The spread of Measurement Uncertainty by Training Seminar for Beginner

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Abstract

In Japan, many metrologists recognized that measurement uncertainty was for calibration and that it was difficult, so it has not become popular in industry. We hypothesized that the problem lurked in the education system; we tried to learn how the uncertainty was educated overseas. We were convinced of not only our misunderstanding but also of the importance of the tutor.
We developed a new uncertainty seminar with our new budget-sheet format in 2002, and began to manage it and to make it downloadable in 2003. More than 300 delegates have already joined and more than 1,200 guests have already downloaded the text by now.

1. Background

1.1 Uncertainty arrival into Japan

To consider the present measurement uncertainty situation in Japan, we have to look back at how uncertainty was first brought into Japan. Some measuring instrument manufacturers were requested by some European customers to use uncertainty as a guard-band [1], but they were not open about the Europeans' requirement in industry. On the other hand, for most industries, especially calibration laboratories, measurement uncertainty and ISO/IEC 17025 came in almost simultaneously. There was no way for most engineers to acquire knowledge about uncertainty from some published report of calibration uncertainty evaluation. Thus, uncertainty became considered to be for ISO/IEC 17025 accreditation; furthermore, the uncertainty has been preconceived to be difficult.

1.2 Working Activity regarding Uncertainty

There were two working groups (WGs) that they were only concerned about the measurement uncertainty situation in Japan. One of them was interested in spreading of uncertainty; the other was concerned with upgrading metrologists, such as standards engineers.

The first group, named "Research regarding the Induction of Metrology Standard's Traceability WG2", was composed of NMIJs' engineers, public organizations' calibration engineers and calibration engineer in industry. At the beginning, this group's discussion items were mostly uncertainty based on GUM; the second group was called "Engineer's Growing-up WG for Japan Metrology Forum"[2]. The composition of the second group was almost the same as that of the first group, but the members were different. This group acted for engineer's growth to comply with the ISO/IEC 17025 requirement. Both groups thought that although measurement uncertainty was necessary, it should be evaluated strictly and there was no choice but to acknowledge it as being difficult. The point of view that uncertainty should be easy to use for industry came out.

1.3 Dispatching into Overseas Seminar

Someone who worked for one of the above WGs wondered why measurement uncertainty being so difficult became popular overseas. Since he thought that there was a problem that lurked on uncertainty education, he decided to dispatch engineers to attend on uncertainty seminar held overseas and to get the whole text. As his first idea, he made three engineers, who were from different sectors, namely NMIJ, a public organization and industry, join the same seminar and allow them to feel the difficulty level individually. Finally, however, he dispatched them to three different seminars that were held by NATA (Australia), A2LA (United States) and UKAS (United Kingdom).

1.4 Difference between Overseas and Japan

In Japan, there were several uncertainty seminars, actually. However, the parts of uncertainty calculation were few; most of the time was spent to explain instances of calibration uncertainty evaluation. The reason was that the promoter also thought uncertainty was for accredited calibration. As a result, most of the metrology engineers working for a standard came to think that uncertainty was for accredited calibration and that it was really difficult. Needless to say, measurement uncertainty did not become popular for industry under such a condition.

On the other hand, overseas, measurement uncertainty was generally recognized to mean a vague statement of measurement results, and in industry it was used as a guard-band and/or TUR [3] to

judge between passing and failing. Standards engineers first join an uncertainty seminar and understand what uncertainty is, enough time is spent to explain the rules of uncertainty calculation, so that they never think uncertainty is difficult from the beginning. Actually, uncertainty is not thought to be only for accreditation, even if it is needed for accreditation.
There is a big difference here compared with Japan.

2. Uncertainty Seminar Development

2.1 Necessity of New Uncertainty Education System

Having joined overseas seminars, it became certain to the participants that there were fudge problems in previous uncertainty seminars held in Japan. We also learned two of the most important things via them. One of them was for uncertainty beginners to feel that uncertainty was not so difficult. The other was about teaching staff.

Then we reached the stance that we had to prepare the uncertainty seminar for beginners and to foster some tutors as soon as possible. However, it was difficult to foster excellent tutors immediately, so we tried to build up a new uncertainty education system by ourselves, referring to overseas seminars first.

2.2 Road Map of Uncertainty Seminars

Since there were several kinds of requests for uncertainty seminars, we laid out an “Uncertainty Education Road Map” before development.

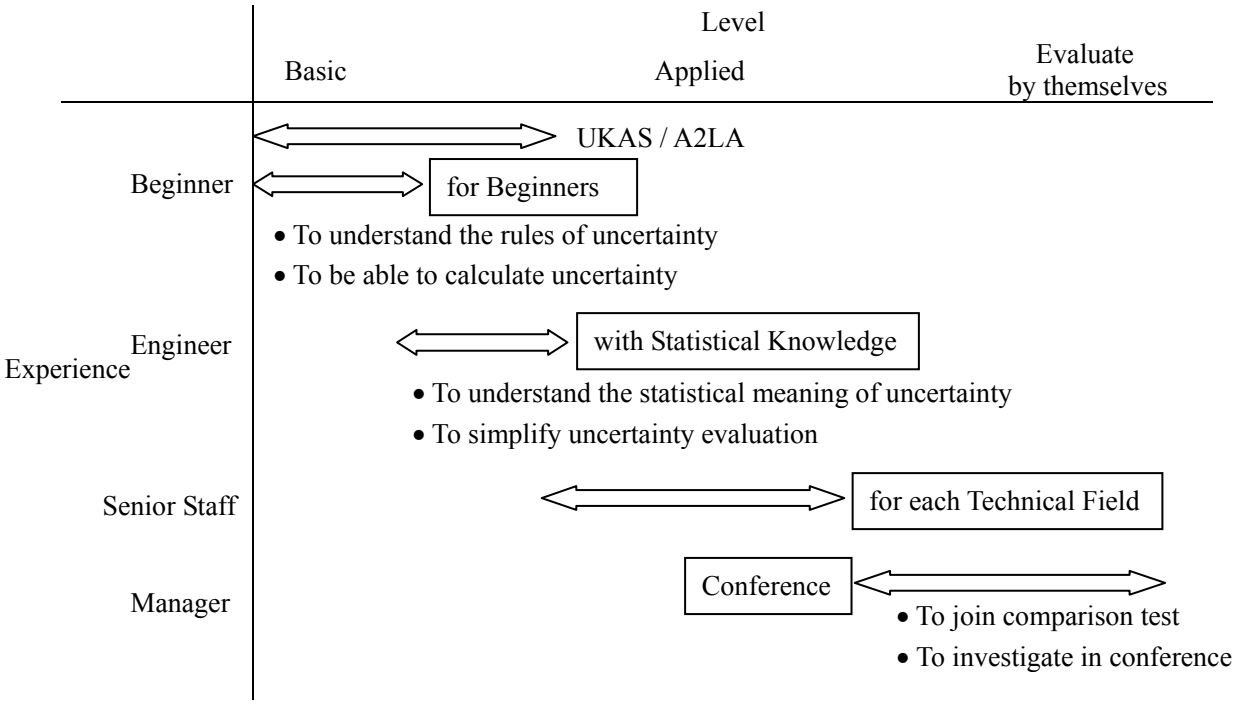

Fig. 1 Uncertainty Education Road Map

Here we subdivide delegate levels into 4 stages according to uncertainty experience.
The first stage is for uncertainty beginners. For this stage, the most important point is for delegates to come to feel that they can understand what uncertainty is. The details of this stage are described below.

The second stage is for engineers who have a couple of years of experience in measurement and basic knowledge of uncertainty. For this stage, they are very interested in reducing the cost of uncertainty evaluation and in making the actual uncertainty value smaller for their business, so the statistical detail should be explained for one-time measurement, long-term-stability evaluation, and other techniques.

The third stage is for senior staff members, such as a team leader. Although this stage is not needed overseas because people are thought to skip this stage and try to evaluate by themselves, we are always requested to provide education the technical evaluation of uncertainty by industry. In reality, however, uncertainty evaluation depends on each situation, so that it is not actually a teaching item.

The last stage is for laboratory managers and/or senior staff members. An opportunity for publication should be prepared as a final stage of uncertainty evaluation. If they publicly present their uncertainty evaluation before many engineers of the same technical field, they are able to obtain several useful comments on their evaluation.

2.3 Concept of New Uncertainty Seminar for beginners

We recognized that we should prepare the basic seminar for uncertainty beginners as a first stage.

The main point of this stage is for delegates not to feel that uncertainty is difficult from the beginning. Of course, Tutor and/or promoter of this new seminar don't forget to make delegates to confirm that uncertainty is for measurement. To achieve this, not only should the program be concluded with an explanation of the basic uncertainty calculation and evaluation rules and an exercise on simple measurement, the tutors and assistants should also always ensure that each delegate understands the rules of uncertainty at all situations. In other words, the highest priority is given for all delegates to understand certainly step by step.

Then we decided to adopt some rules for this seminar as follows;

a) Maximum numbers of delegates: within 20 persons
b) At least 2 teaching staff members should always support delegates.
c) The atmosphere should be relaxed.
d) Delegates should sit in a U-shaped arrangement.
e) The wall between delegates and teaching staff should be cleared.
f) Each delegate should be given the chance to describe anything.
g) Tutors implant the idea that uncertainty is for all kinds of measurement and negate the idea that uncertainty is only for accreditation.
h) Explanations and exercises should be combined in every part of the seminar to ensure that each rule is understood.
i) Uncertainty should be calculated using budget-sheet. (Don't use mathematical modeling and partial derivaitive)
j) The degree of freedom should not be touched.
k) Several interested and simple exercises should be prepared.
l) A group exercise should be prepared.

2.4 Program details

The program details of the uncertainty training seminar for beginners are shown in Table 1.

Day 1st

1. Introduction and Briefing
2. Room Temperature Measurement
3. What is Uncertainty?
4. Definition of Words (Part 1)
5. Guidance on Uncertainty Evaluation
6. Type A Evaluation
7. Calculation Exercise for Type A Evaluation
8. Distribution 1
9. Type B Evaluation
10. Consideration Exercise for Uncertainty Sources (Type B Evaluation Exercise)
11. Free Discussion

Day 2nd

12. 1st day Summary
13. Distribution 2
14. Definition of Words (Part 2)
15. Combined Uncertainty and Expanded Uncertainty
16. Calculation Exercise for Topics up to Expanded Uncertainty
17. Exercise for Finding Mistakes
18. Overall Exercise
19. Compliance with Uncertainty
20. Ending

Table 1. Program of Uncertainty Seminar for Beginners

General guidance and self-introduction are included in the "Introduction and Briefing" part. Each teaching staff member had better describe his/her own uncertainty experience deeply to win the delegates' trust, and delegates should convey their own expectations in this part.

In order to make delegates relax, the lesson starts with a "Room Temperature Measurement" exercise. Each delegate has to measure the room temperature using a handmade thermometer. Since each of those thermometers has a different calibration result and offset among others, each measurement result also gives a different value inevitably. Thus delegates begin to doubt the thermometers, and the atmosphere becomes friendly.

It is important to explain with certainty why uncertainty is needed for industry in the "What is Uncertainty?" part. Since most of the delegates might think that uncertainty is only for accreditation, such an idea should be thrown away to make them feel that uncertainty is not so difficult. If the delegates understand the meaning of uncertainty and individually realize its necessity, the lesson progresses smoothly.

Several words concerning measurement are explained in the "Definition of Words (Part 1)" part. An Introduction to the entire uncertainty evaluation process, the difference between Type A evaluation and Type B evaluation, and other rules are described in the "Guidance on Uncertainty Evaluation" part. Since the details are explained following each part, so this part can be skipped. But whenever uncertainty is evaluated, the evaluator should think about evaluation cost. So this topic should be described in this part.

The difference between the standard deviation of the population and the estimate of the standard deviation and the calculations of both, the standard deviation of the mean, and calculation by calculator and Excel are explained in the "Type A Evaluation" part. Just after this part, the "Calculation Exercise on Type A evaluation" part follows. If delegates fail to understand the calculation for Type A evaluation, members of the teaching staff follow them up individually via this exercise. Most of the delegates understand that Type A uncertainty is calculated not as the standard deviation of the population, but as the estimate of the standard deviation. And sometimes they get confused when calculating using the calculator's statistical functions. The teaching staff should understand that the differences in the symbols used for the estimate of the standard deviation are due to the calculator. The teaching staff should also realize that some delegates forget to divide by $\sqrt{n}$ when calculating the standard deviation of the mean.

The kinds of distribution are introduced in the "Distribution 1" part.

Regarding electrical measurement, temperature measurement, mass measurement and length measurement, the typical sources of uncertainty are introduced and the process on how to decide the value via evaluation example is described in the "Type B Evaluation" part. After this part, "Consideration Exercise of Uncertainty Sources" follows. For practice, delegates attempt to find out uncertainty sources for simple measurement. This is given as a group exercise. Fundamentally, if any value is smaller than 1/10 of the largest value except in the case of Type A, these uncertainty sources are negligible, because there is no influence on the final result.

Day 2^{nd} opens with the "1^{st} day Summary". This time is a good chance for delegates to listen and to confirm the rules up to finding sources of uncertainty simultaneously. Divisors for each distribution are explained in the "Distribution 2" part, and several words concerning uncertainty evaluation are described in the "Definition of Words (Part 2)" part.

The process on how to combine each standard uncertainty and a level of confidence are explained in the "Combined Uncertainty and Expanded Uncertainty" part. The new-style budget-sheet has

an important meaning here, because all units of each standard uncertainty are replaced by the measurement unit given by Ci which is explained without mathematical modeling and partial derivaitives. Regarding the budget-sheet, it is described in the next part. The delegates' understanding is confirmed via the "Calculation Exercise for Topics up to Expanded Uncertainty" part.

Two kinds of relationship between tolerance and uncertainty are introduced. For one of them, half of the uncertainty becomes guard-band; this is ILAC's guideline. The other is TUR and the guard-band test limit [4].

All delegates one by one confirm their individual expectations in the "Ending" part.

2.5 New-Style Budged-Sheet

Because if there were mathematical modeling and partial derivaitives in this seminar, most of the delegates would tend to feel that uncertainty is difficult immediately. Thus, uncertainty has to be calculated using a budget-sheet without partial derivaitives. Then we induce the standard uncertainties that are calculated as values divided by the divisor first and put them in between divisor column and the sensitivity coefficient column. To do this, values are not exchanged into the measurement unit's standard uncertainty directly, so the whole calculation process becomes easy to see. On the other hand, regarding sensitivity coefficient, it is explained as a factor used to exchange the standard uncertainty's unit into the measurement unit.

Symbol	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Standard Uncertainty	Sensitivity Coefficient Ci	Standard Uncertainty (measurement Unit)
Uc( )	Combined Uncertainty		Normal				
U	Expanded Uncertainty		Normal (k=2)				

Table 2 Budged-Sheet

3. Measurement Uncertainty Spreading into Industry

3.1 Main Point of Spreading

This is a big challenge, but we have to destroy the previous bad uncertainty image and replace it with the idea that it is easy for industry in order to spread uncertainty in Japan. Thus we have to give many opportunities for persons dealing with uncertainty to encounter the newly developed uncertainty seminar for beginners.

3.2 Spreading via Delegates

In section 2, it was explained that uncertainty is for measurement reliability and that it is used for pass/fail judgment in industry in this seminar. Since more than 300 delegates from industry have already joined this seminar in the last two years, we think that we might change the uncertainty image for the engineer's level.

3.3 Spreading via Downloading

Since this project has proceeded with our working group's activities being supported by the Ministry of Economy Trade and Industry, we began to open whole texts as free download pages [5] in 2003. More than 1,200 guests have already come this page and downloaded it. We think they likewise feel that uncertainty is for measurement and that it is not so difficult.

3.4 Future Plan

Regarding the developed seminar, since Type A evaluation for testing is not included, we need to develop a testing uncertainty course similar to that of UKAS. We need to build up a tutor growing-up program. Since JEMIC is the sole managing agency of the developed uncertainty seminar now, it is difficult for us to have more seminars and to develop new kinds of seminars. If many uncertainty tutors grow, it is expected that more seminars will be held and that uncertainty will become more and more popular. On the other hand, we need to approach the management level of calibration and/or testing laboratories and to lead them to the understanding that uncertainty is for measurement and not so difficult from the beginning, because they are strongly believe that uncertainty is only for accredited calibration.

4. Summary

We began to build up and manage an uncertainty training seminar for beginners, although a little too late; the image of uncertainty has begun to be recognized as being easy via delegates and downloaders of this seminar. As a result, uncertainty became more and more popular for industry. As a future plan, we will need not only to develop some tutors but also to prepare a couple of new seminars for testing engineers and the management level.

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