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A METHOD OF EVALUATION IN CALCULUS CLASSES BY RUBRIC

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Abstract. *Teachers are always studying how to teach subjects with fun for students and know students' needs to improve lectures. However, it is so hard to prepare interesting lectures and analyze their needs every time. In this paper, we shall show rubrics as one of ways to improve our education to help teachers work.*
Keywords: Rubric, Evaluation, Relationship among units, Higher education

1. **Introduction.** In recent years, education quality assurance has been desired in higher education in Japan, and necessity to clarify "learning outcomes" which undergraduate students should learn has also been pointed out [1]. In addition, according to the report of the Central Council for Education of the Ministry of Education, Culture, Sports, Science and Technology in Japan [2], they recommended to utilize assessment tests, experiential education surveys, rubrics and so on. As to the faculty evaluation, they indicated necessity to consider research and development of evaluation methods, and also discuss ways of dissemination and sharing of expert knowledge on evaluation.

Oki pointed out that regarding the rubric evaluation as a means of visualizing the learning outcomes, case studies and survey research in primary and secondary education are underway in Japan; however, case examples in higher education are still limited to utilization for evaluation of clinical practice at university of medicine and pharmacy and use for partial training at Kansai University of International Studies and Ehime University [3].

Teachers who wish to use rubrics for classes are supported making their own rubrics at the Education Development Center, Kogakuin University. Under the advice of the second author who is also a member of the center, we carried out our own rubric on an experimental basis in the classes of calculus for the first year undergraduate students. In this paper, we shall introduce a method of evaluation in calculus classes by rubric.

2. **Research Questions.** Most teachers do not know well about rubrics. What is a rubric? What are good points of rubrics? How to make rubrics? How to use the rubrics at classes? Are the rubrics useful at "math" classes? Then, it is time to try rubrics.

Rubrics are criteria for judging the degree of accomplishment of a learner by describing the standard of achievement degree on education in several stages separately [4], and

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also tools for arranging certain things that students want to be able to do about a subject [5]. In addition, there are some features of rubrics. By clarifying the achievement level, it is suitable for evaluation of "thinking/judgment", "interest/motivation/attitude", "skill/expression" difficult by the test method [3]. Moreover, rubrics can motivate students to habituate self-evaluation and self-improvement [5].

In mathematics subjects, it is not so hard to evaluate students' ability by examination. Therefore, we think that we do not need rubrics in math classes. However, rubrics have another good point that we can motivate students to make self-evaluation and self-improvement a habit in the classes. Actually, is it effective to use rubrics in math classes?

3. **Methodologies.** The first author conducted our own rubric at the classes of "Calculus I" for students majoring architecture of Kogakuin University in the second semester, 2016. In the "Calculus I" course, students learn differential and integral calculus for functions of one variable. In the school of architecture of Kogakuin University, they are classified into two levels depending on the score of the mathematics placement test at the time of admission because there is a certain number of enrollees who have not learned senior high school "Mathematics III" dealing mainly with differential and integral calculus for "elementary" functions, and they are tailored to the level. The "Calculus I" course which the first author is in charge of this time is the lower level among them. The first author had two classes of "Calculus I" in the second semester. Students of these classes had not enough basic mathematics skills according to the skill level check. Indeed, we got the following result of awareness about calculus (Table 1).

TABLE 1. Students awareness about calculus at the first lecture

Item	Proportion (N = 141)
Good	1%
A little good	7%
Not good and poor	36%
A little poor	26%
Poor	30%

In Table 1, N means the number of students who responded in two classes.

In preparing rubrics according to classes of calculus, the evaluation viewpoints as the vertical axis and the evaluation scales as the horizontal axis are determined. First, as to the evaluation viewpoints, assuming knowledge of calculus at the senior high school "Mathematics II" level, important units in calculus for functions of one variable at university dealing with this subject are as follows.

(1) Differential calculation including composite functions.
(2) Inverse trigonometric functions.
(3) Extreme values.
(4) Limit value calculation by L'Hospital's rule.
(5) Approximate value calculation by Taylor expansion.
(6) Integral calculation.
(7) Integration by substitution.
(8) Integration by parts.
(9) Improper integration.

From that points further down to four, finally we decided as Table 2.

As to the evaluation scales, based on the ideas of Stevens et al., we assumed three levels of effort, "a level requiring effort", "a certain level of achievement but a level requiring further effort", and "a satisfactory level". However, when students make a self-assessment, it is possible to think of where they are located in three levels, and decide to set five levels with intermediate for each level. By narrowing down the levels, there are also aims to

Table 2. The evaluation viewpoints

Viewpoints
(a) "Differential" calculation
(b) "Limit value" calculation
(c) "Approximate value" calculation
(d) "Integral" calculation

Table 3. The evaluation scales

Level	Ability
1	I do not know the formula. Or, I do not know the meaning.
2	Between level 1 and level 3.
3	I understand the formula. And, I can use formula to solve basic problems.
4	Between level 3 and level 5.
5	I can choose formula that should be used for application problems. And, I can guide correct answers.

make it easier to realize the extension at the end of class. Specifically, it was set like Table 3.

Finally, we set our own rubric for calculus using the evaluation viewpoints and scales mentioned before (Table 4).

We here show one lecture plan utilizing this rubric below.

(1) Making a rubric. [Lecture #0 (Before class starts)]
(2) Explanation of the rubric to students. [Lecture #1]
(3) First self-inspection by this rubric as time of beginning of class. [Lecture #1]
(4) Analyzing the first self-inspection. [After lecture #1]
(5) Giving feedback of results of the first self-inspection. [Lecture #7]
(6) Second self-inspection by this rubric as time of ending of class. [Lecture #13]
(7) Analyzing the second self-inspection. [After lecture #13]
(8) Giving feedback of results of the second self-inspection. [Lecture #14]

As a remark, there are 14 lectures and final examination of every semester subject at Kogakuin University because of 105 minutes for 1 lecture there. In other words, the number of lectures is one less than usual 90 minutes for 1 lecture.

4. **Results.** We used this our own rubric at both first time lecture and final time lecture. Then, we got the following results about ability level and awareness.

The number of students who answered both is 102. Particularly, when it was done for the second time, we did not show individual results for the first time. After submission, we returned the individual results for the first time and had each student realize his/her growth.

From the results for the first time, the average value of students was found to be at a level not reached until "Understand the formula, and can use formula to solve basic problems". Actually, the first author who had these classes felt the same. Comparing the first and second results, it is understood that every item is rising (Table 6).

As to the awareness, although weak consciousness seems to have improved somewhat, when looking at the students in the classes, it seems that there were many people who felt

TABLE 4. Our own rubric for calculus

Evaluation viewpoints		Level				
		1	2	3	4	5
(a)	"Differential" calculation	I do not know the formula or the meaning about "differential" calculation.		I understand the formula and can use formula to solve basic problems about "differential" calculation.		I can choose formula that should be used for application problems and guide correct answers about "differential" calculation.
(b)	"Limit value" calculation	I do not know the formula or the meaning about "limit value" calculation.		I understand the formula and can use formula to solve basic problems about "limit value" calculation.		I can choose formula that should be used for application problems and guide correct answers about "limit value" calculation.
(c)	"Approximate value" calculation	I do not know the formula or the meaning about "approximate value" calculation.		I understand the formula and can use formula to solve basic problems about "approximate value" calculation.		I can choose formula that should be used for application problems and guide correct answers about "approximate value" calculation.
(d)	"Integral" calculation	I do not know the formula or the meaning about "integral" calculation.		I understand the formula and can use formula to solve basic problems about "integral" calculation.		I can choose formula that should be used for application problems and guide correct answers about "integral" calculation.

that the contents were difficult and not good as the first author actually thought (Table 7).

We also get the following correlation data among units (Tables 8 and 9). Here, all data are significant at the 5% level.

From these analyses, we could have the following two results:

1) The understanding of all units is related each other.

2) The extension of skill's level of all units is also related each other.

Especially, the relationship between differential unit and integration unit is stronger.

Table 5. Lecture plan

Lec.	Unit	Purpose and outline of class
#0	Before class starts	A lecturer makes a rubric.
#1	Derivative coefficients and derivatives	A lecturer explains a rubric and makes students the first self-inspection by this rubric.
		Students become possible to calculate derivative coefficients and derivatives of arithmetic functions.
#2	Derivatives of elementary functions	A lecturer analyzes the first self-inspection.
		Students become possible to derive the formula and calculate derivatives of elementary functions.
#3	Derivatives of composite functions	Students become possible to calculate derivatives of various elementary functions.
#4	Inverse trigonometric functions	Students become possible to calculate derivatives of inverse trigonometric functions.
#5	Limit calculation of indeterminate form	Students become possible to calculate limit values of indeterminate form using L'Hospital's rule.
#6	Higher order derivatives and Taylor expansion	Students become possible to calculate higher order derivatives and approximate general functions by Taylor expansion with polynomial functions.
#7	Review and exercise	A lecturer gives feedback of results of the first self-inspection.
		Students review units learned before and solve related problems a lot.
#8	Calculating primitive functions	Students become possible to derive and calculate the formula of primitive functions which are the inverse operations of derivatives.
#9	Definition and calculating definite integrals	Students understand the definition of definite integrals and become possible to calculate definite integrals.
#10	Integration by substitution	Students become possible to calculate integrals of functions using integration by substitution.
#11	Integration by parts	Students become possible to calculate integrals of complicated functions using integration by parts.
#12	Integration of rational functions	Students become possible to calculate integrals of rational functions by partial fraction decomposition.
#13	Improper integrals	A lecturer explains a rubric and makes students the second self-inspection by this rubric.
		Students become possible to calculate improper integrals.
Exam	Final examination	A lecturer analyzes the second self-inspection.
		Students solve related problems as a final exam.
#14	Review	A lecturer gives feedback of results of the second self-inspection including final exam.
		Students review all units learned in this class.

Table 6. Comparison between first and final lecture of ability level

Viewpoints	First (N = 141)	Final (N = 104)
(a) "Differential" calculation	2.8	3.3
(b) "Limit value" calculation	2.5	2.8
(c) "Approximate value" calculation	2.0	2.6
(d) "Integral" calculation	2.7	3.1

TABLE 7. Comparison between first and final lectures of awareness about calculus

Item	First (N = 141)	Final (N = 104)	Difference (point)
Good	1%	1%	0
A little good	7%	11%	+4
Not good and poor	36%	36%	0
A little poor	26%	34%	+8
Poor	30%	18%	−12

TABLE 8. Correlation analysis of understanding at the first time lecture

Unit	Differential calc.	Limit value calc.	Approximate value calc.	Integral calc.
Differential calc.	–	0.732	0.589	0.885
Limit value calc.	–	–	0.770	0.702
Approximate value calc.	–	–	–	0.655
Integral calc.	–	–	–	–

TABLE 9. Correlation analysis of extension of skills' levels

Unit	Differential calc.	Limit value calc.	Approximate value calc.	Integral calc.
Differential calc.	–	0.577	0.428	0.774
Limit value calc.	–	–	0.600	0.576
Approximate value calc.	–	–	–	0.585
Integral calc.	–	–	–	–

5. **Conclusion.** From this study, we could know that rubrics make students study easily because they can see the goal precisely and their own skill at that time of this subject. In addition, we could see the relationship among units. Therefore, we show the effectiveness of using rubrics in calculus classes. We also study the relationship between units and results of final exam more precisely. Moreover, we are about to revise this rubric using flowchart under the advice of Professor Yasuhiro Hayashi of Teikyo Heisei University [6].

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