The role of the cognitive style in improving the learning to program

Margherita Pasini
Dept. of Human Sciences
University of Verona (Italy)
margherita.pasini@univr.it

Ugo Solitro,
Dept. of Computer Science
University of Verona (Italy)
ugo.solitro@univr.it

Margherita Brondino
Dept. of Human Sciences
University of Verona (Italy)
margherita.brondino@univr.it

Daniela Raccanello
Dept. of Human Sciences
University of Verona (Italy)
daniela.raccanello@univr.it

Abstract

Nowadays informatics is a part of most university curricula. In particular, in scientific and technological studies, a course in computer programming is often proposed in the first years. Nevertheless learning a programming language and solving problems in an algorithmic way is a hard task for many students. To reduce students difficulties and improve their performance, we think that is necessary to achieve a better comprehension of the cognitive processes involved. In this study, we analyse the relationship between cognitive styles, inside the theoretical framework of the empathizing–systemizing (E–S) theory, and performance in a sample of 46 students attending a course of programming in a *Applied Mathematics* bachelor. In line with the literature, women showed a higher level of empathy than men. However, no differences in performance were found between male and female students, even if for female students a higher level of systematizing quotients was related with a higher performance.

1. Introduction

The role and importance of Informatics as an independent subject in primary and secondary school education have been emphasized in several works (Wing, 2006), (Gander et al., 2013), (Katai, 2015).

The necessity of improving computational skills has been recognized by several educational institution in the world. As a consequence the primary and secondary school curricula are being changed with the purpose of introducing elements of computational thinking in many learning activities. Since among basic abilities considered in computational thinking we have algorithms and coding, we can imagine that the practical implementation of these recommendations shall enable students to cope comfortably with early informatics tasks at the university level.

Even so, it seems that at present time many students have difficulties in thinking about problems in an algorithmic way. Exploring the mechanisms underlying the programming activity, taking into account a psychological perspective, could be a good way to understand this process, and consequently plan adequate teaching activities which consider also individual differences. Furthermore, the importance of motivational and affective aspects has been highlighted also in the context of learning how to program (Pasini, Solitro, Brondino, & Raccanello, 2016), suggesting that research on cognitive processes involved in this challenging task must be deepened analyze.

This study is a first step in an action-research which aims to understand some psychological antecedents – cognitive and affective – of the performance of learning how to program. In this phase, this performance is analyzed considering the cognitive style, inside the theoretical framework of the *Empathizing-Systemizing* (**E-S**) *Theory* (Baron-Cohen, 2002).

2. Empathizing-Systemizing Theory and Programming Aptitude

The *E-S Theory* suggests that people can be classified on the basis of two different cognitive styles: *empathizing*, which is connected with the comprehension of emotional states of other individuals, and *systemizing*, which allow individuals to predict behaviour of systems on the basis of the knowledge of the underlying rules.

Two psychometric instruments had been constructed to measure these two psychological and cognitive styles: the *Empathy Quotient* (**EQ**) and the *Systemizing Quotient* (**SQ**). The *E-S Theory* assumes that a high level of **SQ** should be connected with a good performance in the domains in which this skill is important, such as scientific disciplines, whereas a high level of **EQ** should be more necessary in other domains in which the comprehension of others is important, for instance humanities and social sciences (Wakabayashi et al., 2006).

Also the link between these two cognitive styles and sex has been broadly explored in the literature, showing that women have generally a higher level of **EQ** than men. On the other side, men generally show higher scores in **SQ**.

The link between *E-S Theory* and programming aptitude has been stated by Wray (Wray, 2007), and recently resumed by Coles and Phalp (Coles & Phalp, 2016). These authors found controversial results, making unclear whether it is true that – as "folk" psychology suggests – a high level of systemizing quotient is related to good performance in programming. While Wray found a positive relation between **SQ** and a test for programming ability, and a negative relation between this same test and **EQ**, Coles and Phalp found no correlations between brain type *(S-type* vs *E-Type)* and programming performance, even if the brain type was related with the choice of the degree subject.

In this work, we consider a course of *Computer Programming with Laboratory*, corresponding to 12 ECTS *(European Credit Transfer and Accumulation System)*, which is compulsory in the first year for the bachelor curriculum in *Applied Mathematics* at the *University of Verona*. In the past years, it has been observed that the exam in consideration constitutes a significant difficulty for the students and so a remarkable part of them decides to defer the exam at a later time, and others obtain a low grade.

Given to these difficulties, we decided that this sample could be a good starting point to analyse the relation between cognitive styles, specifically **SQ** and **EQ**, and performance in early programming learning. We consider the first two months of the activities where students learn the basics of imperative programming with `Python`. The aim of this research is to explore the relationship between brain type and performance in programming, also distinguishing between female and male students.

3. The Method

3.1. Participants

The research involved 46 university students (62% males, mean age: 19.75, SD 1.76) enrolled at the first degree in *Applied Mathematics*, attending the course is *Computer Programming with Laboratory*.

According to the information provided by the students, most of them come from a non technical high school *"Liceo"* (80%); also the majority of them (70%) have attended a curriculum with scientific or technical emphasis. Even so very few of them have experience in Programming. As matter of fact *Informatics* was a school subject for a third of them only and an independent subject for a quarter; and, with few exceptions, it is a marginal theme. About coding and programming languages, barely a quarter of students had some experience about. But only a few of them (less than 4%) declare an appreciable knowledge of a programming language.

3.1.1. Brain Type

To evaluate the brain type, we used the short version of the *Empathy Quotient* (**EQ-Short**) and the *Systemizing Quotient* (**SQ-Short**) (Wakabayashi et al., 2006).

This version includes a total number of 60 items, 20 for the **EQ** and 20 for the **SQ** and 20 fillers. We used the Italian translation of items from the *Autism Research Center*(Autism Research Centre, 2016),

Table 1 – Mean value of the variables (standard deviation in brackets), separately for male and female students

	M	F
S-Quotient	20.3 (6.57)	18.75 (5.7)
E-Quotient	17.11 (4.57)	21.31 (6.11)
TH Score	0.73 (0.19)	0.79 (0.17)
PR Score	0.52 (0.26)	0.54 (0.29)

when available, and an Italian translation of the residual items proposed by the research group, also in collaboration with some experts on the topic.

Given the fact that we need a quick version, we decide to remove the fillers. Respondents have to choose their level of agreement on a 4-point *Likert Scale*. Scores can range from 0 to 40 for each scale.

3.1.2. Performance

The didactic work was consists of two parts:

- a "*theoretical*" activity, where the teacher explains the basics of programming and proposes some practical exercises in preparation of the the programming part to be developed in the laboratory;
- and a "*programming*" practice, where, after a short introduction, some problems are proposed to the students that have to solve them following the suggestion of the teacher and with a support of the assistant.

During the practical activity, we follow an adapted version of *eXtreme Apprenticeship* methodology (Vihavainen, Paksula, & Luukkainen, 2011) as described in some previous works (Solitro, Zorzi, Pasini, & Brondino, 2016) and inspired by the work of the Bozen University team (Dodero and colleagues) (Del Fatto, Dodero, & Gennari, 2014), (Del Fatto, Dodero, & Lena, 2015), (Dodero & Di Cerbo, 2012).

After the first two months, the participants took a partial exam that is structured as follows.

1. A few short question about the general concepts of the discipline.
2. Three exercises of coding where the students have to show their skills in
   - understanding a coded solution of a problem,
   - code an algorithm respecting give specification,
   - and, finally, given an informally described problem, define its specification and code the solution.

Performance was operationalized in terms of the score obtained in two different parts of the partial exam: the *theoretical score* (**TH**), and the *programming score* (**PR**). These scores have been standardized to be in the interval $0-1$.

4. Results

Descriptive statistics in the study variables, separately for male and female students, are shown in Table 1.

Considering the **EQ–SQ** scores, in comparison with the scores of students of scientific faculties from previous researches (Wakabayashi et al., 2006), the mean values of both quotients were similar: mean **EQ** was 18.83 ($SD = 5.47$), mean **SQ** was 19.89 ($SD = 6.97$).

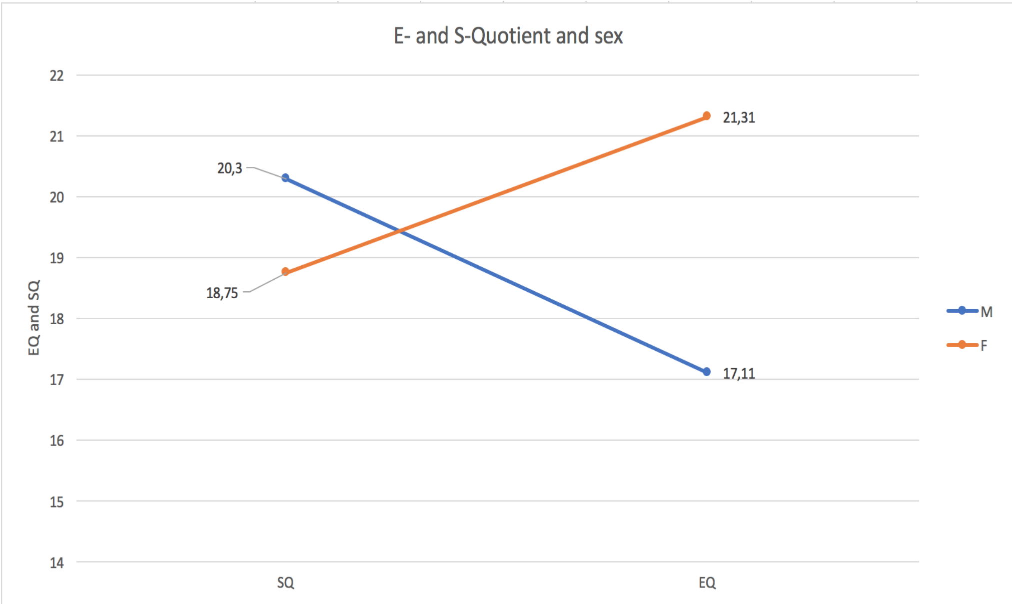

Figure 1 – Systemizing and Empathizing quotient by sex (M = male; F = female).

An independent sample *t-test* was performed to verify whether male and female students differ in some of the scores (*S-Quotient*, *E-Quotient*, **TH** score, **PR** score), and the only significant difference was found on the **EQ** score.

In a second step, in order to better analyze the combined effect of the two factors, sex and **SQ–SE** score, a mixed *ANOVA* was run, with "sex" as the *between factor* and "test" as the *within factor*, with two level (**SQ** vs **EQ**).

Results showed no main effects of the two factors. A significant interaction effect between the two factor, sex and test: $F(1,41) = 5.77$, $p < .05$, $\eta 2 = .123$, which is described in Figure 1.

Male and female students had a different trend in the two quotients, with males showing a higher score in the **SQ** than in the **EQ** one, and female students showing the opposite result.

This result is consistent with the literature (Baron-Cohen, 2002), (Baron-Cohen, Knickmeyer, & Belmonte, 2005): Baron-Cohen and colleagues state that type **S**-brain, that is the brain of people with **SQ** higher than **EQ**, is more frequent in male population, whereas the opposite, that is **E**-brain, is more frequent in female population. Our sample shows the same trend.

Concerning performance, students reached higher results in the theoretical part than in the programming part, and this result was the same for male and female students. The mixed *ANOVA* test showed only the main effect of the type of exam: $F(1,38) = 44.47$, $p < .001$, $\eta 2 = .54$; nor effect of sex neither of interaction sex type of exam was found.

Our second aim was to verify the connection with the brain type and the performance. First, a simple correlation test was carried on, considering the whole sample, and no correlation was found between **SQ**, **EQ** and performance. Second, the same correlations have been computed separately for male and female students. Correlation matrix is shown in Table 2.

No correlation was found for the male sample (excepted the correlation between theoretical and programming scores). In the female sample, a higher level of *Systemizing Quotient* is associated with a higher score in the programming part of the exam ($r = .66$, $p < .001$; see Figure 2.

Also the correlation between **SQ** and theoretical score was positive ($r = .43$; see Figure 3, even if this correlation was not significantly different from zero ($p = .11$).

Table 2 – Pearson's correlation coefficients for the four variables, by sex

		SQ	EQ	TH Score	PR Score
M	**SQ**	1	0	-.12	-.03
	EQ		1	.37	.28
	TH Score			1	.60 ($p < .01$)
	PR Score				1
F	**SQ**	1	.34	.43	.66 ($p < .01$)
	EQ		1	.11	.05
	TH Score			1	.65 ($p < .01$)
	PR Score				1

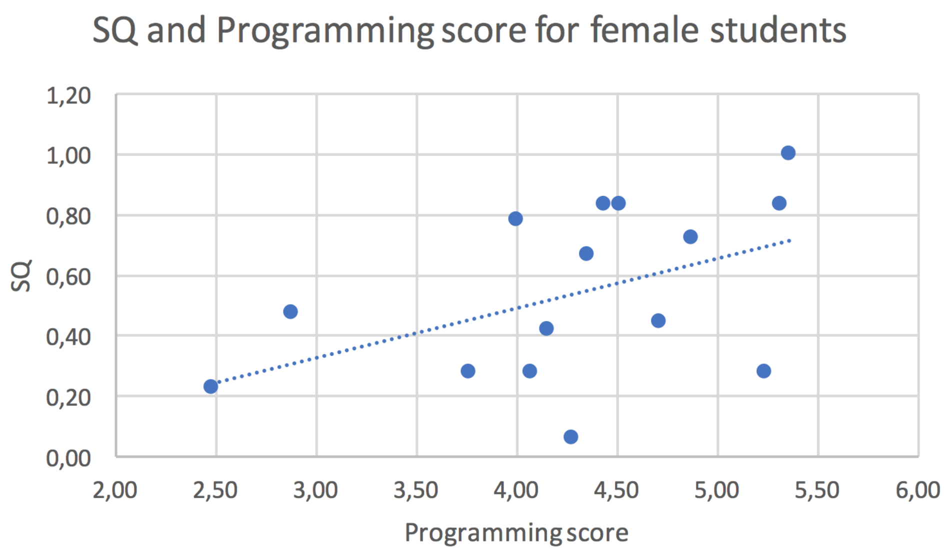

Figure 2 – Correlation between Systemizing Quotient and Programming Score.

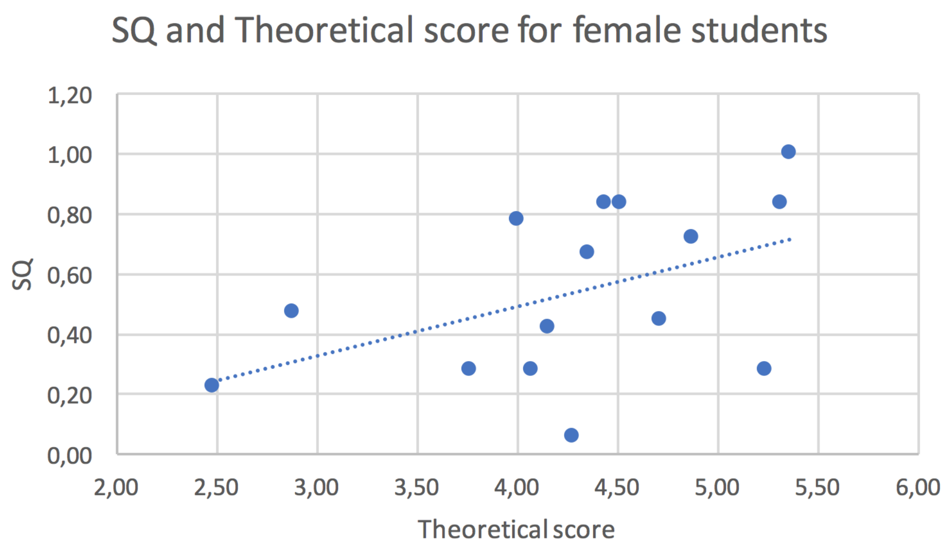

Figure 3 – Correlation between Systemizing Quotient and Theoretical Score.

5. Conclusions

This study aims to explore the role of cognitive style – considering the *S-E Theory* framework – in predicting performance in programming courses for non vocational students.

The first result showed, in line with the literature, that male and female students differ in **EQ**, with women scoring higher than men.

Concerning the hypothesis that a high level of *Systemizing Quotient* lead to a better performance, this hypothesis has been confirmed only for the female subsample, and mainly for the programming practice part.

On the contrary, no correlations were found for the male subsample, nor for the theoretical part nor for the programming practice part.

A limitation of this study concerns the small sample size, and we are still gathering data on this topic to cope with this limitation.

On the other side, given the relevant role of affective and motivational dimensions in predicting performance in university students (Brondino, Raccanello, & Pasini, 2014), it is worth examining how motivational beliefs and achievement emotions are related to the constructs examined in this work.

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