Reformation of Hokkaido University: New Conceptions of a Graduate Research University

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Abstract — The goals of general education in the university are of great importance. This article considers the ethics, base of knowledge, and fundamental academic tools that students may need to work in society after graduation. Students should be prepared to deal with realistic problems concerning ethical principles in order to support the development of the future society. The earth's natural resources are limited and society needs to discover how to live in symbiosis with both natural resources and other living beings. Although human beings are special animals, human beings are nevertheless animals. These opposite aspects of humanism and ecology may instigate complicated discussion about the basis of European monism and Asian pluralism. We have to begin to motivate students to learn to view world issues in their entirety, including perspectives of the cultural, social and natural sciences within the framework of a closed ecological system. This is the starting point where students can consider what ethics are needed to live in the new era. Education about contemporary affairs and history including the history of science and technology is required.

The first goal for students is to acquire the basic tools needed for knowledgeable social activity, literacy in natural languages as well as in electronic information systems. The next goal for students is to develop the appropriate attitudes and decision-making skills grounded in naturalism; this is the philosophical and educational foundation of Hokkaido University. In learning geography, for example, this integrated approach to freshman education would give the student a variety of field experiences, including forest, meadow, volcano and lake studies. The next step in the curriculum would be to learn basic sciences such as literature, sociology, physics, chemistry, and biology. And, we would construct a freshman center equipped with modern information facilities for hundreds of students in a university forest.

In professional schools, students would learn the fundamentals and applications of their special fields. In addition, they need to learn subjects in diverse other academic fields, including the core research procedures, products, and future opportunities and challenges of those fields. This curriculum requires an integrated approach illuminated by parallel sets of subjects that foster thinking with a compound eye view. The inclusion of such parallel subjects is also recommended in introductory courses to acquaint students with their special field within their professional course. The design of such curricula might be best realized on a quarter rather than semester system, offering a day in the weekly class schedule for learning from faculty of other programs.

1. INTRODUCTION

Today, in the fields of science and technology, six years of university education — from freshman to completion of a master's degree in graduate school – is gradually becoming the norm in Japan. For example, the number of students in the school of engineering of Hokkaido University is about 750 per year for a bachelor's degree, about 520 for a master's degree, and about 140 for the Ph.D. program. In the school of science, the numbers are about 310, 230 and 100, respectively. Since World War II, four steps of education have been carried out in the university: the liberal arts level (freshman and sophomore years); undergraduate department-based study (junior and senior years); two years of graduate studies for a master's degree; and three additional years for a Ph.D. (For medical and dental students: two years of liberal arts; four years of medical or dental school for an M.D. or D.D.S. ; and four additional years for a Ph.D.)

In 1995, Hokkaido University abolished its general education faculty, and each of its schools established a four-year fundamental program of study for a bachelor's degree (or a six year undergraduate program for doctoral degrees from its medical, dental, and veterinary medicine schools). The two-year master's program has been connected to the basic undergraduate program for advanced studies (except the above mentioned six year schools) followed by a three-year Ph.D. program. All research groups are reorganizing into graduate research laboratories, and each of the laboratories present a compulsory graduate study program for their essentials. Postgraduate studies for both the master's and the doctor's degrees are becoming a major part of professional education and research in the university. Undergraduate education serves as a foundation for graduate school, teaching the fundamentals of science and technology. The continuing education program is included in the graduate school activities for both the master's and Ph.D. degrees. There are various discussions underway regarding the future structure of the social science schools needed to lead the way into the coming century. However, plans for restructuring the social sciences are not yet fixed, in contrast to the rapid progress in reforming the science and technological schools. This document presents new concepts for developing both graduate and undergraduate programs at Hokkaido University for the next century. Because reform in the social sciences is progressing more slowly, this article focuses on the example of the natural sciences.

2. Educational Levels and Functions

Undergraduate and graduate studies can be classified as follows in terms of the following educational levels and functions:

1) Transition stage from high school to university (freshman). A series of classes provides an adaptable academic background for subsequent university studies. These classes are given to students to compensate for insufficiencies of high school preparation, generally the result of the diversity of the various high school curricula. At the same time, these classes stimulate a transformation of attitude towards the study required at the university level. Acclimation to a university life and way of thinking is an important first step.

2) Undergraduate study for science and technology. Fundamental knowledge of the basic elements of science and technology are given as well as professional perspective and morality.

3) Graduate study for a master's degree: The first step of students' professional education is to acquire specified capabilities in their selected professional fields. This requires a rigorous curriculum. Continuing education will be commenced mainly at this stage.

4) Graduate studies for Ph.D. At this level, education focuses on the expansion of basic knowledge, the acquisition of independent research capability, the upgrading of professional ability, and the cultivation of a new frontier of science and technology. The last activity is the key factor to assess in evaluating the research training provided by the university. The first and second steps, however, are the most important for the faculty to undertake in a well organized educational system.

3. Transformation of the Attitude towards Learning

Most students entering the research university need to adjust their attitudes towards learning and education. Students need to see learning as creating new knowledge and understandings rather than the absorption of existing knowledge.

Changing student attitudes towards learning: From study to creation. In high school, students studied subjects as information to be explained and learned. High school students always had prototypes or models to study or a known level of expertise to reach. However, in a graduate research university, individuals should not be so certain of their educational destinations. Students must enter knowledge realms not previously entered. Therefore, it is very important for students to gain the awareness that, in the world, the quantity of unknown things is much greater than the quantity of known things. Students must change their intellectual attitudes towards learning as the study of known things to learning as the search for what is not yet known. Basic knowledge imparted in undergraduate studies is selected to cultivate the capability to know the unknown and to create new horizons. The well-established pathways idealized in textbooks are often surrounded in practice by many ambiguities. Established theories and procedures are only part of the human capability required for effective action in non-idealized conditions. New knowledge cannot be simply given (by senior professors and researchers): it must be sought. Students must learn that professors, like students, are people seeking better answers through trial and error. Undergraduate students should study the fundamentals, but should not yet attempt to describe whole perspectives with these simple understandings. Broad synthesis should be postponed to a later period in graduate studies.

Adjustment of educational background. A large variety of curricula and pedagogical approaches are evident in Japan's high school programs. High school students entering into the university bring diverse backgrounds and knowledge of the arts and sciences. The flexibility of high school programs sometimes results in an uneven background in the basic knowledge needed for a professional field. Varying levels of basic knowledge can present difficulties for edu-

cating university students. It is therefore essential to compensate for some of the deficiencies in entering freshman students' preparation soon after they enter the university. This difficulty would be avoided if the university required all admitted students to have mastered the fundamentals during high school. But if this requirement were implemented, some flexibility would be sacrificed in high school programs and fewer students would be eligible for the university. The university is considering opening the gate to a wide variety of high school students without requiring large numbers of basic education credits before entering to the university. We are intending to establish graduate study and research as the key focuses of education in the graduate research university. Hence, we are also thinking of the freshman and sophomore levels – as well as the high school program — as introductory steps for professional studies. The program of study should be useful for preparing a capable specialist or researcher at varying rates appropriate to diverse student needs. Those students who need a longer program can stay four years or a little longer at the undergraduate level, whereas those students proficient in basic abilities and able to proceed at a faster pace could skip either the first or last year of study depending on their educational needs and requirements. Academic credits could be accumulated across high school, undergraduate and graduate studies at an optimal rate for each student having a strong intention to enter a graduate research program.

4. Undergraduate Study of Science and the Fundamentals of Professions

In an undergraduate, departmentally-based program, the following two categories are essential:

1) Selected basic studies in engineering science and professional fundamentals

2) Study of professional ethics in social activities

In the university, one can teach only that fundamental knowledge constituting the skeleton of professional activities. To function as professionals, students must develop professional wisdom in addition to mastering basic technical knowledge. Wisdom and professional know-how are hard to teach in a university curriculum; their development depends on broad support from professional societies and others who have accumulated their wisdom over many years. This suggests two important purposes or directions for organizing undergraduate education:

1) Constructing a fundamental skeleton of a profession. One major purpose of the undergraduate curriculum is for students to construct a fundamental skeleton of knowledge needed for their developing professions. Hence, the curriculum should have a sound and flexible structure that supports the continuous exploration and gradual narrowing of professional interests within an initially broad cluster of related professions. Each curriculum should be clearly designed with an established syllabus; curricula corresponding to related professions should be parallel and interconnected. Classes should be as small as possible and several professors should cooperate to offer the parallel classes in related professions. If possible, basic components of the curriculum should be offered throughout the undergraduate years. Transfer students who received various credits from other institutions such as technical colleges, junior colleges and other schools or universities, should have their previous work evaluated for possible transfer of credits. The admission process should be as flexible as possible in order to accept students of diverse backgrounds and interests. Under this kind of system, it would be much easier to provide education for university graduates who return to graduate school after a period of absence from school. During the junior year, the curriculum will concentrate on the basics in professional study. This curriculum should strive to create a broad base of shared fundamental knowledge and methodology for the profession. More specialized content and advanced skills should be provided in the graduate studies which follow.

2) Professional ethics and responsibility. Another major purpose of undergraduate education is to help students acquire a clear sense of professional ethics and responsibility to society. For many years, professionals in each field have performed their duty to society through various traditional activities. For example, in engineering education, the conventional classifications of civil, mechanical, chemical, electrical, and mining engineer have been a part of established university educational programs for many years. These designations in conjunction with various domains of knowledge and levels of expertise within specialties carry significant amounts of information. It is not beneficial to carry out undergraduate education without sophisticated use of these historical accumulations of knowledge and understandings of professional practice. The conception of education and the accumulated knowledge and wisdom inherent in these conventional professional groupings may offer a more effective basis for the design of flexible university programs for imparting the fundamentals of professional education.

Students graduating from the undergraduate program should be prepared to start their careers in practical fields. The majority of the students will be trained under quite different disciplines if they subsequently enter graduate programs. Undergraduate programs should encompass major and minor fields selected to meet each student's particular needs, so that students are able to develop their future careers. Undergraduate studies based upon the essentials of science and professional ethics will serve as the foundation

for later graduate studies.

5. Graduate Studies

The main part of research activities and professional education in the university are conducted in the graduate schools. Breakthroughs in research fields always happen at the eccentric border of common sense. Hence, graduate students whose future careers will focus on creative work must acknowledge the unknown frontier as the most fruitful field of activity for them. The center of the knowledge system for these students should have been learned in their previous basic studies, which serves as a base from which to depart for the new frontier of their chosen field. During the four years of undergraduate and two years of master's programs, students must acquire the basics of science as their foundation, a foundation to take off from or to run out of, but not one to only sit upon.

For many students, the final destination of graduate education at Hokkaido University is a Ph.D., not a master's degree. Six years of professional education including undergraduate work and a master's degree is already very common in Japan, particularly in the natural sciences and technical professional fields. The additional three years beyond the master's typically required for a Ph.D. has been the traditional way to produce university professors and researchers in research institutions. However, in today's rapidly changing and developing fields of science and technology, those three years in a Ph.D. program are now considered to be an indispensable step to develop sufficiently creative and productive researchers, scientists and engineers. In the future, differences between the master and the Ph.D. will be definitive. Independent and productive research capacity will be developed during those additional years of doctoral education.

A two year master's program may immediately follow the bachelor's degree. Some practical experience, however, after the master's degree before beginning a doctoral program — or even before beginning a master's program — is highly recommended because such prior experience helps students apply their knowledge wisely after completing their education. From this perspective, continuing education will become very important to the educational enterprise at Hokkaido University.

Major and minor program system. Science and technology continue to become more complex and specialized. Many frontier areas emerge between established fields of science. Since the 1970's, many new academic departments have been established to provide education and training in newly recognized boundary areas within science and technology. Nevertheless, even with the appearance of these new departments in boundary areas, demands continue to develop additional departments in boundary areas between newly established boundary areas. That the establishment of new departments leads to further demands for additional new boundary areas may seem to be a contradiction. Hokkaido University has already established more than 10 new departments containing about 100 professorial positions to develop the new frontiers of science and technology since 1960. Given the seemingly relentless pressure to form yet additional departments, it is clear that the university must find more efficient ways to respond to the surging requests for programs in emerging areas of science. This section will outline a new idea which will alter our current developmental path.

All department systems are currently based upon an undergraduate chair system. A large department might consist of 6 to 12 chairs. Each chair has its own territory of research and education such as thermodynamics, strength of material, control of viral disease, and so on. Designing a new program for a boundary area or newly developing field of science is carried out by adding one chair or a few chairs to a department. Large scale development is carried out by establishing a new department with 6 chairs. Graduate studies are always housed in the undergraduate departments, with each chair serving both undergraduate and graduate students. Educational programs are designed on the basis of departments or graduate divisions. Hence, the number of programs is almost proportional to the number of departments; for example, there are 16 programs offered by the faculty of engineering which consists of 16 departments. The educational programs offered today are too small and fragmented to support the future development of science and technology. This is particularly true for graduate education.

In response to this growing problem, the school of engineering decided to change its system of research and education, based on a new organizational unit. The new basic organizational unit for education and research is the research laboratory consisting of 3 to 4 professors, 3 to 4 associate professors, and 4 to 6 instructors. This unit is much smaller than the traditional department but much larger than the conventional professorial chair. The research laboratory consists of faculty members with closely related specializations within a field of science and technology. In the faculty of engineering, 43 research laboratories will be established. Each research laboratory has the responsibility to offer a compulsory curriculum of 10 credits. Students belonging to a given research laboratory are required to take that laboratory's 10-unit compulsory program. In addition, students must take the 10 unit program offered by another of the research laboratories. These two programs are the major and minor program. Requirements for the master's degree include these 20 major and minor credits, a seminar in the home research laboratory, and a thesis. Under this new

system, students theoretically could design as many as $_{43}C_2$ 900 distinct graduate programs. This is a much larger number of options than the 16 programs available under the former departmental system. Many students, of course, may select a conventional combination of research laboratory programs that would in effect be similar to a departmental program available in the former system. The new system, however, offers many novel programs based on innovative combinations of research laboratory curriculum modules. These new options will support and facilitate students exploration of new horizons of science and technology, leading to breakthroughs in new areas.

This same curriculum model can be used for designing doctoral as well as masters programs. In the doctoral program of the school of engineering, for example, completion of an additional minor program from a third research laboratory is required before presenting the Ph.D. dissertation. The Ph.D. should be based on very sound knowledge of science and technology. In the engineering school, the restructuring of the graduate programs through the formation of the research laboratories will increase the school's research and training capacity. Faculty working in these new research laboratories will always have students also working in other research laboratories, continuously importing new ideas and methodologies from other research fields. This cross-fertilization will help avoid the narrowness of vision which has all too often been present in professional research activities.

Continuous education. Students studying in a well established area will be able to take new programs offered by different research laboratories to expand and strengthen their career prospects. Socialization of researchers within graduate schools will be greatly facilitated by the introduction of this major and minor system. Hokkaido University's academic calendar is currently based on the semester system. However, the quarter system is much better suited to implementing the major and minor education program and continuous education. On-the-job training under qualified leaders could also be built into these new academic programs.

Implications for the bachelor's degree thesis. The restructuring of graduate education also has interesting implications for undergraduate education. The graduation thesis for the bachelor's degree is the final procedure for completing undergraduate studies, but at the same time, it is often the beginning of the discovery process of research. In the planned reform of graduate education at Hokkaido University, all professors and research facilities will be in the graduate school. Undergraduate students preparing graduation theses for the bachelor's degree in some departments will need to work closely with graduate research laboratories. For students planning to go to graduate school, it is desirable that they experience a smooth transition between their undergraduate and graduate studies (just as we wish high school students have a smoother transition into undergraduate study).

The graduation thesis for the bachelor's degree should accordingly be conducted and evaluated as a learning process for research. For those students going on to graduate school, the bachelor's thesis will effectively be an introduction to graduate studies. Some outstanding students may even be permitted to skip the graduation thesis and become master's students without first receiving a bachelor's degree. In the school of engineering, for example, the first degree received by some outstanding undergraduate students will be a master's degree in engineering.

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As a result of more than ten years of difficult discussions and design work, Hokkaido University is changing its system of education and research. Revolution has reached the half-way point. The author wishes to offer sincere thanks and respect to the university members who have devoted many hours to that end.

〈要　約〉

北海道大学の改革

―研究大学への新しい概念―

大学においては一般教育の目標の設定がとくに重要である。この論文は，学生が卒業後に社会で活動していくために必要な倫理，知識の基盤，そして基礎的な学問の道具立てについて考える。学生は未来の社会の発展を担うための準備として，倫理的な原理にかかわる現実

の問題を扱えるようにならなければならない。なぜなら，地球上の自然資源は有限であり，社会は自然資源と生物とがいかに共存していくかを探っていく必要があるからである。人間は特別な動物であるが，ただの動物にすぎない。ヒューマニズムとエコロジーとの対立視点は，ヨーロッパの一元論とアジアの二元論にもとづいており，複雑な討論を巻き起こすであろう。世界は閉じていることを前提として，人文，社会，自然科学の枠を越えて，学生に世界的視野で総合的に学ばせることから始めなければならない。このことが，学生に新しい時代に生きるために，どのような倫理が必要かを考えさせる出発点となる。科学史，技術史を含む近・現代史の教育が必要となる。

学生にとって第一の目標は，知識の基盤となる社会活動，言語，電子情報システムによるリタラシーに必要な基本的道具立てを学ぶことである。第二の目標は，北海道大学において培われてきた理念と関連して，自然尊重主義に基盤をおいた適切な態度，意志決定の技術を身につけることである。例えば，フレッシュマンに対する地理学の学習では，演習林，牧場，火山，湖などでの学習を含む種々のフィールド体験を学生に与えたい。次の段階では，人文，社会，物理，化学，生物などの基礎科学を学んでもらいたい。そして，大学の演習林に近代的な情報機器を備えた数百人規模のフレッシュマンセンターを建設したい。

学部教育では，学生は専門分野での基礎と応用を学ぶ。さらに，主要な研究方法，成果，その将来性，そして専門領域への挑戦を含む様々な学問領域の課題を学ぶ。このカリキュラムは，複眼視的思考ができるように，平行して開講されているいくつかのセットになった科目で彩られた，総合的なアプローチを必要としている。自分自身の専門分野に精通するためにも，入門課程でこのようなセットになった科目を履修することが望ましい。このようなカリキュラムを実現するためには，2 期制より 4 期制が望ましい。他の学部の科目を履修できるよう，週 1 日を開けてやるべきであろう。

（丹保憲仁）