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The Grades Transfer from One Grading Scale to Other Algorithmization

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Abstract. The article presents the consideration of grading scales used for education outcomes in different countries, describes likeness and differences of applied grading scales. Application of the European Credit Transfer and Accumulation System (ECTS) grading scale is investigated according of the analysis of scientific literature as well as cases of its mistaken application. The article provides a model for grades transfer from one scale into another, specifies the results of experimental testing of the introduced model, and analyzes cases of mistaken grades transfer.

Keywords: grading scale, ECTS grading table, empirical probability decomposition, rating, grade.

1. Introduction

The comparability, transparency and correct interpretation of marks, gained in different countries, institutions, and education spheres shall be named not only as national goals, but also as European goals, in order to create generic and consolidated European space for higher education. Academic progress and outcomes of education of students who is involved in international exchange programmes, continuing education in other academic institutions of different countries and who aspires to succeed in their carrier in other countries shall undergo through exact, valid and transparent evaluation.

The necessity of algorithmization of grades transfer is conditioned by differences observed in grading scales and application procedures applied in different countries. Grades transfer challenge is being analyzed by distinct authors in their treatises. During the comparison of differences in grading scales used in different countries performed in 1997, Haug (1997) underlined that the grading interpretation is as non-objective as the assessment process itself. Correct and objective grades transfer from one grading scale to other using formulas is complicated due to the differences of applied grading scales and their application methods.

Considerable interest was attracted to grades transfer to the ECTS grading scale. Nunes *et al.* (2005) proposed a method to go from a highly differentiated grading scale to

ECTS, taking the legal restrictions of Portugal into account. Warfvinge (2008) introduced model for grades transfer to the ECTS grading scale.

Research objective: to consider grading scales for the assessment of education outcomes in different countries, analyze application of the ECTS grading scale, provide generic method for transfer of grades from one grading scale to another, and introduce the results of experimental testing of the introduced model.

Applied research methods: review of scientific literature, experimental testing.

2. Review of the Grading Scales in Different Countries

During the analysis of grading scales used for education outcome assessment in different countries, information provided by foreign Ministries of Education, Centers for quality assessment in higher education, academic institutions, the information network on education in Europe „Eurydice“, and Internet websites of academic informational centers was used, Laws regulating the order of education outcome assessment were considered, and scientific papers were analyzed.

Different countries have developed different approaches to grading which are deeply rooted in their pedagogical and cultural traditions. It is to be pointed out, moreover, that not only do they have different grading scales, but they also use them differently in the various institutions and subject areas (ECTS User Guide, 2009). Many countries apply numerical grading scale (Karran, 2005), still student achievements from Norway, Italy, and United States of America are evaluated using letters. Academic institutions of Estonia use both scales – literal and numerical (Vaht, 2010). Variety of grading scales can be also observed in Russia (Petrovskaya *et al.*, 2006). Greater number of countries uses increasing scales, i.e., higher grade substitutes the higher level of the assessment result (Karran, 2005). Thought, in Czech Republic and Austria the decreasing scale is used for the assessment of student achievements. Not only the designation of grading scales varies, but also their ranges. In Lithuania, Latvia, Serbia, Slovenia, Macedonia, Bosnia and Herzegovina, and Montenegro the ten-point scale is used. Achievements of Estonian and Finnish students are assessed by the six-point scale. Swedish students of academic institutions are evaluated applying the scale of three or four grades (Warfvinge, 2008). Nowadays differentiating grading scales gain the highest popularity (Warfvinge, 2008).

Grading scales are divided into two parts: positive and negative grades. Many countries introduce grading scales where the greater part of the scale is devoted for positive grades (Karran, 2005). Lithuanian grading scale includes six positive grades, Latvian – seven, and Serbian, Slovenian, Macedonian, Bosnian and Herzegovinian, and Montenegrin only five positive grades from the available ten.

Not only grading scales used for education outcome assessment, but also their application practice vary. In France grades of the bottom part of the scale prevail, in Italy – of the upper part of the scale (ECTS User Guide, 2009). Italian high school students studying engineering get lower marks than students who studies humanities (ECTS User Guide, 2009).

3. The ECTS Grading Scale and Application Challenges

The ECTS grading scale was developed in order to ensure comprehensiveness, transparency and comparability of marks, gained in different countries, institutions, and education spheres. Application of the scale as the instrument used for transfer of grades was recommended to be used in parallel with national scales. Such European scale was based on the statistical distribution of passing grades in each programme (ECTS User Guide, 2009). The ECTS grading scale is a norm-referenced (Karran, 2004). It showed how the national scale was actually being used in that context and allowed for comparison with the statistical distribution of grades in a parallel programme of another institution. The ECTS scale supplements the national grading scale, though it does not replace it. According to Dahl *et al.* (2009) ECTS grading scale is only supplemental and not really a grading scale and it is added as an explanation to the original grade. ECTS grading scale is based on the statistical data and it can be used for marks interpretation of norm-referenced and criterion referenced grading scales.

The first stage of the ECTS scale implementation is the acquisition of statistical data. Statistical data illustrates the sequential assessment model. During the second stage of the ECTS implementation, the statistical distribution curve for each reference group was split into five segments (top/the highest 10%, other 25%, other 30%, other 25%, and the lowest 10%), that are named as A, B, C, D, E, which could become a device for the direct translation of grades gained in one particular country into grades of the another one.

The ECTS scale was criticized a lot. Warfvinge (2008) emphasizes that norm-referenced model of the ECTS scale is inconsistent to pedagogical cultural traditions held in many countries. The ECTS scale application foresees rating processes criticized by Swedish educologists. According to Dahlgren *et al.* (2006), rating of students contradicts such stimulating principles as student co-operation and interaction.

During the implementation of the ECTS grading scale in high schools, the following assessment challenges appeared, according to Karran (2004) the bigger part of European high schools use the ECTS grading system not taking into account its definition core. Criterion referenced grading scales applied by universities are directly converted into the ECTS grading scale without paying any notice to the grade distribution requirements (Warfvinge, 2008). According to Warfvinge (2008), high schools select easier, although mistaken application practice of the ECTS, which does not claim for the consideration of previous assessment data and student rating. Karran (2005) had performed the analysis of the ECTS grading scale application in twenty European universities and determined that ECTS grading is a norm-referenced system, while national systems are usually criterion-referenced, the ECTS conversion tables provided by universities indicate straight line transference from institutional to ECTS grades.

Since the second stage of the ECTS scale introduction is too difficult, the procedure of grade conversion was simplified by the application of the ECTS grading table, which based on the first step of the five-point system (ECTS User Guide, 2009). Thus institutions only need to provide a standard table with statistical distribution of grades within programme or a group of programmes (ECTS User Guide, 2009).

4. Mathematical Model of Grades Conversion

Mathematical model of grade conversion is prepared on the bases of the simplified ECTS grade conversion method – using the ECTS grading table. Created model can be used for norm-referenced and criterion referenced grading scales. Interactions of two grading scales are described by the ECTS grading table.

$a_1, a_2, \ldots, a_n$ in the table define marks of A grading scale, and $b_1, b_2, \ldots, b_m$ – marks of the B grading scale. Marks of both grading scales are presented from the highest to the lowest one. Values of scales are specified using indexes n and m. The above indexes accords with (1) the interactions defined by inequalities:

$$n \geqslant 1, \qquad m \geqslant 1. \tag{1}$$

Data A and B of grading scales is filled in as empirical probability decompositions. Since different countries uses increasing and decreasing scales, and the decreasing ones differ in designation of scales, the new variable is introduced – the assessment index i. Assessment indexes enumerate marks of scales in decreasing order and comply with values of the concerned decomposition features. Values of decomposition features are successive natural numbers. Probabilities of empirical probability decomposition value acquisition are calculated via (2) formulas.

$$p_{Ai} = \frac{k_i}{100}, \quad i = \overline{1,n}, \qquad p_{Bj} = \frac{l_j}{100}, \quad j = \overline{1,m}. \tag{2}$$

In order to convert grade from scale A into scale B, the two-dimensional empirical probability decomposition is used. Gained values of the above decomposition are (i, j), $i = \overline{1,n},\ j = \overline{1,m}$. Decomposition values (i, j) acquisition possibility p_{ij} is the possibility to transfer the assessed knowledge and achievements of A scale marked as index i, to the B scale with the assessment index j.

Probabilities of two-dimensional empirical probability decomposition are calculated via (3) formula:

Table 1

The relation of grading scales A and B

Grading scale A	Grades distribution in grading scale A	Grading scale B	Grades distribution in grading scale B
a_1	$k_1\%$	b_1	$l_1\%$
a_2	$k_2\%$	b_2	$l_2\%$
$\ldots$	$\ldots$	$\ldots$	$\ldots$
a_n	$k_n\%$	b_m	$l_m\%$

Table 2
Two-dimensional empirical probability decomposition of grades conversion

B	1	2	...	m
A				
1	p_{11}	p_{12}	...	p_{1m}
2	p_{21}	p_{22}	...	p_{2m}
..	...	...	...	
n	p_{n1}	p_{n2}	...	p_{nm}

$$p_{ij} = \min\left(p_{Ai} - \sum_{k=0}^{j-1} p_{ik}; p_{Bj} - \sum_{k=0}^{i-1} p_{kj}\right), \quad i = \overline{1,n},\ j = \overline{1,m},$$
$$p_{i0} = 0, \qquad p_{0j} = 0. \tag{3}$$

Grade equivalent is allocated according to the complied two-dimensional empirical probability decomposition. If grades are not rated, the most probable equivalent is assigned.

$$a_i = b_k \quad \text{if } p_{ik} = \max(p_{i1}, p_{i2}, \ldots, p_{im}), \quad i = \overline{1,n}. \tag{4}$$

If grade acquisition possibilities are identical, the maximum equivalent shall be taken, i.e., the grade with the lowest assessment index. Grade a_i of A grading scale matches the grade b_k of B grading scale, if the probability of the appearance of distribution value (i, k) satisfies the relationships described by inequalities (5).

$$\begin{aligned} &a_i = b_k \quad \text{if } p_{ik} = \max(p_{i1}, p_{i2}, \ldots, p_{im}) \\ &\text{if } p_{ik} = p_{il}, \quad \text{then } k < l,\ i = \overline{1,n} \end{aligned} \tag{5}$$

If rating of students is applied, grades are arranged in the decreasing order and the rating is subscribed to all grades. Number of grades sk_i complying with the converted grade a_i is additionally distributed applying (6) formula. Grade b_1 complies with s_{i1} of the highest a_i grades, $b_2 - s_{i2}$ succeeding grades a_i etc..

$$s_{ij} = \left[\sum_{k=1}^{j} \frac{p_{ik}}{\sum_{l=1}^{m} p_{il}} * sk_i + 0.5\right] - \sum_{k=0}^{j-1} s_{ik}, \quad i = \overline{1,n},\ j = \overline{1,m},$$
$$s_{i0} = 0. \tag{6}$$

If the rating of converted feature a_i within the analyzed multitude is r, the grade rating is a_i in the grade group v, then, the number of grades rsk_r, complying with the rating is additionally distributed applying (7) formula. Grade b_1 is substituted by c^i_{r1} of the highest rating r grades, $b_2 - c^i_{r2}$ of succeeding rating r grades, etc..

$$\begin{aligned} &c_{rj}^i = \min\left(s_{ij} - \sum_{k=0}^{v-1} c_{kj}^i;\ rsk_r - \sum_{k=0}^{j-1} c_{rk}^i\right), \quad i = \overline{1,n},\ j = \overline{1,m}. \\ &c_{0j}^i = 0, \qquad c_{r0}^i = 0. \end{aligned} \tag{7}$$

Then the a_i grade of the rating r is substituted by the grade b_k of B grading scale B, if the interconnections described in the equation (8) are satisfied.

$$\begin{aligned} &a_i = b_k \quad \text{if } c_{rk}^i = \max\left(c_{r1}^i, c_{r2}^i, \ldots, c_{rm}^i\right), \quad i = \overline{1,n},\ k = \overline{1,m} \\ &\text{if } c_{rk}^i = c_{rl}^i, \quad \text{then } k < l. \end{aligned} \tag{8}$$

5. The Results of Experimental Testing of the Grades Transfer Model

Grades transfer algorithm is formed using C++ language by Borland C++ Builder programming tool. During the experimental testing of the developed grade transfer model the direct and inverse grade conversion from the scale A into the scale B is applied. For each case the relevance and irrelevance of grades conversions are calculated. Model testing is performed within identical and different scales; the correctness of the model is being checked for the rated and not rated grade multitudes. The experiment is performed for grading scales where positive marks takes 3–10 positions of all grades. Each grade of the scale is substituted by 10 marks of converted grade multitude.

At the beginning of the experiment grading scales of the same size A and B are taken, their grades distribution varies insignificantly. The grades distribution of grading scales A and B varies insignificantly, if (9) are satisfied.

$$\begin{cases} k_i - l_i < l_i, \\ l_i - k_i < k_i, \end{cases} \quad i = \overline{1,n}. \tag{9}$$

The grade distribution of testing grading scales is presented in Table 3.

Grade conversion within grading scales of the same size, and grades distribution of which varies insignificantly is correct and single-valued while converting the rated and not rated grade multitudes. The irrelevancies of conversion were not recorded.

The experiment is continuing within identical grading scales, their grades distribution varies significantly. The grades distribution of grading scales A and B varies significantly, if (9) are not satisfied. The grades distribution of testing grading scales is presented in Table 4.

The irrelevancies of conversion are recorded during the conversion of not rated grading scales of the same size, still the grade distribution of which varies significantly (Fig. 1).

Table 3

The grades distribution of testing grading scales

Grades	4 point grading scale		6 point grading scale		7 point grading scale		10 point grading scale	
index	A	B	A	B	A	B	A	B
1	20%	15%	15%	10%	5%	5%	10%	7%
2	30%	35%	15%	20%	10%	10%	10%	13%
3	30%	25%	20%	15%	20%	15%	10%	7%
4	20%	25%	20%	25%	30%	35%	10%	13%
5			15%	20%	20%	15%	10%	7%
6			15%	10%	10%	15%	10%	13%
7					5%	5%	10%	7%
8							10%	13%
9							10%	7%
10							10%	13%

Table 4

The grades distribution of testing grading scales

Grades	4 point grading scale		6 point grading scale		7 point grading scale		10 point grading scale	
index	A	B	A	B	A	B	A	B
1	40%	20%	20%	10%	10%	5%	10%	20%
2	20%	25%	15%	20%	10%	10%	10%	10%
3	20%	25%	15%	15%	15%	15%	10%	5%
4	20%	30%	20%	25%	30%	35%	10%	5%
5			15%	20%	20%	15%	10%	10%
6			15%	10%	10%	15%	10%	10%
7					5%	5%	10%	10%
8							10%	10%
9							10%	5%
10							10%	15%

Cases of references converting discrepancy are recorded for all tested data sets evaluation not suitable for (10) described relationships of equality.

$$a_i = b_j \quad \text{if } \max(p_{i1}; \ldots; p_{im}) = \max(p_{1j}; \ldots; p_{mj}) = p_{ij}, \quad i = \overline{1,m},\ j = \overline{1,m} \tag{10}$$

Continuing an experiment, the ratings are referred to the control references sets evaluation. The number of the ascribable ratings is minimal, different ratings are ascribable to the different scale's ratings evaluations. Thus, in a 4-point rating scale, ascribable for all ratings evaluation, adequate to the 4th mark 1 rating is being putted; to the 3 mark 2 rating is being putted, to the 2 mark 3 rating is being putted and to the 1 mark 4 rating

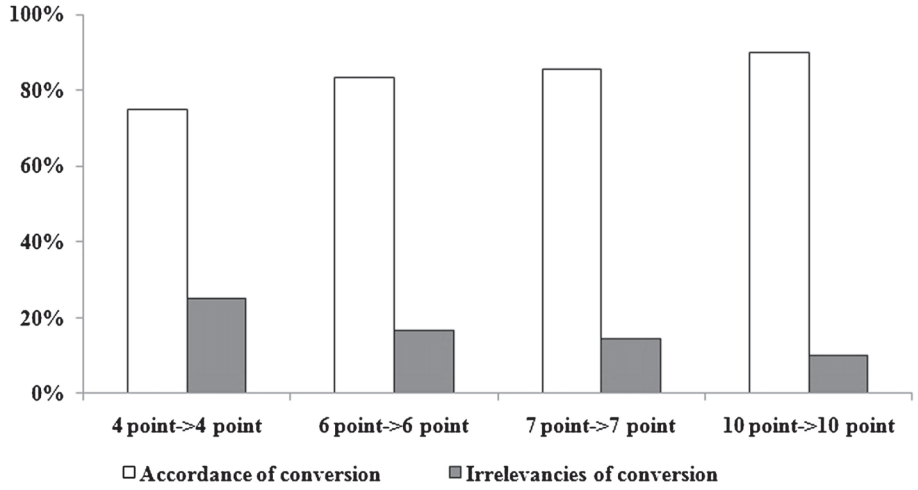

Fig. 1. Grades conversion within grading scales of the same size.

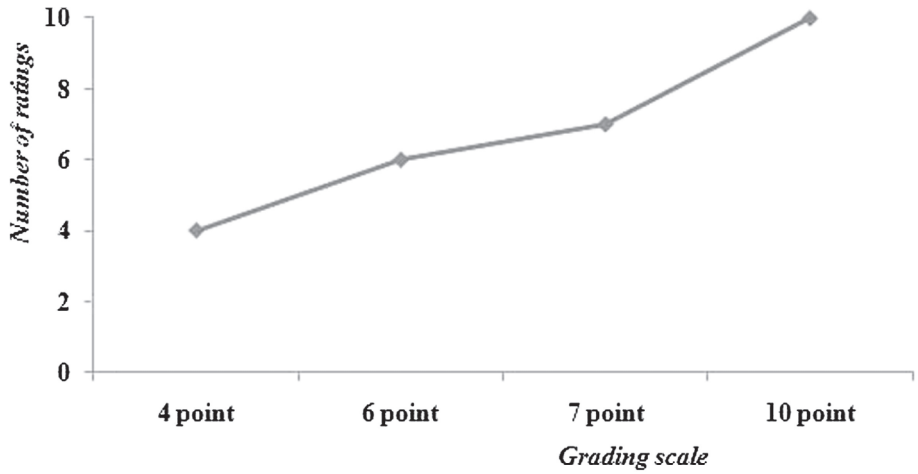

Fig. 2. The number of ascribable ratings and the scale size dependence.

is being putted. The number of ascribable ratings depends on the scale size (Fig. 2). Performing converting in the sets of rating references, the wrong cases of converting are not recorded.

The experiment is continuing within different grading scales. The grades distribution of testing grading scales is presented in Table 5.

Cases of grades converting discrepancy are not recorded while converting the marks in the different size grading scales, when the direct marks' converting is performed from smaller to larger grading scale. This grades converting is exact in rating and non-rating references sets. Though equivalents of non-rating references grades sets are distributed unevenly in the new grading scale.

Table 5

The grade distribution of testing grading scales

Grades index	4 and 3 point grading scales		7 and 5 point grading scales		10 and 3 point grading scales	
	A	B	A	B	A	B
1	20%	30%	5%	10%	10%	30%
2	30%	40%	10%	20%	10%	40%
3	30%	30%	20%	40%	10%	30%
4	20%		30%	20%	10%	
5			20%	10%	10%	
6			10%		10%	
7			5%		10%	
8					10%	
9					10%	
10					10%	

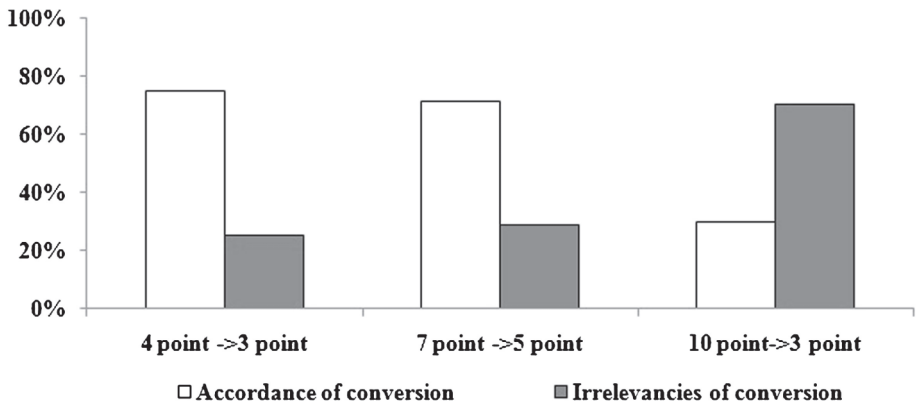

Fig. 3. Grades conversion within grading scales of the different size.

Performing references converting from larger to smaller evaluation scale, cases of references converting discrepancy are recorded in the non-rating evaluation sets. Experimental test results show that the number of grades converting discrepancy cases in the non-rating grades sets depends on the differences of scales' size. If the difference of A and B grading scales' sizes increases then the number of grades converting discrepancies increases, too (Fig. 3).

Continuing the experiment, it was mentioned in the rating control references set that the minimal number of ratings providing unambiguous grades converting from larger to smaller grading scale is equal to larger grading scale size (Fig. 4). This number of ratings is enough for the major converse grades converting performance, if the distribution of references in the larger evaluation scale slightly differs from the evaluation distribution according to ratings.

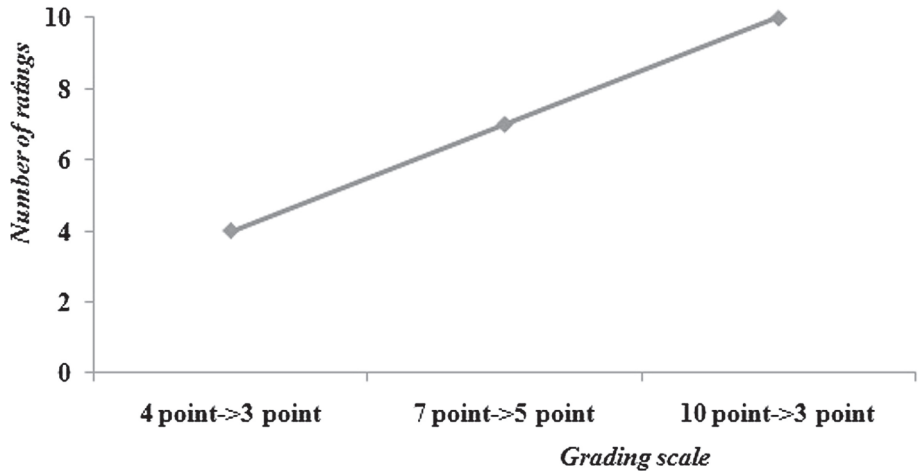

Fig. 4. The number of ratings and the scale size dependence.

Conclusions

The grades transfer model is made on the ground of ECTS grading table and converts grades on the principle of the most probable grade equivalent evaluating the rating of a grade in the group of analyzed grades.

The experimental testing of the developed grades transfer model showed that the case of irrelevance of grades conversion influence the differences of grading scales size and grade distribution.

The results of experimental testing showed that students' rating are necessary for correct and single-valued grades conversion.

Integration of created grade transfer model into e-learning systems would guarantee delivering of united e-courses adapted for learners from different countries.

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Pažymių konvertavimo iš vienos vertinimo skalės į kitą algoritmizavimas

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Straipsnyje nagrinėjamos įvairių šalių studijų rezultatų vertinimo skalės, aptariami taikomų vertinimo skalių panašumai ir skirtumai. Remiantis mokslinės literatūros analize, nagrinėjamas Europos kreditų perkėlimo ir kaupimo sistemos (ECTS) vertinimo skalės taikymas, apžvelgiami klaidingi ECTS vertinimo skalės taikymo atvejai. Straipsnyje pristatomas sudarytas vertinimų konvertavimo iš vienos vertinimo skalės į kitą modelis, pateikiami sudaryto modelio eksperimentinio testavimo rezultatai, analizuojami klaidingi vertinimų konvertavimo atvejai.