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原著

Novel visualization for curriculum *in silico* using syllabus by a combination of cosine similarity, multidimensional scaling methods, and scatter plot:
Dynamic curriculum mapping (DCM) for syllabus

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コサイン類似度、次元圧縮法、散布図を用いた
カリキュラムの新可視化法
～動的カリキュラムマップ (DCM)～

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Summary

Japan's Ministry of Education, Culture, Sports, Science and Technology recently recommended that higher learning institutions publicly disclose their course syllabuses and curriculum maps as part of a larger effort to improve the quality of education. Two well-known concerns regarding curriculum maps exist. First, curriculum maps do not include all the curricula of a given university. Second, the construction of a new map every year is difficult for most universities. To address each of these problems, we developed a novel visualization for curriculum using syllabuses by a combination of cosine similarity, multidimensional scaling methods, and scatterplots. We call this method dynamic curriculum mapping (DCM).

Key words: dynamic curriculum mapping (DCM), syllabus, multidimensional scaling methods

要 旨

近年、文部科学省は、高等教育機関に対し、教育の質保証や実質化を求めている。その一環として、様々な大学において、教育の質改善に重要な役割を果たすカリキュラムマップが作成されている。しかしながら、カリキュラムマップには、毎年の更新が難しいなどの問題があることがわかっている。そこで我々は、これらの問題を解決するために、シラバスをもとに、コサイン類似度と多次元尺度法と散布図を組み合わせで作成する新しいカリキュラムマップを開発し、動的カリキュラムマップと名付けた。本学のシラバスをもとに、この動的カリキュラムマップを作成したので、併せて報告する。

キーワード：動的カリキュラムマップ (DCM)、シラバスと多次元尺度構成法

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Introduction

In 1991, Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) recommended a system of self-review and self-evaluation to be implemented by universities and colleges in an effort to improve the quality of higher education and research¹⁾. Institutions that participated in the self-review process naturally began to use syllabuses as well, which provided a way for universities and colleges to report the results of self-evaluation publicly. By 1992, eighty Japanese universities had introduced the use of course syllabuses²⁾; by 1994, 176 institutions had done the same²⁾; and by 2006, nearly all Japanese institutions of higher education had followed suit, with all but four percent of institutions having implemented this practice^{3,4)}.

Stanford University defines a syllabus to students as follows: "...your guide to a course and what will be expected of you in the course. Generally, it will include course policies, rules and regulations, required texts, and a schedule of assignments. A syllabus can tell you nearly everything you need to know about how a course will be run and what will be expected of you"⁵⁾.

A 2008 report conducted by MEXT's Central Council for Education placed great emphasis on continued efforts to improve the general quality of higher education in Japan⁶⁾. To this end, curriculum maps, as a way of understanding and achieving learning outcomes, play a key role⁷⁾.

The *curriculum map* was first developed at Yamaguchi University in Japan⁸⁾. However, the original concept of a curriculum map was defined by Walter Wager in terms of instructional curriculum mapping (ICM) in 1976⁹⁾. ICM was created as a way to visualize each item in a given curriculum¹⁰⁾ and was introduced into Japanese medical education in the 1990s. Recently, independently run organizations responsible for the evaluation of Japanese universities have enforced the use of curriculum maps as a standard tool for curriculum assessment. While this means that most institutions must create curriculum maps, it is difficult to create a single curriculum map that includes all the curricula of a given college or university¹¹⁾.

The plan, do, check, act (PDCA) cycle was introduced in a 1950 lecture by Dr. W. Edwards Deming¹²⁾. In the last decade, PDCA has been applied in endeavors to improve the quality of Japanese higher education.

Curriculum maps can be used to improve a curriculum in the *check* and *act* stages of the PDCA cycle¹³⁾. However, as mentioned above, the construction of a new curriculum map every year is decidedly difficult, because it must be reconstructed repeatedly by any given faculty.

Curriculum maps are useful for students, who need to understand the relationships among courses and lectures as they study. When teachers design or plot curriculum maps, they are required to choose *x* and *y* axes. In many cases, such plotting is discussed among faculty during faculty development activities. To assist such faculty by addressing the problems involved in the process, we propose in this article a novel kind of curriculum mapping procedure, which we call dynamic curriculum mapping (DCM), as set out below.

Methods

Cosine similarity for a vector space

Cosine similarity can be used as a method to measure the difference between documents. Cosine similarity is defined by

$$\cos(\vec{a}, \vec{b}) := \frac{\vec{a} \cdot \vec{b}}{|\vec{a}| |\vec{b}|} = \frac{\sum_{i=1}^{|V|} a_i b_i}{\sqrt{\sum_{i=1}^{|V|} a_i^2} \cdot \sqrt{\sum_{i=1}^{|V|} b_i^2}}$$

Cosine similarity is a measure of similarity among vectors. Because in this paper a vector means a syllabus, cosine similarity entails similarity between two syllabuses. The maximum value of cosine similarity is 1, and the minimum is -1. When two syllabuses are the same, cosine similarity is 1.

Cosine similarity for normalized vectors is defined by

$$\cos(\vec{a}, \vec{b}) := \vec{a} \cdot \vec{b} = \sum_{i=1}^{|V|} a_i b_i$$

Preparation to calculate cosine similarity

To calculate cosine similarity, we prepared a vector space in which each vector represented a syllabus of a course offered by Kobe Tokiwa University and Kobe Tokiwa College in 2015. Each syllabus was freely available on the institution's official homepage¹⁴⁾.

Each syllabus was available in Portable Document Format (PDF). Because cosine similarity is defined for vectors, we computed a vector representation of each syllabus. We first converted the PDF files to plain text using an open-source UNIX command-line tool called *pdftotext*, encoding the text in UTF-8¹⁵⁾.

We then performed morphological analysis of the Japanese language in each file using MeCab¹⁶⁾. MeCab comprises open-source software and a tool for morphological analysis developed by Taku Kudo in 2005. Using MeCab, we reduced each syllabus to a collection of word frequencies.

Finally, we calculated the cosine similarity between each resulting vector, each of which represented a syllabus. Note that the dimension of the vector space was equal to the total number of distinct words used in the collection of all syllabuses.

Results and Discussion

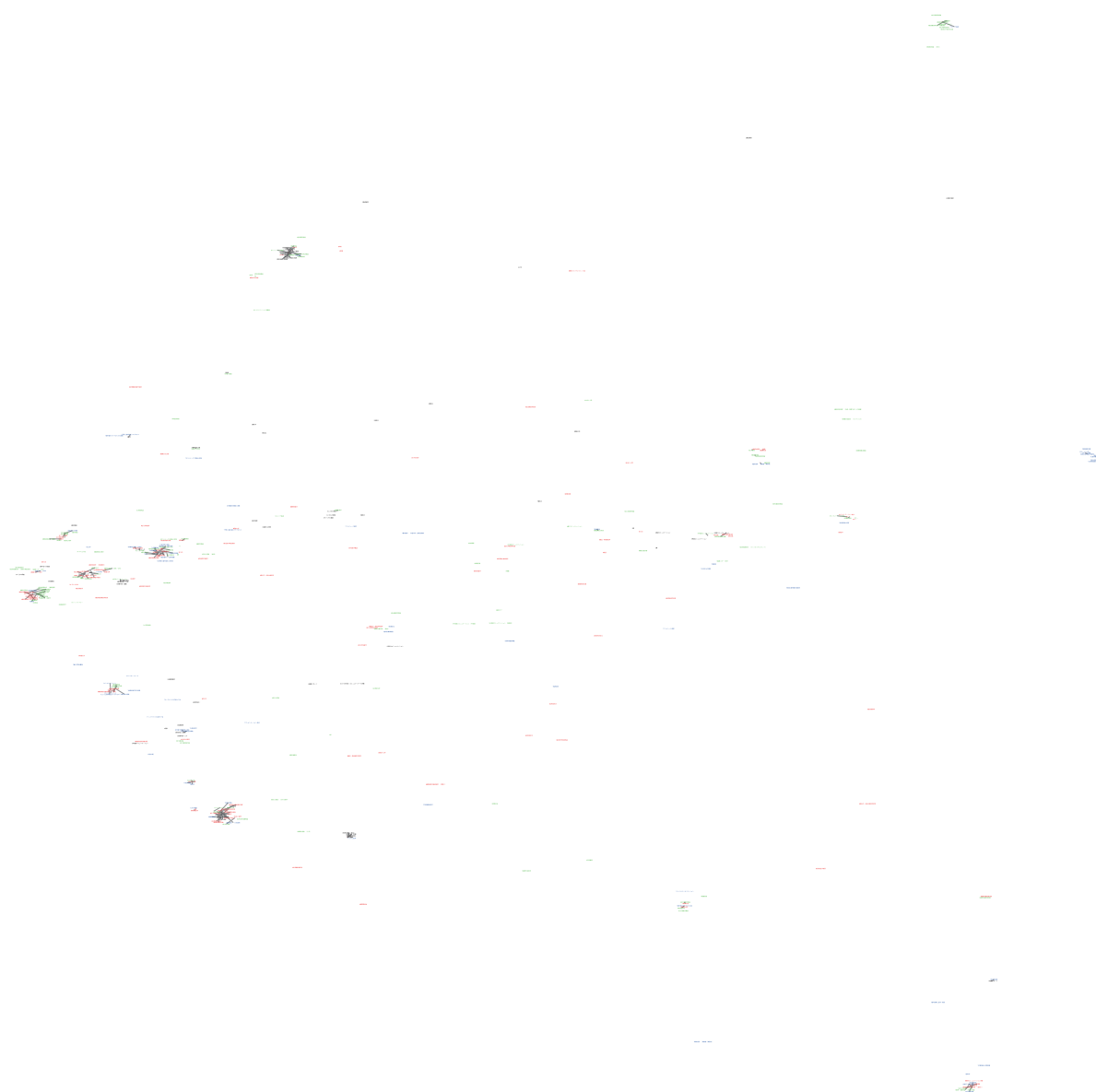
Kobe Tokiwa University has three departments, namely Medical Technology, Nursing, and Education. Kobe Tokiwa College has only one department, namely Oral Health. These four departments had 71, 117, 126, and 75 syllabuses, respectively, giving a total of 390 syllabuses.

The cosine similarities of each possible pair of syllabuses can be represented by a 390×390 matrix in which each entry in the matrix is the cosine similarity between two syllabuses represented by

corresponding rows and columns. It is trivial to show that the cosine similarity matrix is a symmetric matrix with a diagonal of 1s, as in the cosine similarity matrix for our syllabuses below:

$$(390 \times 390 - 390) \div 2 = 75855.$$

We visualized the cosine similarity matrix using multidimensional scaling (MDS) methods. MDS essentially reduces the 390-dimensional representation of our syllabuses to a 2-dimensional one while preserving the distances (representing similarity) between each document. This method produced a



Extended Figure 1: Scatterplot of cosine similarity between each syllabus, created using MDS. The x and y axes were defined by MDS. Distance of each syllabus in 390 dimensions is maintained in 2 dimension by MDS. Black, red, green, and blue letters show syllabuses from the Departments of Education, Medical Technology, Nursing, and Oral Health, respectively. Japanese subject names are used because Kobe Tokiwa University does not provide full English names.(see details in the extended figure in this article's Online Repository at <https://kobe-tokiwa.repo.nii.ac.jp/>)

scatterplot of x and y locations in two dimensions for our 390 syllabuses. The x and y axes were defined by MDS. The x and y axes of MDS are similar to the first and second principal components of principal component analysis, respectively.

Because the resulting scatterplot is too big to fit in an A4-sized figure, we present the plot in PDF as Extended Figure 1 (see Extended Figure 1 in this article's Online Repository at <https://kobe-tokiwa.repo.nii.ac.jp/>). In Extended Figure 1, black, red, green, and blue letters represent the syllabuses of the four departments of Kobe Tokiwa University and Kobe Tokiwa College.

Several groups, or islands, of syllabuses can be seen in Extended Figure 1, which we have classified into three categories. The first category comprises the set of points belonging to an island of syllabuses that involve only one department (Figure 1). The second category is defined by points that belong to islands that involve at least two departments but fewer than three departments (Figure 2), and the third category is defined by the set of points belonging to islands with syllabuses involving three or more departments (Figure 3).

A category one island (Figure 1) can be seen at the edge of Extended Figure 1. Unsurprisingly, this island contains syllabuses of courses that focus on practical training and career paths, which happen to be similar topics.

There is only one category two island (Figure 2). This island includes syllabuses of the departments of Nursing and Oral Health combined. Syllabuses of courses in the former department again deal with practical training, while those of the latter pertain mostly to career paths, which is somewhat analogous to the category one island above.

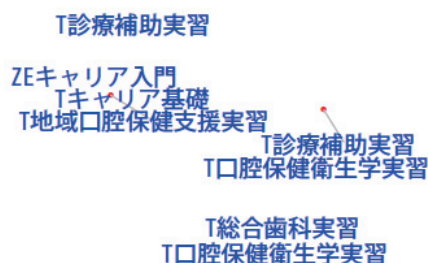


Figure 1. Category One Island: Island that consists of syllabuses from only one department. T indicates the Department of Oral Health. The Chinese characters 診療補助実習, キャリア入門, キャリア基礎, 地域口腔保健支援実習, 口腔保健衛生学実習, 総合歯科実習, and 口腔保健衛生学実習 indicate Clinical Practice Basic, Introduction to Career, Basis of Career Development, Clinical Oral Health, Clinical Practice and Oral Hygiene Process, Clinical Practice, Clinical Practice and Oral Hygiene Process, respectively.

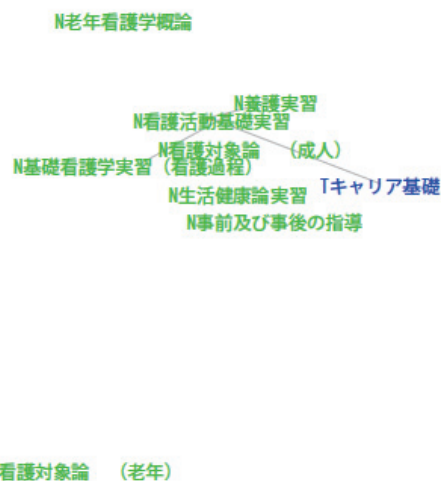


Figure 2. Category Two Island: Island that consists of syllabuses from two departments. N and T reflect the Departments of Nursing and Oral Health, respectively. 老年看護学概論, 養護実習, 看護活動基礎実習, 看護対象論 (成人), 基礎看護学実習 (看護過程), 生活健康論実習, 事前及び事後の指導, 看護対象論Ⅲ (老年), indicate Introduction to Aged Nursing, School Nursing Practicum, Fundamental Nursing Skills Practicum, Objectives of Nursing (Adults), Fundamental Nursing Practicum (Nursing Process), Health and Lifestyle Practicum, Pre- and Post-Practicum Guidance (School Nursing), Objectives of Nursing (Aged), and Basis of Career Development, respectively.

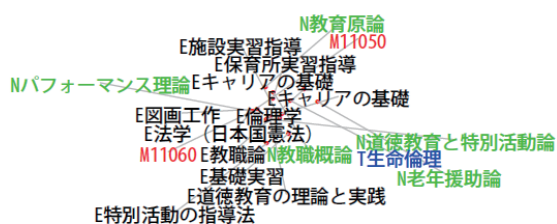


Figure 3. Category Three Island: Island that consists of syllabuses from many departments. N, T, E, and M indicate the Departments of Nursing, Oral Health, Education, and Medical Technology, respectively. The Chinese characters 教育原論, パフォーマンス理論, 道德教育と特別活動論, 教職概論, 老年援助論, 生命倫理, 施設実習指導, 保育所実習指導, キャリアの基礎, 図画工作, 倫理学*, 法学 (日本国憲法)*, 教職論*, 基礎実習, 道德教育の理論と実践, 特別活動の指導法, M11050, and M11060 indicate Principles of Education, Manners and Self-Expression, Moral Education and Extracurricular Activities, Introduction to the Teaching Profession, Theoretical and Clinical Aged Nursing, Bioethics, Guidance for Practical Training at Nursing, Guidance for Practical Training at Nursery School, Career Foundations, Arts and Crafts, Ethics, Law, Studies in Contemporary Teaching Profession, Apprenticeship, Moral Education: Theory and Practice, Teaching Methods for Extracurricular Activities, Writing and Composition, and Logic, respectively. Note that names with asterisks were not defined, so we assigned English terms, which are therefore unofficial names.

There are also some category three islands, i.e., islands with syllabuses from three or more departments (Figure 3). We also observed a special case of a category three island (Figure 4) that includes syllabuses from many departments while also having a well-defined separation between clusters of syllabuses from the same department.

In this paper, we demonstrate the construction of a curriculum map from course syllabuses by using a combination of cosine similarity, MDS methods, and scatterplots. This DCM provides a possible way to generate a curriculum map capturing all the curricula at a given university, and a way to create curriculum maps more quickly in general, including those that must be recreated every year.

We have used cosine similarity to reflect similarity among syllabuses in this paper. The close proximity of syllabuses A and B in Figure 1 reflects their similar distribution of particular words. Thus, similar subjects are located further apart when their syllabuses contain different distributions of words. This is a limitation of using both cosine similarity and the syllabuses. However, this method holds an advantage in constructing curriculum maps *in silico* and is a first step toward DCM *in silico*. To address this limitation, we propose in further research to use Kobe Tokiwa University's competencies and diploma policies in syllabuses as distance, rather than the syllabuses themselves. The present syllabuses of Kobe Tokiwa University do not contain their competencies or diploma policies but will do so in the near future. If we use distance as both cosine similarity of competencies and diploma policies, rather

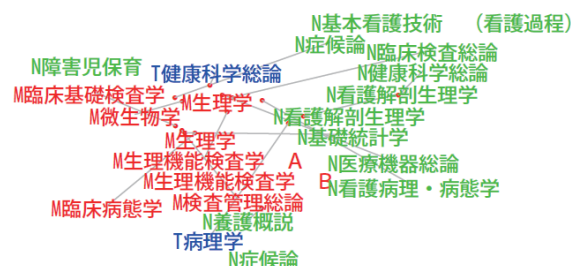


Figure 4. Category Three Island: Island that consists of syllabuses from many departments. These syllabuses are well separated in terms of department. N, T, E, and M indicate the Departments of Nursing, Oral Health, Education, and Medical Technology, respectively. The Chinese characters 基本看護技術IV (看護過程), 症候論, 臨床検査総論, 健康科学総論, 看護解剖生理学, 基礎統計学, 医療機器総論, 看護病理・病態学, 養護概説, 障害児保育, 健康科学総論, 病理学, 臨床基礎検査学, 生理学, 微生物学, 生理機能検査学, 検査管理総論 and 臨床病態学 indicate Fundamental Nursing Skills (Nursing Process), Symptomatology, Introduction to Medical Technology, Health Sciences, Anatomicophysiology in Nursing, Introduction to Statistics, Introduction to Medical Appliances, Clinical Pathophysiology, Introduction to School Nursing, Symptomatology, Nursing Care of Children with Special Needs, Introduction to Medical Science, Pathology, Fundamental Clinical Laboratory Medicine Laboratory Medicine, Physiology, Microbiology, Clinical Physiology, General Clinical Laboratory Management, and Clinical Pathology, respectively.

than cosine similarity of syllabuses, we will produce a novel scatterplot as a DCM. For example, consider judgment as a competency. When students want to know how they might learn about judgment in university courses, we can provide a scatterplot reflecting judgment as a DCM. Kobe Tokiwa University currently covers 19 competencies and 4 diploma policies, entailing the construction of 92 curriculum maps, which is impossible. Therefore, DCM may play an important role at the university, allowing us to provide visualization of curricula for each competency and diploma policy as a guideline for students.

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