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An approach to chemical education at medical technologist training institutions in Japan

Hidetsugu Kohzaki[1,2], Yoichi Fujita[2] and Yoichi Ishida[2]

1) Department of Cell Biology, Institute for Virus Research, Kyoto University

2) Department of Medical Technology, Kyoto College of Health and Hygiene

Corresponding author: *Hidetsugu KOHZAKI*, PhD, Department of Cell Biology, Institute for Virus Research, Kyoto University, Shogoin-kawahara-machi 53, Sakyo-ku, Kyoto, Japan 606-8507. E-mail: charaznable.k@gmail.com

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Abstract

We teach chemistry at a medical technology school. Chemistry is not necessarily the favorite subject of Japanese students receiving paramedical education. However, many biochemical, microbiological, and advanced genetic tests are performed in the medical setting, and solutions and media also have to be prepared. Nurses and paramedics including medical technologists rarely prepare solutions because of automation in the medical setting and a lack of time. However, they might feel uneasy about certain aspects of medical practice, such as the use of infusions and injections, if they do not know how to prepare and label solutions. In addition, the annual national examinations include questions on concentration calculations.

In this article, we introduce our approach to providing chemical education for medical technologists.

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Introduction

In Japan, chemistry acted as the main driver of growth during the high-growth period. Thus, at that time, chemical education supported Japan. However, the academic ability of Japanese students has declined markedly because of the trend towards “science phobia” and pressure-free education; e.g., teaching the value of “π” as 3 and not requiring students to memorize the periodic table of elements. Since the introduction of IT, information science has been required in various fields (1). However, this is not true of chemistry. Recently, many Japanese researchers have won the Nobel Prize. Thus, science education, especially chemical education, has come to be reevaluated. We teach chemistry at a medical technology school. Although many of our students are good at IT, they lack chemical knowledge. Japanese junior high school students must choose between humanities or science courses. However, adequate chemical education is provided at junior high school. Thus, even students who enroll in a humanities course should be able to answer the chemical questions on the National Center for University Entrance Examinations. However, the students on the humanities courses stop studying chemistry because their main goal is to pass the college entrance examination. Thus, chemistry is only studied at junior high school by the students who take science courses. In addition, some students lose interest in chemistry because of their desire for pressure-free education.

Thus, chemistry has become unfamiliar to many students entering paramedic schools, such as nurses and medical technologists. In fact, many students have not seen the periodic table of the elements (ref.2 Chapter 1 I, Table.2 Science I ”Basic of chemistry”, Chemistry “Chemical bond”) or cannot write the molecular formulae of water and/or carbon dioxide (ref.2 Chapter 1 I.5, Table.2 Science I ”Basic of chemistry”, Chemistry “Chemical bond”), much less the structural formulae of covalent (ref.2 Chapter 1 II.9, Table.2 Science I ”Basic of chemistry”, Chemistry “Chemical bond”) or ionic bonds (ref.2 Chapter 1 II.8, Table.2 Science I ”Basic of chemistry”, Chemistry “Chemical bond”) or amino acids (ref.2 Chapter 5 IV.2, Table.2 Science I ” Amphoteric electrolyte”, Chemistry “Chemistry of proteins”).

However, paramedics should have some knowledge about amino acids (ref.2 Chapter 5 IV.2, Table.3 Science I ” Amphoteric electrolytes”, Chemistry “Chemistry of proteins”), sugars (ref.2 Chapter 5 IV.1, Table.2 Chemistry “Chemistry of sugars”), lipids (ref.2 Chapter 5 IV.3, Table.2 Chemistry “Chemistry of lipids”), ions (ref.2 Chapter 1 II.8, Table.2 Chemistry “Chemistry bond”), and osmotic pressure (ref.2 Chapter 2 V). Laboratory test values should be correctly understood by all medical practitioners because they will encounter a wide variety of test parameters during their jobs, such as measures of *in vivo* enzyme function (enzymatic activity in blood is affected by metabolite levels and diseases) (Table.2 Science I ” Enzyme reaction”, Table.4 1.B.”Unit of enzyme”), and the shortage of physicians in Japan is increasing the burden placed on medical institutions. In addition, there is also an increasingly broad range of medicines in use because of the rapid development of novel agents, and numerous diagnostic kits have also been developed. Furthermore, since the completion of the human genome project, chromosomal gene tests have become more common, and pharmacogenomics and personalized medicine have advanced. As a result, chemical questions have arisen on the National Examination for Paramedics (Table.4).

Methods and results

Medical technology schools produce curricula that help their students to pass the National Examination for Medical Technologists. Hence, they provide technical knowledge and skills, but allow no time for chemistry (Table 1). As such, students do not learn the chemistry they will require during medical practice. In addition, students cannot learn all the contents of basic textbooks for medical technology schools (2). Thus, an exam was conducted to evaluate the basic scientific knowledge of our students. This written exam included questions pertaining to the measurement of acids and alkalis with litmus paper (ref. 2 Chapter 3 IV), the three states of water (ref. 2 Chapter 2, I, II, III), the chemical formula for water (ref. 2 Chapter 1 I. 5), and how to calculate the percentage concentration of NaCl (ref. 2 Chapter 2 IV. 1). It was used to assess whether the students possessed academic knowledge that they were supposed to have learnt during middle school.

In fact, about 20% of the enrolled students answered less than 50% of the questions in the science and chemistry tests correctly. Most of the enrolled students did not possess chemical knowledge because they did not take chemistry as an elective subject in high school due to a desire for pressure-free education. Thus, we used Mendeleev's periodic table to make them familiar with the chemical world (Table 2). In Science I, we taught chemical bonds, molar concentrations, solution preparation, specific gravity, etc. Colorimetry is important because it is used for the measurement of protein and nucleic acid concentrations, immunostaining, etc., in biochemistry (Table 2A). Thus, chemical knowledge is necessary to understand biochemistry. we also taught enzyme reactions and alcohol metabolism in the living body as well as the in vivo behaviors of proteins and sugars (Table 2B).

	Information science	English education	Biochemical examination	Clinical physiological examination	**Chemistry***	Total credit points
Credit points (hours))	2 (90 hrs)	4 (115 hrs)	10 (330 hrs)	10 (315 hrs)	2 (48 hrs)	115 (3435hrs)
%	1.7 (2.6)	3.5 (3.3)	8.7 (9.6)	8.7 (9.2)	1.7 (1.4)	100

Table 1. Credits and time devoted to chemistry education at medical technology schools

*Chemistry includes 'Science I' and 'Chemistry', which are described in Table 2.

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A. Science I

Implementation term: First semester of the first year

Time: 18 hours

Teaching method: Lectures

Number of units: One unit

Contents: Exponent notation and significant figures

Molecular weight and concentrations

Syllabus

Subjects	Number of lectures	Contents
Significant figures	1	Significant figures; Exponent notation and significant figures SI units
Units	1	SI units and derived units Prefixes of units and unit conversion
Basics of chemistry	2	Valency and chemical bonds Element symbols
Concentrations	3	Molecular weight and molar concentration Normality and percentage concentration Converting concentrations Specific gravity and calculating molar concentrations using specific gravity
Chemical equilibrium	2	Chemical equilibrium and pH
Electromagnetic waves	1	Classification by wavelength and absorbance
Amphoteric electrolytes	1	Amino acids and proteins; electrophoresis
Enzyme reactions	2	Michaelis constant, measurement of substrate concentrations, and measurement of enzyme

		concentrations

B. Chemistry

Implementation term: First semester of the first year

Time: 30 hours

Teaching method: Lectures

Number of units: One unit

Contents: Atoms and molecules; bonds; structures of carbon compounds and various linking groups; and the chemistry of sugars, lipids, and proteins

Syllabus

Subjects	Number of lectures	Contents
Atoms and molecules	2	Symbols of elements, atoms, and molecules Atoms, protons, electrons, and neutrons Calculation of atomic weight and molecular weight
Chemical bonds	2	Ionic bonds, covalent bonds, and hydrogen bonds Number of elemental associations
Carbon compounds	3	Carbon compounds and organic chemistry Double bonds and hydroxyl groups Oxidation, aldehyde groups, and carboxyl groups
Chemistry of sugars	2	Polyhydric alcohols and sugars, and sugar conformations Glycosidic linkages and polysaccharides

Chemistry of lipids	3	Carboxylic acids, unsaturated bonds of fatty acids Ester bonds and soap Phosphoric acid, phospholipids, surfactants, and biomembranes
Chemistry of proteins	3	Amino groups, amphoteric electrolytes, and peptide bonds Basic properties of proteins Catalysts and enzymes

Table 2 Syllabus for chemistry education at medical technology schools

A: Science I; B: Chemistry.

In Science I, we teach basic chemistry. In Chemistry, we teach biochemistry and chemistry required by medical technologists.

The education program was structured as follows (Remedial classes were introduced in 2008. Students who received these classes took the 55th or later National Examination.)

1. Remedial classes were organized for students who performed poorly in the tests conducted at enrollment in order to review the science and chemistry lessons provided to them at elementary and junior high school. This class usually contained about 10 students each year. Table 3 shows the remedial class of 2010, which contained 16 out of 40 enrolled students. They reviewed their exam results and deepened their understanding of chemistry after school for approximately 1.5 hours a

week to help them understand the Science I and Chemistry classes (Table 2).

2. A quiz was given on the topics covered in the abovementioned class to improve the students' understanding. Topics associated with a low percentage of correct answers were repeated.

3. Further remedial classes were organized after school for the students who performed poorly in the quiz to provide thorough individualized instruction; i.e., they repeatedly solved the questions that they had found difficult.

Details of the remedial classes for the "biology class" (3) and "mathematics class" (4) are submitted respectively.

The achievements of the enrolled students were assessed by the final examination. The mean score exceeded 70 every year. All of the students that scored 50% or less in the enrollment tests achieved scores of 60% or above. Some students achieved increases in their scores of 60 points or more. Thus, the main goal of my program seemed to have been achieved.

The effects of the remedial chemistry classes on chemistry scores were confirmed. The effects of the remedial mathematics and biology classes were also confirmed.

Some students who took the remedial chemistry classes actually achieved higher scores in the Science I examination. On the other hand, the results of the mean score and score distribution of introductory statistics showed that the remedial mathematics classes were ineffective (Table 3A). However, they also showed that the remedial chemistry and mathematics classes were more effective at improving the students' chemistry scores than the remedial biology classes (Table 3B). The increases in the Science I and Chemistry scores of the students who took the remedial mathematics classes might have been due to improvements in their ability to calculate concentrations, such as molar concentrations.

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A

	Science I		
Scores	Students who took the remedial chemistry classes	Students who took the remedial mathematics classes	All students
90-100	1	0	19
80-89	5	2	26
70-79	6	2	18
60-69	1	2	6
50-59	2	1	2
49 or below	1	1	3
Total	16	8	74
Mean	74.1	72.9	79.8

B

Scores	Chemistry			
	Students who took the remedial chemistry classes	Students who took the remedial mathematics classes	Students who took the remedial biology classes	All students
90-100	2	0	0	13
80-89	6	2	1	24
70-79	3	1	1	14
60-69	1	2	2	4
50-59	2	0	0	7
49 or below	2	2	1	11
Total	16	7	5	73
Mean	69.9	57.9	60.0	71.5

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Table 3. Effects of the remedial classes on the final examination scores

A: Effects of the remedial classes on the examination scores for Science I

B: Effects of the remedial classes on the examination scores for Chemistry

* Total number of students who took the remedial mathematics classes differs between Tables A and B, because one student quit school.

The range of possible questions for the National Examination for Medical Technologists (5) is shown in Table 4, and some chemical questions are included on the test. In addition, chemistry is essential for clinical chemistry. Thus, chemistry is a fundamental subject that can have a broad influence on students' education.

1 Basics of biochemical analysis	A Physicochemical properties	Physical properties of compounds
		Properties of solutions
	B Units	Units of chemical analysis
		Units of enzyme activity
		SI units
	C Analytical reagents	Standard substances
		Handling and preparation
	D Test samples	Blood collection and blood collection conditions

		Sample stability
		Sample treatment methods
		Influence of coexisting substances
2 Principles behind and methods of biochemical analysis	A Absorptiometers	Relationship between the wavelengths and colors of electromagnetic waves
		Visible and ultraviolet light
		Sources of visible and ultraviolet light
		Complementary colors
		Lambert-Beer rule
		Molar extinction coefficient
		Principles of spectrophotometry and components of spectrophotometers
		Principles of atomic absorption spectrophotometry and components of atomic absorption spectrophotometers

Table 4. Range of possible chemistry questions for the National Examination for Medical Technologists

Discussion

Japanese medical institutions have undergone considerable automation, and most test parameters are now automatically examined in clinical laboratories. In addition, the ISO15189 (6) guidelines have been established for clinical laboratories, and the standardization of test data has also been demanded. The following international standards are relevant to clinical laboratories: ISO15193 (In vitro diagnostic medical devices -- Measurement of quantities in samples of biological origin -- Requirements for content and presentation of reference measurement procedures)(7), ISO15194 (In vitro diagnostic medical devices -- Measurement of quantities in samples of biological origin -- Requirements for certified reference materials and the content of supporting documentation)(8), ISO17511 (In vitro diagnostic medical devices -- Measurement of quantities in biological samples -- Metrological traceability of values assigned to calibrators and control materials)(9), and ISO18153(In vitro diagnostic medical devices -- Measurement of quantities in biological samples -- Metrological traceability of values for catalytic concentration of enzymes assigned calibrators and control materials) (10). ISO9001 (quality management systems) (11) is also applicable. Thus, it is vital that medical technologists are able to produce accurate test data.

Considering the trends in exams over the past 7 years, a mean of 32 chemical questions, including biochemical questions, are set annually as clinical chemical questions in the National Examination for Medical Technologists (5). However, chemistry includes the fields of biochemistry and clinical chemistry (Table 4). To become a medical technologist, students must pass the national examination, which requires a high score.

We educate medical technologists and have prepared curricula that promote the understanding of biochemistry and clinical chemistry (Table 2). Correctly calculating the effects of our curricula is difficult. However, the results of the National Examination for Medical Technologists show that the mean score for Clinical Chemistry was 10% higher than those for

Genetic Testing and Information Science, which we were also responsible for (12) (Table 5), but 4% lower than that for Biology & Biochemistry.

The authors have been offering a remedial chemistry course because it is difficult to encourage students to undergo the basic course for medical technologist training institutions due to the recent reduction in students' interest in science and their lack of scientific knowledge. In fact, some students withdrew from the school because they could not keep up with the class, and the pass rate for the National Examination had begun to decrease (Tables 5 and 6). Although it has been only a few years since the remedial classes were adopted (Table 3), the National Examination scores of our students have increased by 4.4% for clinical science and 2.1% for all subjects, and the pass rate was also 4.2% higher among the students who took the remedial classes than among those who did not. The 'Science I' and 'Chemistry' curricula that we introduced are not the only the reasons for the increased pass rate; however, it is considered that increases in the students' scores for clinical chemistry contributed to it (Table 6). Basic chemistry provides a solid foundation for further studies in related sciences including clinical chemistry and gene testing, particularly biology and biochemistry.

Therefore, we've admitted that our program was not a complete success; however, it seems to have helped the students to pass the National Examination (Figure 1, Table. 6).

	Clinical Chemistry		Genetic Testing		Biology&Biochemistry		Information Science		National Examination (NE)					
	KCHH	Questions	KCHH	Questions	KCHH	Questions	KCHH	Questions	KCHH		Ministry of Health, Labour and Welfare			
Edition	Mean (%)	Number	Mean (%)	Number	Mean (%)	Number	Mean (%)	Number	Mean (%)	pass rate	Pass Rate	Exaninees	SC	Number
56th	71.9	32	47.8	5	75.8	16	70.3	4	66	78.7	67.8	4,060	2,753	200
55th	71.3	32	69.5	2	70.7	17	69.5	4	68.6	91.8	71.8	3,701	2,657	200
54th	65.1	31	64.7	3	68.2	19	48.7	3	65.2	81.6	73.7	3,997	2,947	200
53th	67.5	32	73	6	77	8	65	4	65.3	80.5	74.7	4,023	3,004	200
52th	79.9	32	59.5	6	87.3	15	77.3	3	70.8	94.9	72.9	4,071	2,968	200
51th	69.1	32	51.8	4	68	15	70.8	4	67.5	85.5	75.2	4,025	3,164	200
Mean	70.8	31.8	61	4.3	74.5	15	66.9	3.7	67.2	85.5	72.7	3979.5	2915.5	200
S.D.	4.09	0.17	4.09	0.67	2.99	1.53	3.99	0.21	0.9	2.67	1.1	56.77	74.51	0
N	6	191	6	26	6	90	6	22	6	6	6	23877	17493	1200

Table 5. Scores for clinical chemistry on the National Examination for Medical Technologists

Chemistry is included in clinical chemistry. KCHH: data for the Department of Medical Technology, Kyoto College of Health and Hygiene. Ministry of Health, Labour, and Welfare: National Examination for Medical Technologists scores for the whole of Japan. SC : successful candidates. Number: the number of questions.

Remedial classes	NE edition	Mean clinical chemistry score	Mean NE score	NE pass rates

+	55th & 56th	71.6 %	67.3 %	85.3 %
-	54th & 53th	67.2 %	65.2 %	81.1 %

Table.6 Contribution of remedial classes to National Examination scores.

*NE: National Examination

* Because the pass rates of the 53rd or prior national examinations exceeded 90%, students did not require remedial classes.

* Since the contents of examination markedly changed after the 53rd national examination, the test results before the 53rd national examination were excluded from this study.

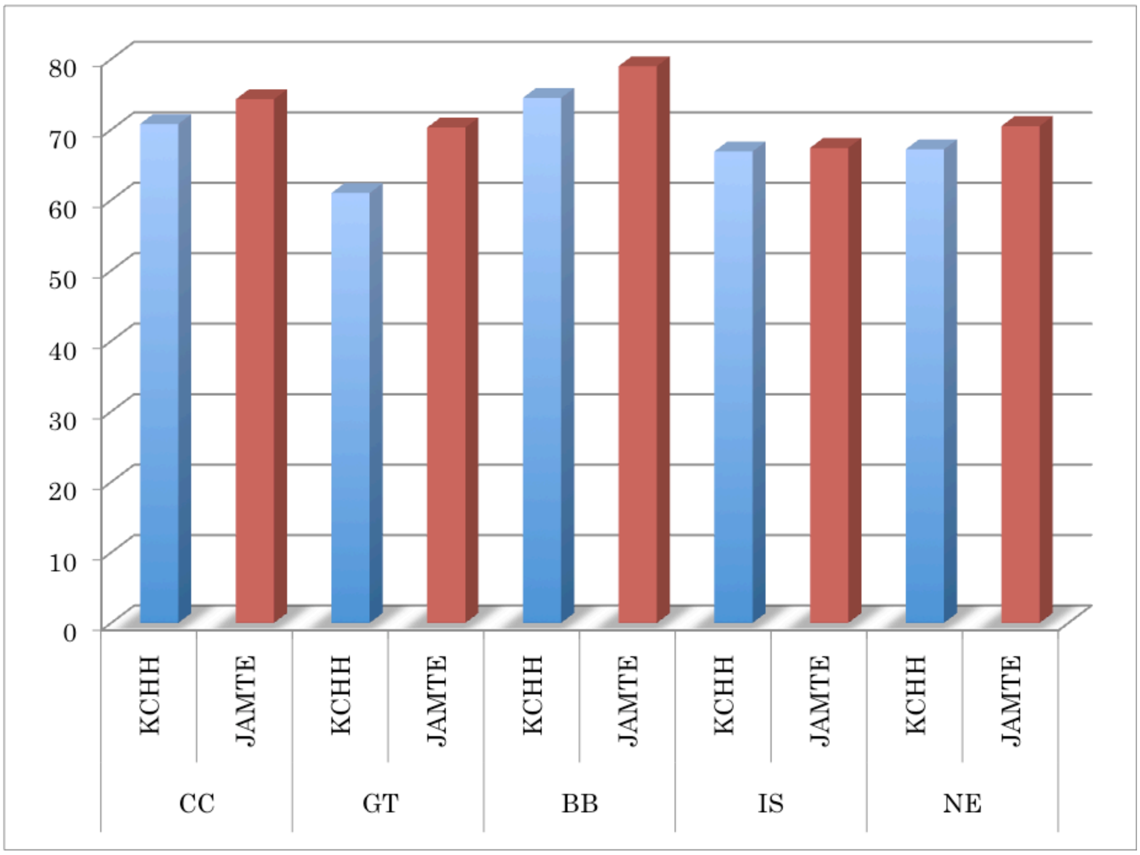

Figure 1. Comparison of the scores obtained on the National Examination for Medical

Technologists between our school and others across Japan (5). The Japanese Association of Medical Technology Education (JAMTE) is composed of medical technology schools (13). KCHH: the mean score for Kyoto College of Health and Hygiene, JAMTE: the mean score for the medical technology schools belonging to the JAMTE. CC: Clinical Chemistry, GT: Gene Testing, BB: Biology & Biochemistry, IS: Information Science, NE: National Examination.

Furthermore, qualifications, such as the Qualified Class 1 and 2 Laboratory Technologist qualifications (14) and the Japan Society of Clinical Chemists qualification (15), have been established to improve the skills of medical technologists. Knowledge about clinical chemistry and the skills necessary for quality control should be obtained through these qualifications. Quality control is required to keep medical treatment fees low and also contributes to hospital management.

In Japan, the management of toxic, highly poisonous, and hazardous substances is strictly regulated. These substances should be similarly handled in hospitals and clinical laboratories. Thus, paramedics should have chemical knowledge about these substances to allow them to handle them appropriately.

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