be finally passing the second stage examination after studying every day for several

years. Some even said that they spent thousands of hours of studying before passing the examination.

I was aware that I was quite behind, but I didn't want to give up and waste the application fee. Despite its reputation for being extremely difficult, I hadn't even known about the qualification until the previous year. I underestimated that the reputation made it sound more difficult than it actually was.

On the other hand, passing the examination in this situation would feel great. I decided to pass the test by formulating a strategy to significantly enhance my studying efficiency.

However, how can I come up with such a convenient strategy? I had no idea, but I had nothing to lose. I decided to start with analyzing past exam questions.

These contents slightly deviate from the main purpose of this report, but I would like to introduce this because I came to an interesting result.

5.1 Exam Questions Area Prediction Model

I looked at exam questions for the past 5 years that I obtained from the official website of the Institute of Professional Engineers, Japan. I couldn't solve any of the essay questions, which are regarded as difficult. However, I realized that there is a certain tendency concerning the contents of the exam questions. For example, in case of an essay question discussing nonlinear springs or a jump phenomenon, we can categorize this as a common technology by regarding this as vibration of nonlinear systems. When we consider these small areas, it seems that we can categorize the essay questions from the past 5 years into 13 areas, which are shown in Table 4. I thought studying this question appearance tendency and predicting the exam question areas for 2014 would help me study efficiently, so I decided to prepare a prediction model.

Needless to say, the exam question appearance frequency differs for each area. When you consider this frequency as the expectation value, it becomes a prediction model P_R based on the exam question appearance rate. However, such an easy model is not interesting. Therefore, I read deeper into the psychology of the examination preparers who would think "This area was in last year's examination, so let's not include it this year". I decided to formulate another model. This is the model shown in Fig. 2, using the Marcov process.

Taking the nonlinear system vibration area as an example, this area is included in the examination every year except for 2011. From the phenomenon aspect of stochastically shifting this into the 2 states of being included in the examination and being excluded from the examination, the probability of this being excluded from the examination in the year after it was included would be 0.33, and the probability of it being included in the examination in the year after it was included would be 1.00. The characteristics of the state of the next point being stochastically determined based on the state of one point is called the "Markov property", and a series of these characteristics is called the "Markov process". I formulated the Markov model P_M by calculating the Markov process state transition probability for all areas.

I came up with 2 models, but I was unable to perform sufficient precision verification due to lack of data. Because of this, I used the integrated model P_I, which equally integrated the 2 models, as the exam question area appearance prediction model as shown in formula (1).

$$P_I = (P_R + P_M) / 2 \quad (1)$$

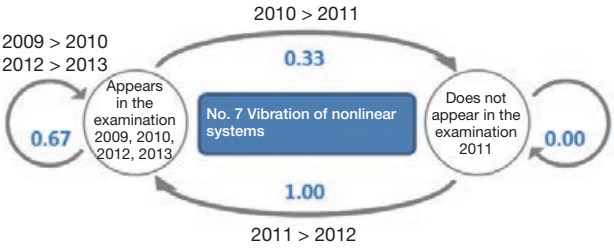

Fig. 2 Markov process

5.2 Priority Study Area Decision Model

Once the exam question area prediction was completed, I started to get excited. The upcoming examination aside, the result of abstracting and numerically analyzing the examination preparation was more interesting. In order to further advance this model, I decided to prioritize the study areas next.

You would think that simply prioritizing and studying the areas with higher exam question appearance frequency would be effective, but that may require a

Table 4 Area information for the past 5 years, including exam question appearance tendency

No.	Question area	Past questions					Actual examination	Probability model	Markov model	Integrated model	Study time	Study priority	Total study time
n		'09	'10	'11	'12	'13	'14	P_R	P_M	P_I	T	F	
1	Frequency domain inherent question	✓	✓		✓	✓		0.80	0.66	0.73	4	0.183	4
2	Vibration measure		✓	✓	✓	✓	✓	0.80	1.00	0.90	6	0.150	10
3	FF/FB control	✓		✓	✓			0.60	1.00	0.80	6	0.133	16
4	Vibrating excitation mechanism			✓			✓	0.20	0.33	0.27	2	0.133	18
5	Rotary machine vibration		✓	✓			✓	0.40	0.50	0.45	4	0.113	22
6	Mode analysis	✓		✓	✓			0.60	1.00	0.80	8	0.100	30
7	Nonlinear vibration	✓	✓		✓	✓		0.80	0.66	0.73	8	0.091	38
8	System stability		✓			✓	✓	0.40	0.00	0.20	4	0.050	42
9	PID control					✓		0.20	—	0.20	6	0.033	48
10	Coupled vibration				✓			0.20	0.33	0.27	10	0.027	58
11	Piping system vibration	✓	✓					0.40	0.00	0.20	8	0.025	66
12	Cases and measures					✓	✓	0.20	—	0.20	8	0.025	74
13	Bearing vibration property	✓						0.20	0.00	0.10	10	0.010	84
14	Transfer function	Exam question did not appear in the past examinations					✓	—	—	—	—	—	—

massive amount of time to study areas that I do not know well. On the other hand, studying areas that I was already familiar with would take little time. The significance of being able to efficiently study would be great, even if the exam question appearance rate is relatively low. Due to this, I decided to incorporate into the model the idea that studying my favorable areas would contribute to the enhancement of study efficiency.

Table 4 also shows the exam question area prediction result, the study time T for each area, etc. in addition to the past exam question areas. This study time T shows values, which are the number of hours spent on studying until I can score over 60% estimated in a subjective manner. Then, I calculated the study priority level F from formula (2) based on the exam question area prediction model P_I and the study time T.

$$F=P_I/T \tag{2}$$

Areas with higher study priority level F are areas which have high exam question appearance rates and short study time while simultaneously being areas where I can aim for scores over 60%. Therefore, all I needed to do was to start studying the areas with a higher value of the study priority level F first.

5.3 Passing Rate Estimation Model

As you can see, the model I developed by blindly grasping in the dark showed great applicability. However, there was more room to improve. This was deciding the areas not to study.

If I had to ultimately study all of the areas, there was no point in determining the priority. If I spread too wide, I wouldn't be able to sufficiently respond to areas other than the essay questions. If my objective is to pass the examination, studying all areas is worse than just being wasteful, as it requires the resources of time and concentration. Therefore, I decided not to spend any time on areas with low study priority level F. However, how many areas could I afford not to study? In order to make this determination, I then performed the passing rate estimation according to the progress of each area to study.

I'd like to simplify and explain the examination format to help you understand the passing rate estimation. There are 6 essay questions in the professional engineer second stage examination. You select 3 exam questions out of them and answer them. In addition, it has been disclosed that the passing criterion is that the average score of the 3 exam questions is over 60%. With this examination format in mind, I made the following passing rate estimation.

Based on the trend of past exam questions, it is assumed that the 6 exam questions would be from the total of 13 areas without overlapping. There are 1,716 combination patterns, based on ${}_{13}C_6$. We can expect that one of these patterns would be the essay questions in the examination, but the exam question appearance rate is biased for the 6 areas constituting the combination. Due to this, the incidence rate of each combination is not consistent. Therefore, I calculated the incidence rate of each combination by considering the exam question appearance rate.

First of all, the 1,716 combination patterns are expressed as C_i by using the suffix i ($1 \leqq i \leqq 1{,}716$). Combination C_i consists of 6 areas with different exam question appearance rates of P_I. This is expressed as formula (3) as a set of exam question appearance rates P_{In}. The suffix n here means a serial number ($1 \leqq n \leqq 13$) for each area.

$$C_i = \{x \mid x \in \{P_{In}\},\ P_I \text{ included in the } i\text{th combination}\} \tag{3}$$

By considering the exam question appearance rate P_{In} of each area as the weight and adding all of the exam question appearance rates P_{In} of 6 areas in the combination C_i, the weight W_i for each combination is calculated (formula (4)).

$$W_i = \prod_{n=1}^{6} C_i \tag{4}$$

There are 1,716 patterns of this combination weight Wi, and adding all of them amounts to the weight of the overall examination. Due to this, the C_i incident rate R_i is calculated by subtracting the weight of the overall examination from the weight W_i of each combination, as shown in formula (5).

$$R_i = W_i / \sum W_i \tag{5}$$

The above calculation determined R_i, which are the incident rates for 1,716 combination patterns for the 6 areas included in the examination in 2014. I can only pass the examination when one of these combinations is included in the examination if the appeared combination C_i includes at least 3 areas in which I can score over 60%. (Areas that I cannot score 60% are assumed to be 0 points.) Therefore, I expressed R_i as shown in Fig. 3, which is the incident rate of the combinations C_i in which I can expect to pass if I studied according to the order of the study priority level F. I am also including the passing rate, which was calculated by adding the appearance rate R_i.

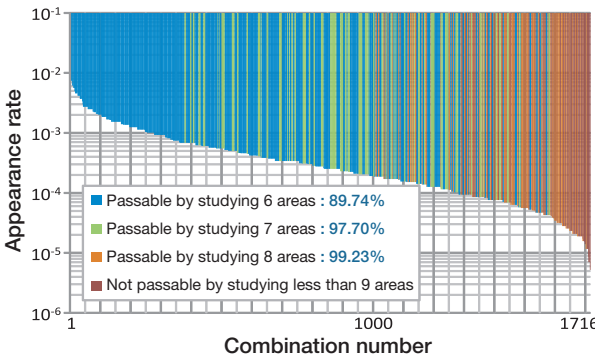

Fig. 3 Passing rate by study progress

The figure shows incident rate R_i in the vertical axis and all 1,716 combinations in the horizontal axis so that incident rates R_i are in descending order. This figure shows that I can pass the test as long as I study 6 or 7 areas in the order of higher priority level F for approximately the top 1,000 patterns with the higher incident rate R_i. In addition, while studying 7 areas would

present the 97.70% passing rate for the written examination, studying of 8 areas would present 99.23%, only presenting a minute difference. Therefore, I can determine that studying areas beyond the 8th area is a waste of time and that it is appropriate to continue studying 7 areas. In addition, as Table 4 shows, the total number of hours required for studying 7 areas is approximately 38 hours.

You can say that I scientifically made an educated guess based on the data. This unexpectedly enabled me to reduce the amount of studying required for the written part, which is considered to be the key point in the second stage examination for the professional engineer examination, by half. If the preparation for the written part only requires 38 hours, securing the time and maintaining concentration would be easy. I would be able to secure sufficient time to study for categories other than the written part. Determining the essence of matters and coming up with a format that we can apply to reality is the duty of professional engineers. I can say that this model was created by this spirit, although somewhat ironically.

The development of this mathematical model, which I formulated out of mere curiosity, was completed even with the added touch of the passing rate when presenting the studying strategy. Mad scientist-like villain characters in comic books often say something like "Hehehe…the chance of you beating me is only XX%!", and I expect that the design philosophy behind these calculation models is similar to my model. I'm extremely happy about being able to see a glimpse of their philosophy.

6. From Studying to the Result Announcement

All I had to do then was study. I decided to study for approximately 4 hours every day. After about 2 weeks, I was done with the study and even struggled with the time on my hands until the examination day.

On the day of the written examination, I selected 3 subjects from the areas that I had studied, as I had expected, for the essay part. I received the passing notification at a later date. As Table 4 shows, there was one question from an area which did not exist in the past examinations. However, this had no effect on my prediction that as long as you study 7 areas, the probability of at least 3 of them being included in the examination was extremely high. As far as I can tell from completing the experiment verification of N=1, it seems as though the established model satisfied the expected functions and worked.

The remaining part of the examination is the oral examination, which was to be held in the following year. The passing rate seems to be about 60%, but this part is more troublesome than the written part because you cannot formulate a clear preparation method. The examination guidelines say that this part is checking your experience, application capabilities, engineer ethics, understanding toward the professional engineer system, etc. However, the examination day came while I still had no idea exactly how I was supposed to prepare.

In the end, no special question was asked. Questions were about the professional engineer system and engineer ethics as well as regarding my motivation to take the examination and skills. The examination ended without me being able to offer any especially impressive answers, and I wasn't confident about the result. As far as I researched on the internet, it seems as though all the other examinees had similar impressions. Therefore, the passing criteria for the oral examination is still a mystery.

I was nervous on the day of the announcement, as one would expect. However, I was happy to learn that I had passed in the end. Back in 2014 when I took the examination, the passing examinees were disclosed in the official gazette. When I saw my name in the official gazette, it stimulated my sense of belonging as a member of this country. I remember being motivated to make efforts for the society.

7. Looking back on Obtaining the Qualification

As I have already explained, my examination preparation period was much shorter than the average time spent by others who passed the examination. One of the reasons for this achievement was that I formulated a strategy without studying at random and succeeded. However, I think the bigger contribution was the fact that my work experience in KYB supported my technical capabilities.

Professional engineer examinations don't simply test knowledge. They test your technical capabilities that you cannot acquire in a short period of time. You can strategically reduce the amount of studying, but it is impossible to reduce the difficulty level of the exam questions. I don't think I could have passed the examination if I only had a small amount of work experience. In other words, my experience that I have accumulated through work as a mechanical engineer has refined my expertise and, with regards to the mechanical engineering category, even made obtaining the professional engineer qualification easy despite the fact that it is considered to be extremely difficult. In fact, I briefly looked at past questions for the computer science category, which is not my field, after I passed the examination. I couldn't even understand the meaning of the question, which made me realize just how difficult professional engineer examinations are. This experience was also a good opportunity for me to be impressed by the quality of work in KYB.

Based on this experience, it seems as though the professional engineer qualification is something that middle-ranking engineers can naturally obtain. While this is generally considered to be a highly difficult qualification, it is not true in a sense. This is because we engineers are isolated from the general public especially in technology. If one spends more than 7 years in the specialized field and spends the time using his/her brain to develop technology, this would amount to as many as 5,600 hours of studies, even at 4 hours a day and 200 days per week. I think it's natural that one should have suitable expertise.

This is the reason why I recommend fellow engineers with experience to take these examinations to measure your own expertise. If you pass, it should give you a sense of pride for the experience you have accumulated. If you fail, it would give you an opportunity to notice what you lack and study again with humbleness.

Being a professional engineer has other perks. Since I obtained the qualification, I have been encountering new experiences and situations, such as conversations developing when I exchange business cards with people, being inquired to co-write an engineering book, and being requested to write articles for books like this. Gathering with other engineers from various fields but with kindred spirits is especially guild-like, and it often gives me important inspirations to exchange with other industries. Having the professional engineer qualification doesn't drastically change anything, but I feel as though the opportunities and situations such as the above are priceless rewards.

8. In Closing

Upon aiming to obtain the professional engineer qualification, I was able to extract a logical strategy by formulating a numerical model for the boring territory of examination preparation in all seriousness. Even with this kind of math, which was partly for fun, it still brought me joy to think, uncover unexpected discoveries, and get excited. The course of developing this model was far more enjoyable than the examinations themselves. Although the main topic for this report was the professional engineer qualification, I hoped to share my experience as an example that even a boring thing can be fun if you work with seriousness while knowing that it will become useful. I would be happy if you could use my experience for reference in the future.

I will stop here, as it will significantly deviate from the main topic. However, the approach of creating models for various matters to comprehend the framework is effective not only in this example but also in all types of thought experiments. Therefore, the approach is effective both to deepen consideration and to fulfill curiosity. Personally, I would like to recommend not only taking on the challenge for the professional engineer qualification but also of learning this idea itself. If you are interested, I would recommend that you research the key phrase of "Fermi estimate [4]", as it is a similar concept.

While I was glad to obtain the professional engineer qualification, this was neither a goal nor a passing point for me but rather one of the many efforts with the aim of making challenges and pursuits into habits. Although there is no end to these efforts, there is no limit to interests in the world and challenges that I want to take. I think it is up to your frame of mind whether or not to enjoy life, as the alleged death poem by Shinsaku Takasugi reads;

"What makes a world with no interest interesting is your mind".

If this is the case, I would like to take after the spirit of the samurai and continuously grow as a professional engineer worthy of its name and as a father without forgetting the perspective of freely enjoying (*asobi*) with science.

Finally, the word "*asobi*" comes from Buddhism. Its original meaning apparently is quite serious, leading to enlightenment. With this in mind, I would like to conclude my report by sharing a quote that recently moved me.

- Quote -

I feel as though the mindset to "enjoy research" is related to this "*asobi*". Enjoying does not mean choosing an easy way or being satisfied with immature ideas. If you are to pioneer a new world that no one knows, you need the strength to take a step into the wasteland. In order to enjoy research, you must have the spirit to enjoy free pursuits supported by great expertise and deep knowledge. This is the true pleasure of research [5].

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