Score Calibration Method for Assessment Motivation

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Abstract

Assessment is one of the powerful tools that can influence motivation of students. Importance in giving fair and objective feedback can be seen not only during the instruction but especially in those cases when students' success and ranking depends on scores gained in the competition. Scores for independently scored parts of assessed problems can be considered as random variables. Dependency of scores at Physics Olympiad of Slovak republic was analysed by determining covariance matrix. Scoring scheme, according to which the performance is assessed by scores, is usually proposed by teachers or skilled authors of physics problem. However, it was found out that independency of random variables is not their general feature when scores were analysed. The reason for it could be found from the qualitative analysis of skills needed for successful solution of particular parts. Some skills and knowledge are needed in more than one part giving advantage for those students who have these skills or knowledge. The higher scores, the better performance, is not always true in this case. Therefore, we proposed unambiguous and general procedure to modify scores in order to get independent random variables. Modified scores can be then calibrated according to the aim of assessment – for example to increase the number of successful competition participants to motivate them. The main features of proposed calibration method are expressed and results of its application on statistical data from Physics Olympiad of Slovak republic are presented. This approach can be applied also in the assessment as it is based on statistical analysis of student' scores.

Keywords: *Scoring scheme, Physics Olympiad, Covariance, Decomposition procedure, Motivation*;

1. Introduction

Scoring is widely used assessment method in physics competitions as well as in physics introduction. International Physics Olympiad (IPhO) ranks its participant according to achieved scores since its beginning in 1967. Physics Olympiad (PhO) in Slovakia, the Czech republic started its history in former Czechoslovakia with assessment method using 3 or 4 level classification scale but nowadays scoring is the only assessment method [1][2]. Physics problem is divided into few separately and independently scored parts. We consider scores gained by PhO participants for separately scored parts as random variables. Knowledge and skills are needed for correct solution of physics problem and some of them are shared between few parts [3]. According to the results of our previous research [2], independency of scores as random variables is not their general feature, although they are scored by experienced assessors. In this article, suggestions of correct and objective statistical-based calibration method are discussed and its graphic interpretation is presented. This method was described in [3], [4], in more details. Modification of scores to independent variables enables us to calibrate them according to the aim of assessment. According to [5], significant correlation between succeeding in PhO and interest in repeated participation in PhO (in the next year) was observed. Regional Committee of PhO concluded that if success of younger PhO participants in categories E, D (for primary schools) increases, number of PhO participants in higher categories would rise.

2. Methods

Statistical-based data analysis of PhO participant's scores (random variables) gained for independently scored parts was done. Covariance matrix was used to examine independency of random variables $\boldsymbol{X}^j, \boldsymbol{X}^k$ (scores for j-th and k-th part). Non-zero covariance was identified in all cases when covariance was calculated as follows:

$$\mathrm{cov}(\boldsymbol{X}^j, \boldsymbol{X}^k) = E[(\boldsymbol{X}^j - \mu^j)(\boldsymbol{X}^k - \mu^k)].$$

According to these results, original scores are not independent random variables in general. In Fig. 1 is presented usually applied approach for modification of scores in order to increase number of scores – changing maximum values of original scores. This is usually done when participants gain low overall

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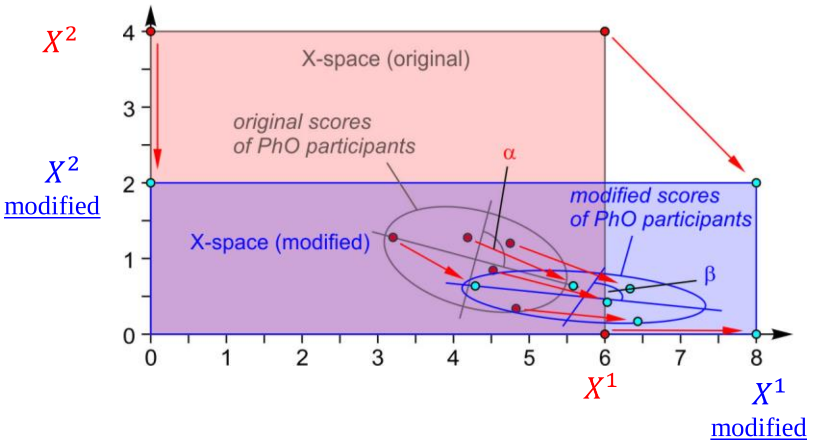
scores. In the depicted case (Fig. 1), original scores of PhO participants have two-dimensional normal distribution presented by ellipse where their axes (α is right angle) presents the aforementioned independent variables in X-space – scores gained for solution of parts X^1, X^2 (in the most simple 2-dimensional case). In order to increase scores, modified maximum values of scores are calculated as well as modified scores k_1X^1 and k_2X^2 ($k_1 < 1 < k_2$) of PhO participants resulting into changes of coordinates in X-space (red arrow showing the move of samples). Angle β is not right angle and indicates, that modified scores were not independent random variables and therefore this change is not correct.

Fig. 1: Example of incorrect modification of scores in X-space



Eigenvectors of covariance matrix with coordinates a_{jr} are calculated in order to determine independent random variables – new scores ξ_k^j of the k-th participant gained in the j-th task of physics problem, as follows: $\xi_{\mathrm{k}}^{\mathrm{j}} = \sum_{r \in J} a_{jr} X_k^r$.
Graphical approach can be used to explain mathematical background of this method. Eigenvectors are perpendicular to each other and direction of $\xi^1, \xi^2, \ldots, \xi^n$ axes of independent variables are given by these eigenvectors (fulfilling the additional condition that maximum scores are positive numbers). In Fig. 2a) is depicted relationship between values of scores in X-space and ξ-space of independent random variables. Letter A stands for scores of particular PhO participant, whose scores ξ_A^1, ξ_A^2 are within ellipse including scores of other PhO participants. Maximum values ξ_{max}^1 and ξ_{max}^2 of ξ-scores are determined as coordinates of $[X_{max}^1, X_{max}^2]$ in ξ-space. These values are then calibrated to maintain maximum value of overall scores same as in X-space. Modified ξ-scores of the PhO participant A are then determined. Modification of scores in the direction of eigenvectors are free of constrains as ξ-scores are independent random variables. Depicted case is the example in which the best way to increase scores is to increase maximum scores on ξ^1-axes (and proportionally lower maximum scores on ξ^2-axes). Effect of this procedure (calibration) on results of PhO participants one can see in the graph (Fig. 4) comparing original scores to modified ξ scores.
Recalibration of modified ξ-scores into X- space is done by determining coordinates of modified ξ scores in X-space. This recalibration has effect on maximum scores in X-space (X_{max}^1 modified, X_{max}^2 modified) as well. Example of this is depicted in Fig. 3. New X scores obtained after recalibration are not independent random variables, but the independent ξ variables saved their independency and this approach can be considered to be correct. Effect on overall scores can be observed in graph (Fig. 4) as modified scores X.

Fig. 2 Calibration of scores in ξ-space of independent random variables

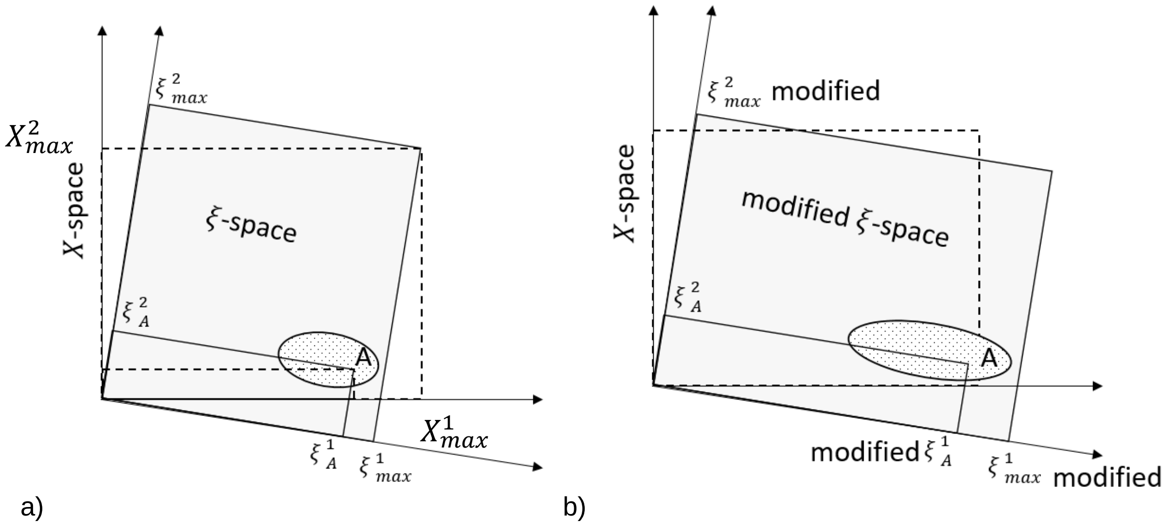
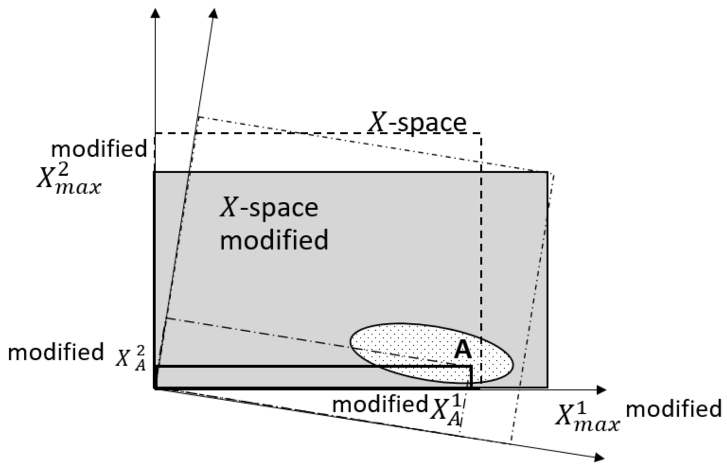


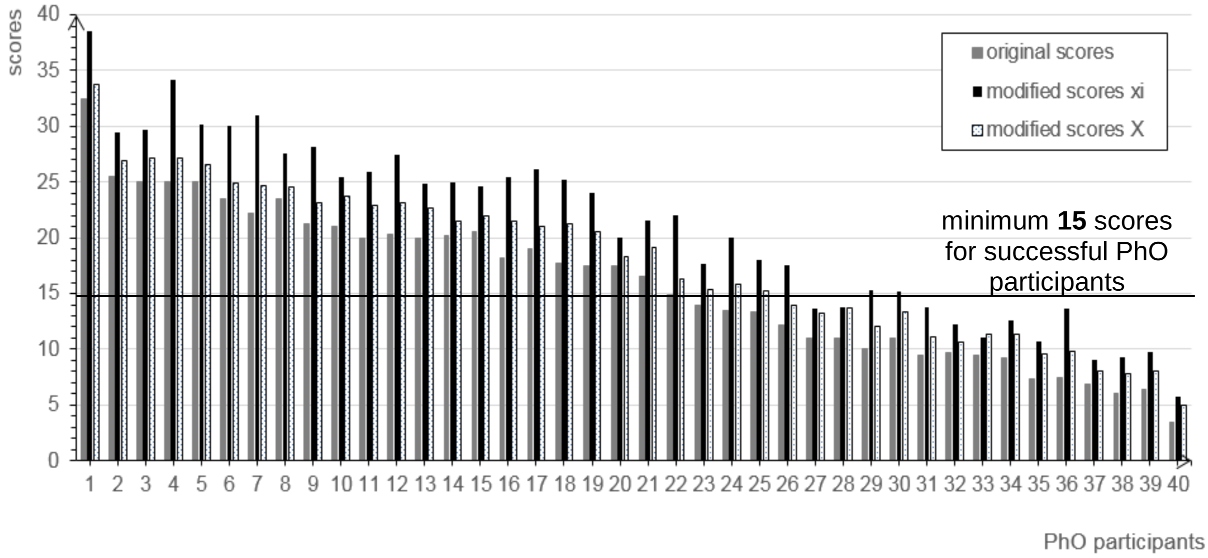
Fig. 3 Recalibration of modified scores to X-space



3. Results

Sample of scored solutions of 40 PhO participants taking part in 3rd round in E category in Physics Olympiad in Slovak republic, school year 2016/2017, was analysed. Original assessment resulted in 21 successful PhO participants, 53 %. Modified scores ξ (xi) are obtained after calibration and modifying ξ-space according to the aim of assessment. Number of successful PhO participants increased to 28 (70 %). Recalibrating these modified scores ξ (xi) into X-space resulted in 25 (63 %) of successful PhO participants. Modified overall scores ξ or X are higher than original scores in all cases with higher observed differences for modified scores ξ. It can be seen that few participants whose scores was slightly lower than minimum score (15 points) needed to become successful PhO participant obtained just enough score to cross this minimum value. This resulted in the increased number of successful PhO participants with positive effect on their motivation. Number of successful PhO participants can be slightly changed by modifying parameters. However, this number should be 60-70 % and no negative values of maximum scores for modified parts should be obtained.

Fig. 4 Comparison of original scores and modified scores ξ (xi) and X



In a ten years long study of Lacsny et al. [6]-[13] analysing the dynamics of cognitive processes in solving physics problems, a strong correlation between the number of necessary elementary physical, resp. mathematical steps and the success in solving problems in physics was found. They are able to model the attainable success of students in solving physics problems by using model ENKI based on the detailed structure of solution. Their findings indicate that mathematical skills of students influenced the success of students more than their physics skills.
Assessment methods in physics competitions need to focus more on skills in physics than on mathematics. Skills in physics and skills in mathematics are independent of each other and the recalibration method described here is a good tool to recognize these skills and to separate them for assessment that is more suitable.

4. Conclusion

Method proposed for modification of scores according to the aim of assessment was successfully applied on statistical data – scores of PhO participants. Number of successful PhO participants was increased up to 60-70 % in order to motivate them by experience of success. Independent random variables are modified in this method, which is correct approach. This method could be used as well in learning assessment as it is general statistical based method.

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References

[1] Hanáková, M. “Assessment in Physics Olympiad”, Third International Conference "Organizational Development: Culture, Education and Knowledge Management", Buenos Aires, CENTED, 2017, 74-78

[2] Hanáková, M., Teleki, A. “Modification of Scoring Scheme in Physics Olympiad and Its Possible Utilization in Analysis of Assessment”, http://dx.doi.org/10.1063/1.4974382, Melville, AIP Publishing, 2017, 040003 1-8

[3] Hanáková, M., Teleki, A., Lacsný, B. “Statistical-based calibration procedure used for modification of scores as the motivation tool”, Third International Conference "Organizational Development : Culture, Education and Knowledge Management", Buenos Aires, CENTED, 2017, 80-83

[4] Hanáková, M., Teleki, A., Lacsný, B. “Modification of Scoring Schemes Using Decomposition Procedures on Statistical Data”, DOI: http://dx.doi.org/10.12955/cbup.v5.997, Prague, Central Bohemian University, 2017, 627-632

[5] Krajská komsia Fyzikálnej olympiády, “Správa o priebehu: Krajské kolo 58.ročníka FO v šk. roku 2016/2017 [Regional Committee of Physics Olympiad “Report of Regional 58th PhO]”, Nitra, Constantine the Philosopher University in Nitra, 2017, 32 pp.

[6] Lacsný, B. “Rast aplikačnej úrovni znalostí”, CoPhys International Physics Workshop 2008, Nitra, Constantine the Philosopher Univesity in Nitra, 2008,109-122.

[7] Benko, M., Lacsný, B. “Model rastu aplikačnej úrovne”, Poznatky modernej fyziky a ich aplikácia vo vyučovaní, Ružomberok, VERBUM, 2011, 129-133

[8] Benko, M., Lacsný, B., Podoba, R., Teleki A.: “Role of Certain Features Observed in Knowledge Increase Testing”, Scientia Iuvenis : Book of Scientific Papers from 14th international scientific conference of PhD. students, young scientists and pedagogues, Nitra Slovak Republic, 2013, 457-464

[9] Benko, M., Lacsný, B., Podoba, R., Teleki A.: “On the meaning of the features in learning curve measurements by MGKR”, Czlowiek Media Edukacja, Krakov, 57-62

[10] Benko, M., Teleki, A., Lacsný, B. “Určenie parametrov rastu znalostí opakovaným riešením fyzikálnych úloh”, Horizons of Mathematics, Physics and Computer Sciences, vol. 43, No. 4, Nitra, Jednota slovenských matematikov a fyzikov, 2014, 45-49

[11] Dudáková, S., Benko, M. Lacsný, B., Teleki, A. “Microscopic Model of Knowledge Increase and Its Verification”, DOI http://dx.doi.org/10.12955/cbup.v4.872. In: CBU International Conference on Innovations in Science and Education Conference, Prague, Central Bohemia University, 2016, 888-895

[12] Dudáková, S., Lacsný, B., Teleki, A.: “ENKI - A tool for analysing the learning efficiency”, DIDFYZ 2016 : From the Roots to Contemporary Education - Proceedings of the 20th

[13] Belicová, S., Lacsný, B., Teleki, A. “E-Homework with Feedback on the Topic of Momentum in the E-learning Environment Moodle and Its Analysis”, New Perspectives in Science Education, 7th edition, accepted abstract, Florence, Pixel, 2018