EFFECTIVENESS AND EFFICIENCY OF TEACHING STATISTICAL SUBJECTS AT UNIVERSITIES

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Abstract

The aim of the paper is to assess the effectiveness and efficiency of learning the statistical subject at universities. Primary research held in November 2016 on subject *Time-series* at university in Prague questioned 115 students about the most effective learning method that leads them to achieve good results from the test. Students mostly marked individual explanation on tutoring or by classmate and solving exercises according to the teachers' explanation at seminars. But only the later mentioned helped them to achieve good results. Students from grammar school achieved more points than others. The outputs (points from the test) were compared with the inputs (hours of learning) using DEA. Average efficiency was 48.59% under constant and 59.86% under variable returns to scale. We recommend using practical methods of learning the *Time-series*. Individual explanation by tutor or classmate might be convenient, but practical solving of statistical exercises brings better results.

Keywords

Data Envelopment Analysis, Effectiveness, Efficiency, Learning, Time-series

Introduction

Subjects related to the calculations such as *Mathematics*, *Statistics*, *Econometrics*, or *Time-series* are often problematic to learn by the students and hence not popular. Very often are the learning difficulties of the calculations rooted in the fact that they are taken by the most students without its reference to any reference in real world. Brahim et al. (2014: 3367) suggests that "to restore the meaning of calculation, the allocation of spatial place for students to a formal expression is needed." This requires certain didactic methods and teachers' skills. There are teaching methods suggested to teach effectively such subjects. For example Lupu (2014) states following eight principles that should be followed by the teachers in order to create conditions for the effective learning of pupils: (1) the principle of positive formative orientation of the maths lesson, (2) the principle of systematization of the maths lesson, (3) the principle of accessibility, (4) the principle of the optimal participation in the lesson, (5) the principle of interdependence between intuitive knowing and logical knowing, (6) the principle of interaction between theory and practice, (7) the principle of essential results (in assessing the class), and (8) the principle of permanent self-regulation of activities.

Ismail, Shahrill and Mundia (2015) examined the factors that contributed to effective *Mathematics* teaching in Brunei. They found out that the most important were the teachers themselves, whereas the school context or the school administration only seems to impact teaching effectiveness to a minimal extent. The success of learning the subject depends of course on also depends on the students' ability to learn. Lai and Hwang (2016: 126) found "that the higher self-regulation students showed significantly different learning achievements when learning with different approaches, while there was no significant difference between lower self-regulation students with the different learning approaches." They suggest integrating the self-regulated strategy into learning as it can improve students' self-efficacy and their strategies of planning and using study time, and hence they can learn effectively and better. (Lai and Hwang, 2016).

The aim of the paper is to examine the effectiveness and efficiency of learning the subject *Time-series.* The methods used to assess the effectiveness and efficiency are introduced and then the data obtained from primary research are described. Next section presents and discuss the results. Final section concludes and gives recommendations.

Materials and Methods

The effectiveness was examined in terms to what extend the aims of the learning were achieved. Whether the learning methods achieve the set goals. There were several types of learning methods taken into consideration. The students were asked what is the best way how they learn the curriculum of the subject. As the *Time-series* subject requires calculation and computation skills, it was expected that the most effective method of learning will be independent calculations of exercises. On the other hand, passive types such as mere reading of the textbook or listening to the topic at seminars was expected to be less effective in learning *Time-series*.

Examined methods included: (1) independent analysis of solved exercises (e.g. from textbooks, lectures, seminars), (2) independent calculations of exercises, (3) solving exercises according to the teachers' explanation at seminars, (4) individual explanation on tutoring or by classmate, (5) independent reading of the textbook, (6) listening to the explanation of the curriculum at lecture, (7) listening to the explanation of the curriculum at seminar. Students can evaluate each method by certain number of points: "none" – I do not learn this way, 1 – I learn the best this way, I learn almost everything, 2 – I learn well this way, 3 – I learn poorly this way, 4 – I learn the worst this way, I learn almost nothing. We calculated average mark and suggest appropriate type of learning. The most convenient method was put to the relation with points from the test.

It was also expected that type of previous students' education could have influence their results in the test from subject *Time-series*. According to Shapiro-Wilk test the distribution of the points from the test among students was not normal. A non-parametric two-sample Wilcoxon rank-sum test was used to test the differences between groups. Null hypothesis (H_0) stated that the results do not statistically significantly differs based on whether the student previously studied general grammar or other type of school. Similarly, it was also examined if the results depend on the gender (H_0: The results do not depend on gender of the student).

Then, it was surveyed how long took the different types of preparation on the test: a) participation at lectures, b) at seminars (1 lecture and seminar = 1.5 hours), c) learning at home, and d) tutoring. A linear regression model was estimated by ordinary least squares method to see how the number of points increase with time spend by various types of learning.

The efficiency was understood from the input oriented point of view. It was assessed how to minimize the inputs to achieve the same output. The approach searched the minimum effort of the students that must be expended to achieve desired results. There were $n = 4$ inputs and $m = 1$ output. As inputs (x_{jk}) were considered the number of hours spent by the preparation to the test – see above. Output (y_{ik}) was the number of points achieved from the test. Input oriented data envelopment analysis (DEA) was used to calculate technical efficiency (TE) under the assumption of constant returns to scale (RTS) and pure technical efficiency (PTE) under variables returns to scale. Two DEA model were elaborated: (1) CCR model introduced by Charnes, Cooper and Rhodes (1978) that assumes constant returns to scale and (2) BCC model, proposed by Banker, Charnes and Cooper (1984). The value of efficiency equal to 1 means that the student (decision making unit) is 100% efficient in preparation for the test. Lower values suggest that the student could have done better.

CCR model maximizes the efficiency level of a student. There were Q = 115 students. Efficiency is expressed as the ratio of weighted outputs and weighted inputs. The condition is that efficiencies of other units are equal or less than 1. After Charnes-Cooper transformation (Jablonský and Dlouhý, 2004), CCR model can be expressed by general formula as (1):

$$\begin{aligned} &\max\ z = \sum_{i=1}^{m} u_i y_{iq}\ , \\ &\text{r. c.}\ \sum_{i=1}^{m} u_i y_{ik} \le \sum_{j=1}^{n} v_j x_{jk}, \qquad k = 1, ..., Q, \\ &\sum_{j=1}^{n} v_j x_{jq} = 1, \\ &u_i \ge \varepsilon, i = 1,...,m \\ &v_j \ge \varepsilon, j = 1, ..., n \end{aligned} \tag{1}$$

where z is efficiency of a student, x_{jk} is the value of the j^{th} input, y_{ik} is i^{th} output, u_i are weights of inputs, v_j are weights of outputs, ε is infinitesimal constant (usually 10^{-8}), that ensures that weights of all inputs and outputs are positive. It maximizes the sum of weighted outputs of a student when the weighted sum of outputs of other students is less or equal to weighed sum of inputs and sum of weighted outputs is equal to one.

BCC model differs from CCR by adding variable μ, that represents the difference from constant returns to scale and has value of 0 in case of constant returns to scale, less than 0 when non-increasing returns to scale and higher than 0 in case of non-decreasing returns to scale (2).

$$\begin{aligned} &\max\ z = \sum_{i=1}^{m} u_i y_{iq} + \mu\ , \\ &\text{r. c.}\ \sum_{i=1}^{m} u_i y_{ik} + \mu \le \sum_{j=1}^{n} v_j x_{jk},\ k = 1, ..., Q \\ &\sum_{j=1}^{n} v_j x'_{jq} = 1, \\ &u_i \ge \varepsilon, i = 1,...,m \\ &v_j \ge \varepsilon, j = 1, ..., n \\ &\mu \in \Re \end{aligned} \tag{2}$$

where μ can have any real value ($\Re$). For details of DEA see e.g. Jablonský and Dlouhý (2014).
Survey by questioning method using anonymous questionnaire with closed answers was done at the university in Prague from 30th November to 2nd December 2016. A sample contained 115 university students from which 46 were females (40%). The students were from the 1st year of the master studies having subject *Time series*. Majority of university students graduated from grammar school, only 26% from others, mostly business academy (almost 15). Four persons had technical and one person economical lyceum. The distribution of the points was skewed to the right as majority of students got more than 20 points out of 25. On average, the students got 18 points from the test. Median was even higher (19 points). Male students had 18.1 points on average and females 17.9. Statistical description of the data is at Table 1.

Type of high school	No. of observation	Average points from test
Grammar school	85	18.4
Economic lyceum	1	18.0
Technical lyceum	4	19.0
Vocational high school	8	15.6
Business academy	17	14.3
Total	115	18.0

Table 1: Statistical description of the data (source: own research and calculation)

Results and Discussion

The effectiveness of learning depends on the convenience of the used method. Students could have evaluated different methods by points from 1 to 4, where 1 was the best way and 4 the worst, none point were given when the student is not using this type. On average, the highest mark (1.56) had solving exercises according to the teachers' explanation at seminars. Second highest (1.88) was given to both independent analysis of solved exercises and listening to the explanation of the curriculum at seminars. Then was valuated the individual explanation on tutoring or by classmate by 1.95 points. However, in this case, the average number of points from test was only 16.1. Hence, even preparation on tutoring is not sufficient to get desirable results. It may be due to the passive nature of the tutoring or explanation by classmate where the student does not have to practice the calculations individually. In absolute terms, the most convenient way how to learn was according to 64 students the solving exercises according to the teachers' explanation at seminars.
On the other hand, as expected, independent reading of the textbook (2.81) was assessed as the less convenient way of learning, followed by the lectures (2.77). Students do not consider the way of learning convenient if there is no possibility to try the calculations by themselves. It was astounding that 12 students were not learning the subject by independent solving of exercises. Considering that it is mathematical subject, the individual solving and practicing of solving should be crucial. When the students marked as the most convenient independent analysis of solved exercises and solving exercises according to the teachers' explanation at seminars, their average achieved points were the highest (18.5). The results are displayed at Figure 1.

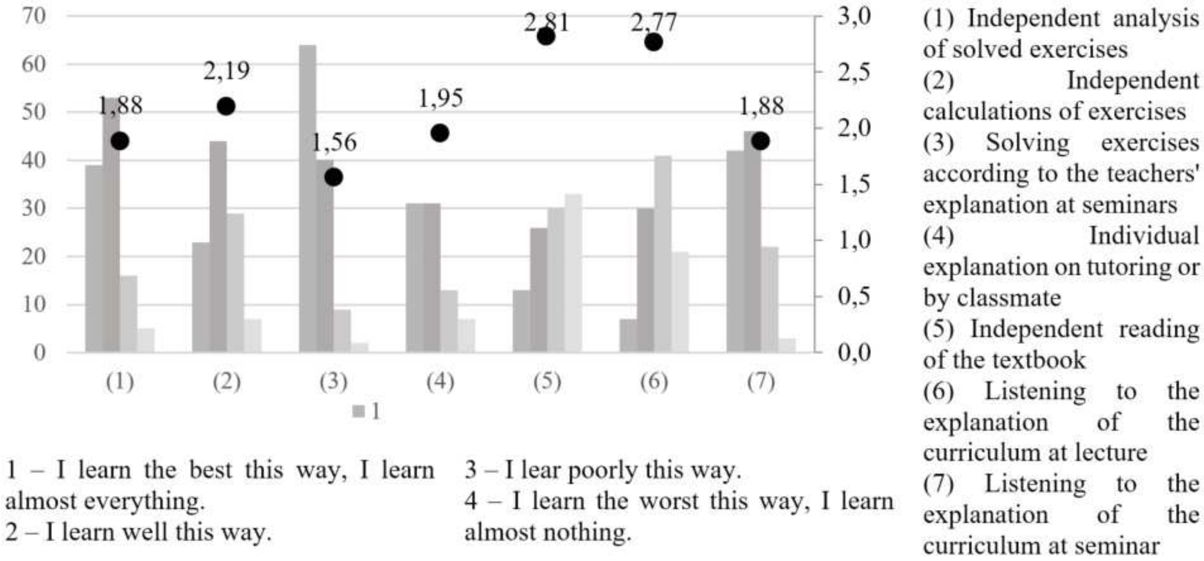

Figure 1: Effectiveness of ways of learning *Time-series* (source: own elaboration)

Despite certain preferences for individual explanation on tutoring or by classmate when learning new curriculum, we take caution to recommend only one type of studying. "Students may simultaneously hold multiple conceptions of learning rather than using a dominant one while learning". (Wang et al., 2017: 92) The transfer of the knowledge "is a complex phenomenon due to the involvement of several interacting categories of variables, namely, learner characteristics, learning and transfer tasks, and instructional and transfer contexts", (de Corte, 2007: 28). As it was proved by Crawford et al. (1998) approaches to learning mathematics are related to differences in students' conceptions of mathematics, their experiences of studying the subject and their performance on assessments. A comprehensive review of relationships between learning strategies, conceptions of learning, and learning orientations can be found in Vermut and Vermetten (2004).

It was tested whether the results of students statistically significantly differ based on gender or previously studied school. It was found (p-value of Wilcoxon rank-sum test = 0.7790) that gender does not influence students' results. However, it is important, what type of school the students studied (p-value = 0.0005). While the students from grammar school had 18.4 points, from other types was the average 16.5 points.

The efficiency of learning put into the relation the number of hours spent by different types of learning and achieved points. The most time took to the students learning at home (14.0 hours on average). Students also participated at the seminars (7.5 hours on average that means that they mostly visited 5 of them, i.e. the maximum). On the other hand, the students attended only 3 lectures on average. Average hours of tutoring were about 38 minutes. Linear regression model did not reveal any statistically significant influence on the length of the preparation on the number of points gained. While the number of hours spent by attending the lectures and seminars helped to increase the number of points, longer tutoring decreased it. It seems that preparation at home does not influence the results at test at all. However, we must keep in mind, that the research considered only the length of the preparation, not the actual content. It would be harder to assess the curriculum, intensity of concentration etc. of the student that undoubtedly influence his or her performance at the test.

The poor school performance and results in general may depend on many things. Robison et al. (2017) showed that across all models that they constructed, juvenile justice contact and school expulsion were the best predictors of negative school outcomes. Besides according to Masci, de Witte and Agasisti (2016), the students' performance in mathematics is partly correlated with the management practices adopted by the school principal/head teacher. "Schools and schooling can only explain a minor part of the variance in achievement scores, however, and the characteristics of the students themselves play the most significant role." (Masci, de Witte and Agasisti, 2016: 1) Similar results were achieved in Australia in a study by Geiger, Anderson and Hurrel (2016). "A finding of the study is that 'successful' practice is strongly tied to school context and the cultural practices that have been developed by school leaders and teachers to optimise student learning opportunities." (Geiger, Anderson and Hurrel, 2016: 1).

Results of VRS input oriented DEA efficiency shows that on average, students learning was efficient from 59.86% if we consider only constant returns to scale, then only 48.59%. The effort that students put into the learning process was not that fruitful as it could have been.

Variable	Obs.	Mean	Std. dev.	Min	No. of 100% efficient
CRS TE	115	0.4859	0.1828	0.0184	4
VRS PTE	115	0.5986	0.2051	0.1961	14

Table 2: Efficiency of learning subject *Time-series* (source: own research and calculation)

As benchmark units can serve those that are 100% efficient. For example, student no. 1 despite that she did not attend any lecture and only 1 seminar, spent 2 hours by preparation at home and 4 hours at tutoring, got 23 points from the test. Good result without big preparation might be caused by her background as she graduated from technical lyceum. Student no 3. from grammar school gained even 1 point more as he prepared at home for 6 hours and attended all seminars. Student no. 5 that also graduated from grammar school got only 17 points, but it was due to less time spent by preparation (only 2 lectures, 2 seminars and 1 hour at home). Student no. 82 attended only all seminars and prepared at home for 3 hours and got more points (19). All those students were 100% efficient under constant and variable returns to scale, hence they managed to be also scale efficient.

We must keep in mind that DEA method has certain limitations and hence the interpretation of the results of measuring learning efficiency must be careful. DEA is relative method that compares the inputs and outputs, so the situation, when the student did not prepare at all (it is not the case of our sample) and got some points from the test might be evaluated by DEA as efficient. But the student can fail as the number of points might not be sufficient (student can fail also from second test). Therefore, complete evaluation is available only after the end of the semester and DEA shall be accompanied by the analysis of total results of the students.

Research can be further enlarged in the way of searching the factors that affect the efficiency. Then the second stage regression analysis using efficiency scores can be done. Zhang and Wang (2014) showed that affection of mathematics learning is the most important factor that influences learning efficiency. "Efficiency is highly correlated with the advance of mathematics academic performance", (Zhang and Wang, 2014: 67). Mathematics learning can also differ based on whether it is practiced in or out of school. "Many of the differences can be narrowed by creating experiences that engage students in doing mathematics in school in ways similar to mathematics learning and practice outside of school", (Masingila, Davidenko and Prus-Wisniowska, 1996: 175) Similarly the efficiency of *Time-series* learning can be influenced by many factors that shall be examined in future research.

Conclusion

The aim of the paper was to assess the effectiveness and to analyse efficiency of learning the curriculum of the statistical subjects at universities. Particularly we examined the subject *Time-series* that is taught at university in Prague. Primary research was held in November 2016. We asked 115 students about their learning and preparation methods and about the results from the test. The most effective method of learning was understood in terms what type of learning leads students to achieve their set goals. The students of *Time-series* marked that the most convenient way of learning the curriculum solving exercises according to the teachers' explanation at seminars. This type of learning similarly to learning by individual calculations of exercises by lead the students to achieved 18.5 on average. Therefore, we can recommend the students to prefer practical methods of learning while preparation for the test.

The efficiency compares the outputs of the learning process (points from the test) with the inputs (hours of learning by various ways). On average, the students were efficient from 60% (when it is assumed that one unit of input brings still the same amount of output – i.e. constant returns to scale) and from 40% (under variable returns to scale). However, it cannot be clearly stated what method of preparation on the test is the best in terms of efficiency, as the hours spent by learning at lectures, seminars, tutoring or at home is only an approximation for the effort. Real curriculum and content of learning cannot be assessed easily. Besides, the length of the preparation for the test cannot capture all factors that are influencing the success at first test. It seems that high school from which the students graduated is also important in determination of the efficiency of *Time-series* learning. Therefore, the challenge for future research is to search for the factors that are influencing the efficiency and include them into second-stage regression analysis.

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