

A Two-Step Approach for Syllabus Development and Evaluation using Machine Learning such as Doc2Vec based on Eduinformatics : Advancements and Challenges in Adopting Rubrics for Grading Criteria in Japanese Higher Education

Akira Ito^{*,#}, Hibiki Ito[†], Sayaka Matsumoto[‡], Ikuhiro Noda^{*},
Kenya Bannaka^{*}, Keita Nishiyama[§], Takafumi Kirimura^{**},
Taion Kunisaki^{††}, Kenichiro Mitsunari^{*}, Katsuhiko Murakami^{‡‡},
Ryosuke Kozaki^{§§}, Aoi Kishida^{***}, Mizuki Kondo^{*}, Shotaro Imai[‡],
Masao Mori[‡], Yasuo Nakata^{*}, Masato Omori^{*}, Kunihiko Takamatsu[‡]

Abstract

This study examines the adoption of rubrics in grading criteria at Japanese universities. Between 2016 and 2020, the percentage of universities explicitly stating grading criteria in syllabi increased to 98.1%. However, the use of rubrics for all subjects at the undergraduate level only rose from 2.9% to 6.1%, indicating challenges in rubric adoption. A two-step approach was proposed to address faculty members' difficulties in creating rubrics: 1) introducing a reference rubric (R2) based on common learning outcomes in diploma policies, and 2) having faculty members create rubrics for their individual learning outcomes. Successful implementation of this approach was reported at a university where rubrics were introduced for all subjects. Furthermore, the study evaluated the comparison between R2 and syllabi rubrics using doc2vec, pre-trained by Wikipedia text data, and cosine similarity to assess the degree of optimization for educational goals of each departments.

Keywords: Two-Step Approach, Grading Criteria, Reference Rubrics (R2), Machine Learning, Eduinformatics

* Kobe Tokiwa University, Kobe, Japan
† University of Helsinki, Helsinki, Finland
‡ Tokyo Institute of Technology, Tokyo, Japan
§ Sensyu University, Tokyo, Japan
** Hirosaki University, Aomori, Japan
†† Fukui Prefectural University, Fukui, Japan
‡‡ The University of Tokyo, Tokyo, Japan
§§ International Pacific University, Okayama, Japan
*** Kobe City Nishi-Kobe Medical Center, Kobe, Japan

1 Introduction

1.1 Evaluation using rubrics in Japan

In recent years, evaluation using rubrics has been a crucial term in higher education in Japan by the report of the Ministry of Education, Culture, Sports, Science and Technology (MEXT)[1]. The rubric is defined as follows “1: an authoritative rule 2: an explanation or definition of an obscure word in a text [syn: gloss] 3: a heading that is printed in red or a special type v: adorn with ruby red color.” by WordNet in 1997. And the book “Introduction to Rubrics: An Assessment Tool to Save Grading Time, Convey Effective Feedback, and Promote Student Learning” shows that “At its most basic, a rubric is a scoring tool that lays out the specific expectation for an assignment” [2]. In more detail, a commonly used definition is a document that articulates the expectations for an assignment by listing the criteria or what counts and describing levels of quality from excellent to poor[3][4][5][6]. Most faculty who use rubrics for designing their classes may understand that rubric evaluates students and leads to good learning in formative assessment[4][5]. Moreover, the rubrics are beneficial not only for students when learning but also for teachers when they teach.

In Japan, the Central Council for Education in MEXT first reported explicit evidence of the usefulness of the rubric for higher education in 2008 in “Toward the construction of undergraduate education (Japanese)” [1]. MEXT has repeatedly shown the importance of using rubrics in Japanese universities[7][8]. In 2012 MEXT showed that rubrics have been used as a concrete measure of learning outcomes. The importance of rubric research and development has been pointed out[9]. In 2018, MEXT indicated that it expected increased rubrics use, as it seeks greater visibility of individual student learning achievements rather than just the assessment of final examinations[10]. However, the MEXT report in 2022 shows that only six percent of Japanese universities provide rubrics in syllabi for all classes.

In this paper, we show the results of questionnaires administered to MEXT from 2013 to 2020 about syllabi and rubrics and discuss syllabi and rubric use in Japan. We propose that universities can easily introduce rubrics into syllabi for all classes using our two-step method.

1.2 Eduinformatics

Eduinformatics is a new field that combines both education and informatics[11]. We show the concept of eduinformatics in Fig. 1 [12]. We incorporated not only the relationship between eduinformatics and information and communications technology (ICT) [13][14] but also the relationship between Eduinformatics and digital transformation (DX) [15]. In addition, we propose new data-driven university reform based on eduinformatics[16]. We reported the importance of eduinformatics with a specific usage example and developed new informatics analytical methods to solve educational issues [13][14][15]. Moreover, we proposed new analysis methods called “feasibility-sustainability analytics (FSA)” to improve sustainability in institutional research (IR) [17] and reported some practical findings of FSA [18].

2 Methods

2.1 Data preparation

The number of universities whose class syllabi include rubrics was prepared based on the result of questionnaires answered by MEXT compared to all universities in Japan from 2011 to 2020 [1], [19].

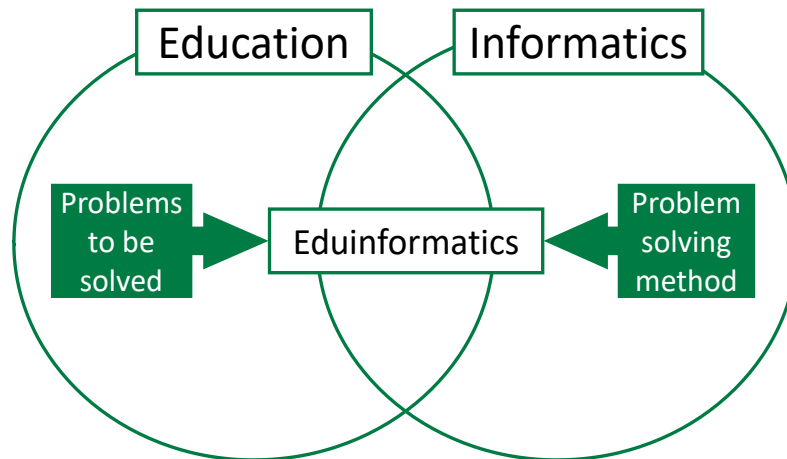


Fig. 1: Concept of eduinformatics (from [16])

The text of the rubrics for the various competencies in all subjects in the 2020 syllabus (the first year in which the syllabus for years 1-4 was replaced by the new syllabus format) was difficult to obtain for the following reasons.

Microsoft word® forms are distributed to each teacher by the Academic Affairs Department. Teachers fill in the syllabus on the word® form and send it as an email attachment to the Academic Affairs Section. In response, the syllabus writer creates a pdf using publishing software, and the printed paper is returned to the teacher. The teacher proofreads the returned paper syllabus and returns it to the teaching department.

Ultimately, the pdf syllabus is distributed on the university website at the same time as the paper syllabus is distributed. This means that the rubric texts for the various competencies in all subjects in the 2020 syllabus were difficult to collect automatically from the pdf and had to be copied manually and collected in a Google spreadsheet.

2.2 Analysis of similarity using Doc2Vec

There are several types of methods for comparing similarity through sentences. Three types are introduced here.

(A) Methods that simply calculate the cosine similarity from the word frequencies.

(B) Methods that use Word2Vec to machine learn (ML) a vector representation of words and then obtain the cosine similarity from the vectors.

(C) A method for ML vector representations of sentences using Doc2Vec and obtaining cosine similarity from the vectors.

(Method (A) is a widely used method. In practice, we simply obtained the word frequencies from the information in the 2015 syllabus (before the first university reform), calculated the cosine similarity based on these frequencies, obtained a matrix of similarities between subjects, and used multidimensional scaling methods (MDS) to obtain the cosine similarity from the vectors. A new visualisation method for curricula (dynamic curriculum map) was developed, in which the dimension was reduced to two dimensions using multidimensional scaling methods (MDS) to obtain a scatter plot [20]. However, the paper's reviewers stated that subjects with similar content were sometimes placed far apart on the map in practice and that further improvements were needed for practical use. Therefore, we found that simply using method (A) did not always find the (ideal) similarity between texts.

We have subsequently improved on these methods and, based on the 2017 syllabus, calculated the cosine similarity between subjects based on the proportions of 19 different competencies for foundational subjects, developed a new visualisation method using MDS [20], or developed a method for easier classification. A new visualisation method using t-distributed stochastic neighbour embedding (t-SNE), which is easier to classify [21], has been developed. Furthermore, the maps obtained by this visualisation method have been used in practice to guide students in their coursework [22].

(The method Word2Vec in (B) is similar to (A), where words are represented as vectors. The similarity between two words can be obtained by calculating the inner product of the vectors obtained. In particular, it was shown for the first time that this method could acquire information by computing between vectors representing different concepts. For example, "queen" is approximately established in the following four words: "king" - "man" + "woman" = "queen"[23].

(The Doc2Vec method in (C) is for representing a sentence/document unit, which is a set of words, as a vector. The similarity between two sentences can be obtained by calculating the inner product of the obtained vectors[24].

In this study, Doc2Vec was used to determine the extent to which R2 was used as a reference when creating the subject syllabus.

The cosine similarity between the R2 and the subject syllabus was calculated using the Doc2Vec model trained with the Japanese version of Wikipedia.

3 Results and Discussions

The MEXT report about syllabi and rubrics in Japanese universities shows both the number of universities where all subjects are clearly specified by rubrics and the number of universities where some subjects are specified by rubrics from 2011 to 2020[1], [19]. We combined and visualised the data (Fig. 2). Fig.2 shows that the number of universities using rubrics for some or all classes increased. Moreover, the growth trend is almost the same for national, public, and private universities.

The result of the last survey in 2020 shows that between 2016 and 2020, the percentage of universities explicitly stating grading criteria in syllabi increased to 98.1%. However, the use of rubrics for all subjects at the undergraduate level only rose from 2.9% to 6.1%, indicating challenges in rubric adoption. These results show that introducing rubrics into syllabi in all classes in universities is challenging.

As described above, MEXT indicated that rubrics are an important evaluative tool. However, many universities do not show the rubric in syllabi. Prof. Hamana clarifies four reasons universities do not use rubrics in syllabi[25]. (1) Rubrics are more time-consuming than tests and other quantitative evaluations. (2) Creating a rubric alone does not completely eliminate inter-rater error, and it is necessary to continue to adjust for inter-rater error through ongoing workshops and other means. (3) Developing a common rubric creates challenges, for example, with setting the levels between criteria. (4) Rubrics may be incorporated as a multidimensional assessment method in the assessment plan.

However, we point out that some higher education faculty lack teaching qualifications such that primary and secondary education in Japan. Therefore, some teachers do not know how to incorporate rubrics as evaluative measures in their classes. When universities decide to use rubrics for all classes and require every teacher to show the rubrics in their syllabi, teachers struggle to meet the demand. We analysed the class “The Institutional Research Theory”. In the class, teachers make rubrics for socialite students. However, Tokyo Institute of Technology’s syllabi do not show rubrics for every class. When universities decide to use rubrics for all classes, faculty

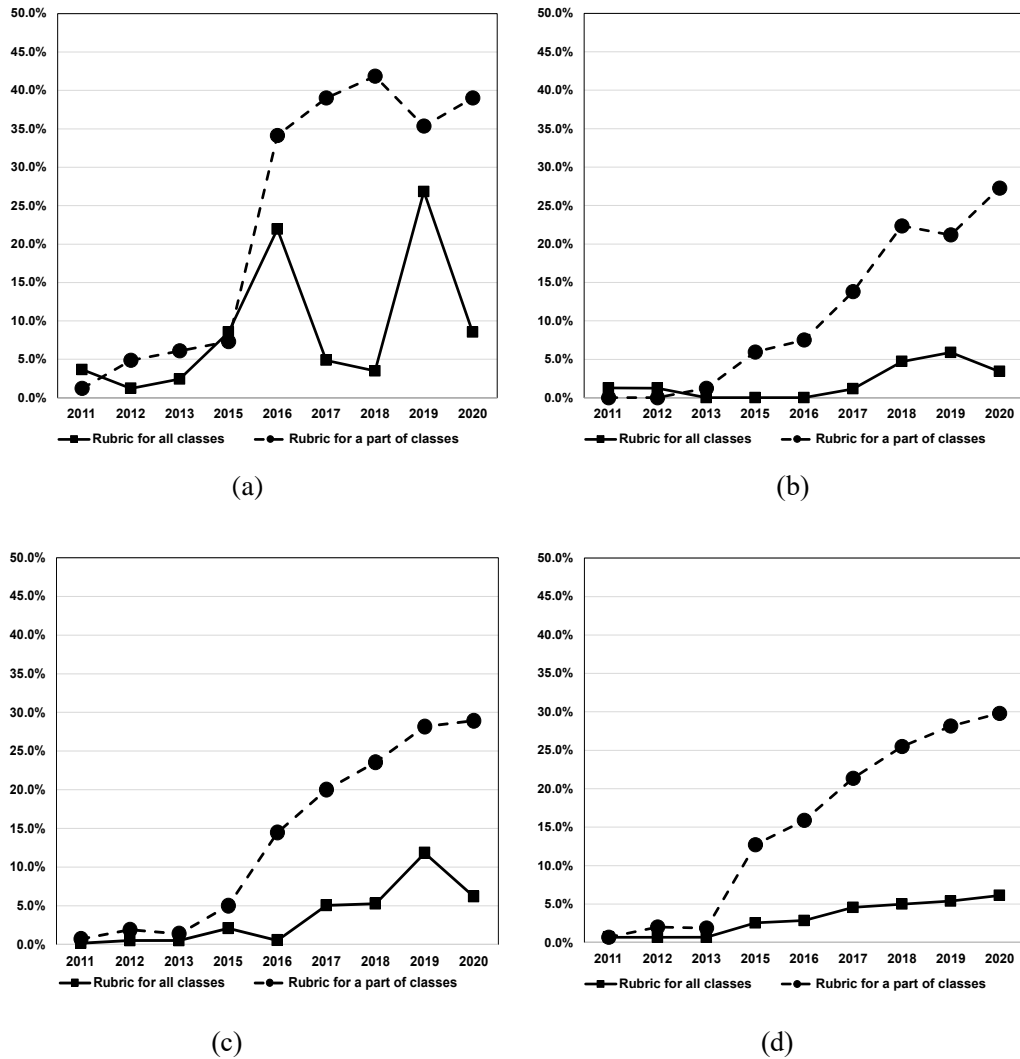


Fig.2 The number of university rubrics for all classes and a part of classes. (a) National University (b) Public University (c) Private University (d) any of (a) to (c)

development specialists must teach all faculty members how to apply them. The first author belongs to Kobe Tokiwa University. In Kobe Tokiwa University, all class syllabi have shown rubrics since 2020. Why could Kobe Tokiwa University could introduce rubrics in every class? Kobe Tokiwa University performed its first university reforms between 2014 and 2016. As the result, in 2017, new curricula were developed. In the curricula, the university measures 19 Kobe Tokiwa competencies (Table 1).

In addition, teachers must select a maximum of 6 Kobe Tokiwa competencies and show their rubric in their syllabi. The university provides an R2 based on common learning outcomes in diploma policies. When faculty include rubrics in their syllabi, they can use a modified R2. The introduction of rubrics into syllabi progressed annually, with only first-year subjects introduced

Table 1: Competencies from the Student Handbook of Kobe Tokiwa University from [20]

Abbreviated Name of Competency	Competency
1. Culture	Ability to use liberal arts as the foundation of human nature, which can involve a variety of people
2. Common Sense	Ability to behave sensibly and show sound judgment in practical matters
3. Professionalism/Expertise	Having the necessary knowledge and skills to perform the duties of each profession
4. Media Literacy	Ability to collect, organize, and analyze necessary information from various media sources for proper thinking and judgment
5. Logical Thinking	Ability to consider situations logically based on evidence.
6. Critical Thinking	Ability to have a multilateral, critical perspective that can grasp and consider various ideas
7. Intellectual Curiosity	Ability to be curious, to learn and remember things, and to have fun and take pleasure in learning
8. Exploration	Ability to think deeply about things and methods
9. Continuity	Ability to maintain a consistent stance on issues and act knowledgeably and thoughtfully
10. Self-Management	Ability to manage one's physical and mental health appropriately
11. Reflection	Ability to continually seek ways to improve oneself by reflecting on one's thinking and behavior
12. Design Thinking	Ability to design solutions and develop comprehensive knowledge
13. Presentation	Ability to appropriately communicate one's personal feelings and thoughts to others
14. Judgment	Ability to make appropriate decisions given the circumstances, based on valid information and sound thinking
15. Implementation	Ability to take specific actions based on one's feelings and thoughts and without fear of failure
16. Responsibility	Ability to behave and face things responsibly as a member of society
17. Contribution	Ability to feel happy for others and take actions that are useful for others
18. Communication	Ability to listen to others' opinions, without which it is impossible to have a creative dialogue
19. Cooperation & Collaboration	Ability to set aside personal and individual interests to work together harmoniously

in 2017, up to second-year subjects in 2018, third-year subjects in 2019, and all subjects from the first to fourth year in 2020.

In 2021, the university carried out a second round of reforms and, based on data analysis, abolished 19 competencies, leading to the creation of four new competencies. Accordingly, teachers set their own achievement targets for each subject in their syllabi and created rubrics for them. Teachers had no questions or confusion about the new and changed method from 2022 because the whole faculty understood how to use rubrics from their experience with the 2017 to 2021 syllabi.

To find out why all classes at the university were able to adapt to rubric grading, we compared the syllabi and R2s of each subject in 2020, the first year of rubric implementation, using Doc2Vec and cosine similarity. Since rubric grading was introduced prior to some departments at that time, we expected that the degree of change from R2 would vary from each department.

The results show that the violin plot shapes differed across departments(Fig.3). It can be seen that the nursing department, which introduced rubric-based grading earlier than the other departments, showed a larger deviation from R2[26].

This research shows a two-step approach proposed to address faculty members' difficulties in creating rubrics.

- 1) Introducing a R2 based on common learning outcomes in diploma policies
- 2) Having faculty members create rubrics for their individual learning outcomes.

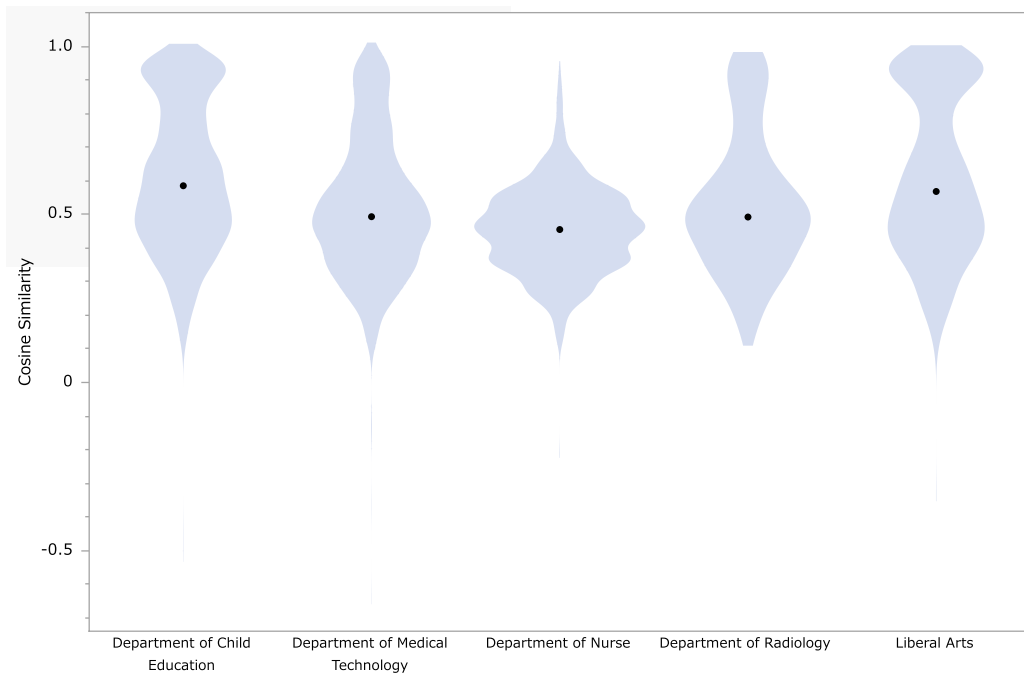


Fig.3: Violin Plot of each department and cosine similarity. Circle show the median. From[26].

Successful implementation of this approach was reported at a university where rubrics were introduced for all subjects. This two-step approach is useful for extending rubric use to all classes in universities.

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