Factors affecting students' choice of science and engineering in Portugal

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Abstract

The work reported on this paper concerns the results of research carried out in Portugal through questionnaires to high school students, which tend to investigate the influence of different factors on a student´s decision to choose/not choose a higher education course in one of the physical sciences or engineering. Some factors are related to what goes on in school and in the science lessons, hence can be controlled to some extent by the individual teacher. Some factors are quite external to the school, and are related to the status of science and engineering careers. Other factors are dependent on the individual students themselves, their aptitudes, their abilities and their home background. Some significantly different influences were detected between male and female students and between future scientists and non-scientists.

Introduction

There are many reasons for teaching science in schools. One is directed towards the general scientific literacy of all citizens, that should be able to take part in responsible decision-making policies, appart from enjoying and appreciating the physical world around them; the other concerns the encouragement of some students to proceed into careers and higher education in science and engineering.

The research described in this paper is part of a more general study initiated in The United Kingdom by Woolnough [1,2]. This work was later spread over another five countries and a comparative study was published by Woolnough et al. [3]. The present paper contains the results of the individual studies carried out in Portugal by de Almeida et al. [4] and its analysis, not yet published, follows closely the model set up at the equivalent english survey by Woolnough [2]. Data collection was based on a questionnaire answered by 499 last year students picked up from 49 different high schools. It attempts to find out what factors, in school and out of school, influenced students towards or away from higher education courses in one of the physical sciences or engineering. It also investigates whether there are differences between different subgroups of students, between males and females and between potential scientists and non scientists.

The sample

In this survey, 499 students attending the year 12th (final year) of 49 different high schools across Portugal completed the questionnaire. The schools were chosen so that the sample contained students from different sized schools, both from large and small cities, from the more developed seaside or from within the countryside.

For the analysis the sample was subdivided by student type according to the subject they intended to study at higher education, as shown in Table 1. At this stage, students had already made a broad choice of subjects.

The questionnaire

The questionnaire (Woolnough [2]) consisted of four sections. Section A asked the students about the subjects they were studying at year 12th; whether they whished to study at higher education, and if so what; the marks they had had, to have an idea of their ability; details of their home background and at what stage they had decided towards or away a career in science and engineering.

Section B collected information about the type of science activity that they prefered at school. It consisted of a Likert grid of 18 statements recorded in Table 2. The students were asked to answer for each statement whether they strongly agreed, agreed, disagreed, strongly disagreed or whether it was not applicable.

Section C sought information about the actual factors that the students felt had encouraged or discouraged them in their decision about science or engineering. It is another Likert grid containing 26 items illustrated in Table 3, and the students were asked to respond for every item whether its influence had been very positive, positive, negative, very negative or not applicable in encouraging them to study one of the physical sciences or engineering.

Section D looked for information about the student´s personality. They were asked how they related themselves on various personality characteristics and a semantical differential scale was set up on 19 items. The actual axes are recorded in Table 4.

Table 1.
Grouping of students according to subject to be studied at higher education.

Student Type 1	going to do Physics, Astronomy or Physical Engineering at higher education
Student Type 2	going to do Chemistry or Biochemestry at higher education
Student Type 3	going to do Computer Sciences, or Electrothecnical Engineering at higher education
Student Type 4	going to the Army or to do any Engineering not included in groups 1, 2 or 3, at higher education
Student Type 5	going to do Mathematics or other Sciences not in groups 1-4 or 6, at higher education
Student Type 6	going to do Biological Sciences or Health Sciences, at higher education
Student Type 7	going to do Economy or Busness at higher education
Student Type 8	going to do Arts, Law, or other similar courses, at higher education

Table 2.
Statements used in section B to ascertain student response to various activities in school science.

10	I found the opportunity to plan my own experiments very satisfying
11	I felt happiest when clear instructions were given to follow when doing practical experiments
12	School science should be about learning scientific facts and theories
13	School science should be about learning to do science through scientific investigations
14	Standard experiments, written up correctly, give confidence to continue with science
15	Extended practical projects showed me what science was like and got me interested in it
16	The best notes are short and concise
17	I feel I need to write quite a lot to really express myself satisfactorily
18	I feel most confident when the science lessons are well structured and teacher directed
19	I valued the opportunity when the teacher let us plan our own activities in lessons
20	Student work should be marked objectively by the teacher
21	The most effective form of assessment is self-assessment by the student
22	The times when the school suspends its normal timetable for extended projects are not very useful
23	Involvement in science clubs is un unhelpful distraction from the learning of real science
24	Parents should not be involved in the work of the school science department
25	Involvement in science and technology competitions is great fun and useful
26	Local engineers can bring a stimulating dimension into science lessons
27	Work experience in science-based industry turns people off jobs in science or engineering

The results

The results were analysed using the SPSS-X package. Frequency variables, with means and distributions were obtained for each student type, for males and females separately, for students grouped as scientists (Student types 1+2+3+4+5) and non-scientists (Student types 7+8). An analysis by school dimension and geographical area showed no significant differences and so is not reported. A factor analysis was produced from the students' responses to sections B and C, where strong, sensible groupings were produced in each. Tests for significant differences were made between different groups, males and females, scientists and non-scientists, using Pearson´s chi-squared test.

Background information – section A

The results of section A allow us to conclude that the students aiming to continue studying physics and chemistry were of higher ability then their peers, engineers coming between those and mathematicians. The physicists have a high probability of coming from a scientific home background. Both physicists and chemists have decided very early to go on studying physical sciences. Students wanting to pursue careers on chemistry, mathematics, biology, health sciences and arquitecture were the ones that have decided earlier what type of career they wanted in higher education.

Table 3.
Statements used in section C to ascertain student response to encouraging or discouraging influences.

28	The quality of the teaching in the science department
29	The personal encouragement given by science teachers

30	Supportive maths teaching in the school
31	Supportive technology teaching in the school
32	Advice from careers staff
33	The practical nature of the science lessons
34	The intellectual satisfaction of doing science
35	The amount of involvement with human issues
36	The amount of self-expression allowed in science lessons
37	The tradition of good exam results in science
38	Outside speakers and visits to science firms
39	Local engineers coming into the school
40	Work experience in local companies
41	Involvement in science clubs (photographic, radio, etc.)
42	Involvement in science competition (e.g., great egg races)
43	The level of difficulty of the sciences at school
44	The amount of work required for school sciences
45	The ease of entry to HE for science and engineering
46	The possibility of sponsorship in HE
47	The status of jobs in science and engineering
48	The likely salaries in science and engineering jobs
49	The likely job satisfaction in science and engineering
50	The sophisticated technology used in military weapons
51	The situation in local science-based industry
52	Experience of your family in science-based industry
53	Scientific hobbies and fiddling with gadgets at home

Science activity in schools – section B

The data from section B are reported in Tables 5a and 5b. The individual results from Studtyp 7 are not reported because this group had only 2 students so that statistical analysis was meaningless.

The results reflect a rather conservative students population: they felt happiest when clear instructions were given when doing practical experiments (Q11); they value standard experiments, written up correctly, as giving confidence to continue with science (Q14); they think that the best notes are short and concise (Q16); they want their work objectively marked by the teacher (Q20) and not by the students (Q21). However they believe that school science should be more about learning to do science through scientific investigations (Q13) rather than about learning scientific facts and theories (Q12). They enjoy involvement in science and technology competitions (Q25) and think that local engineers can bring a stimulating dimension into science lessons (Q26).

The main differences between males and females are related to girls needing to write a bit more than boys to express themselves satisfactorily (Q17), and about parents not being involved in the work of the school department (Q24): although they all think on average that parents should indeed participate in school activities, girls feel stronger about this.

Potencial scientists and non-scientists also differ on questions 17 and 24, the non-scientists having averages similar to the female overall group. The scientists valued a bit more extended practical projects than the non-scientists, who did not specially appreciate such way of doing science (Q15).

One can see from Table 5b that chemists are the ones that appreciate more being given clear instructions to follow when doing practical experiments (Q11), while physicists and computer science students really prefer short

Table 4.
Axes used in section D to ascertain student self-perception of their personality type.

54	Hard working/lazy
55	Clever/stupid
56	Introverted/extroverted
57	Self-confident/insecure
58	Task-centred/person-centred
59	Verbose/concise
60	Tender-minded/tough-minded

61	Abstract thinker/practical worker
62	Interested in people/interested in ideas
63	Creative/systematic
64	Convergent thinker/divergent thinker
65	Gregarious/a loner
66	Communicating best in words/ Communicating best in diagrams
67	Dominant/submissive
68	Conscientious/casual
69	Adventurous/timid
70	Self-sufficient/dependent on others
71	Mercenary/generous
72	Enthusiastic/sober

Table 5a.
Mean student response to various activities in school science, section B

Question	Student group	All (499)	Males (224)	Females (275)	Scientists (183)	Non-Scient (96)
10		3.3	3.3	3.4	3.4	3.3
11		4.0	3.9	4.0	4.0	4.0
12		3.4p	3.4	3.5	3.4	3.3
13		4.5	4.4	4.5	4.4	4.5
14		4.4	4.4	4.4	4.4	4.4
15		3.2	3.3	3.2	3.3	2.9**
16		4.1p	4.1	4.1	4.1	3.9*
17		2.6p	2.3	2.8**	2.3	2.9***
18		3.6p	3.5	3.7*	3.5	3.5
19		3.6p	3.6	3.7	3.6	3.9*
20		4.0p	4.0	4.1	4.0	4.1
21		2.4p	2.5	2.4	2.4	2.3
22		2.5p	2.6	2.5	2.7	2.4*
23		2.5	2.6	2.4*	2.6	2.4*
24		2.6p	2.8	2.4**	2.8	2.3**
25		4.0	3.9	4.0	4.0	4.1
26		4.1	4.1	4.1	4.1	4.2
27		2.4	2.4	2.4	2.4	2.4
StudCent		22.7	22.6	22.9	22.8	22.9
TeachCen		7.5	7.4	7.6	7.5	7.4

Likert scale from 5 (strongly agree) to 1 (strongly desagree).
The responses marked p had a polarized response, with two distinct peaks.
Any significant difference between males/females or scientists/non-scientists is marked *(<5%), ** (<1%) or *** (highly significant, <0.1%).

Table 5b.
Mean student response to various types of activities in school science by student type, section B

Question	Student type	1 (8)	2 (7)	3 (18)	4 (128)	5 (22)	6 (124)	8 (94)
10		3.9	3.1	3.4	3.4	3.4	3.2	3.3
11		4.0	4.4	3.9	4.0	3.7	4.1	4.0
12		3.6	3.1	3.7	3.4	3.4	3.6	3.2
13		4.6	4.3	4.3	4.4	4.6	4.5	4.5
14		4.5	4.6	4.6	4.3	4.3	4.5	4.4
15		3.9	3.3	3.3	3.3	3.4	3.4	2.9
16		4.5	3.9	4.4	4.1	4.1	4.2	3.9
17		2.5	2.1	2.7	2.2	2.6	2.6	2.8
18		3.1	4.3	3.7	3.4	3.7	3.8	3.5
19		4.4	3.7	3.4	3.6	3.6	3.5	3.8

20	4.4	4.3	4.4	3.9	3.8	4.2	4.1
21	2.4	2.1	2.4	2.3	3.0	2.4	2.3
22	3.4	2.9	2.7	2.7	2.2	2.4	2.3
23	2.4	2.4	2.8	2.5	2.9	2.4	2.4
24	3.0	2.7	3.3	2.7	2.8	2.3	2.3
25	4.5	4.0	3.9	3.9	3.9	4.0	4.1
26	4.1	4.0	3.9	4.1	4.3	4.0	4.2
27	2.6	2.3	2.5	2.3	2.3	2.6	2.4
StudCent	25.4	22.4	22.2	22.7	23.2	22.6	22.8
TeachCen	7.0	9.0	7.9	7.3	7.3	7.9	7.4

Table 6.
Group factors relating to student activity in school science, section B.

Student centred =	+ PlanExp(10) + LearnDo(13) + ExtProj(15) + PlanAct(19) + + Compet(25) + LocalEng(26)
Teacher centred =	WorkSh(11) - LearnDo(13) + StrExp(14) + Struct(18)

and concise notes (Q16); again the chemists felt more confident with well structured and teacher directed lessons (Q18) differing from the physicists who value the opportunity given when the teacher let them plan their own activities in lessons (Q19). Finally, the physicists definitely like more than the others the involvement in science and technology competitions (Q25), although all the students react very positively to this issue.

One of the key points was to verify whether the degree of teacher direction of the science activities made any difference. The individual items above suggest that it does. Furthermore, factor analysis produced a grouping of items which fitted the description of being student centred (StudCent) or teacher centred (TeachCen). The items so grouped are listed in Table 6. From Tables 5a and 5b one clearly sees that students value lessons well structured by the teacher (all the scores are above 6, the neutral value) but clearly centred on the student (neutral value equals 18) specially so for the physicists.

Encouraging and discouraging factors - section C

The data from section C are reported in Tables 7a and 7b. This section sought to find out from the students what factors they considered had encouraged or discouraged them towards or away from one of the physical sciences.

Males and females reacted overall in a similar way, the most significant difference being the stronger positive influence of scientific hobbies and fiddling with gagets at home on males (Q53).

Table 7a.
Mean student response to encouraging or discouraging influences, section C.

Question	Student group	All (499)	Males (224)	Females (275)	Scientists (183)	Non-Scient (96)
28		3.2p	3.1	3.2	3.4	2.7***
29		3.1p	3.2	3.1	3.5	2.6***
30		2.8p	2.8	2.8	3.1	2.4***
31		3.3p	3.3	3.3	3.4	2.9**
32		3.1	3.1	3.1	3.1	3.2
33		3.0	3.1	3.0	3.2	2.9*
34		3.2p	3.4	3.1*	3.7	2.6***
35		3.3	3.3	3.3	3.3	3.1*
36		3.1	3.3	3.0*	3.4	2.5***
37		2.9	2.9	2.9	3.0	2.5**
38		3.0	3.1	3.0	3.1	2.9*
39		3.0	3.0	2.9	3.0	2.8*

40	3.0	3.0	2.9	3.0	2.8*
41	3.0	3.1	3.0	3.1	2.9*
42	3.1	3.2	3.1	3.2	2.9*
43	2.9p	2.9	2.9	3.0	2.6**
44	2.9p	2.9	3.0	3.0	2.8*
45	2.5	2.5	2.5	2.4	2.5
46	2.7	2.8	2.6*	2.7	2.7
47	3.6	3.7	3.5*	3.7	3.3**
48	3.6	3.7	3.4*	3.8	3.4**
49	3.8	3.9	3.7*	4.2	3.1***
50	3.2	3.3	3.0*	3.2	3.0*
51	2.8	2.8	2.8	2.9	2.7*
52	2.8	2.8	2.8	2.9	2.7*
53	3.6	3.8	3.4**	3.9	3.2***
ExCurAct	15.1	15.4	14.9	15.4	14.3
DnClassAct	21.8	22.3	21.6	23.5	18.9
CareerAsp	11.0	11.3	10.6	11.7	9.8
ExtFacts	12.4	12.7	12.0	12.9	11.6
DiffOfSub	5.8	5.8	5.9	6.0	5.4
HEDncent	5.2	5.3	5.1	5.1	5.2

Likert scale from 5 (very positive) to 1 (very negative).
The responses marked p had a polarized response, with two distinct peaks.
Any significant difference between males/females or scientists/non-scientists is marked *(<5%), ** (<1%) or *** (highly significant, <0.1%).

Unsurprisingly, the future scientists reacted significantly more positively to nearly all the items, the most influencial being the personal encouragement given by science teachers (Q29), the intelectual satisfaction of doing science (Q34), the status of jobs in science and engineering (Q47), the likely salaries in science and engineering (Q48), the likely job satisfaction in science and engineering (Q49), and the scientific hobbies and fidlling with gagets at home (Q53).

When factor analysis was applied, six strong groupings emerged clearly as tabulated in Table 8. This is important as it shows that different types of students are influenced by quite different factors. The physicists are influenced by extracurricular activities such as speakers and visitors, links with local industry, science clubs and competitions. The computer science group is more influenced by career aspects, such as the status, the salary and the job satisfaction of a career in science and

Table 7b.
Mean student response to encouraging or discouraging influences by student type, section C.

Question	Student type	1	2	3	4	5	6	8
		(8)	(7)	(18)	(128)	(22)	(124)	(94)
28		3.0	3.4	3.4	3.4	3.0	3.4	2.7
29		2.3	3.6	3.3	3.5	3.7	3.4	2.5
30		3.1	3.4	3.3	2.9	3.4	2.9	2.4
31		3.0	3.9	3.7	3.5	3.1	3.6	2.9
32		3.5	3.7	3.4	3.0	3.4	3.1	3.1
33		3.8	4.0	3.3	3.1	3.1	3.0	2.9
34		4.8	3.7	3.6	3.7	3.4	3.4	2.5
35		3.1	2.7	3.6	3.3	3.5	3.4	3.1
36		3.5	3.4	3.7	3.4	3.1	3.3	2.5
37		3.3	3.6	3.1	3.0	2.7	3.2	2.5
38		4.4	3.3	3.2	3.0	2.8	3.2	2.9
39		3.9	3.3	3.2	3.0	2.7	3.0	2.8
40		3.3	3.0	2.9	3.0	2.6	3.0	2.8
41		4.0	3.3	2.8	3.1	2.5	3.2	2.9
42		3.9	3.3	3.2	3.3	2.7	3.2	2.9
43		2.9	3.0	2.9	3.1	2.6	3.1	2.5
44		3.4	3.1	3.1	3.1	2.6	3.0	2.8

45	3.6	2.4	2.5	2.4	2.2	2.5	2.5
46	3.4	2.7	3.1	2.7	2.1	2.8	2.7
47	3.5	3.4	3.8	3.8	3.5	3.7	3.3
48	3.5	3.7	4.3	3.8	3.5	3.4	3.4
49	4.8	4.6	4.2	4.2	3.9	3.9	3.1
50	3.0	3.4	3.4	3.3	2.8	3.2	3.0
51	3.5	3.0	3.4	2.8	2.7	2.8	2.7
52	3.3	3.0	2.9	2.9	2.9	2.8	2.7
53	4.3	3.9	3.9	4.0	3.2	3.4	3.2
ExCurAct	19.5	16.2	15.3	15.4	13.3	15.6	14.3
DnClassAct	23.8	24.4	24.0	23.4	22.5	23.1	18.7
CareerAsp	11.8	11.7	12.3	11.8	10.9	11.0	9.8
ExtFacts	14.1	13.3	13.6	13.0	11.6	12.2	11.6
DiffOfSub	6.3	6.1	6.0	6.2	5.2	6.1	5.3
HEDncent	7.0	5.1	5.6	5.1	4.3	5.3	5.2

Table 8.
Group factors relating to encouraging and discouraging influences, section C.

Extracurricular activities =	+ SpAndVis(38) + LocEng(39) + WkExp(40) + ScCl(41) + + ScCompet(42)
In-class activities =	+ QualTec(28) + TeacEnc(29) + PracNat(33) + IntSat(34) + + HumanIs(35) + SelfExp(36) + GdExams(37)
Career aspirations =	+ Status(47) + Salary(48) + JbSatisn(49)
External factors =	+ Weapons(50) + LocalSBI(51) + FamExp(52) + + Hobbies(53)
Difficulty of subject =	+ DiffOfSc(43) + WrkInSc(44)
HE Incentive =	+ HEEntry(45) + Spons(46)

engineering. A fourth group including physicists, chemists, computer science and engineers is attracted by external factors, like the family background on science or technology, local science-based industry, scientific hobbies and sophisticated technology. Finally a last group dominated by the physicists, is encouraged by the ease of entry and the possibility of sponsorship for higher education in sciences.

Personality traits - section D

The data from section D are recorded in Tables 9a and 9b. In this section the student personality is considered to check whether certain personality types were associated with becoming a scientist or engineer.

Females perceive themselves as being more hard-working (Q54), more tender-minded (Q60), more interested in people (Q62), more convergent thinker (Q64), more gregarious (Q65), communicating best in words (Q66), more self-sufficient (Q70) and more enthusiastic (Q72) than males.

Table 9a.
Mean student response to personality traits, section D.

Question	Student group	All (499)	Males (224)	Females (275)	Scientists (183)	Non-Scient (96)
54		4.1	3.9	4.2*	3.8	4.2*
55		4.5	4.7	4.4*	4.6	4.4
56		3.6	3.7	3.5*	3.8	3.4*
57		4.9	5.0	4.8*	4.9	4.9
58		5.3	5.3	5.3	5.4	4.9*
59		3.7	3.7	3.7	3.6	3.9
60		5.5	5.3	5.7**	5.2	5.9***
61		3.3	3.3	3.3	3.2	3.7*

62	4.7	4.4	5.0***	4.2	5.2**
63	5.2	5.3	5.2	5.2	5.6*
64	4.3	4.0	4.5***	4.2	4.5
65	5.5	5.4	5.7*	5.3	5.6
66	5.5	5.2	5.8***	5.0	6.2***
67	4.8	4.9	4.8	4.9	4.7
68	4.2	4.3	4.0*	4.2	4.2
69	4.9	5.0	4.8*	4.9	4.7
70	4.7	4.4	4.9***	4.6	4.7
71	2.4	2.7	2.2***	2.6	2.5
72	4.3	4.2	4.5**	4.1	4.5*

Seven-point semantic differential scale. An axis defined by two personality traits was drawn and the students invited to tick along the line. The higher the score the more the students perceived themselves nearer the first-named characteristic. Any significant difference between males/females or scientists/non-scientists is marked * (<5%), ** (<1%) or *** (highly significant, <0.1%).

Scientists saw themselves as being more task centred (Q58), more tough-minded (Q60), more interested in ideas (Q62), more systematic (Q63) and communicating best in diagrams (Q66) as compared to non-scientists.

Discussion

Individual students are different and react differently to the same stimulus. But there are some similarities within some groups of students, as could be noticed from this work. However it is not clear from this research whether this personality traits determine the choice of a higher education course and career or whether it is the earlier choice that moulds the students personality.

Perhaps one strong message from this work concerns the importance of the quality of the science teachers. They should have not only a good scientific background but also the capacity to empathise with the students, in order to perform a well structured scientific based teacher centred approach, but at the same time giving the students enough liberty for individual contributions to the planing of the lessons and experimental work.

Another strong message seems to be the relevance of extracurricular activities in science, such as the existence of science clubs, links with local industries, invitations of speakers and the planing of scientific visits as an important encouragement factor for the students' choice of a scientific or an engineering career.

Table 9b.
Mean student response to self-perception of personality traits by student type, section D.

Question	Student type	1 (8)	2 (7)	3 (18)	4 (128)	5 (22)	6 (124)	8 (94)
54		4.1	3.9	3.0	3.8	4.3	4.6	4.1
55		5.6	5.3	4.4	4.7	4.1	4.4	4.4
56		4.6	3.6	3.9	3.7	3.6	3.5	3.4
57		4.5	5.0	4.6	5.0	4.6	5.3	4.9
58		4.4	5.6	5.4	5.5	5.3	5.5	5.0
59		2.6	4.4	3.4	3.7	3.9	3.8	3.9
60		5.0	5.7	5.3	5.1	5.7	5.7	5.9
61		5.8	3.7	3.1	3.1	2.9	3.1	3.8
62		3.1	3.4	4.2	4.1	5.6	5.3	5.3
63		5.3	4.6	5.2	5.3	4.8	5.1	5.6
64		4.3	3.9	4.2	4.2	4.5	4.4	4.5
65		5.3	5.6	5.5	5.2	5.5	6.0	5.6
66		4.8	4.6	4.8	5.0	5.3	6.0	6.2
67		5.9	4.4	4.4	5.0	4.6	4.9	4.7
68		5.9	4.4	3.8	4.2	4.1	4.1	4.2
69		4.4	5.1	4.7	5.1	4.0	5.0	4.7
70		6.4	4.4	5.1	4.3	5.1	4.9	4.8
71		1.9	2.4	3.1	2.6	2.4	2.0	2.5
72		3.8	4.0	3.9	4.1	4.5	4.5	4.5

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