EVALUATING THE EFFICACY OF A TRAINING FOR IMPROVING PROBABILITY AND STATISTICS LEARNING IN INTRODUCTORY STATISTICS COURSES

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The aim of the present paper is to ascertain the efficacy of a training acting on both cognitive and non-cognitive factors in improving probabilistic and statistics learning in psychology students enrolled in introductory statistics courses. We previously tested the relationships between performance and students' general and mathematical background (cognitive factors), maths self-efficacy and attitudes toward statistics (non-cognitive factors). Results stressed the role of both factors. Thus we developed a training focused on competences and self-efficacy and we verify that it helped students in improving probability and statistics learning as well as their confidence.

Key words: Probability Learning; Statistics Learning; Training; Introductory statistics

INTRODUCTION

Being able to provide good evidence-based arguments, and to critically evaluate data-based claims are important skills that all citizens should have, as stated by the European Parliament and Council in defining the key competences within the Lifelong Learning Program (2006). Thus, from an educational point of view, it is fundamental to develop students' statistical reasoning, and to provide them with tools and knowledge to understand and use quantitative information. The ability to think statistically about uncertain outcomes, and to make decisions on the basis of probabilistic information is relevant in many fields (e.g., for businesspeople, physicians, politicians, lawyers), and an inability to make optimal choices can be extremely costly, not only at the individual level, but also for society in general.

Then, statistics has been introduced as part of a wide range of curriculum programs in many countries. However, the discipline is viewed as a difficult and unpleasant topic. At the university level, students often perceive statistics courses as a burden, encounter difficulties, experience stress and anxiety, and, eventually, many of them fail to pass the exams. It is also common for students to have low expectations regarding statistics classes, and to have negative attitudes towards statistics. Finally, as passing exams in statistics is a requirement for many degree courses, failing to achieve this might result in students' abandoning their chosen professions.

Starting from these assumptions, several researches have focused on the identification of models in which the role of non-cognitive factors, such as beliefs and feelings, has been taken into account in explaining learning statistics. These 3factors appeared to be related to maths aptitude, previous maths knowledge, educational background and reasoning ability. Thus, statistics achievement might be the result of the interplay between cognitive and non-cognitive factors (Budé et al., 2007; Chiesi & Primi, 2010; Dempster & McCorry, 2009; Tremblay, Gardner & Heipel, 2000).

Starting from this premise, the present work aimed to assess the impact of both cognitive and non-cognitive factors on probability and statistics learning in psychology students enrolled in introductory statistics courses (Study 1). In light of the results of Study 1 we developed a training and we verified its efficacy (Study 2).

STUDY 1

It was hypothesised that achievement was related directly to students' general background and maths competence, as well as to their maths self-efficacy, beliefs about their own ability in dealing with statistics and feelings toward the discipline. The causal paths among variables related to achievement were explored using structural equation modelling (SEM) techniques in which cognitive and non-cognitive factors were considered as the exogenous latent variables having an impact on learning, i.e., the endogenous latent variable in the model (Figure 1). Konold and Kazak (2008) suggested that some of the difficulties students have in learning basic data analysis stem from a lack of rudimentary idea in probability. For this reason, learning was operationalized including both probabilistic and statistical reasoning.

Methods

Participants

Participants were 238 psychology students attending the University of Florence in Italy enrolled in an undergraduate introductory statistics course. Most of the participants were women (86%). This proportion reflects the gender distribution of the population of psychology students in Italy. All students participated on a voluntary basis after they were given information about the general aim of the research (i.e., collecting information in order to improve students' statistics achievement).

Description of the Course

The course covered the usual introductory topics of descriptive and inferential statistics (including basic concept of probability theory and calculus), and their application in psychological research. It was scheduled to take place over 10 weeks, and takes 6 hours per week (for a total amount of 60 hours). During each class some theoretical issues were introduced followed by exercises. Students were requested to solve exercises by paper-and-pencil procedure, and computer packages were not used.

Measures

General Background Test (GBT). This is a scholastic assessment test consisting of 100 multiple-choice questions (one correct out of five choices) divided into five sections: Maths, Biology, English comprehension, critical reading and reasoning. The time for the test was 85 minutes. A single composite score, based on the sum of correct answers less the wrong answers (the score for a wrong answer was -.25) was calculated.

Prerequisiti di Matematica per la Psicometria (PMP, Galli, Chiesi & Primi, 2011). The PMP measures maths abilities needed by psychology students enrolling in introductory statistics courses. The scale is a 30-problem test. Each problem presents a multiple choice question (one correct out of four alternatives). A single composite score, based on the sum of correct answers, was calculated.

Survey of Attitudes Toward Statistics (SATS-28©, Schau, Stevens, Dauphine & Del Vecchio, 1995; Italian version: Chiesi & Primi, 2009). The scale provides a multidimensional measure of attitude. It contains 28 Likert-type items using a 7-point scale ranging from strongly disagree to strongly agree, assessing four components: *Affect* measures positive and negative feelings concerning statistics (6 items); *Cognitive Competence* measures students' attitude about their intellectual knowledge and skills when applied to statistics (6 items); *Value* measures attitudes about the usefulness, relevance, and worth of statistics in personal and professional life (9 items); *Difficulty* measures students' attitudes about the difficulty of statistics as a subject (7 items).

Solution of Maths Problems (Kranzler & Pajares, 1997). This is a subscale of *Mathematics Self-Efficacy Scale-Revised* (MSES-R, Kranzler & Pajares, 1997; Italian version: Galli, Chiesi, & Primi, 2010). The subscale is composed of 18 problems with different levels of difficulty and it has been developed to assess the students' confidence to solve these problems.

Probabilistic Reasoning Questionnaire (PRQ, Chiesi, Primi & Morsanyi, 2011). This questionnaire contained 10 multiple-choice probabilistic reasoning tasks (one correct out of three alternatives). Each task was scored either 1 (correct) or 0 (incorrect). The scores on the probabilistic reasoning tasks were summed to form a composite score.

Introductory Statistics Inventory (ISI, Chiorri, Piattino, Primi, Chiesi & Galli, 2009). This test consists of 30 multiple-choice items (one correct out of four choices) to evaluate learning at the end of an introductory statistics course. Half of the problems refers to descriptive statistics and the other half to inferential statistics. Each task was scored either 1 (correct) or 0 (incorrect) and a composite score was obtained.

Procedure

The GBT was administered before the beginning of the course. The SATS was presented during the first day. The PMP was completed during the second day, and the PRQ and the ISI at the end of the course.

RESULTS

As shown in the table (Table 1), significant correlations were found between Probabilistic and Statistic Learning with the other variables. These results support the hypothesised relationships. Concerning Attitude towards Statistic, only two scales Cognitive Competence and Affect were significantly correlated with Probabilistic and Statistic Learning. For this reason we did not introduce Difficulty and Value in the model.

	M	*sd*	1	2	3	4	5	6	7	8	9
1. General Background	*44.43*	*10.32*									
2. Maths Basics	*22.70*	*4.20*	.41**								
3. Maths Self-Efficacy	*83.40*	*11.21*	.28**	.38**							
4. Cognitive Competence	*27.50*	*6.00*	.08	.29**	.44**						
5. Affect	*24.11*	*6.35*	.02	.24**	.32**	.77**					
6. Difficulty	*23.80*	*4.48*	.04	.16**	.36**	.55**	.59**				
7. Value	*45.51*	*7.88*	.08	.13*	.22**	.42**	.35**	.23**			
8. Probability Learning	*6.20*	*1.40*	.31**	.22**	.24**	.25**	.15**	.02	.15*		
9. Descriptive Statistics Learning	*11.14*	*2.24*	.54**	.25**	.24**	.23**	.19**	.08	.05	.34**	
10. Inferential Statistics Learning	*9.63*	*2.75*	.19*	.26**	.19**	.23**	.14*	.13	.02	.14*	.48**

* $p < .05$, ** $p < .01$

Table 1. Means, standard deviations (in brackets) and correlations among the measured variables.

The final model included three latent variables and nine observed variables: Cognitive Factors and Non-Cognitive Factors were the exogenous latent variable that influenced directly the Statistic and Probabilistic Learning. Cognitive Factors were measured through the GBT (General Background) and the PMP (Maths Basics). The two scores of the SATS subscales (Cognitive Competence and Affect) and the score of the MSES-R (Maths Self-Efficacy) were used as indicators of Non Cognitive Factors. A covariance path was traced between errors of subscales measuring the attitude dimensions since the high correlation (r = .77) between the two subscales. Another covariance path was traced between Maths Basic and Maths Self-Efficacy (r

= .38). The endogenous latent variable (Probability and Statistics Learning) was measured through two scores of the PRQ scale - obtained by dividing the test randomly in two parts with 5 items for each (Probability 1 and Probability 2) - and two scores of the ISI scale - obtained considering separately the descriptive and the inferential items (Descriptive and Inferential). Covariance paths were traced between the two indicators derived from the PRQ and the two indicators derived from the ISI.

SEM analyses were conducted with AMOS 5.0 (Arbuckle, 2003) using maximum likelihood estimation on the variance-covariance matrix. Univariate distributions of all variables included in the model and their multivariate distribution were examined for assessment of normality. Skewness and kurtosis indices (ranging respectively from -.78 to .26 and .57 to .47) attested that the departures cannot be expected to lead to appreciable distortions (Marculides & Hershberger, 1997). The index of Multivariate Kurtosis (Mardia, 1970) (β = 1.86, *c.r.*= 1.02, p > .05) indicated that there was not a significant departure from multivariate normality. That is, data met the assumption of multivariate normal distribution required by SEM. The model showed a good fit to data (χ^2/df = 2.45; *CFI* = .94; *TLI* = .90; *RMSEA* = .07) and all the estimated coefficients were statistically significant.

As expected Cognitive and Non Cognitive factors had a significant direct effect on Probability and Statistics Learning. However, the relationship with the Cognitive factors was stronger.

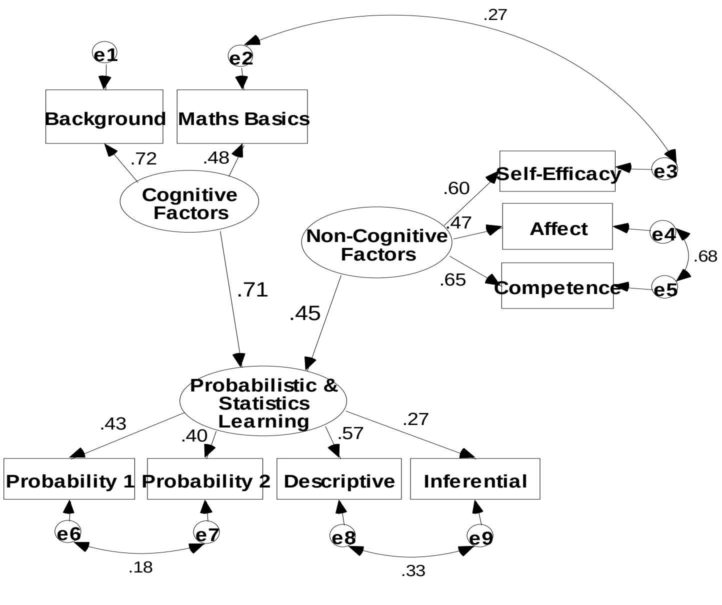

Figura 1. Final model with standardized parameters (paths are all significant at .05 level).

DISCUSSION

In line with previous research, general background and mathematical knowledge acquired during the high school, had a direct and strong effect on learning probability and statistics. Additionally, maths and statistics self-efficacy as well as feelings toward the discipline affected learning, that is, perceived competences and affect concurred in determining performance.

Given that cognitive and non-cognitive factors concur to determine learning, there is potential for developing interventions which will modify both competences and perceived competences. Such interventions should focus on helping students to believe that they have the capacity to cope with the demands of introductory statistics courses. This might require some remedial teaching of basic mathematics in order to improve both students' competence and confidence in approaching the subject.

STUDY 2

Starting from this premise, we developed training for consolidating the basic mathematical skills required during the course. Whereas the assessment of statistics achievement does not depend solely on these basic mathematical abilities, they constitute a necessary tool to keep in touch with statistics. Indeed math skills, such as understanding ratios, maybe important to understand what some statistical measures, such as the standard deviation, mean and how to interpret them. Moreover, helping students in mastering these competences might enhance their confidence in learning statistics. We proposed working group activities in which students should experience that they can master the topics, and feedbacks were provided in order to allow them to monitor their progress.

Methods

Participants

Participants were psychology students enrolled in an undergraduate introductory statistics course. One hundred twenty-four students were randomly assigned to the training group and 55 to the control group.

Training activities

The training consisted in two didactic units lasting two hours each. Students were divided into groups (about ten students for each group). In each unit each student received a booklet with a series of exercises about some maths basics deemed necessary to successfully complete the introductory statistics courses. In detail, exercises included: a) addition, subtraction, multiplication, division with fractions, and exponentiation, required in descriptive and inferential procedures; b) fractions and decimal numbers from 0 to 1 necessary to deal with probability; c) first order equations necessary in the standardization procedure and in the regression analysis; d) relations between numbers included in the range from -1 to 1, and the meaning of absolute value necessary for drawing conclusions in hypothesis testing.

Each student had to perform individually reporting how he/she solved it. Then the groups discussed about the correct solutions and the more common errors producing for each exercise a report of the group's activities. At the end of each unit, the teacher presented the solutions to the class and students might have other exercises to do at home.

As for the training group, the activities of the control group were organized in two didactic units. Students were divided into groups (about ten students for each group) and requested to solve exercises by paper-and-pencil procedure referring to frequency distributions, graphs, means and standard deviations. They solved them individually and then a group activity followed to discuss about exercises' correct resolution and errors, and to produce a report. At the end of each unit, the teacher presented the solutions to the class and students might have other exercises to do at home.

Measures and Procedure

At the end of the training all students were administered the *Probabilistic Reasoning Questionnaire* (PRQ) to measure the probabilistic learning and the descriptive problems of the *Introductory Statistics Inventory* (ISI - Descriptive) to measure the statistics learning. We added for each problem of the ISI a scale to measure how self confident they were to solve it.

Moreover, we took into account an achievement measure. Since some students were unsuccessful in the final examination and therefore they needed several attempts to attain their goal, the number of failed attempts was registered.

RESULTS

Significant differences were found between the training group and the control group. In particular, the training group improved in probabilistic learning, statistic learning, and confidence (Table 2).

	Training		Control		t	d^a
	M	SD	M	SD		
Probability Learning	15.38	2.50	13.80	3.03	3.14^{**}	.57
Statistics Learning	7.45	1.27	6.90	1.52	2.51^{*}	.39
Statistics Learning Confidence	37.83	5.52	35.98	5.65	2.02^{*}	.33

*p<.05,**p<.01. [a] *d* is a measure of effect size. Cut-offs are the following: small ≥ .20, medium ≥ .50, large ≥ .80.

Table 2. Mean scores compared with t test (and related effect sizes) for the Training and the Control groups.

Furthermore to measure the association between training and achievement we created two groups: one with the students who never failed (no failure group) and the other one with students who fails one or more times (failure group). As we can see from the graph (Figure 2), we found a significant association between the training and the failure ($\chi_2(1,N = 174) = 3.93$, $p < .05$) with a small the effect size ($\phi = .15$). In particular there is a higher possibility to pass in the training group than in the no training group (64% *vs*. 48%).

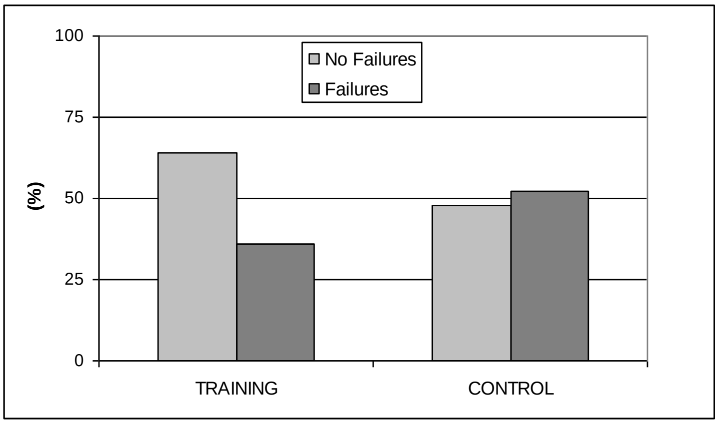

Figure 2. Percentage of failures in the Training and the Control groups.

DISCUSSION

The present study attested that students who participated to the training had positive changes not only in statistics and probabilistic learning but also in their confidence. Further the training seems to reduce the probability of failures. In sum, these results suggest that this training offers an example of an educational approach to introduce in introductory statistic course.

CONCLUSION

Teaching statistics with psychology students produces difficulties. Students are not primarily interested in statistics and dislike anything “mathematical”, often they do not have a strong background in Maths and they are not confident about their capabilities. The first aim of the present work was to investigate the impact of both cognitive and non-cognitive factors on psychology students’ probability and statistics learning. As expected, and in line with previous research (Leight Lunsford

& Poplin, 2011; Tremblay et al., 2000) mathematical knowledge acquired during high school had a direct and strong effect on achievement. Additionally, mathematics self-efficacy and attitudes toward the discipline (i.e., perceived competences and affect) concurred in determining performance in statistics (Dempster & McCorry, 2009).

The second aim was to develop and testing the efficacy of a training to strengthen basic mathematical skills and improve students' confidence in learning statistics. Individual and working group activities were proposed in which the students could perceive that they handled the basic tools to deal with an introductory statistics course. In this way they both consolidate their abilities and acquired more confidence. Students in the control group who solved statistics exercises without reinforcing before their mathematical skills showed worse performance and less confidence when compared to the training group. Indeed, math skills help in understanding and interpret statistical measures.

In conclusion, our findings suggest that maths competences are a necessary tool to keep in touch with statistics and to help students to believe that they have the capacity to cope with the demands of an introductory statistics course.

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