Chapter 15
The Future of European STEM Workforce: What Secondary School Pupils of Europe Think About STEM Industry and Careers

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15.1 Introduction

A relative drop in the number of STEM (science, technology, engineering and mathematics) graduates coupled with a shortage of workers with high-vocational and technical skills has increasingly become a matter of political and economic concern in most European countries. Recruitment to the STEM sector and a proportionate decline in a qualified STEM workforce are publicly recognised as EU-wide problems that require urgent and systemic countermeasures (Eurobarometer 2008). In both public and academic discourses, the issue has become firmly linked to young people's disengagement with STEM subjects in school and their decreasing interest in STEM careers (ERT 2009; Sjøberg and Schreiner 2010).

Multiple research studies register a growing decline of pupil's interest in STEM subjects, which is particularly noticeable in secondary school (Rohaan et al. 2010) and which is exacerbated by the parallel development of stark gender differences (Jenkins and Nelson 2005). To explain variations in pupil's engagement with STEM subjects and careers, researchers have identified various social, cultural and economic factors.

For example, the UK scholars investigating educational and career aspirations of school children within the project ASPIRES (2013) developed a concept of *science capital* as the main explanatory tool that helps to understand how pupil aspirations are shaped. *Science capital* relates to the level of interest, knowledge and

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understanding of science matters encapsulated in pupil immediate environment (family and friends). It is important because it directly influences a young person's disposition towards STEM learning and careers: increase in *science capital* makes a pupil more likely to continue learning STEM subjects post-16 and to consider a STEM-related job in the future. Being a powerful heuristic and explanatory concept, it also implies that the key forces that determine and sustain pupil aspirations lay outside the classroom. Consequently, raising *science capital* is a crucial but a very difficult task that requires structural social changes as well as long-term and large-scale social investments.

A different line of enquiry is focused on the quality of teaching STEM at school as well as on the quality and relevance of career advice. For instance, Cleaves (2005) shows how school experience of STEM could make a crucial difference in young people's predisposition to STEM learning and careers. However, the nature of formative processes shaping career aspirations at school is not well understood.

The present study examines secondary pupils' views on different aspects of STEM subjects and careers, including their personal interests, views on school teaching of STEM and their social attitudes, and considers their relative role in fostering young people's inclination towards STEM-related careers.

15.2 Rationale

The data for this paper comes from the pan-European project inGenious (also known as ECB – the European Coordinating Body for STEM education), which involved over 40 partner organisations representing European industry, policy makers and STEM educators. The project, which overarching aim was to foster young people's interest in STEM education and careers, was launched in spring 2011 and finished in autumn 2014. To this purpose, inGenious facilitated existing school-industry partnerships and supported the development and dissemination throughout Europe of innovative STEM educational practices designed by industry partners.

While participation in inGenious was open to all schools in Europe reaching nearly 2000 classrooms by the end of the project, the project also recruited 150–170 teachers in each of the three testing cycles as 'pilot' teachers, who were provided with additional professional development opportunities and learning resources in exchange for their school participation in a more rigorous evaluation process of inGenious practices. Participating pupils and teachers were asked to fill in the questionnaires at the beginning, during and after each pilot cycle. The collected data was used for evaluation purposes, but it also provided valuable insights into the current state of STEM teaching and learning, personal and social views and job aspirations. More importantly, this data enabled us to consider the relative role a personal interest, school teaching, social attitudes, industry and job stereotypes play in shaping pupil's predisposition to STEM-related careers in different parts of Europe.

Drawing on the existing research that investigates formative processes that shape career choices, our research questions were:

- How do pupil participants of inGenious perceive various aspects of STEM education and employment?
- Are there any gender and regional differences in their views and experiences?

In addition, we were also able to make exploratory analysis of some possible links between pupils' views on and experiences of STEM in school and their inclinations towards STEM-related careers.

15.3 Methodology

This study is based on the analysis of 7,601 responses from secondary pupils (11–16-year-olds) of schools participating in the pilot testing of the inGenious practices. The data was collected in 23 European countries and two EU partner countries (Turkey and Israel) at the onset of the two consecutive pilot cycles of the project. 2,756 questionnaires were received in the first pilot year, which was a shorter cycle, and 4,845 in the second pilot year.

Due to the nature of the project and the way schools were recruited to the 'pilot', the study faced a number of methodological limitations. First, the survey was administered in 15 different languages, so that the majority of pupils answered questions in their native language. However, where the number of participating schools in a country was between one and three, e.g. Bulgaria or Macedonia, both pupils and teachers used English questionnaires. To overcome this limitation, the survey instruments were designed to be robust and simple: pupils were presented with a number of themed statements and asked to show how much they agree with each of them on a four-point scale ranging from *strongly disagree* (1) to *strongly agree (4)*.

Second, the number of participating schools and pupils in each country varied from one school to 11 schools, and for some countries, the number of participating schools was different in each pilot cycle. Therefore, the analysis has been carried out by grouping the schools into five larger geographical areas in Europe (Table 15.1).

Finally, despite the wide geography and high volume of collected responses, we have no exact knowledge of how representative our sample is. The results show that we achieved a reasonable gender representation in each region (Table 15.2), but due to the nature of the sample, we also anticipated some positive skewness of the data. Given the self-nominating and voluntary mechanism of participation in the project, it was assumed that the inGenious teachers were more enthusiastic and better performing teachers than an average teacher in their respective countries and that this was likely to impact their pupils' views and attitudes to STEM. In addition, some of these teachers could have selected their better performing and more motivated STEM pupils for testing inGenious practices and filling in the questionnaires.

Overall, data collected through inGenious reveals a mixed picture of pupils' interests, attitudes and career preferences in STEM. Our results were found to be slightly more optimistic than the findings reported in other research projects

Table 15.1 Respondents per country and geographical area

Region	Country	Pupils
Eastern Europe		2178
	Bulgaria	65
	Croatia	572
	Czech Republic	609
	Estonia	339
	Hungary	13
	Lithuania	44
	Macedonia	25
	Romania	31
	Slovakia	530
Northern Europe		1556
	Denmark	293
	Finland	486
	Netherlands[a]	453
	Sweden	324
Southern Europe		1466
	Greece	48
	Italy	335
	Portugal	615
	Spain	468
Western Europe		1454
	Austria	221
	Belgium	10
	France	262
	Germany	438
	Ireland	13
	United Kingdom	510
EU partner countries		947
	Israel	442
	Turkey	505
Total		7601

[a]Although geographically the Netherlands is not part of Northern Europe, in terms of their approach to STEM education this country has more in common with 'Nordic' countries than with countries in the Western European group. This decision was discussed and received endorsement in a series of consultations with education experts and other project stakeholders from this part of Europe

Table 15.2 Gender representation in each region

Region	Girls to boys ratio (%)
Eastern Europe	51:49
Northern Europe	50:50
Southern Europe	51:49
Western Europe	59:41
EU partner countries	45:55
Total	51:49

(Sjøberg and Schreiner 2010), which supported our initial hunch of a certain positive skewness of the sample. However, should such selection bias exist, it is also expected to be universal, i.e. applicable to all participants in our sample. This means that the nature of the relationship between variables should not be affected, and we were still able to explore the relations and differences between key categories of pupils. A relatively large sample size also helped to offset the selection bias. Indeed, when we compared results from each of the testing cycles, most of our findings showed high year-on-year consistency and largely confirmed trends and gender/regional differences identified in earlier studies (Sjøberg and Schreiner 2010).

15.4 Results

15.4.1 Interest in STEM Topics

We had a number of statements designed to measure the level of pupil's interest and enjoyment of science, technology and maths in and outside the school. The answers were measured on a four-point scale, yet for some of the analyses, those were collapsed to a binary scale (*disagree* vs. *agree*).

On total, more than 70 % of pupils claimed some interest in science and technology (S&T) topics (Fig. 15.1), but there were clear and significant gender and regional differences. Overall, boys were more likely to give a positive answer ($M = 3.02$, $SD = 0.78$) than girls ($M = 2.76$, $SD = 0.77$). Running an inferential statistical analysis of the data showed that gender differences in pupil interest in S&T were statistically significant, $t(7744) = 14.80$, $p < .001$, yet the effect size was moderate ($d = .43$).

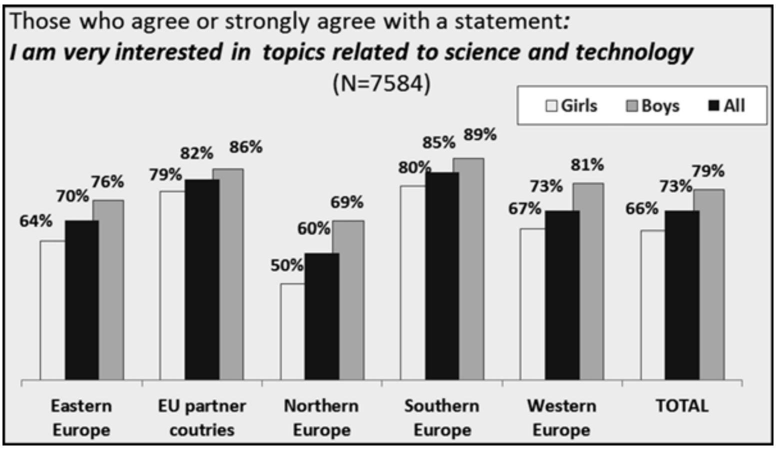

Fig. 15.1 Pupils' interest in science and technology topics

When different regions of Europe were compared, Southern European students came across as the ones with the highest levels of interest in S&T. 85 % of pupils in this region gave a positive answer ($M=3.09$, $SD=0.71$), while Northern European youngsters scored the least ($M=2.66$, $SD=0.82$) with only 60 % of youngsters showing enthusiasm for S&T. To assess the significance of a regional variable to pupil interest in S&T, we applied a one-way ANOVA test, which verified the existence of significant regional differences in how interested in S&T pupils were, $F(4,7741)=83.13$, $p<.001$ It is also noteworthy that the South European cohort had the lowest difference between genders, 9 %, while their peers in Northern Europe showed the greatest gender divide (19 %).

The same North-South divide was visible when pupils reported on their interest in S&T lessons: 66 % in the European North ($M=2.75$, $SD=0.78$) vs. 84 % in the South ($M=3.07$, $SD=0.711$) considered their S&T lessons interesting (Fig. 15.2). The importance of regional dimension for the interest in lessons reported by pupils was proven statistically significant, $F(4,7722)=48.17$, $p<.01$. To evaluate the difference between Northern and Southern cohorts, we administered a separate *t*-test, which showed that this difference was indeed statistically significant, $t(3001)=12.02$, $p<.001$ with a moderate effect size ($d=.42$).

Testing for gender differences, we received confirmation that gender also plays some role in the way pupils perceive their S&T lessons $t(7725)=9.61$, $p<.001$. However, the effect size for this variable was smaller ($d=.22$).

Interestingly, when we compared boys' and girls' interest in S&T lessons to their general interest in science maters, we observed a gender-related pattern of a different sort. Girls appeared to be more interested in STEM lessons ($M=2.85$, $SD=0.75$) than in S&T matters in general. Boys demonstrated an opposite trend as boys were more likely to report general interest in S&T than interest in S&T lessons ($M=3.01$,

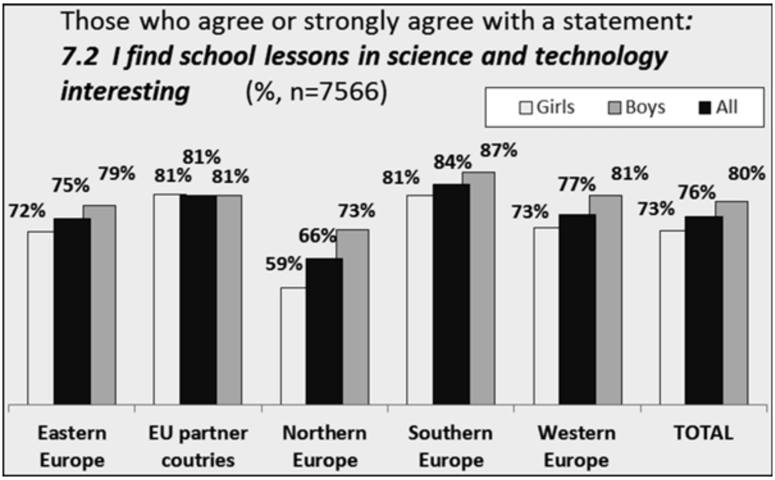

Fig. 15.2 Pupils' interest in science and technology lessons

Table 15.3 Science learning outside the classroom – comparing boys and girls across the regions

	Region	Girls	Boys	*t*-test[a]	Effect size
I learn a lot about science and technology matters outside my school lessons (by reading or watching a programme on the topic, attending science club, etc.)	Eastern Europe	$M=2.39$ $SD=.81$	$M=2.68$ $SD=.89$	8.72	$d=.38$
	Northern Europe	$M=2.23$ $SD=.80$	$M=2.60$ $SD=.84$	8.76	$d=.46$
	Southern Europe	$M=2.49$ $SD=.85$	$M=2.73$ $SD=.85$	5.3	$d=.28$
	Western Europe	$M=2.31$ $SD=.83$	$M=2.50$ $SD=.94$	4.14	$d=.23$
	EU partner countries	$M=.56$ $SD=.87$	$M=2.83$ $SD=.87$	4.79	$d=.32$
	Total	$M=2.67$ $SD=.89$	$M=2.37$ $SD=.83$	14.93	$d=.32$

[a]With $p<.01$ unless stated otherwise

$SD=0.76$). Testing the relation between general interest in S&T and interest in lessons for both genders yielded a moderate level of correlation (boys, $r=.57$, $N=3773$, $p<.001$, and girls, $r=.58$, $N=3992$, $p<.001$).

When pupils were asked about their STEM-related learning outside classroom, only 60 % of boys and 44 % of girls said they were engaging in learning about S&T outside classroom. This level of engagement in STEM is nearly 20 % lower than the level of interest in STEM registered through the two previous questions. The relationship was evidenced as statistically significant for both genders across all regions (Table 15.3), although the effect size ranged from small to medium. Reviewing the results for this question helped to reassess an overtly optimistic picture of pupil interest in STEM, which emerged from measuring pupil interest in STEM topics and STEM school lessons only.

The existence of considerable differences in the level of pupils' exposure to STEM outside the classroom is an important observation, which is in tune with the findings of the longitudinal research project ASPIRES (2013). Investigating the role of various factors in shaping pupil career aspirations, this project pointed to the key influence played by a pupil's immediate environment (like family or friends) and developed the notion of *science capital* to embody such an influence on a young person's level of interest, knowledge and understanding of science (Archer et al. 2012). The research carried within the project inGenious also showed that for many children, and especially for girls, school remains the key point of contact with STEM and consequently the main source of information about and motivation for STEM careers.

15.4.2 Views on STEM in School

Further analysis of pupils' views on their school experience of STEM subjects (Table 15.4) revealed that while pupils are more likely to consider science rather than mathematics as their favourite school subject (55 % vs. 44 %), the reverse is

Table 15.4 Views on STEM subjects in school – comparison between boys and girls

	Pupils who agree/strongly agree with the statement					
	Girls (%)	Boys (%)	Girls	Boys	*t*-test[a]	Effect size
Lessons in science and technology are among my most favourite subjects at school	48	64	$M=2.48$ $SD=.85$	$M=2.77$ $SD=.86$	14.94	$d=.34$
I like mathematics more than most other subjects at school	40	48	$M=2.31$ $SD=.95$	$M=2.49$ $SD=.86$	8.08	$d=.21$
I think school mathematics will have practical use in my daily life	69	70	$M=2.82$ $SD=.85$	$M=2.84$ $SD=.89$	0.81 **ns**	$d=.02$
School science and technology will help me with everyday practical problems	60	66	$M=2.65$ $SD=.76$	$M=2.75$ $SD=.81$	5.73	$d=.13$

[a]With $p<.01$ unless stated otherwise

true with their views on the practical importance of school knowledge in science and mathematics (63 % vs. 70 %). This dichotomy is particularly visible for girls: only two in five girls name mathematics as their favourite subject, yet more than two thirds of them agree that they mathematics has practical importance in their life. In contrast, almost half of girls enjoy science lessons; however, only 60 % consider the knowledge they receive there as relevant to real life.

15.4.3 Social Views and Personal Relevance

The examination of pupil views on the social significance of STEM (Table 15.5) shows greater regional and gender homogeneity as well as an overall high awareness of the role the STEM sector plays at present (73 %) and will play in the future (84 %). In a similar fashion, when pupils were asked to consider their own future education and career, they attributed high importance to learning STEM (79 %).

Gender gap is reduced as more than ¾ of girls and more than $^4/_5$ of boys agreed that '*doing well in mathematics, science and technology is important for my further education and career*' and fewer than 30 % in each gender category did not think that STEM knowledge would be useful in their future. At the same time, girls showed a slightly lower self-esteem when asked to assess their personal suitability for work in this sector: 39 % of girls vs. 29 % of boys agreed with the negative statement *I do not have personal qualities and skills necessary for a career in industry, science or technology*.

Although the difference between boys' and girls' views on the role of STEM in society and in their own life were smaller than in other areas, gender was found as a statistically significant variable for all of the above statements. However, the effect size was negligible ($d<.1$).

Table 15.5 Social views on STEM and its relevance to personal future (pupils who agree/strongly agree with the statement)

	N > 7518	All (%)	Girls (%)	Boys (%)
Social views	Today all people, regardless of their career choices, need to learn science, mathematics and technology	73	74	73
	In the near future, our society will need more engineers, technicians and scientists	84	82	85
	Jobs in industry, science and technology can be very different, and they need people with very different personal qualities and skills	88	88	89
Vision of personal future	Doing well in mathematics, science and technology is important for my further education and career	79	76	83

15.4.4 Attitudes to STEM Jobs

While a very high number of pupils, boys and girls alike, acknowledged the importance of STEM in society and showed awareness of the diversity of STEM-related jobs with a variety of personal qualities and technical skills required, many pupils, and especially girls, did not consider STEM education/career path for themselves. Overall, boys showed more positive attitude to the prospect of having a STEM-related career ($M = 2.78$, $SD = .94$) than girls ($M = 2.43$, $SD = .87$) with this difference confirmed as statistically significant, $t(7492) = 16.26$, $p < .01$.

The comparison of pupil predispositions to STEM jobs and of their willingness to learn about job opportunities revealed stark regional differences (Fig. 15.3). Pupils in the Northern and Western parts of Europe demonstrated the lowest levels of interest in STEM careers (Northern Europe $M = 2.54$, $SD = .79$; Western Europe $M = 2.55$, $SD = .83$), while pupils in the Southern region and in the EU partner countries showed the highest level of enthusiasm (Southern Europe $M = 2.89$, $SD = .72$; EU partners $M = 2.97$, $SD = .82$). Applying ANOVA to evaluate the importance of regional variable confirmed its statistical significance, $F(4,7687) = 69.37$, $p < .01$.

The situation in the North is exacerbated by a vast gender gap. Only 28 % of girls in Northern Europe indicated that they would like a job related to S&T, pushing the mean score for this group to the lowest level, $M = 2.1$, $SD = .84$. In contrast, the number of boys, who answered positively to this question, was almost twice as much (51 %), and the mean score for this group was .47 points higher, $M = 2.57$, $SD = .93$. On the other side of the spectrum were pupils from Turkey and Israel (the EU partner group) with 60 % of girls ($M = 2.7$, $SD = .97$) and 70 % of boys ($M = 2.96$, $SD = .97$) indicating their positive dispositions towards STEM jobs.

When pupils were queried on their attitude to learning about STEM-related jobs, more pupils across the regions, and especially more girls, said they like receiving information about careers (Fig. 15.4). Comparing to their current career aspirations,

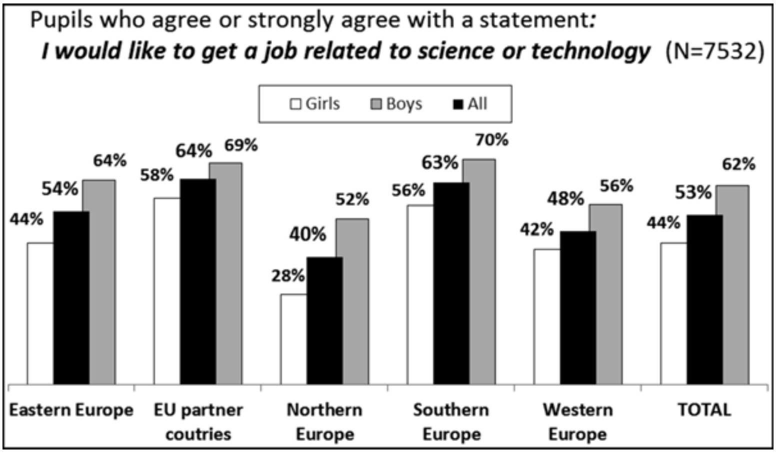

Fig. 15.3 Pupils' interest in getting a job related to science or technology

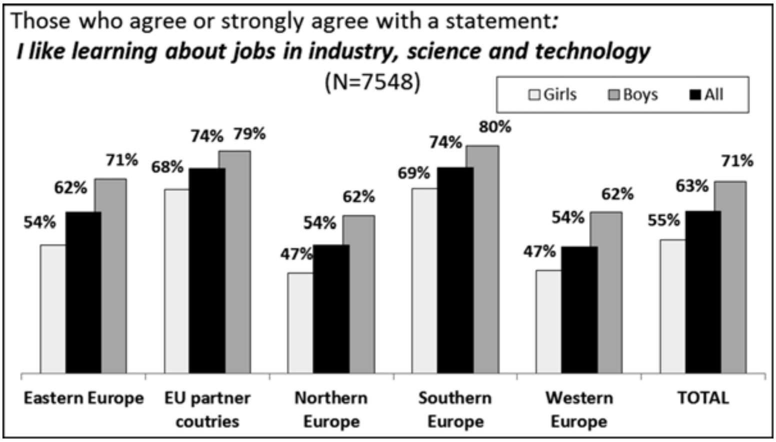

Fig. 15.4 Interest in learning about jobs in industry, science and technology

the mean score on this question was higher for both genders (boys $M=2.86$, $SD=.80$; girls $M=2.58$, $SD=.79$). Once again, the difference between boys and girls was statistically significant, $t(7705)=15.27$, $p<.01$, so was the difference between regions, $F(4,7702)=76.90$, $p<.01$.

Interestingly, in Northern Europe, the percentage of girls who were interested in learning about STEM jobs was almost double on the share of girls who displayed an existing interest in such a career. Comparing to the group mean score for the previous question, the North European girls' average for interest in learning about careers was .3 points higher, $M=2.41$, $SD=.76$, and was closer to the overall girls' mean for this question, $M=2.58$, $SD=.78$.

Overall, the data in Figs. 15.3 and 15.4 hints of a serious problem with the quality of career information and a lack of career advice in some schools across Europe.

15.4.5 What Helps to Foster STEM Career Choices?

In this study we also examined the relationship between variables that describe pupils' attitudes and views and tried to determine factors most helpful in explaining pupils' positive dispositions to STEM careers.

The first connection to explore was the link between career inclinations and a general interest in STEM subjects. Checking for the linear relationship between these variables revealed a moderate level of correlation ($r = .57$, $p < .01$), and performing a linear regression showed that interest in STEM was a significant predictor of pupil career aspirations, $\beta = .6$, t (7674) = 60.89, $p = 0$, explaining 33 % of the observed variance, $R^2 = 33$, $F(1,7678) = 3707.85$, $p < .01$.

To explore the relationship further, we collapsed the four-point scale to a binary one (*disagree* vs. *agree*) for both questions and then looked at their cross-tabulated results (Table 15.6).

Such data representation confirmed the link between interest in S&T and interest in STEM careers, but it also showed that this relation was nonlinear. On the one hand, nine out of ten pupils who agreed with a statement 'I would like to get a job related to science or technology' also said they were interested in S&T topics. On the other hand, in the cohort of pupils with *no interest* in STEM jobs, almost half of the respondents, and this number is 58 % for boys, nevertheless stated their general interest in S&T matters. Overall, the cross-tabulated data indicated that having an interest in STEM topics was not enough for generating an interest in STEM careers and that it was *a necessary but not sufficient condition* for selecting a STEM-related career path.

Looking at the inferential statistics for these groups of pupils gave support to our assertion that interest in S&T is important and statistically significant in explaining differences in pupil predisposition towards STEM careers, t (7676) = 50.14, $p < 0.01$.

Table 15.6 Cross-tabulation of interest in STEM careers and interest in a job related to STEM

			I am very interested in topics related to science and technology	
$N = 7184$			Disagree (%)	Agree (%)
I would like to get a job related to science or technology	Disagree	Girls	53	47
		Boys	42	58
		All	49	51
	Agree	Girls	9	91
		Boys	7	93
		All	8	92

The average career aspiration score of pupils who stated no interest in S&T matters was much lower, $M = 2.47$ SD = .74, than the group average of pupils with an interest in S&T, $M = 3.26$ $SD = .63$.

As mentioned earlier, the data obtained from the analysis of individual questions related to STEM jobs (i.e. 'I'd like to get a job…' and 'I like learning about jobs…') was suggestive of the likely role school experiences and classroom practices play in shaping personal dispositions on STEM careers. To examine this relationship further, we investigated the relationship between the following statements:

– At school I learn about different career choices available in industry, science and technology.
– I would like to get a job related to science and technology.

Testing for correlation showed that the variables were in a positive and statistically significant, yet relatively weak, relation ($r = .27$, $p < .01$). However when we collapsed the scale to a binary one and investigated the cross-tabulated results, the relationship was more evident. Indeed, this showed that adding the element of career learning to school STEM education could lead to a 20 % increase in the number of pupils positively considering a career in STEM (Fig. 15.5).

Comparing group averages and testing for the significance of group differences gave further support to the idea that when pupils are provided with information and advice on STEM careers, their aspirations towards such careers will increase (Table 15.7).

Overall, classroom practices that contextualise information on STEM jobs should be beneficial to all pupils. Yet, for those who generally like S&T, but who have not yet decided what career to choose, such information could be particularly useful in helping to relate theoretical knowledge to their own experience and to sway their career choice towards STEM.

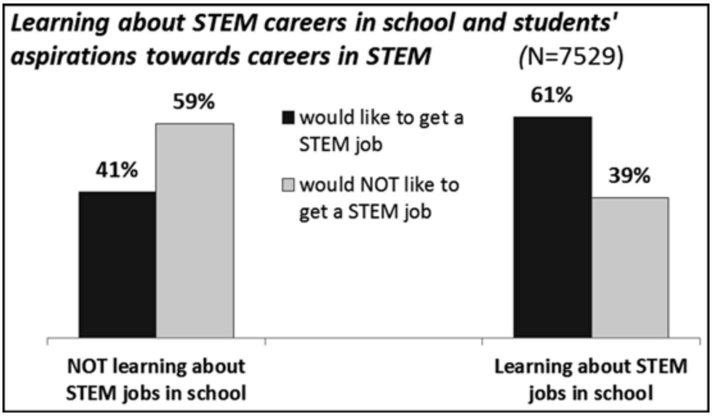

Fig. 15.5 STEM career aspirations of pupils who recall learning about STEM careers in school compared to students who say they do not learn about STEM careers in school

Table 15.7 Comparison of career aspirations of pupils who say they receive career information in school and those who do not recall learning about STEM careers

	'At school I learn about different career choices available in industry, science and technology'			
	Pupils who strongly disagree/ disagree	Pupils who strongly agree/agree	*t*-test[a]	Effect size
Girls	$M=2.18$ $SD=.88$	$M=2.59$ $SD=.93$	13.70	$d=.46$
Boys	$M=2.52$ $SD=.95$	$M=2.92$ $SD=.89$	12.8	$d=.45$
All pupils	$M=2.34$ $SD=.93$	$M=2.76$ $SD=.93$	19.42	$d=.46$

[a]With $p<.01$ unless stated otherwise

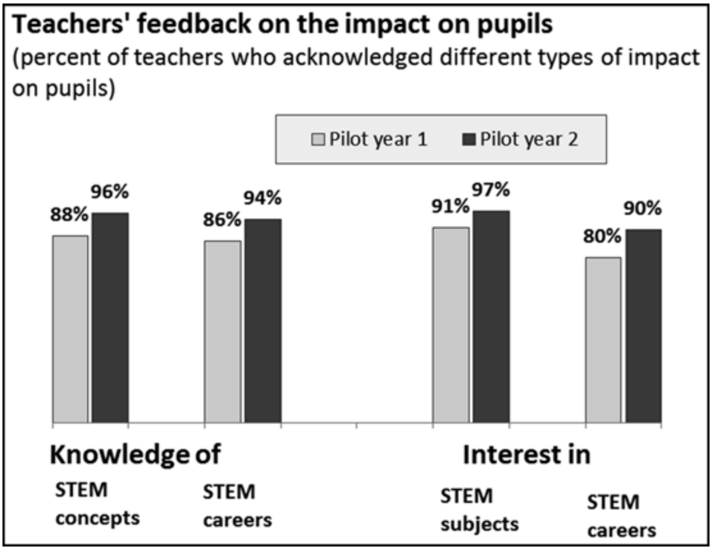

Fig. 15.6 Teachers' feedback on the impact on pupils

The feedback collected from participating teachers gave additional support to this finding (Fig. 15.6).

In addition, there is some anecdotal evidence that when done properly (e.g. by bringing motivational role models), career information and advice can themselves generate or boost interest in the subject and improve pupils' attainment and progress.

15.5 Conclusions and Implications

Career choice is a complex phenomenon, where multiple personal, cultural and socio-economic factors interplay (Cleaves 2005) and no single answer could be found to reverse a declining trend. Some of these factors, like family cultural and socio-economic background captured in the notion of 'science capital', are very important, but not easily changeable. On the other hand, school experience, the way science is taught in classroom and beyond, could make a difference across social boundaries and is a factor that could be improved more rapidly. Our research shows that just making science lessons interesting or informing pupils about social significance of STEM is not enough to sway young people towards STEM careers. While a majority of pupils see science lessons as 'fun' and agree that STEM is very important for society and useful qualifications to have, many, especially girls, do not identify with STEM careers. On the other side, when information about the modern state of STEM jobs and real-life applications is blended in with STEM education in a meaningful way for young people, it can trigger important changes in career choices. The direct contact between pupils and industry fostered by such projects as inGenious goes along these exact lines.

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References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal, 49*, 881–908.

ASPIRES. (2013). *Project final report: Young people's science and career aspirations aged 10–14*. London: King's College London. http://www.kcl.ac.uk/sspp/departments/education/research/aspires/ASPIRES-final-report-December-2013.pdf

Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education, 27*, 471–486.

ERT. (2009). *Mathematics, science and technology education report, the case for a European Coordinating Body*. European Roundtable of Industrialists (ERT). Retrieved from http://www.ert.eu/sites/default/files/MST%20Report%20FINAL.pdf

Eurobarometer, (2008). *Young people and science, analytical report* (Flash EB Series 239). Retrieved from http://ec.europa.eu/public_opinion/flash/fl_239_en.pdf

Jenkins, E., & Nelson, N. W. (2005). Important but not for me: Students' attitudes toward secondary school science in England. *Research in Science & Technological Education, 23*, 41–57.

Rohaan, E. J., Taconis, R., & Jochems, W. (2010). Reviewing the relations between teachers' knowledge and pupils' attitude in the field of primary technology education. *International Journal of Technology and Design Education, 20*, 15–26.

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project. An overview and key findings.* Retrieved from http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf