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It is a pattern common to many countries that engineering students have trouble passing mathematics. The manifold reasons so far explored mirror various perspectives on the transition from secondary to tertiary education. Focusing on learning strategies presents a promising supplement to this range, as they have the potential to account for its cognitive complexity and affective considerations. By means of the LIST questionnaire, we explored learning strategies for two samples of 113 Spanish and 159 German engineering students. The findings show that both samples differ regarding their scoring on the scales Organizing, Elaboration, Repeating, and Metacognition. Finally, five clusters were used to group students according to their similarities, supporting the decisive role of metacognitive skills.

Keywords: Engineering, learning strategies, secondary-tertiary transition.

INTRODUCTION

For many engineering students, learning mathematics in tertiary education is a critical issue. They encounter epistemological/cognitive, sociological/cultural and didactical obstacles (cf. Guzman, Hodgson, Robert, & Villani, 1998) as mathematics at university differs significantly from school mathematics. Some authors even label the transition "abstraction shock" since university mathematics adds a formal world to the mathematics encountered at school (Artigue, Batanero, & Kent, 2007; Tall, 2004). Besides these studies that focus on cognitive perspectives, other researchers additionally identified epistemological, conceptual, social-cultural, motivational as well as metacognitive and affective variables having an influence on students' performance. Some authors explicitly elaborate on specific learning strategies students may not have developed throughout school time (Rach & Heinze, 2011). These learning strategies address a combination of both skills and attitudes such as self-organisation, perseverance and frustration tolerance (cf. Pintrich, Smith, Garcia, & McKeachie, 1991; Weinstein & Palmer, 2002; Wild & Schiefele, 1994). In particular, investigating the role of learning strategies allows for revealing the cognitive dispositions as well as affective barriers and pathways, and studying the interrelations between them (Wild, 2005).

Both Spain and Germany face alarmingly high numbers of students giving up studying due to mathematical problems. In engineering courses in Spain, students were usually enrolled for 52.4 credits, but only succeeded passing 31.8 credits, mathematics being one of the subjects with the highest fail rate (MEC, 2013; Rodríguez Muñiz, 2011). The situation is comparable in Germany as 48% of engineering students fail in their first year university studies (Heublein, Richter, Schmelzer, & Sommer, 2012). In this paper, we explore for the two countries which cognitive dispositions and beliefs of students seem advantageous to successfully continue their studies.

THEORETICAL FRAMEWORK

Studies exploring the transition from school to tertiary education mostly concentrate on cognitive aspects when it comes to question challenges in mathematics. These studies elaborate on cognitive difficulties and conceptual obstacles that students experience in how mathematics is communicated to them (Artigue, Batanero, & Kent, 2007), particularly referring to the formal level of university mathematics and the prevalent role of proofs within (Selden & Selden, 2005).

Cognitive processes involve affective stances that moderate the tension between modes of intuitive and analytical thinking (e.g., Fischbein, 1987; Stavy & Tirosh, 2000). In particular, the theory of dual processes in cognitive psychology has been adapted to mathematics education, and the role of affective variables has been pointed out in this context (e.g., Gómez-Chacón, García-Madruga, Vila, Elosúa, & Rodríguez, 2014). Some studies additionally investigate the connection between affective variables and student performances. Findings reveal that students' cognitive reflection, as a metacognitive variable, their beliefs about mathematics, and their self-efficacy, are all correlated positively and significantly with mathematical achievement (Gómez-Chacón, García-Madruga, Rodríguez, Vila, & Elosúa, 2011; Gómez-Chacón et al., 2014). There is also evidence that metacognition impacts positively on learning strategies which in turn influences achievement (Griese, Glasmachers, Härterich, Kallweit, & Rösken, 2011).

An instrument focusing on cognitive, metacognitive and resource-related strategies is presented by the LIST questionnaire comprising 13 dimensions of learning strategies grouped accordingly. The LIST questionnaire (Wild & Schiefele, 1994) for measuring learning strategies in academic studies was first compiled in the 1990s and has since been modified and tested several times. It encompasses general items that can be applied to all kinds of subjects (for examples, see Table 1 below) and uses Likert scales. One root of the LIST questionnaire is the Motivated Strategies for Learning Questionnaire (MSLQ) which measures college undergraduates' motivation and self-regulated learning relating to a special course (Pintrich, Smith, Garcia, & McKeachie, 1993). Apart from *Motivation*, the scales from LIST are derived directly from MSLQ, although the number of items varies. The main difference between the two questionnaires is that MSLQ puts more emphasis on including different aspects of motivation as *Goal Orientation*, or *Control of Learning Beliefs*. Another essential study influencing the LIST questionnaire is the Learning and Study Strategies Inventory (LASSI) by Weinstein and Palmer (2002) which also separates cognitive aspects. LASSI scales partly cover the same contents as LIST though holding different names. As there are no analogous German / Spanish questionnaires on learning strategies, our study opted for the LIST questionnaire, thus hoping for the further asset of a parallel instrument for both countries.

RESEARCH QUESTIONS

In both countries engineering students struggle with mathematics, and in a first attempt to capture differences or commonalities, we used parts of the LIST questionnaire to explore students' learning strategies with respect to *Organizing, Elaborating, Repeating* and *Metacognition.* We therefore translated the German LIST questionnaire into English and then into Spanish (and back into German for additional dependability) and checked for scale reliability. Finally, we investigated if students can be grouped based on their ratings of the different dimensions of the questionnaire. In our comparative study, we particularly pursued the following research questions:

Research question 1a: Does the Spanish translation of the LIST questionnaire yield sufficient scale reliability?

Research question 1b: How do Spanish and German engineering students' differ with respect to their learning strategies?

Research question 2: How are the different learning strategies of students in both countries correlated?

Research questions 3: How can students from both countries be classified with respect to their learning strategies?

METHODOLOGY

Participants and instrument

The two samples from Spain and Germany are comparable in terms of age, gender percentage, and academic year in engineering studies. Moreover, their academic courses are similarly organised.

113 (71.7% male) Spanish undergraduate students attending the first academic year of the *Industrial Engineering Degree* participated in this study. Students enrolling in this course must have obtained high scores in the test of university entrance, even higher than for other engineering degrees. The mathematics module consists of 200 minutes of traditional lectures per week, with optional tutorials and digitalized learning material. The examination is a written test with a focus on calculation and normally without proofs. If students fail, they must retake the course.

Dimension	# Items	Example Item
Organizing	8	I go over my notes and structure the most important points.
Elaborating	8	In my mind I try to connect newly learnt facts to what I already know.
Repeating	7	I learn the subject matter by heart using scripts or other notes.
Metacognition (Planning)	11	Before starting on an area of expertise, I reflect upon how to work most efficiently.

Table 1: LIST dimensions and example items

159 German students (72.3% male) were selected from a larger sample from an ongoing research project to match the Spanish data. The German students had enrolled in different kinds of engineering courses at a university (meaning a slightly more challenging course, compared to a technical college) all starting with near identical mathematics lectures in traditional format, lasting 180 minutes per week, with optional tutorials and digitalized learning materials. As in Spain, there is a written test with focus on calculations. If students fail, they must retake the course, multiple fails result in expulsion. In both groups of students, attendance of lectures is optional and often low.

Originally, the LIST questionnaire comprises 13 dimensions of learning strategies, grouped into cognitive, metacognitive, and resource-related strategies. They each contain between three and eight items. For the study at hand we concentrate on cognitive and metacognitive strategies; an overview on example items is provided in Table 1.

The *Metacognition* scale contains the three subscales *Planning*, *Monitoring* and *Regulating*.

Data analysis

In both cases (Spain and Germany) the data was analyzed by computing the means, standard deviation and internal consistency (Cronbach's α) for each of these scales of the survey (based on Likert scales, from 1 to 5 respectively from 1 to 4); the correlation between scales; the factor pattern matrix; and clusters. Factor analysis was conducted using the extraction method of *Principal Component Analysis* and the rotation method of *Varimax* with Kaiser normalization. For rescaling the data, we calculated $2.5[1/n(x_1+...+x_n)-1]$ for the 5-point Likert scales respectively $100/3[1/n(x_1+...+x_n)-1]$ for 4 points and were thus able to correct the effect of the different numbers of items in different scales. This finally yielded scores from 0 to 100 (scale scores under 25 describing rare use, between 25 and under 50 infrequent use, between 50 and under 75 regular use, 75 or more continual use of the learning strategies).

Regarding clustering the data, the most common partitioning method is the k-means cluster analysis. Conceptually, the k-means algorithm follows the following process: it selects k centroids (k rows chosen at random), assigns each data point to its closest centroid (determined by the Euclidean distance), recalculates the centroids as the average of all data points in a cluster (i.e. the centroids are p-length mean vectors, where p is the number of variables) and assigns data points to their closest centroids. Steps 3 and 4 are repeated until the observations are not reassigned or the maximum number of iterations is reached. The distances are reported in Table 2.

The results obtained show the closest clusters are 1 and 5 or 1 and 3. For the hypothesis contrast, we obtain that the clusters represent data in variables of *Organizing*, *Elaborating*, *Repeating*, *Planning*, *Monitoring* and *Regulating* because of having $p<0.0001$ for values of the p-values. We note that for mathematic academic performance the centroid of this variable is 0 in some clusters and we have significance $p<0.02$ for mathematic academic performance.

Clusters	2	3	4	5
1	56.14	44.00	55.01	39.45
2		61.91	95.47	46.06
3			52.09	44.50
4				54.85

Table 2: Distances between the final centroids

RESULTS

Research question 1a. We calculated scale reliability for the factors *Organizing*, *Elaboration*, *Repeating*, and *Metacognition*. All Cronbach's alpha values are higher than 0.7, except for *Metacognition* in the Spanish study, see Table 3. In sum, the results show sufficient reliability between the different items. The comparative analysis between both countries indicates that there are no significant differences, except for *Elaborating* strategies. For this dimension, Cronbach's α is slightly higher in the Spanish study.

Research question 1b. The results of the factor analysis let to the four main dimensions *Organizing*, *Elaboration*, *Repeating*, and *Metacognition* and the three subscales *Planning*, *Monitoring* and *Elaborating* for the *Metacognition* scale. The variance explained by this factor structure is 54.7 % for the Spanish data and 43.92 % for the German data. In Table 4 we provide an overview on how the students rated in the different dimensions. Students' learning strategies differ significantly across the two countries. In all factors of the LIST questionnaire, except for *Monitoring*, we noted distinctly higher values for the mean in the Spanish than in the German results. For this metacognitive variable there are no significant differences between both means. In terms of standard deviations, Spanish students on the whole produce lower values.

Regarding the maximum and minimum scores, they are the exactly the same for *Organizing* and *Regulating*. For *Elaborating*, *Planning*, *Monitoring*, and *Metacognition* as a whole, the maximum value is higher in Germany, for *Repeating* it is lower in Germany. For the minimum values, we obtain significant differences between all variables but *Organizing*. The results show that the Spanish minimum values for these variables are always higher than the German ones.

Research question 2. In addition to comparing the means for the Spanish and the German data, we explored the correlations among the factors. An overview is provided in Table 5, where the additional variable *Mathematics Academic Performance* is coded as 1 for pass and 0 for failing the exam. It is worth to point out the highly significant strong correlation of the variable *Organizing* (defined as the ability to structure and restructure matter) with the three variables of metacognitive skills: *Planning* (r_S=.45 for Spain, r_G=.48 for Germany), *Monitoring* (r_S=.51 respectively r_G=.48) and *Regulating* (r_S=.46; r_G=.34). In the German data, there are significant and strong positive correlations between *Organizing* and *Repeating* (r_G=.60), *Elaborating* and *Monitoring* (r_G=.52) and *Repeating* and *Monitoring* (r_G=.57). For the mathematic academic performance, results show a negative (though not significant) correlation with *Repeating* for the German data (r_G=-.47) which cannot be found in the Spanish sample.

Research question 3. We realized a k-means cluster analysis with the 272 participants from both countries (113 Spanish (81 male and 32 female) and 159 German

Scale/Country	Spain	Germany
Organizing	.84	.82
Elaboration	.83	.74
Repeating	.73	.73
Metacognition	.65	.73

Table 3: Scale reliabilities for the Spanish and German data

	Mean		Std. Deviation		Maximum		Minimum	
	S	G	S	G	S	G	S	G
Organizing	61.92	47.87	20.67	22.16	100	100	0	0
Elaborating	59.21	48.76	16.58	17.47	90.63	95.83	6.25	0
Repeating	50.60	40.34	15.44	18.73	92.86	85.71	17.86	0
Meta – Planning	57.80	47.78	16.90	21.78	93.75	100	6.25	0
Meta – Monitoring	47.01	46.27	18.53	21.16	87.5	100	6.25	0
Meta – Regulating	72.35	65.15	15.48	20.58	100	100	25	0

Table 4: Descriptive statistics for Spanish and German students

(115 male and 44 female)) according to the variables *Organizing*, *Elaborating*, *Repeating*, *Planning*, *Monitoring* and *Regulating*, using the k-means method. In this case, we present the results using five clusters (Table 6).

The interesting part is how to describe the clusters in reference to the learning strategies employed by the respective students. Table 6 shows the number of participants that belong to each cluster in the last row. *Cluster 1* has high values (>55) in *Planning* and *Regulating* and a comparatively low value in *Monitoring* (<40). *Organizing*, *Elaborating*, and *Repeating* score medium. In this cluster there are 42 students (15.44%), of them 15 (35.72%, 13 male and 2 female) are Spanish and 28 (64.28%, 22 male and 6 female) are German. *Cluster 2* has high values (>55) in *Organizing*, *Elaborating* and *Repeating* strategies and *Metacognition*. In this cluster there are 95 students (34.93%), of them 61 (64.21%, 37 male and 24 female) are Spanish and 34 (35.79%, 20 male and 14 female) are German. *Cluster 3* has relatively high values in *Planning* and *Organizing* and medium values in *Monitoring* and *Regulating* but low values in *Elaborating* and *Repeating*. In this cluster there are 28 students (10.29%), of them 6 (21.43%, 3 male and 3 female) are Spanish, and 22 (78.57%, 15 male and 7 female) are German. *Cluster 4* has low values in all variables except medium values in *Regulating*. In this cluster there are 39 students (14.34%). Very few (2) are Spanish (5.13%, 1 male and 1 female). The rest (37) are German (94.87%, 23 male and 14 female). *Cluster 5* has high values (>55) in *Regulating* and *Elaborating* and medium in *Organizing*, *Repeating*, *Planning* and in *Monitoring*. In this cluster there are 68 students (25%), of them 29 (42.65%, 26 male and 3 female) are Spanish and 39 (57.35%, 27 male and 12 female) are German.

In summary, the data shows that 54.93% of students are concentrated in cluster 2 and cluster 5, whose students show medium and high levels in their learning strategies. However, there are differences between countries. 79.65% of the Spanish students are in these clusters, contrasting with only 45.91% of the Germans.

	E		R		MP		MM		MR		MC		MA
	S	G	S	G	S	G	S	G	S	G	S	G	S
O	.20*	.29**	.32**	.60**	.45**	.48**	.51**	.48**	.46**	.34**	.66**	.57**	.04
E	1	1	.16*	.32**	.11	.29**	.41**	.52**	.44**	.26**	.43**	.47**	.19*
R			1	1	.28**	.44**	.33**	.57**	.12	.24**	.36**	.58**	.06
MP					1	1	.32**	.33**	.06	.31**	.69**	.78	.16
MM							1	1	.40**	.27**	.84**	.75**	.07
MR									1	1	.59**	.64**	.10
MC											1	1	.08

(O = *Organizing*, E = *Elaboration*, R = *Repeating*, MP = *Metacognition-Planning*, MM = *Metacognition-Monitoring*, MR = *Metacognition-Regulating*, MC = *Metacognition*, MA = *Mathematics Academic Performance*)

Table 5: Pearson correlation (1-tailed, *p<0.05, **p<0.001) for the factors

Factors/Cluster	1	2	3	4	5
Organizing	39.14	72.35	61.94	19.31	42.85
Elaborating	40.35	63.97	31.66	23.37	57.17
Repeating	42.52	55.69	23.51	21.80	39.22
Metacognition – Planning	66.12	64.47	50.67	26.71	38.51
Metacognition – Monitoring	25.05	59.63	40.77	25.27	47.09
Metacognition – Regulating	69.25	80.18	47.02	50.21	70.06
Students (total = 272)	**42**	**95**	**28**	**39**	**68**

Table 6: Final centroids of the cluster analysis and number of students

Regarding German students, it is remarkable that there is a group of 23.27% with low levels of learning strategies (cluster 4).

CONCLUSIONS AND DISCUSSION

In our exploration of two samples, we were able to detect commonalities between first-year engineering students of both countries: As much as three quarters of engineering students are male, only one quarter are female. That may seem unbalanced, but it describes a steady growth towards equality over the last decades. Our comparisons cannot be generalized to universal statements about two societies, but provide interesting insights into students' learning behaviour against the background of different economic conditions (where the unemployment rate of 25% in Spain raises higher demands than Germany's 6%).

We found that the questionnaire employed works well in both countries, despite the initial double translation, backed up by the fact that the retranslated items correspond well to the original ones. The differences in learning strategies between the two countries can be condensed in the fact that the German engineering students showed more variation and often scored lower, meaning that the Spanish students tended to state desired behaviour, i.e. diligent learning activities. Both groups score equally low on *Monitoring* skills, which can be interpreted as a teaching perspective.

For both countries, the interrelations between the variables (apart from forming a complex pattern) stress the fact that metacognitive skills are at the core of learning behaviour, and can be viewed as an effective lever by which to influence learning strategies and thus learning success. However, there are no clear indications as for which learning strategies support examination success.

As our sample consisted of 41.5% Spanish and 58.5% German students, we would expect this distribution to reflect on the different clusters as well. That is more or less the case for all clusters but one: Cluster 4 contains almost exclusively German students and can be described as incorporating students who generally score very low, i.e. they do not report to work very ex- or intensively for their studies. This might be traced back to the fact that in Spain, you cannot enter a university course in *Industrial Engineering* without proving your commitment, motivation and capability in an exacting university entrance test. In Germany, there is restriction to university education, too, but it is less strict (meaning they can be sidestepped by time or space). These conditions may have influenced the pattern on cluster 3 as well, where Germans are overrepresented. This cluster contains students with high scores on learning strategies that reflect good intentions (*Planning* and *Organizing*), but low scores on actually realizing these in tedious day-to-day work (*Elaborating* and *Repeating*). Identifying clusters of students with homogeneous learning behaviour implies offering customized courses fostering specific deficiencies.

As a final outcome, our interest in describing, developing and evaluating metacognitive strategies with respect to short- and long-term achievement in mathematics has been kindled. We expect to learn more from future investigations, particularly from a comparative exploration of Rasch analyses of the two surveys. Additionally, we would like to conduct qualitative research which can help to enlighten the quantitative data we already have.

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