"MEASUREMENT SCIENCE" AND EDUCATION
to cultivate Scientific Basic Knowledge of People

Komyo KARIYA [1], *Shigeru TAKAYAMA* [2]

[1].Emeritus Prof., Ritsumeikan University, BKC, Shiga, JAPAN
[2] Faculty of Science and Engineering, Ritsumeikan University, BKC, Shiga, JAPAN

Phone: +81-77-561-2662, Fax: +81-77-561-2663(Univ.)
E-mail: [1] kariyako@ymail.plala.or.jp (Private), [2] s-tkym@se.ritsumei.ac.jp(Univ.)

Abstract: We had already expressed the importance of "Measurement Science" .on the education to rise up the scientific sense for the people live in the society carried on natural science, technique and information. It is the liberty to apply how "Science" to the Education, an answer is in this paper.. And we had reported the contents by some papers [1],[2],[3],[4],[5],[6],[7]. This paper suggests the usefulness of application of "Measurement Science" for the stage 1 and stage 2 education (Compulsory Education) and the stage 3 education (Semi-Compulsory Education), when classify National Education in 5 stages.

Keywords: Measurement Science, Compulsory Education, National Education

1. WHY NEED "SCIENTIFIC BASIC KNOELEDGE" OF PEOPLE

AND

WHY CULTIVATE THE KNOWLEDGE BY "MEASUREMENT SCIENCE"

The change of society by era is indicated like next.
• First term --------Primitive era
• Secondary term -Hunting era
• Third term -------Farming era
           (Firm civilization)
• Forth term -------Industrial Revolution era
           (Mechanical culture)
• Fifth term -------- After Industrial revolution era
           (Electric and Electronics culture)
• Sixth term -------Modern Information era
           (Information culture)

In the First term (Primitive era), there was an idea to keep lowermost life of a man, and it is able to show as an origin of tool.

In the Secondary term (Hunting era), there was the wisdom to divide hunting game to avoid the quarrel, and here it is able to show the origin of measure.

In the Third term (Firming era), a calendar was considered to clear the sowing and harvest time. This is a scientific consideration and a culture grew up by the festival day celebrates harvest. And then the barter that the harvest was set in base had flourished, and a society that a producer is a consumer in same time had bone. Here an act of measure was essential.

In the Forth term (Industrial Revolution era), a lot of machine is invented, and by using the machines the thought of automatic and measurement had advanced. These current helped industrialization of society. The industrialization had diversified the object to treat (control objects, measurement objects, ---), and here many sensors had going developed. Besides signal and information analysis became important more and more. And a big consumer society that the consumer was divided from the producer had formed .

In the Fifth term (After Industrial Revolution era), Semiconductorization of electronic circuit by the invention of transistor had advanced, and it had accelerated the development of computer. And automation used computer and communication technologies (OA, HO, CAD, CAM, C&C, etc.) had expanded. Here, adding digitalization, information science, and life science appeared. Then, it becomes easy to get information individually so that the society was going to individualism society. The role of measurement in this era had became important more and more. Those are development of sensors, signal conditioning of sensor signal, signal analysis, information analysis, acquisition of knowledge, etc..

In the Sixth term(Modern Information era), the communication systems have developed and now this term is progressing.. If the fifth term is called as Information revolution era toward Industrial revolution era of the forth term, the sixth term will say as its grows term. But, the society of the fifth term had developed by using non-renewing resources so that in the sixth term, the recycle of resources and the environments must be studied. Here, the control of resources and environments by information becomes important, and the measurement must be carry out its role.

Like this, there are thought and method in each term. The thought corresponds to science and the method corresponds to technique to practice the thought. Namely, the development of society depends on scientific thought and its realization technique. And it is clear that an act of "Measure" relates with the realization of scientific thought in each term. Fig.1 shows these relations.
. .Besides, it is regarded that the connection with "Measure" and the practice of scientific thought in each term is mainly doing to avoid the quarrel and to keep balance of society.
On these verification, it becomes clear that the education of scientific basic knowledge for the people live in the society carried on natural science, technique and information needs and as the subject "Measurement
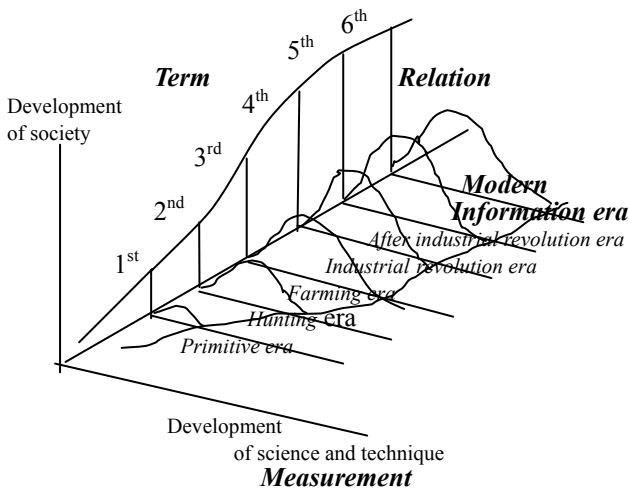
Science" is appropriate
.

Fig.1　Relation with development of Science,
Technique and Society

2. BASIC POSTURE OF EDUCATION METHOD

Fig.2 **(A), (B)** shows the basis posture of education by "Measurement Science".

(A) is a reference to understand the meaning. At an education class of the first stage, when put an apple on the teacher's desk, consider what education subjects are possible to set. Foe example, if the "Production" and "Agriculture" are set as the subjects, the distribution structure of fruits and the fertilizer to nourish are possible to educate. And especially, education of the　　　basis of chemistry as scientific education becomes possible. Other side, weather, quality, nutrition,--- problems are able to educate.
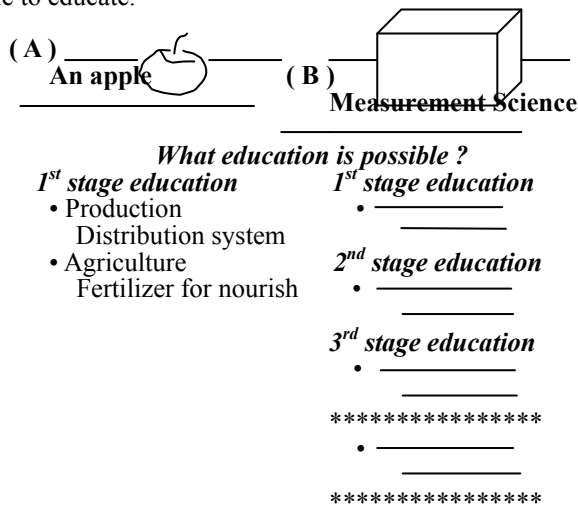

Fig.2　Posture of education method

(B) is a diagram which changed an apple to a box of "Measurement Science". Here, what education subjects possible to set according to the education stages　?, and how possible doing basic scientific education ? These problems are the proposal of this paper.

3." MEASUREMENT SCIENCE" EXPRESSED BY FOUR CONCEPTS AND THE DEFINITION FUNCTIONS

On the stand point of education, we had given Four measurement concepts on the structure of "Measurement Science" under the basis of measure, and had indicated by numerical expression [5],[6],[7]. The numerical or mathematical expressions of measurement have studied by some scientists [8].[9].[10], and these studies are almost discussed based on "Set Theory". In this study, it is not saying to use "Set Theory", but we give the specific character on "Meaning of "Set". There are nature of a man and an animal, disposition of an act of a man, composition of a man, quality of a man, the matter and the thing, and so on

Here, in the first, "Basis of measure" is expressed, and "Definition functions " are set on the relation of the causality (cause and effect, input and output). And in the second, "Four concepts of measurement" are given.

(1). Basis of measure
- ◎ "An act to measure" : M
- ◎ "Need of an action of a man" : N
- ◎ "Relation with M and N "
  $$:Mapping \quad f : N \rightarrow M \qquad (1)$$
- ● **"**General factor of measurement"
  $$: M_p \ (p = 1,2,3,-----). \leftarrow (M|N) \qquad (2)$$
  $$P \ \text{decides by} \ N$$
- ◎ "Causality needs for M_p "
  $$:\text{Cause or Input} \ I, \text{Effect or Output} \ R$$
- ◎ "Practical measurement"
  $$: I \cdot [M_p] \rightarrow R \quad \text{or} \quad I \times [\![M_p]\!] \Rightarrow R \quad (3)$$
  $$: \cdot : \text{a Product}, \quad \times : \text{a Cartesian Product}$$
- ◎ "Definition function"
  $$: \text{Technical definition function} : [M_p]$$
  $$: \text{Scientific definition function} : [\![M_p]\!]$$

(2) Four concepts of measurement

There are various I and R, on the Practical measurement so that M_p is studied, discussed , concerned and practiced. In this time, by treating this "Definition function" similarly with Technical function and Scientific function, the concept of measurement becomes easily understandable. Already we had given Conceptual diagram of "Measurement Science" for Liberal Education by these thought [5],[6],[7]. Here, Four Concepts have given.
- ◎ Concept 1 **:** "An act of sensing"
  $$: I \cdot [M_{p=1}] \rightarrow R \qquad (4)$$
  $$: m(t) \cdot [S|N] \rightarrow s(t) \quad \text{or} \quad s'(t) \qquad (5)$$
  Where,
  $m(t)$ **:** Change of state or situation of Measurement object
  $s(t)$ **:** time series signal got by sensing
  $s'(t)$**:** conditioning signal of $s(t)$
  S **:** Sensing
- ● Concept 2 **:** "An act of analysis"
  $$: I \cdot [M_{p=2}] \rightarrow R \qquad (6)$$
  $$: s(t) \text{ or } s'(t) \cdot [A|N] \rightarrow s(d) \qquad (7)$$
  Where,
  $s(d)$ **:** signal on domain except time domain
  A **:** Analyzing
- ● Concept 3 **:** "An act to get knowledge"
  $$: I \times [\![M_{p=3}]\!] \Rightarrow R \qquad (8)$$
  $$: m(t) \text{ or } s(t) \text{ or } s(d) \times [\![U|N]\!] \Rightarrow K \qquad (9)$$
  $$: K = \text{--- for example ---} \{K_1, K_2, K_3, ---, K_i ---\} \qquad (10)$$
  Where,
  U**:** When uses effectively information, the information becomes Knowledge. U has a role to extract the knowledge. Then U is Information

processing or Information analyzing. Here, scientific discussion needs on the standpoint of utilization of knowledge.

K : Knowledge.

● Concept 4 : "An act for individual activity and social activity".

$$: I \cdot [\![M_{p=4}]\!] \Rightarrow R \qquad (11)$$
$$: K \times [\![OP | N]\!] \Rightarrow C \qquad (12)$$

$: C =$ --- for example -- $K=\{K_1, K_2, K_3, ---, K_i ---\}$, ---$OP=\{OP_1, OP_2, OP_3, ---, OP_j, ---\}$, --- ,

$$
= \begin{pmatrix}
(K_1,OP_1) \ (K_1,OP_2) \ --- \ (K_1,OP_j) \ ------ \\
(K_2,OP_1) \ (K_2,OP_2) \ --- \ (K_2,OP_j), \ ----- \\
------------------------------ \\
------------------------------ \\
(K_i,OP_1) \ (K_i,OP_2) \ --- \ (K_i, OP_j) \ ----- \\
------------------------------ \\

\end{pmatrix}
$$

(13)

When Knowledge K_i was practiced by OP_j.

The Contribution becomes C_{ij}.

Where,

OP: : We should make good use of Knowledge to individual and to society. OP has a role to discusses the utility of knowledge. Then OP is Knowledge operating. Here, scientific discussion needs with the relation of N,K,OP and C.

C : Contributing

Fig.3 is these expression by diagram.

4. UPLIFTE OF EDUCATION TO RISE UP SCIENTIFIC SENSE BY FOUR CONCEPTS OF MEASUREMENT SCIENCE

Everyone will allow that the national education is most important, and the nation having high level education system makes exiting progress. In almost developed countries, the education stage is classified in four or five stages.

The first and the second stages are ranked as National Compulsory Education, and the culture, the society and the natural science are taught. The third stage education is set as the stage to lean the basis of special course, and the basic subjects of each field are taught. And sometimes this stage is located as Semi-Compulsory Education. The fourth and the fifth stage education are set as special Course Education, and the basis of learning and the development are discussed and studied.

School takes these are, for example in the case of Japan, the first stage corresponds to Elementary School (Primary school), the second stage corresponds to Middle School (Junior High School, Intermediate School), the third stage corresponds to High School (Senior High School, Upper Secondary School), and the fourth stage is University, the fifth stage is Graduate School (Post Graduate School).

The scientific education to rise up the sense of natural science, technique and information is doing generally through the education on mathematics, physics and other natural science subjects. And the education is practiced on from the first stage to the third stage education. But the merits and demerits of natural science, technique and information on society are not took up and not educated so strongly.

"The behavior of a man (An action of a man)" is done by "An act to measure", and the cultural and the social activity are consisted by the act to measure of people. Then when regard to "Learning" authorized "An act to measure" of human being as "Measurement Science", it is possible to educate the role that the natural science, the technique and the information carry out on the development of society with the scientific education itself

.Aim of this paper is a proposal to slot the contents of "Measurement Science" in each education stage (mainly in from first stage to third stage).
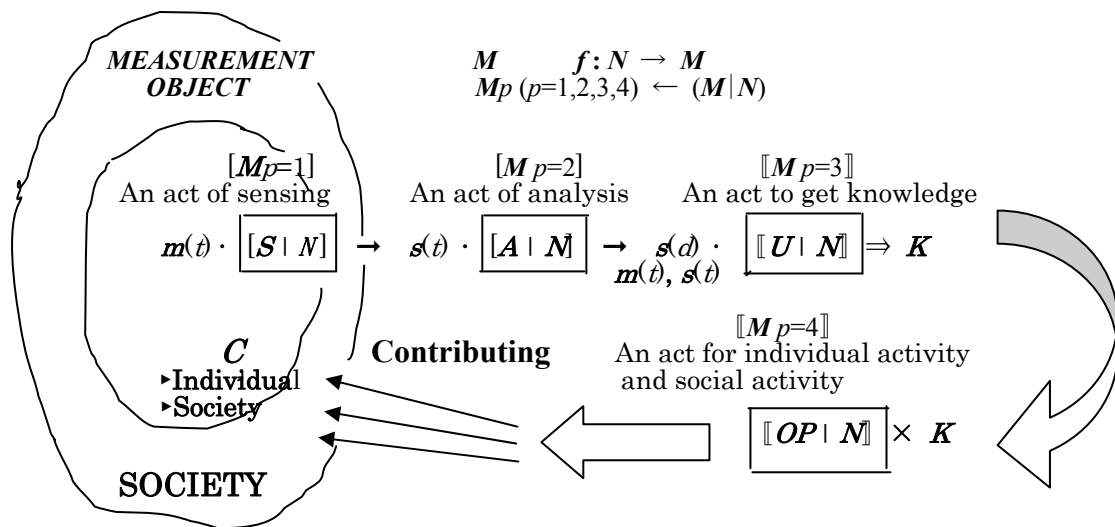

Fig.3　Conceptual diagram of "Measurement Science" expressed by Four concepts.

In below, an example of [Subjects of "Measurement Science" to use in Education to cultivate Scientific Basic Knowledge of People] is shown.

This example was constructed by referring a education book of "Measurement Science"(using about ten years over) for social and cultural course student of University written by one of authors (k.Kariya)[11]. And also this example was considered as the premise to use Conceptual diagram of "Measurement Science" (Fig.3) and Basis of measure, Four concepts and Definition functions (Formula (1) ~-(13)).

.
An Example of [Subjects of Measurement Science " to use in Education to cultivate Scientific Basic Knowledge of People].

First step ----- It is desirable to apply to the fist stage of education

■ Positioning of "Measurement Science" in Learning System.
  ▸ What is measurement?
  ▸ Technical side and Scientific side of measurement.
  ▸ Measurement system.
  ▸ Sociality of measurement.
  ▸ Various measurement object.
  ▸ Measure, Measurement ,and Metrology.

■ Relations with Measurement and Society.
  ▸ Relations with the development of an act to measure and the progression of society.
  ▸ Main society and measurement.

■ Information and Knowledge, and Method to get information and knowledge
  ▸ Meaning of information(All things we get).
  ▸ Meaning of knowledge(Information we recognize the value).
  ▸ Sensing to get signal .in time domain.
  ▸ Analyzing to get signal in the domain except time domain.
  ▸ Information processing or Information analyzing to get knowledge.

■ Three Works of Measurement and Three Missions.
  ▸ The work of metrology.
    □ Responsibility for society of metrology.
    □ Setting of standard of metrology and the supply.
    □ Traceability and keep of metrological standard.

  ▸ The work to grasp information and to get knowledge.
    □ Signal and information.
    □ Analysis of signal and information, and knowledge,.
  ▸ The work to utilize knowledge.
    □ Improvement of state and situation status.
    □ Calculation of future.

Second step ----- It is desirable to apply to the second stage of education,

■ Foundation of Measurement.
  ▸ Structure of measurement.
  ▸ Measure scale.

■ Systematization and Measurement System**.**
  ▸ Philosophy of systematization of measurement.
  ▸ Measurement system as the progress of individual and society.
  ▸ Measurement system in measurement engineering.
  ▸ Operation element to solve the problems on a man and society, and measurement system.

■ Static Measurement and Active Measurement.
  ▸ Static measurement and accuracy.
  ▸ Active measurement and signal.

Third step ----- It is desirable to apply to the third stage of education.

■ Sensor and signal.
  ▸ Three modes to construct sensors.
  ▸ Output signal of sensors.
  ▸ Sensitivity of sensor and signal.

■ Signal Analysis and Information Processing (Information Analysis).
  ▸ Easy understandable explanation of signal.
  ▸ Signal structure.(Stochastic process).
  ▸ Signal analysis.
    □ Distribution of the amplitude of signal (Amplitude Probability Density Function).
    □ Fluctuation of signal (Frequency Distribution Function).
    □ Relation with signal to signal (Correlation Function).

  ▸ Information processing (analysis).
    □ The results of signal analysis, and information.
    □ Extraction of knowledge at the relation with the change of measurement object (the change of state and situation).
    □ Transition process of the elements of signal analysis, and knowledge.
    □ Transition process of state and situation in measurement object.

■ Application of Knowledge..
  ▸ Grasping of the present status of measurement object.
  ▸ Modification to standard.
  ▸ Improvement of measurement object.
  ▸ Prediction of the state and situation of measurement object.
  ▸ Activity for individual progression and contribution to society.

Here, the explanation in each education stage at present education becomes important.
In the first step, the concept of measurement should be taught simply, and also the relation between measurement and society, the role and mission of measurement in society and the grasping knowledge should be emphasized. And it becomes important to understanding Fig. 3 and the meaning of symbolic numerical expression of Basis of measure, Four concepts of measurement (Concept 1~4). Teacher should be use effective diagrams and explanations.
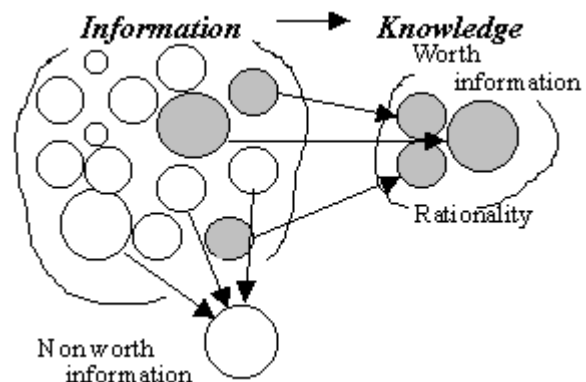

Fig.4   One of example of diagrams to make easy understanding in education stage 1 and 2 (Understanding of Information and Knowledge).

Fig.4 is one of example to be made understanding the meaning of Knowledge.

In the second step, the basis of measurement, namely, Foundation of measurement, Measurement system, and Static and Active measurement should be taught. In that time, the relation of Mapping: $f\ N{\rightarrow}M$, the Need N , the practical measurement $M_p{\leftarrow}(M|N)$ should be explained. Especially the relation with standard and Need N is important.: And keeping special position , the effort of teachers to get enough understanding becomes need. Well understandable diagrams should be thought. Fig.5 is one of example to explain of the relation of measurement standard and Need N. And the meaning of this diagram is possible to understand by referring "Body temperature measurement" and "Blood pressure measurement" on healthcare.
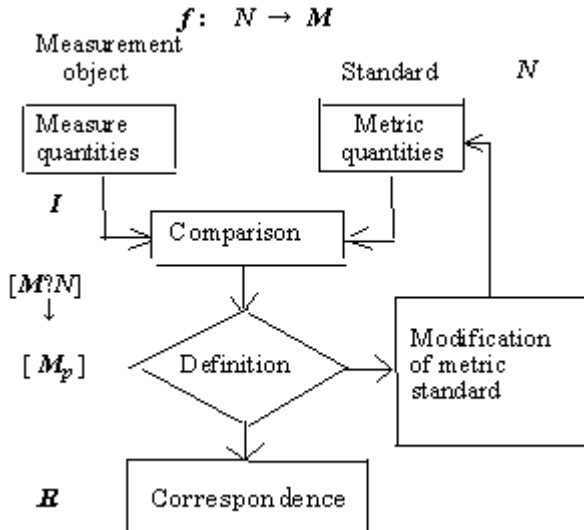

Fig.5　One of example of diagrams to make easy understanding in education stage 2 (Understanding of the relation of measurement standard and Need N.

In the third step, on the understand of education contents of the first step and the second step, Sensor and signal, Signal analysis, Information processing (analysis), Application of Knowledge are lectured.
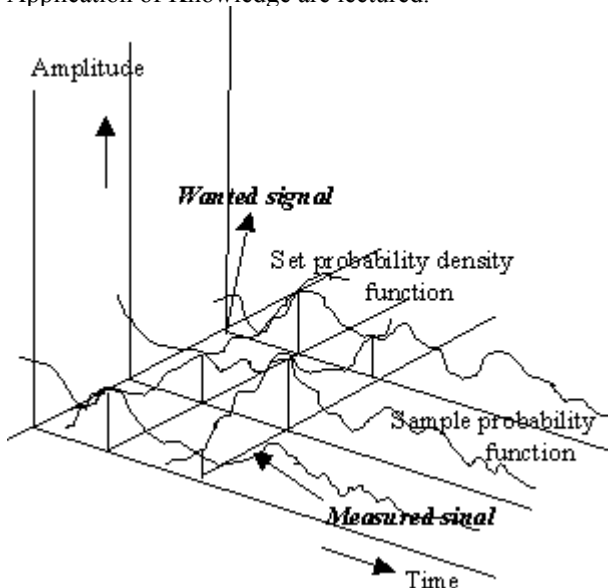

Fig.6　An example of diagrams to make understanding of signal structure.

These explanations become important for not special course students on the third stage education. But, on the base of understanding of the meaning of signal in the time domain and signal in the domain excepted time domain educated at first step, here, the structure of stochastic process of signal should be taught easily. In the explanation of static and stochastic problems, it is possible to use a lot of understandable diagrams. Especially, Amplitude probability density function and the sample probability density function and the set probability density function are important for the understand of stochastic process of signal. Fig 6 is an example which showed a part of the diagram to explain signal structure. Here, the understanding of the signal which want to know and the signal which get by measure is important.

In the acquisition of information, it goes without saying that the application of computer and the system . are effective But it should recognize that the education to teach the relation among information, knowledge and measurement object is more important. Namely, in the education, we must teach the importance of applying the knowledge get by the act of measurement .Fig.7 is an example of contribution to society of measurement. Here, by how apply the result of measurement ($R{\rightarrow}K$), the contribution will be established.
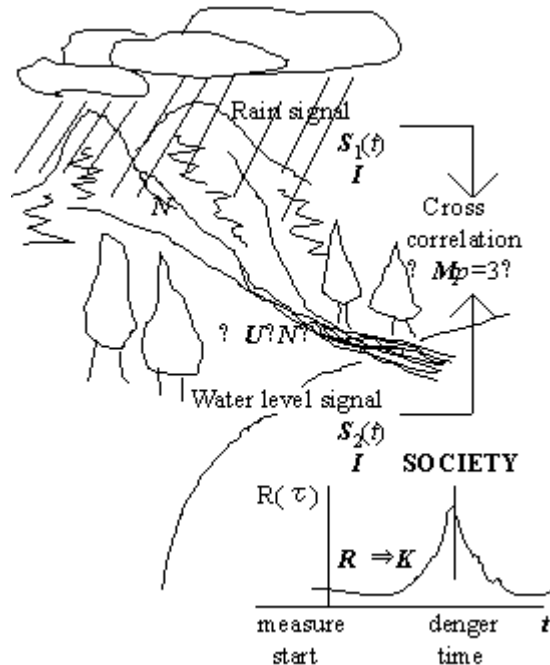

Fig.7　An example of diagram to explain the contribution to society of measurement.

5. USING METHOD IN EDUCATION OF CONCEPTS, DEFINITION FUNCTIONS AND CONCEPTUAL DIAGRAM

Already, the using method in education of proposal Four concepts, Four definition functions and Conceptual diagram showed in Fig.5 and Fig.7. These using method will becomes main point of this proposal so that indicates in totally using an example (This example had showed in one another paper[7]. Again shows by some adjustment).

Using method of "Measurement Science" expressed by Four concepts and Four Definition functions.
-----An example of measurement against noise on motor way (freeway) -----

Basis

	N	<u>The need</u> against noise on motor way.
	M	How an act of measure concern ?
$(M|N) \to M_p$		Noise measurement.
$I \cdot [M_p] \to R$		Causality.

Concept **1** "An act sensing"

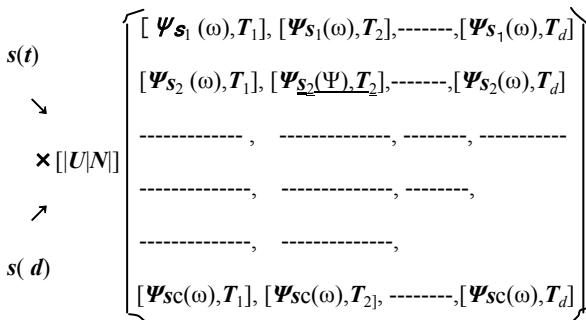I — Noise information from tire, engine, phone, wind, --- $\to$ Acoustics noise.

$I \cdot [M_{p=1}] \Rightarrow I \cdot [S|N] \to s(t)$

<u>An action</u> to sense the information I.
Microphone(selected).
Acoustics signal.

Concept **2** "An act of analysis"

I — Noise information oriented signal $s(t)$.

$I \cdot [M_{p=2}] \Rightarrow s(t) \cdot [A|N] \to s(d)$

<u>An action</u> to analyze the signal $s(t)$.
Frequency analyzer $\to$ Power spectral density analyzer $\to \Psi_s(\omega)$

Concept **3** "An act to get knowledge"

I — Noise information in power spectrum $\psi_s(\omega)$

An action to discuss the signal $\psi_s(\omega)$

$I \cdot [M_{p=3}] \Rightarrow I[|U|N|] \, s(t), s(d)[|U|N|] \Rightarrow I_{eff} \Rightarrow K$

Discussion of power spectral density at time slot $\Psi_{si}(\omega; t_i)$.

$$
\begin{array}{c}
s(t) \\
\searrow \\
\times[|U|N|] \\
\nearrow \\
s(d)
\end{array}
\left[
\begin{array}{cccc}
[\Psi_{s_1}(\omega), T_1], & [\Psi_{s_1}(\omega), T_2], & \text{-------}, & [\Psi_{s_1}(\omega), T_d] \\
[\Psi_{s_2}(\omega), T_1], & [\underline{\Psi_{s_2}(\Psi)}, \underline{T_2}], & \text{-------}, & [\Psi_{s_2}(\omega), T_d] \\
\text{-----------}, & \text{-------------}, & \text{--------}, & \text{-----------} \\
\text{-------------}, & \text{-------------}, & \text{--------}, & \\
\text{-------------}, & \text{-------------}, & & \\
[\Psi_{sc}(\omega), T_1], & [\Psi_{sc}(\omega), T_2], & \text{--------}, & [\Psi_{sc}(\omega), T_d]
\end{array}
\right]
$$

Knowledge K_1, K_2, K_3, --- exist in this formula. For example, the knowledge at time slot T_2 becomes
$K_1 = \Psi_{s_1}(\omega)$, $K_2 = \Psi_{s_2}(\omega)$, ---

Concept **4** "An act for individual activity and social activity".

I — Knowledge with noise measure.

$I \cdot [M_{p=4}] = C$ — An action to discuss the noise measure by Power spectral density at time slot.

$I \Rightarrow K_i, C \Rightarrow ISO$
$K_i \times \llbracket ISO \rrbracket \Rightarrow C_{i1}, C_{i2}, C_{i3}, ---, C_{ij}, ---$

If the power spectral density $[\Psi_2(\omega), T_2]$ is large and it must be controlled, the social operation becomes need.

.Power spectral Density for safety level of people

$\Psi(\omega)$

$\searrow$

$\times \quad \llbracket ISO \rrbracket \rightarrow \llbracket \Psi_{s_2}(\omega), \Psi(\omega) \rrbracket \rightarrow C_{i1} \Rightarrow$

$\nearrow$ *Contribution*

$[\Psi_{s_2}(\omega), T_2]$

C_{i1} is an absorption wall had Power spectral density $\Psi(\omega)$.

6. CONCLUSION

In this Paper, the progress had past reported was shown, and the outline of effectiveness of national education to rise up the scientific sense of people by using "Measurement science" was recognized. Here, the structure of "Measurement Science" was indicated by the basis and four conceptions. These thought consists by the introduction of four definition functions, and is supported by the basic setting "An action of a man" and "An act to measure". In this paper, an example of slotting the contents of Measurement Science to each education stage of National Education is indicated and emphasized..

REFERENCES

[1] K.Kariya, S.Takayama,"Education View point of Measurement Science", ACTA IMEKO 2000(Austria Vienna), Vol.2,pp.51-54, 2000.

[2] K.Karriya, S.Takayama," Expansion of Measurement Education from Engineering to Science", MEASUREMENT 2001(Smolenice), Slovakia Science Academy, pp. 3-6, 2001.

[3] K.Kariya, S.Takayama, "Proposal to introduce 'Measurement Science' in Education on All Fields and Ranks", ACTA IMEKO 2003 (Croatia Dubrovnik), pp. 145, 2003.

[4] K.Kariya, S.Takayama, "National Education to rise up Sense of Natural Science and Technology through Activity of Measurement", MEASUREMENT 2003 (Smolenice), Slovakia Science Academy , pp.27-30, 2003.

[5] K.Kariya, S.Takayama, "Four Expression of Fundamental Structure of Measurement Science", Proceedings of IMEKO TC-7 10th Symposium (Russia, Saint-Petersbug), pp98-101, 2004.

[6] K.Kariya, S.Takayama, "Measurement Science for liberal Education to rise up Scientific and Technical Sense on Society", MEASUREMENT 2005 (Smolenice), pp.117-120, 2005.

[7] K.Kariya, S.Takayama, "Appropriate Example of Basic Concepts of 'Measurement Science' for Liberal Education", Proceedings of Joint International TC-1+TC-7 Symposium (Germany, Ilumenau), pp.54-55, 2005.

[8] L.Finkelstein, M.S.Leaning, "A Review of the fundamental concept of measurement", Measurement Vol.2, No.1, Jan-Mr, pp.146-155, 1984...

[9] M.Morimura, "(Japanese) Theoretical Structure of Measurement", KEISOKU TO SEIGYO(Japan), Vol.19, No.1, pp.150-162.

[10]S.Takada,"(Japanese) Scientific Basis of Measurement", C ORONA SHA, pp.1-232, 1987.

[11]K.Kariya,"(Japanese) Measurement Science", SANNGYOU TOSHO, pp.1-155, 1997.