A New Way of Visualizing Curricula using Competencies: Cosine Similarity, Multidimensional Scaling Methods, and Scatter Plotting

Kunihiko TAKAMATSU
Educational Innovation Organization
Research Cooperative Division
Life Science Center
Center for the Promotion of Excellence in Research and Development of Higher Education
Kobe Tokiwa University
Kobe, Japan

Katsuhiko MURAKAMI
School of Bioscience and Biotechnology
Tokyo University of Technology
Hachioji, Japan

Takafumi KIRIMURA
Educational Innovation Organization
Kobe Tokiwa University
Kobe, Japan

Kenya BANNAKA
Research Cooperative Division
Center for the Promotion of Excellence in Research and Development of Higher Education
Kobe Tokiwa University
Kobe, Japan

Ikuhiro NODA
Research Cooperative Division
Center for the Promotion of Excellence in Research and Development of Higher Education
Kobe Tokiwa University
Kobe, Japan

Mayumi YAMASAKI
Educational Innovation Organization
Kobe Tokiwa University
Kobe, Japan

Raphael-Joel Wei LIM
Stanford, USA

Kenichiro MITSUNARI
Faculty of Education,
Academic Affairs Committee
Center for the Promotion of Excellence in Research and Development of Higher Education
Kobe Tokiwa University
Kobe, Japan
Regional Liaison Unit, Center for the Promotion of Interdisciplinary Education and Research,
Kyoto University
Kyoto, Japan

Tadashi NAKAMURA
Tamada Educational Institution
Kobe, Japan

Yasuo NAKATA
Educational Innovation Organization
Kobe Tokiwa University
Kobe, Japan
y-nakata@kobe-tokiwa.ac.jp

***Abstract*— This article outlines a new way of visualizing curricula using competencies via a combination of cosine similarity, multidimensional scaling methods, and scatter plotting. We have already published a report using syllabi with the same methods. In this report we show that using competencies is more useful than using syllabi. Usually, most students are only interested in the course content when they select their courses. This new visualization of curricula using competencies gives a new perspective on the course to students. We believe that this visualization is useful when students select their courses.**

Keywords—new way of visualizing curricula; competency; cosine similarity; multidimensional scaling methods; scatter plotting

I. INTRODUCTION

Over the past decade, the circumstances of Japanese universities have changed significantly. During the 2016 International Conference on Data Science and Institutional Research (DSIR 2016), we reported on the enhanced collaboration between faculty and staff at Kobe Tokiwa University using a strengths, weaknesses, opportunities, and threats (SWOT) analysis, as well as a complex network analysis [1]. Our findings suggested that to make the university a better place, it is critical that all faculty and staff are aware of the need for improvement. Our results led to the creation of a task force at the university. In this article, we report on the task force's activities and data, which we analyze using information that was gathered by the team.

II. METHODS

Cosine similarity can be used to measure the differences between documents. Cosine similarity is defined by:

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

TABLE I. Tokiwa competencies

Abbreviated name of competency	*Competency*
1. Culture	Establishing the liberal arts as the foundation of human nature, which can involve a variety of people
2. Common Sense	Establishing that members of society should acquire knowledge and behave in certain ways
3. Professionalism/Expertise	Having the necessary knowledge and skills to perform the duties of each profession
4. Media Literacy	Collect, organize, and analyze the necessary information for proper thinking and judgment
5. Logical Thinking	Based on evidence, a situation can be considered logically
6. Critical Thinking	A multilateral, critical perspective captures ideas and can be considered
7. Intellectual Curiosity	To know something, to learn, and remember it with fun and joy
8. Exploration	By thinking deeply about things and methods, it is possible to be like Mikiwameyo in terms of essence
9. Continuity	By learning and thinking, it is possible to maintain one's stance and make efforts to act
10. Self-Management	It is possible to handle one's physical and mental health appropriately
11. Reflection	By reflecting on one's thinking and behavior, it is possible to always seek ways to improve
12. Design Thinking	It is possible to design a solution and develop a comprehensive variety of thoughts and knowledge
13. Presentation	It is possible to convey one's feelings and thoughts to others
14. Judgment	Based on information and thinking, it is possible to make an appropriate decision given the circumstances
15. Implementation	Without fearing failure, it is possible to take a specific action based on one's feelings and thoughts
16. Responsibility	It is possible to face things and have responsibility as a member of society
17. Contribution	I feel joy for someone when something is useful for them, and it is possible to take a specific action
18. Communication	Listen to others' opinions, which can result in creative dialogue
19. Cooperation & Collaboration	Looking beyond one's own interests and those of others, it is possible to work together

Cosine similarity is a measure of similarity among vectors. Since in this paper, a vector means a syllabus or course's pattern of 19 competencies, cosine similarity entails the similarity between two syllabi or courses (TABLE I). The maximum value of cosine similarity is 1, and the minimum is -1. When two syllabi or patterns of competencies are the same, then cosine similarity is 1.

It is easy to calculate the cosine similarity of competencies. To calculate the cosine similarity of syllabi, we prepared a vector space in which each vector represents the syllabus of a course offered by Kobe Tokiwa University in 2017. Each syllabus will be freely available on the institution's official homepage [2].

We prepared each syllabus in portable document format (PDF). We converted the PDF files to plain text using an open-source UNIX command-line tool called pdftotext, encoding the text in UTF-8 [3], and performed a morphological analysis of the Japanese language in each file using MeCab [4]. Finally, we calculated cosine similarity using these files.

We visualized the cosine similarity matrix using multidimensional scaling (MDS) methods by employing the R package "lsa" (latent semantic analysis) [5], scatter plotting, and R's "maptools" package [6] using R [7].

III. Results and Discussion

A. Preparation for reform in Higer Education

The findings led to the creation of a task force at the university. Tadashi Nakamura, the Director-General of Tamada Gakuen, affiliated with Kobe Tokiwa university, gathered together the authors of this article and built a task force for university reform under the president's team in December 2015 [8].

The task force has three main goals: (1) To lay the foundations for learning and teaching management for university reform; (2) To foster advanced collaboration between faculty and staff; and (3) To lay the foundations for liberal arts at the university.

The task force's primary goal is to lay the foundations for learning and teaching management for university reform. Learning and teaching management consists of the "design, operation, and management of an educational system in order to achieve university-wide educational goals" [9].

The Central Council for Education (CCE) used to be part of the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) [10]. In 2008, the CCE reported on the future of higher education in Japan. The report proposed integrating the admissions policy (AP), curriculum policy (CP), and diploma policy (DP).

All faculty members at our university jointly defined each of the three policies. Previously, the faculty members at our university were not connected to these policies. Almost all universities in Japan face the same situation, in which the faculty members are not connected to AP, CP, and DP [11].

We proposed forming a relationship that involves the three polices between each faculty and the president's team. Because our university had no unified policies, we proposed integrating AP, CP, and DP into the president's team. Creating them led us to conclude that in order to enhance teaching

TABLE II. Thirty-nine courses, 19 competencies, and a group of MDS

course nam \ competency	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	total	MDS group
01. Academic Skills and Deep Learning I	0	0	0	0	0	0	0	20	0	10	25	10	15	0	0	0	0	0	20	100	5
02. Academic Skills and Deep Learning II	0	0	0	0	0	0	0	20	0	10	25	10	15	0	0	0	0	0	20	100	5
03. Freshman Seminar I	0	0	0	0	0	0	25	35	0	0	20	0	0	0	0	0	0	20	0	100	3
04. Freshman Seminar II	0	0	0	0	0	0	25	35	0	0	20	0	0	0	0	0	0	20	0	100	3
05. Leadership and Facilitation	0	0	0	0	0	0	0	0	0	0	40	15	0	0	0	10	10	5	20	100	3
06. Information Technology Basics	35	0	0	35	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	4
07. Health and Sports Science II	0	0	0	0	0	0	0	0	0	30	0	0	30	0	0	20	0	0	20	100	1
08. Academic Writing	0	0	0	15	25	15	25	0	0	0	0	0	15	5	0	0	0	0	0	100	1
09. English Communication I	0	0	0	19	30	23	15	0	0	0	0	0	13	0	0	0	0	0	0	100	1
10. English Communication II	0	0	0	10	35	35	10	0	0	0	0	0	10	0	0	0	0	0	0	100	1
11. Basic Communicative English	0	0	0	0	0	0	20	0	0	0	0	0	60	0	0	0	0	20	0	100	1
12. Intermediate Communicative English	0	0	0	0	0	0	25	0	0	0	0	0	60	0	0	0	0	15	0	100	1
13. Sign Language	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	10	100	2
14. Life and Symbiosis	20	0	5	25	0	10	0	40	0	0	0	0	0	0	0	0	0	0	0	100	2
15. Global Environment	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	100	6
16. Mathematics	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	100	1
17. Statistics	0	0	0	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	50	100	1
18. Physics	35	0	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0	0	30	100	4
19. Chemistry	29	0	0	0	21	0	29	8	0	0	0	0	8	0	3	0	3	0	0	100	4
20. Basic Anatomy and Physiology	30	0	0	10	0	0	20	0	0	10	10	0	10	0	0	0	0	10	0	100	2
21. Life Sciences	40	0	0	0	20	15	0	0	0	0	0	0	20	0	0	0	5	0	0	100	4
22. Safety Science	20	20	0	20	0	0	0	0	0	0	0	0	0	0	0	20	0	0	20	100	2
23. Agriculture	20	25	0	0	0	5	10	18	0	0	0	0	5	0	0	13	5	0	0	100	2
24. Introduction to Programming	0	0	0	0	30	0	0	0	0	0	0	45	0	0	0	0	25	0	0	100	1
25. Life and Ethics	0	0	0	0	25	50	0	0	0	0	0	0	25	0	0	0	0	0	0	100	1
26. Literature	35	0	0	0	0	0	40	0	0	0	25	0	0	0	0	0	0	0	0	100	2
27. Japanese History	10	0	0	0	20	0	0	0	0	0	10	0	40	0	0	10	0	10	0	100	1
28. Modern Sociology	35	0	0	0	0	0	25	20	0	0	0	20	0	0	0	0	0	0	0	100	2
29. Economics	20	0	0	20	30	30	0	0	0	0	0	0	0	0	0	0	0	0	0	100	7
30. Clinical Psychology	0	30	0	0	30	0	20	0	0	0	0	0	20	0	0	0	0	0	0	100	1
31. Human Relations Theory	0	0	24	0	0	24	0	0	0	0	0	0	24	0	0	0	0	24	4	100	1
32. Education	0	0	24	0	0	24	0	0	0	0	0	0	23	0	0	0	0	24	5	100	1
33. Collaboration with Community I	60	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	20	0	100	2
34. Collaboration with Community II	0	10	0	0	0	0	0	0	0	0	50	0	0	0	10	10	10	0	10	100	3
35. Disaster and Community Development	0	0	0	0	0	0	0	25	25	0	0	0	0	0	0	25	25	0	0	100	3
36. Community Design	0	0	0	15	15	15	0	10	0	0	0	25	20	0	0	0	0	0	0	100	1
37. Life Design	0	0	0	15	15	0	10	10	0	0	0	35	15	0	0	0	0	0	0	100	1
38. Constitutional Law of Japan	35	0	0	0	20	0	0	0	0	0	20	0	10	0	0	10	0	5	0	100	2
39. Philosophy	0	0	0	0	25	0	50	0	0	0	0	0	25	0	0	0	0	0	0	100	1

management, more than three policies are necessary; three are not enough.

To continue the plan–do–check–act or plan–do–check–adjust (PDCA) cycle in order to verify the quality of teaching at the university, we considered three policies, along with an assessment policy (ASP). Recently, some reports released by the CCE stress the importance of connecting an ASP with AP, CP, and DP [12].

We proposed a new policy called the student support policy (SSP) to the president's team; AP, CP, and DP only deal with regular curricula. We think it is important for students to be exposed not only to regular curricula, but also to quasi-regular and extra curricula. Quasi-regular curricula are used in remedial education, and extra curricula consist of volunteer and club activities.

To evaluate and connect the aforementioned policies (AP, CP, DP, ASP, and SSP), we needed to create a common evaluation indicator. We developed a list of the 19 Tokiwa competencies that students acquire through regular, quasi-regular, and extra curricula (TABLE II).

In this article, we define competency as a functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem-solving [13].

The second aim of the task force is to foster advanced collaboration between faculty and staff. In 2008, Tadashi Nakamura founded the Research Cooperative Division (RCD) to facilitate efforts among faculty and staff to work together [1]. Two members of the RCD hold both faculty and staff positions; only three are staff. Most members of the RCD are a core part of the task force.

Tadashi Nakamura had good foresight, because SSP deals with not only regular, but also quasi-regular and extra curricula. At our university, members of staff are involved in both quasi-regular and extra curricula; the key aim of such curricula is to facilitate SSP collaboration between faculty and staff. Since the task force has a congenial relationship with the faculty and staff, based on the RCD, it is very easy for us to encourage them to work together.

Until several years ago, there was a clear distinction between faculty and staff at universities [14]. Recently, the importance of joint work by faculty and staff has been recognized [15]. We have already published news of their cooperative efforts, and have proposed a novel perspective using knowledge [16]. This article is based on a knowledge model that we proposed [17], [18].

The third purpose of the task force is to build a foundation for liberal arts at the university. Until this year, our university had no common liberal and general education curricula. In 2014, to prepare the curricula, the Educational Innovation Organization (EINO) was established. Some authors of this article are members of EINO. EINO members tried to create common liberal and general education curricula, but this was impossible. Since the EINO is exclusively comprised of staff, the task force helps the EINO to start introducing liberal arts to the university. We proposed draft versions of liberal arts courses to the president's team. Finally, the EINO prepared 39 courses (TABLE II).

As described above, five policies (AP, CP, DP, ASP, and SSP) were developed based on 19 competencies. Since liberal arts courses are regular curricula, there is a need to connect them with the competencies.

To resolve this problem, we discussed how to evaluate AP, CP, DP, ASP, and SSP using competencies, along with an assessment policy team from the EINO. Luckily, some members of the task force are also part of the EINO's assessment policy team, so it is easy to maintain contact with them.

Rubrics are one way of assessing the courses, and are frequently used in elementary, junior high, and high schools. In higher education, they have hardly been used [19]. When pitching to the presidential team, we proposed using both a rubric and competencies (which are part of the rubric) to assess the courses. We think this provides a good solution to the problem.

The president's team decided that comprehensive syllabi of common liberal and general education courses revealed a rubric for evaluation. The rubric includes the competencies that were previously evaluated (TABLE II).

B. Curriculum mapping

In 1991, MEXT recommended a self-review, self-evaluation system to improve the quality of higher education and research [20]. A 2008 report conducted by MEXT's CCE underscored ongoing efforts to enhance the general quality of higher education in Japan [21]. To this end, curriculum maps came to play a key role in understanding and achieving learning outcomes [22]. In 1976, Walter Wager defined the original concept of a curriculum map in terms of instructional curriculum mapping (ICM) [23]. ICM was created as a way to visualize each item in a given curriculum [24]. The curriculum map was first developed at Yamaguchi University in Japan [25].

C. Dynamic curriculum mapping

We developed a new way to visualize curricula using syllabi via a combination of cosine similarity, MDS, and scatter plotting [26]. We call this method dynamic curriculum mapping (DCM). As a virtual method, DCM differs from the usual curriculum mapping created by humans. To address this problem, we used competencies instead of syllabi to visualize curricula in this paper.

D. Preparing to analyze the data

We were able to prepare 39 syllabi for common liberal and general education courses in 2017. Unfortunately, since we could not obtain two syllabi, we decided to remove them from our analysis. We used a rubric for all syllabi to evaluate their courses, and revealed the relationships among the 19 competencies in the rubric (please see TABLE II).

E. Visualizing curricula using competencies

Now a course can be regarded as a vector with 19 dimensions. Using cosine similarity, we can calculate whole cosine similarity between two courses. The result is 39C2=741. To apply DCM, we changed from cosine similarity to distance, i.e., 1 – (cosine similarity), such as a distance for MDS. Using these data, we plotted the information in 2 dimensions (Fig. 1).

There are seven groups in Figure I (Fig. 1 and TABLE II).

The first group took Intermediate Communicative English, Mathematics, Statistics, Introduction to Programming, Life and Ethics, Japanese History, Clinical Psychology, Human Relations Theory, Education, Community Design, Life Design, and Philosophy.

The second group took Sign Language, Life and Symbiosis, Basic Anatomy and Physiology, Safety Science, Agriculture, Literature, Modern Sociology, Collaboration with Community I, and Constitutional Law of Japan.

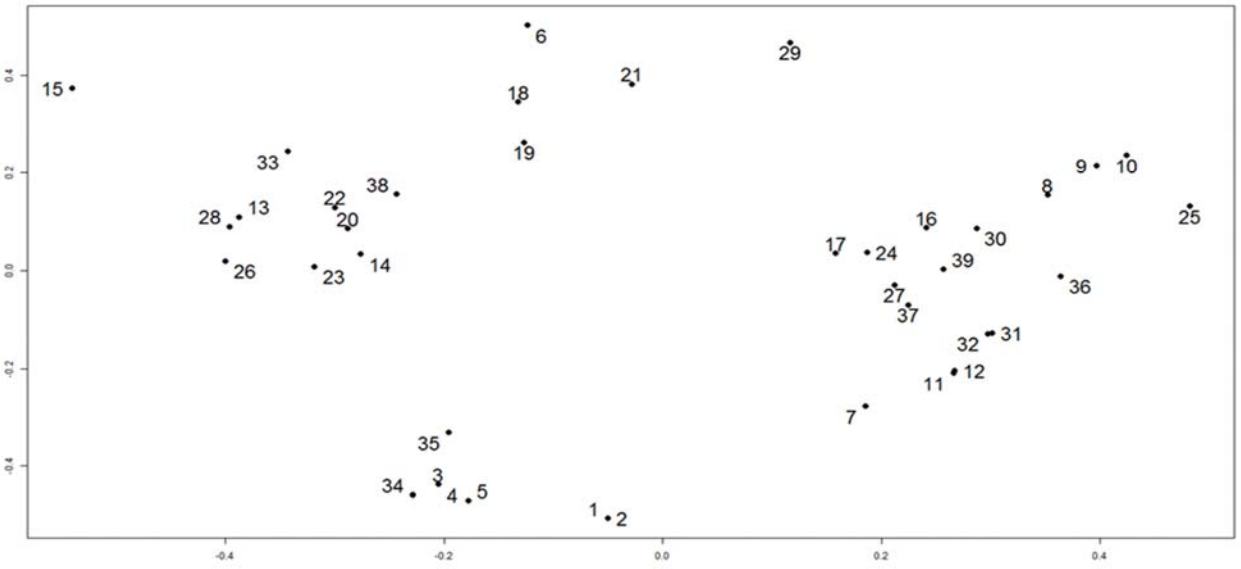

Figure 1 Visualizing curricula using syllabi; using 19 competencies for 39 courses, we visualized MDS via scatter plotting.

The third group took Freshman Seminar I, Freshman Seminar II, Leadership and Facilitation, Collaboration with Community II, and Disaster and Community Development.

The fourth group took Information Technology Basics, Physics, Chemistry, and Life Sciences. The fifth group took Academic Skills and Deep Learning I, as well as Academic Skills and Deep Learning II. The sixth group took Global Environment. The seventh group took Economics.

As you can see, each group involved different courses. Usually, we think that there is no relationship between these courses, but the visualized curricula show some overlap in the relevant competencies. This finding is very important.

This is a very important result for this article. Most students are only interested in the course content, but not the competencies that they can acquire through the courses. Curriculum maps are very useful for students, who need to understand the relationships among courses and lectures as they study. However, curriculum maps do not consider course content alone.

When students choose courses, these groups are useful. For example, if students want to obtain a wide range of competencies, they have to choose courses from different groups. Thus, visualizing curricula using competencies is very useful for students. Yet until now, such maps have not existed.

F. Comparing competencies and syllabi

We have already visualized curricula using syllabi, rather than competencies, via a combination of cosine similarity, MDS, and scatter plotting. Next, we will compare syllabi with competencies.

We visualized curricula using syllabi from 39 courses, instead of competencies (Fig. 2). As there is only one big group, it is possible to understand that this map is not useful in comparison with both curriculum maps, which were developed by humans; it is also possible to visualize curricula using competencies.

During the last conference, DSIR 2016, we reported on a complex network analysis for a SWOT analysis of our university [1]. Developing networks is one type of visualization method. We confirmed whether networks function better than MDS.

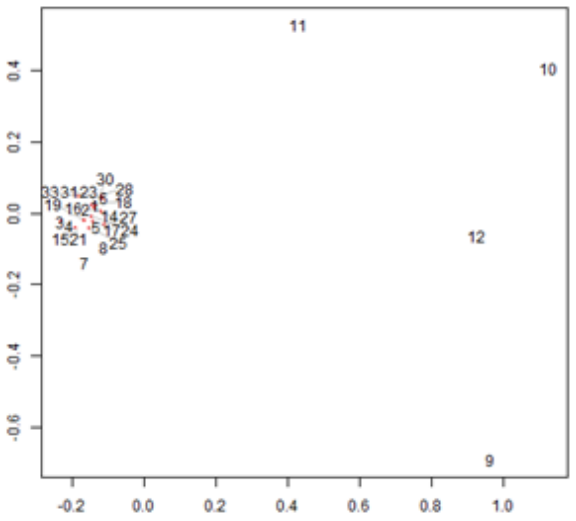

Figure 2. Curricula, visualized by employing syllabi; using syllabi from 39 courses, we visualized MDS via a scatter plotting.

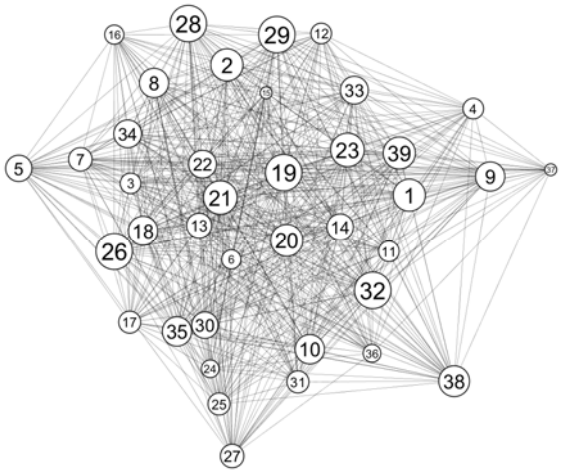

Figure 3. A network, visualized; using 19 competencies from 39 couses, we visualized this network with Cytoscape.

In terms of visualizing curricula using competencies, we obtained the symmetric matrix of cosine similarity. This matrix-vector is known as an adjacency matrix in network analysis. Next, we transformed the adjacency matrix to an adjacency list using the igraph library [27]. We visualized this data using the open-source software Cytoscape [28] (Fig. 3). Since this figure has too many connections, we cannot clearly understand the relationships among courses.

Next step we will attempt to advice students based on their competencies using figure 1. Scatter plotting of MDS is relative. So it will change if courses are added or deleted. But when we use scatter plot of MDS to advice students, it is useful, regardless of whether the map is changing or not.

In conclusion, we believe that visualizing curricula is the best way to employ competencies and MDS, rather than using syllabi or network visualization; this visualization is useful when students select their courses.

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