Learning Science Through Work Experience: Ciencia Viva Internships Program for Secondary School Students

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Abstract

This enquiry examines a Science Internships Program (SIP) for high school students (K-10 to K-12) in Portugal. A survey of 4,207 apprentices was both quantitatively and qualitatively analysed to identify key underpinning themes expressed in students' descriptions of their experience as science learners working alongside scientists in the workplace. The study ran throughout an eight year long nationwide science program, using a mixed-methodology approach combining qualitative and quantitative analysis of students' experiences based on their own accounts and subjective ratings. It showed that this input from the scientific community provides opportunities for youngsters to understand the nature of scientific challenges, their application to real-world problems and ultimately, their societal implications, through first hand contact with the processes of science and the cultural environment in which they take place.

Introduction

The scientific community is being increasingly called upon to work with educators to help reverse the declining interest of students in scientific careers, both in Europe and in the USA. Apprenticeship models are recommended as one component in a strategy to provide students with opportunities to learn through engagement with the cultural practices of a specific community, its language, tools and knowledge (Collins *et al*., 1989; Lave & Wenger, 1991; Rogoff, 1990). This approach fits well with the context of students working alongside science and technology practitioners in laboratories and other research sites (Barab & Hay, 2001; Bleicher, 1994; Pei-Ling & Roth, 2008; Richmond & Kurth, 1999; Sadler *et al.,* 2010).

Social studies of research laboratories' cultures have recognized that they serve both as workplaces and environments that support continuous learning, with a well-established tradition of apprenticeship (Goodfield, 1991). The making of real science is itself a process whereby junior researchers work for and learn with, more experienced ones. Senior undergraduate students start their research careers by supporting someone else's research projects with the expectation that, at a later stage, they will take ownership of their own research agenda (Gafney, 2005). When these students collaborate with an experienced scientist, they engage in a type of contextualized learning through which they appropriate a body of knowledge, but also, most importantly, tools that allow them to understand the scope and nature of research, to recognize the values and norms held by the scientific community (Merton, 1973), to acquire the spoken and written characteristics of scientists' discourse (Gilbert & Mulkay, 1984), and ultimately to understand the content and culture that shape professional practice (Pickering, 1992).

It is widely recognized that both research laboratories and school laboratories have an invaluable part to play in learning. Yet there are few examples of research that attempts to understand the potential contribution of the scientific community to the science education of pre-university students. The results of these studies suggest that such learning experiences can and do change students' personal relationships with science (Bequette, 2005) and broaden their views of science and of scientists (Jelinek, 1998). Experiences of this kind provide extended opportunities for learning and *doing* science (Pei-Ling & Roth, 2008), increase students' school science achievement (Parker & Gerber, 2000; Ryken, 2003); constitute a suitable and appropriate provision, especially for highly talented and motivated pupils (Stake & Mares, 2001), and have the potential to attract under-represented groups such as school science underachievers, females and members of ethnic minorities, to science and science-related careers (Munoz, 2002; Rahm *et al*., 2005).

All this suggests that university-based science intervention programs for pre-university students should be offered far more extensively and also be the subject of systematic review and evaluation. The present study seeks to contribute to this body of research.

Method

Research Setting.

Ciencia Viva is a major National Science Program designed to promote scientific and technological culture throughout Portugal. Its mission is carried out through four main strands: (i) a program to stimulate and support inquiry-based learning in schools; (ii) national science awareness campaigns, providing the population with the opportunity to make scientific observations and to establish a direct and personal contact with science practitioners, (iii) a national network of interactive science centres, and finally (iv) a program of summer science internships for high school students in universities and scientific institutions – the Science Internship Program (SIP) (Catalao, 2007).

Ciencia Viva SIP combines three main features. Firstly, it operates nationwide; secondly, it is not limited to university departments (in fact, other scientific institutions constitute the majority of the SIP partners); thirdly, it is based on internship and apprenticeship models, whereby students go to science research laboratories to work with scientists in real-life, on-going research projects. Since its launch in 1997, 8.942 high school students have already attended science apprenticeships in research centres, higher education institutions, museums and science centres (Catalao, 2011).

Research Purpose

The purpose of this study was to identify what the students felt were the most important characteristics of learning science through the experience of working alongside scientists in their workplace. To further refine the analysis, the study also examined the extent to which student views might be influenced by the characteristics of the institutions and/or the specific internship activities which they undertook.

Instruments.

The Ciencia Viva Questionnaire (CVQ) was administered to the students, from 2005 to 2010, after completion of each internship program. The following items were used for the purpose of this study: (i) student rating of the level of difficulty of the internship (i.e., too easy vs. adequate vs. too difficult) and duration (i.e., too short, adequate or too long), (ii) student answers to the open-ended question about what they enjoyed most, and (iii) an overall evaluation of the internship (i.e., poor, fair, good or excellent).

The Student Attitudes Survey (SPS), a 12 Likert-type four-point scale items survey, was administered to the students from 2005, as a complement to the CVQ survey. The design of the items was based on a qualitative analysis of student answers to the CVQ open-ended questions. The wording of the items was drawn from the most representative statements written by the students who attended the program over the previous two years. The reliability coefficient of the items was 83.4.

Participants

A total of 4,207 students, with an average age of 16.6 (SD = 1.22) participated in this study, corresponding to 66.3% of the students who attended Ciencia Viva SIP from 2005 to 2010. The majority of the respondents (70%) attended SIP in the two years immediately before going to university (see Table 1 for the respondents' distribution, according to gender, type of institution and institutions' scientific domain).

Research Design.

A ‘mixed methods’ approach combining qualitative analysis and survey was used for eight consecutive years. Quantitative data were obtained via both the CVQ closed questions and the SPS items; qualitative data was analyzed through coding of the CVQ open-ended questions with NVIVO, and later quantified by methods of content analysis (Weber, 1990) and other recognised techniques developed for the *quantification* of qualitative information (Onwuegbuzie & Teddlie, 2003).

Analytical Procedures.

We started by qualitatively analyzing the data provided by students’ written responses to open-ended questions describing their perceptions of their experience. The themes emerging from this were then quantified and assessed against a number of factors, such as the characteristics of the internships in which they participated. We then quantitatively analyzed the results of SPS.

The analytical procedure involved the following steps. First, student statements (N = 1,171) were coded into a list of non-repetitive characteristics (i.e., units). Second, according to their meaning within the context of the students’ statements, the characteristics were aggregated *a posteriori* in distinct emergent themes. Third, the themes were *quantitized* (Tashakkori & Teddlie, 2003; Onwuegbuzie & Teddlie, 2003) using the following procedure: a database was designed to incorporate an *inter-respondent matrix* (i.e., participant x theme) with a record for every candidate. Each record contained a set of fields corresponding to all themes. For each field, a score of ‘1’ or ‘0’ was entered depending on whether the corresponding theme or category was represented in the candidate’s response.

Quantitative analysis included descriptive statistics and group comparisons (t-test and ANOVA). A Principal Component Analysis (PCA) was used for data reduction purposes, in order to condense the variables of the SPS scale to a smaller set of components. For the PCA, the KMO test yielded a value of .895 and the Bartlett’s test of sphericity was significant, $x^2(66, N = 3{,}519) = 10828.07$, $p < .001$; therefore the analysis was deemed appropriate. Given the large sample, it was justifiable to assume Kaiser’s criterion, and drop all factors with eigenvalues under 1.0 (Field, 2005), retaining *three* components, which we called learning, identity and career. A varimax type of rotation was used to obtain the correlations among factors. For these data, a cut-off of .50 (values in bold in Table 4) was applied as a minimum limit.

Results

Quantitative Analysis of the CVQ Closed Items (2003-2010)

Four in five respondents (77.5%) participated in the internships because they intended to pursue a science-related career. Up to 7% were there because they loved science, even though they had no aspirations for a career in science. The majority were happy with the timetable and the difficulty level of the internships. However, one-third thought the internships were too short. The overall evaluation of the program was extremely positive: more than half of the respondents (52.8%) rated it as ‘excellent’ and 42.1% classified it as ‘good’.

The students’ ratings of the ‘overall evaluation’ item were affected by several factors, such as the type of the institution, its scientific domain and the characteristics of the internship. Respondents from research institutions rated their internships more highly than their colleagues who attended other types of institutions.

Table 1

T-tests for the CVQ Item 'Overall Evaluation' (N = 4,207, df = 1)

Variables[1]	*N*	*%*	*M*	*SD*	*Mean diff.* [2]	*t*	*Effect size*[3]
Type of institution							
Research institutions	2867	68.1	3.49	.62	.07	3.67**	.1
Gender							
Girls	2588	61.1	3.49	.60	.06	4.39*	.1
Institutions' scientific domain							
Life sciences	1523	58.4	3.60	.56	.20	10.03**	.3
Exact sciences & Engineering	2457	36.2	3.40	.64	-.18	-9.52**	-.3
Social sciences	227	5.4	3.45	.59	-.02	-.54	.0
Difficulty level							
Too easy	145	3.4	3.01	.81	-.47	-9.21**	-.7
Appropriate	4012	95.4	3.50	.59	.53	11.87**	.7
Too difficult	50	1.2	2.84	.89	-.64	-7.35**	-.8
Duration							
Too short	1335	31.7	3.59	.55	.18	8.83**	.3
Appropriate	2720	64.7	3.44	.62	-.07	-3.78**	-.1
Too long	152	3.6	2.88	.72	-.62	-12.41**	.9

[1] All variables were converted to *dummy* (i.e., contrast) variables

[2] Compared with the cases not represented by the variable

[3] Effect sizes were measured by the Cohen *d*

* $p < .01$; ** $p < .001$

Nevertheless, although the mean difference in the overall evaluation is statistically significant ($p > .001$), its practical significance, as accounted by the correspondent effect size, is weak. Indeed, as we will see later in the analysis, the influence of the type of institution is more noteworthy in other perception items than in the students' overall evaluation of their internships. On the other hand, both large effect sizes and statistical significance were found in relation to the characteristics of the internships, such as duration and difficulty level. Respondents from the group of the Life Sciences institutions gave their internships a higher overall score, with statistically significant difference, but with a medium effect size. The student ratings dropped significantly in internships considered to be too easy, too difficult or too long (62% of these respondents attended internships that lasted for more than two weeks). Strikingly, this was not the case when internships were seen as too short.

Qualitative Analysis of the CVQ (2003-2005)

Seven major themes emerged from the qualitative analysis of the students' responses to the CVQ open-ended questions. Table 2 presents, in descending order, the aspects the students enjoyed most from their internships.

Table 2

Endorsement Rate of Themes Emerging from Students' Responses to the item 'What did you enjoy most?' in CVQ, from 2003 to 2005, (*N* = 1,171)

Themes	*N*	%
Practical work *Practical learning activities*	706	60.3
Student-scientist interaction *Working alongside scientists in their workplace*	351	30.0
Peer interaction *Acquiring skills and knowledge through teamwork with students with similar interests*	323	27.6
Knowledge and skills *Understanding scientific knowledge and engaging in scientific practices*	265	22.6
New learning *Being exposed to new teaching approaches*	205	17.5
Laboratory life *Gaining insights into the practice and the culture of the scientific community*	163	13.9
Career development *Perceiving career opportunities*	81	6.9

Throughout the qualitative analysis, it became increasingly clear that the students most enjoyed the extended opportunities for engaging in practical work (60%) and the supportive atmosphere provided by the contact with researchers (30%). This sense of participation facilitated learning but was also experienced as part of a genuine working relationship. It was through participation in all these activities that many students came to perceive themselves as doing real science, contributing in meaningful ways to the work of the researchers. In general, the qualitative analysis appears to suggest that the cultural, practical and social dimensions of the experience outweighed perceived knowledge acquisition and career motivation.

Since not all the respondents addressed the same issues in their open-ended answers, the representativeness and generalizability of these themes may benefit from a comparative procedure, such as that provided by a Likert-type survey applied to a wider sample.

Quantitative Analysis of SPS items (2005 to 2010)

Table 3 presents the results of 3,519 students' ratings of the most representative statements formulated in the written responses provided by students who responded to the open-ended question analysed in the previous section.

Table 3

Student Ratings of the SPS Items from 2005 to 2010 (N = 3,519)

	Items	*SA*	*A*	*D*	*SD*
1	This internship helped me to choose a future career	15.6	54.7	25.5	4.1
2	I had the opportunity to participate in the scientific work carried out by professionals	55.4	38.8	5.3	0.5
3	The practical part of the internship was important: we learned the theory and how to apply it in practice	63.8	32.8	3.0	0.4
4	The researchers stimulated us to think and question ourselves about what we were doing	50.0	45.2	4.0	0.3
5	This internship allowed us to put into practice what we had learned instead of just observing how things were done	69.3	27.0	3.0	0.8
6	A fantastic team spirit was created which helped us to carry out our work	56.6	37.5	4.8	1.1
7	What I have learned may be very important for my professional future	47.8	43.5	8.0	0.7
8	The researchers were always available to help us and clarify our doubts	80.6	18.2	1.0	.02
9	The researchers helped us to understand why we were learning the theory	61.4	36.5	1.8	0.3
10	I have worked with materials and equipment that don't exist in my school	69.5	22.9	5.6	2.0
11	This internship allowed me to 'get under the skin' of a scientist, living 'in loco' the day-to-day routine of science work	46.7	44.0	8.0	1.2
12	I would like to recommend this internship to my friends	64.5	31.5	3.2	0.7

For data reduction purposes, a PCA was applied to items 1-11, having resulted in 3 Components. This method of extraction yielded a first component on which six from eleven variables loaded at .50 or higher. Consideration of the degree of association between these items (items 3-6 and 8-9) and the first component suggested an interpretation of this component as a measure of the students' perceptions of the learning aspect of their internships, so for brevity it was named "Learning".

A second component includes three items loading at .60 and above (items 2, 10 and 11). This could be interpreted as measure of the students' perception of their engagement with aspects of the culture of the scientific community, particularly their practices, tools and language – the "Identity" component.

The third component particularly favors items 1 and 7. It became clear that this component measures the students' perception of the importance of the internship for their future, both in terms of a career choice (loading at .84) and in terms of their professional future (.74) – a "Career" component.

In sum, the analysis of the PCA loadings suggests an interpretation consisting of three components, representing three dimensions of perception, respectively, *Learning, Career and Identity*.

Table 4

Loadings for Principal Component Analysis using Varimax Rotation

Items (*brief description*)	*PCA* 1	2	3
1. Career Choice	.06	.19	**.84**
2. Worked with scientists	.37	**.60**	.13
3. Applied learning	**.66**	.35	.05
4. Critical thinking	**.67**	.12	.19
5. Hands-on	**.58**	.40	.07
6. Team work	**.51**	.09	.19
7. Professional future	.32	.10	**.74**
8. Teachers support	**.68**	.07	.13
9. Purposeful learning	**.75**	.07	.15
10. Scientific equipment	.04	**.79**	.08
11. Felt like a scientist	.32	**.65**	.27

For each component, a *t-test* was applied to identify differences between the ratings of students whose internships were in research and those in non-research institutions; a one-way ANOVA was conducted to compare the effect of the institutions' scientific domains.

Learning. No statistically significant differences were found between respondents in research institutions and others, suggesting that the students' rating of the learning component was not affected by the nature of the host organization. However, there was a significant effect ($F_{5,\ 3513} = 21.25$, $p < .001$) from the institutions' scientific domain on this component. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the Life Sciences ($M = 22.01$, $SD = 2.04$) was significantly different from those of the Exact Sciences and Engineering ($M = 21.29$, $SD = 2.38$) and the Social Sciences ($M = 21.58$, $SD = 2.25$), but not between these latter two science domains.

Identity. There was a significant effect for type of institution, $t\ (3519) = 6.04$, $p < .001$, with research institutions receiving higher scores. Type of institution showed a statistically significant difference ($F_{2,\ 3516} = 42.66$, $p < .001$), with respondents from research institutions rating the items under this component more highly, compared with those in universities and other institutions. The ANOVA showed a significant effect for the scientific domain ($F_{5,\ 3513} = 48.74$, $p < .001$), indicating that the score for the Life Sciences ($M = 10.95$, $SD = 1.21$) was significantly higher than in Exact

Sciences and Engineering (*M* = 10.22, *SD* = 1.56) and in Social Sciences (*M* = 9.98, *SD* = 1.66). Again, no significant difference was found between Exact Sciences and Engineering and the Social Sciences.

Career. Type of institution showed a statistically significant difference t (3519) = 3.99, $p <$ .001, with respondents from research institutions rating the items under this component more highly, compared with other institutions. Type of institution showed a statistically significant difference ($F_{2,\ 3516}$ = 42.66, p < .001). Students from research institutions valued the Career component more highly then their counterparts in universities and other institutions. Moreover, there was also a significant effect from the scientific domain for the three conditions ($F_{5,\ 3513}$ = 23.33, p < .001). Post hoc comparisons revel that the respondents attending internships in Life Sciences institutions (*M* = 6.39, *SD* = 1.15) rated this component significantly higher than those in Exact Sciences and Engineering (*M* = 6.11, *SD* = 1.1.20) and in Social Sciences (*M* = 6.07, *SD* = 1.06), with no significant differences between these two last two levels.

These findings suggest that the type of host institution was not a determinant factor in students' perceptions of the learning-related dimensions of their internships. However, when compared to students in non-research institutions, those who attended research institutions were more likely to value the importance of the experience for both their career and the development of their identity as future scientists.

The duration of the internships was also a determinant variable in some students' perceptions. In particular, students from shorter internships (i.e., that lasted for less than two weeks) were less inclined to mention aspects that were relevant for their colleagues in longer internships, particularly in terms of their relationships with researchers and peers. It is therefore unsurprising that they rated their experience less highly than all the other participants.

The institutions' scientific domain was another influential aspect. The students in health, medical, biology and other life related sciences rated their internships higher than their counterparts in exact sciences, engineering and social sciences. The most significant differences were related to career choice and self-perception as future scientist, e.g. importance for respondents' professional futures and participation in on-going science research.

Discussion

The findings show that students perceived their internships to be beneficial for learning science and in shaping their future career aspirations. These perceptions were significantly different between participants in research institutions and those who attended internships in universities and museums, and also between different scientific domains.

Findings are consistent with previous research on science education and particularly with domain-related research on summer science enrichment program. A first indisputable finding is that, for the large majority, the most satisfying aspect of the internship was the opportunity to engage in practical work in an authentic real-world science context. Indeed, the importance of practical work in science education was extensively stressed, particularly when related to physical phenomena that students encounter in everyday life. In the present study, the students' enjoyment of their hands-on experience was not dependent on any particular teaching approach, such as inquiry or discovery learning. Firstly, practical work was felt to make understanding of science concepts easier because it gave students experience of the real-life applications of academic subjects. Secondly, and consistent with previous research (Bequette, 2005; Schenkel, 2002), students particularly appreciated the fact that the activities were conducted in state-of-the-art science facilities which provided opportunities to try out up-to-date techniques and equipment not normally available at school. Finally, many students reported their satisfaction at having taken part in on-going scientific research or, at least, in the everyday tasks characteristically performed in a professional science setting – a result which corroborates the findings of previous studies (Barab & Hay, 2001; Richmond & Kurth, 1999; Ritchie & Rigano, 1996; Ryken, 2003). Participation in the scientists' on-going professional work and the handling of scientific equipment was frequently associated with the perception of self as a scientist. More than one-third strongly agreed, and half agreed, that the internships led them to feel like scientists, living 'in loco' the daily routine of science work. Moreover, the SIP students particularly appreciated the fact that they had been encouraged to think for themselves and adopt a sceptical, questioning attitude towards received knowledge.

The second most commonly cited statement in the students' qualitative responses was about interaction with the scientists. It was also the most highly rated statement in the survey, showing the high value placed upon being surrounded by experts who were always available, providing help and clarifying issues and problems. The educational advantages of such interaction have been extensively highlighted by previous research into students working in scientific laboratories (Barab & Hay, 2001; Bequette, 2005; Bleicher, 1994; Ritchie & Rigano, 1996; Schenkel, 2002), not only because it changes the students' images of scientists (Jelinek, 1998), but also because it provides role models for a future science-related career (Cavallo *et al.*, 1999) and gives students their first exposure to the discourse of the scientific community (Bleicher, 1995), itself a central tool for the development of an identity as a scientist (Richmond & Kurth, 1999). The qualitative analysis showed that such advantages were also frequently voiced in the students' responses to the CVQ. Also, in expressing their views about the scientists' observed behavioral traits, internees depicted them as 'nice', 'available', 'helpful' and 'friendly', qualities which, combined with the scientists' knowledge and enthusiasm about their work, gave a strong boost to the students' motivation to learn. Moreover, the availability of the researchers to help the students and "clarify our doubts" was the most valued item in the SPS survey.

However, it was not only the interaction with the scientists that led to the students' satisfaction; interaction with other students also played an important role. The fact that they worked in mixed-school groups was cited as a stimulus to co-operate with colleagues whom they had not previously met. This endorses the idea that the role played by peer interaction in science learning, particularly amongst highly motivated students and/or underrepresented groups in science, which has been extensively acknowledged by previous research (Goldberg & Sedlacek, 1995; Koch, 1998; Meyer, 1998; Lee, 2002; Stake and Mares, 2001; Stake & Nickens, 2005).

It is noticeable that internees from medical, health, agriculture and other life-related science institutions rated their internships more highly than colleagues who went to other institutions. One explanation could be that the former had more opportunities to engage in practical work and therefore to start seeing themselves as future scientists or even identify new science-related career opportunities. However, there is no evidence for this proposition, which would require different kinds of data, focusing on the characteristics of both the students and their apprenticeships, and with the specificities of student-scientist interactions. The examination of types of activities, social processes, interactions and discourses occurring between students and scientists calls for a more qualitative and naturalistic approach, but that is out of the scope of this article.

Also, the gender dimension is absent from the study, even though it was a visible differentiating factor. Indeed, one of the first and most striking features in each of the eight years analysed, is that the Ciencia Viva SIP program has always attracted more girls than boys. However, the wide variety of forms in which the evidence exists means that the gender-related findings in this study would require a full examination that is also out of our current scope.

These limitations suggest that there is a strong case for further research, combining survey with a range of interconnected qualitative methods, such as observation, interviewing and document analysis, and addressing the apprenticeship nature of the program (Richmond, 1998), the social interactions and discourses involved in the scientific laboratory (Latour & Woolgar 1986; Lynch, 1985) and the influence of the students' images and constructs about the nature of science (Leach, 1996; Charney *et al.*, 2007).

It is hoped that our findings about the way that students viewed their experience of learning science by and through working alongside scientists in their workplace can suggest guidelines for education providers interested in enhancing their students' active engagement with science.

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