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UNIVERSITY-SCHOOL PARTNERSHIPS: POLYMER CHEMISTRY DAYS RUN AT A UNIVERSITY FOR 14-15 YEAR OLDS AND THEIR IMPACT ON ATTITUDES TO SCIENCE

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Abstract: Polymer Chemistry days run by Bristol ChemLabS at the School of Chemistry, University of Bristol for year 10 (14-15 year olds) school students are described. Pre and post questionnaires were analysed to determine the impact on attitudes to science. There was no change in attitudes to the importance of science or practical work in science, but increases were observed in attitudes to learning science in school, self-concept in science, science outside of school and future participation in science. Using a two-tailed t-test at the 2σ level of significance (95% confidence level) or higher a 'combined interest in science' (combining items from learning science in school, science outside of school and future participation in science) was significantly increased. Using a two-tailed t-test at the 3σ level of significance (99% confidence level) or higher self concept in science was increased. Such an increase at such a high tolerance level is noteworthy. Both males and females attitudes to science increased as a result of the polymer workshops but scores for males were consistently higher than for females. Students studying individual science subjects (triple science) and combined science at GCSE (UK) both returned very high scores for enjoyment of the day. The results of these surveys are discussed in detail in the paper.

Keywords: Attitudes to science**,** Bristol ChemLabS, polymer workshops, School Teacher Fellow, University-School Partnerships.

1. Introduction

Bristol ChemLabS is a national Centre for Excellence in Teaching and Learning in tertiary level Chemistry in the UK and is housed within the School of Chemistry at the University of Bristol. However, part of the Bristol ChemLabS project (Outreach) involves working with primary and secondary school students in the UK to provide opportunities to carry out hands-on activities that cannot be carried out by the schools for either cost or health and safety reasons [1, 2]. A unique aspect of the Bristol ChemLabS project and one of the main reasons for its success is the employment of a School Teacher Fellow (STF) [3, 4, 5], an experienced secondary school teacher who works full-time with the project. Combining the experience of the STF with the facilities of a well equipped undergraduate University laboratory provides an excellent combination and has led to numerous highly successful interactions between Bristol ChemLabS and School students [e.g. 5, 6]. In this paper we describe some aspiration raising polymer chemistry days for 14-15 year old students (year 10 in the UK) delivered by Bristol ChemLabS and assess the impact these days have on the students. During these days students are introduced to new chemistry practical techniques and equipment, to interact with postgraduate chemists and have an opportunity to experience a university science department. They are also given a talk on university life in general to give an insight into being an undergraduate student and related talks on cutting-edge research by postgraduate researchers. In the 2004 report 'Europe Needs More Scientists' [7] Professor José Mariano Gago and his committee commented on science practical work, 'Done well, practical work can both inspire and instruct pupils: done badly, it is a standard subject of complaint by uncomprehending, disaffected students….' and 'SET [Science, Engineering and Technology] laboratories and equipment are vital to pupils' education in these subjects – both in directly educating pupils about areas of science and technology and in interesting and enthusing them to study these subjects further. Also Recommendation 3 of the Rocard report [8],

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which looked at ways that the decline in the uptake of sciences and mathematics and the subsequent consequences on Europe's future economy, says 'Specific attention should be given to raising the participation of girls in key school science subjects and to increasing their self-confidence in science.

Objectives and activities of the Polymer Chemistry Day

The day is an opportunity for school students to take part in practical work that is not usually possible during school science and to see first-hand activities that occur in science labs outside of school. Students are able to see the facilities that are available at a University, what university laboratories look like and what they can expect to see and make use of if they choose to do a science degree. The day is also an opportunity for students to work alongside postgraduates (researchers studying for a Ph.D. who are typically between 22-27 years old) who can act as positive role models and provide a young perspective and information on studying science at university.

The practical period of 2.5 hours duration involves a circus of three practical stations, each led by a postgraduate researcher with the School Teacher Fellow in overall supervision. One station looks at nylon formation by condensation polymerisation (the infamous nylon rope trick) and also spends half the time producing the casein by denaturing proteins in milk. A second station investigates the effect of cross-linking in polyvinyl alcohol (PVA) solution and the change in physical properties produced. This slime-making experiment is then repeated using commercial PVA found in paper glue. A shorter experiment on thermoplastic properties completes this station. The last station differs from time-to-time. One experiment is to produce a sample of benzoic acid, a precursor to a nylon monomer, from sodium benzoate. The alternative is the production of rayon from cellulose.

Triple Science is the term in the UK used to describe a curriculum of science delivered as separate Biology, Chemistry and Physics courses for students aged 14-16, that occupies ~30% of lesson time. This accounts for approximately 15+% of the UK cohort and usually, but not exclusively, the brighter students. Brighter students at 14 years of age do have an entitlement to a triple science course from their school.

In addition the answers to three questions regarding the effects of the day on students'

- attitudes towards science
- confidence in science
- intentions to study more science

were investigated through pre and post questionnaires.

2. Methods

Sample

105 students attended polymer chemistry days from three schools over two days. 80 students completed both the pre-event and post-event questionnaires, and were used in the analysis. Students were aged between 14 and 15, in year 10 of their secondary schooling in the UK.

Data Collection

Students were asked to complete a paper questionnaire when they arrived at Bristol ChemLabS and on leaving. The questionnaire included demographic questions such as age and gender, and a science attitude scale first developed by Kind et al. [9]. This scale measured seven facets of attitude towards science:

- Learning science in school;

- Self-concept in science;

- Practical work in science;

- Science outside of school;

- Future participation in science;

- Importance of science;

- Combined interest in science (Items from learning science in school, science outside of school and future participation in science combined).

Measuring attitudes towards science has been a contentious issue in recent research, and a large number of different scales have been developed. A review by Blacock et al. [10] evaluated 66 science attitude instruments, most of which were only used in a single study. Their findings suggested there were few instruments which had been rigorously tested enough to warrant recommendation. They suggest that rather than develop further instruments, existing instruments should be used in further research to provide reliability and validity testing and allow the most useful instruments to be developed further. For this reason, a suitable instrument for this study was sought within science attitude measurement literature, rather than developing yet another instrument.

The attitude towards science measure developed by Kind et al. [9] was developed as part of an evaluation with 11-14 year old school students in England. It was developed for a physics-related outreach evaluation, but the attitude refers to 'science' in general rather than a particular branch of it, and so could be used for the present research. It is debatable whether a chemistry-specific instrument would have been more suitable for the students attending the Bristol ChemLabS polymer chemistry day, but given the lack of such a measure for this particular age group, and the recommendation to develop current measures rather than developing new ones, the measure designed by Kind et al. [9] was selected for use.

Data analysis

Total scores were calculated for each measure on the attitudes to science scale. Scores were then converted back to the original scale (1-5) for each score by dividing each total score by the number of items in that measure. This was done to aid comprehension of the final scores and comparison between the different measures. Paired-samples t-tests were used to compare scores on attitude towards science measures before and after the summer school.

3. Results & Analysis

Attitudes towards Science

The means of students' pre and post scores for the seven measures of attitudes towards science scale were compared, and can be seen in Table 1. Paired-sample t-tests indicated that the difference between the mean pre and post scores on 'self-concept in science' was significant. This led to a significant difference between pre and post scores on the 'combined interest in science' measure, although neither of the other measures that make up this combined measure was significantly increased. There was no significant difference (2σ) between the pre and post scores on other measures, although there was a slight increase in each, and none of the measures decreased post-activity.

Table 1. *Mean attitude towards science measure scores before and after the polymer chemistry day.*

	Mean score		
	Pre polymer chemistry day	**Post polymer chemistry day**	**Sig (2-tailed)**
Learning science in school	3.30	3.38	.150
Self-concept in science	3.37	3.49	<.001**
Practical work in science	3.95	3.92	.566
Science outside of school	2.72	2.82	.124
Future participation in science	2.63	2.73	.131
Importance of science	3.63	3.63	1.000
Combined interest in science	2.91	3.01	.039*

* indicates difference is significant at the 95% confidence level or above

** indicates difference is significant at the 99% confidence level or above

Gender and Attitudes towards Science

The mean scores for males and females on both the pre and post measures of the attitudes towards science scale were compared, as shown in Table 2.

Table 2. *Mean attitude towards science measure scores before and after the polymer chemistry day for males and females.*

	Pre polymer chemistry day			Post polymer chemistry day		
	Males	**Females**	**Sig (2-tailed)**	**Males**	**Females**	**Sig (2-tailed)**
Learning science in school	3.56	3.01	.001**	3.63	2.99	<.001**
Self-concept in science	3.60	2.95	<.001**	3.73	3.15	<.001**
Practical work in science	4.13	3.80	.010*	4.11	3.65	.001**
Science outside of school	2.97	2.36	.001**	2.96	2.62	.075
Future participation in science	2.86	2.38	.008**	2.90	2.48	.018**
Importance of science	3.89	3.27	<.001**	3.86	3.27	<.001**
Combined interest in science	3.16	2.59	<.001**	3.20	2.71	.002**

* indicates difference is significant at the 95% confidence level or above

** indicates difference is significant at the 99% confidence level or above

Enjoyment

After attending the polymer chemistry day, students were asked to answer on a scale of 1 to 5 'How much did you enjoy today's activities?' with 1 being 'Not at all' and 5 being 'A great deal' The mean enjoyment score for all attendees was 4.30. Scores were compared for males and females and students studying and not studying triple science, as shown in Table 3.

Table 3. *Score from 'enjoyment' post event questionnaire*.

	Males	Females	Sig (2-tailed)
Enjoyment (mean)	4.62	3.89	<.001**
	Not studying or planning to study triple science	Studying or planning to study triple science	Sig (2-tailed)
Enjoyment (mean)	4.00	4.68	<.001**

** indicates difference is significant at the 99% confidence level or above

An independent samples t-test indicated that the mean scores for males and females were significantly different, with males rating their enjoyment of the day significantly higher than females.

An independent samples t-test indicated that the mean scores for a student studying and not studying triple science were significantly different, with those studying triple science (Biology, Chemistry and Physics individually) rating their enjoyment of the day significantly higher than students not studying triple science.

4. Discussion

Attitudes towards Science: Pre and post measures of attitudes towards science indicate a change in students' scores on the measure of 'self-concept in science', with higher scores being given after attending the polymer chemistry day. Self-concept has been shown to be important for developing students' conceptual understanding in chemistry [11] – so an improvement in students' self concept as found in this study may potentially (if it is maintained) lead to improvements in students' understanding of the subject of chemistry.

For the five other measures of attitudes towards science (excluding combined interest in science, as it is a combination of other measures) there was no significant (at the 2σ or higher level) difference between pre and post measures for students attending the polymer chemistry days. This suggests that activities such as this may not impact on aspects of attitudes such as those defined in this instrument but this is discussed further later on.

Practical work in science: It is interesting that attitudes towards practical work in science did not change, given that the polymer chemistry days are very practical and hands on. However, scores were higher for this measure than any other prior to attendance at the polymer chemistry day, so the experience may have rather confirmed students' generally positive attitudes towards this aspect of science, rather than increase it. In other surveys we have found that teachers select their better students to attend workshops at Bristol ChemLabS and that these students are already interested in practical work. Therefore, the baseline high score is probably the more telling factor.

Future participation in science: The attitude to science measure that received the lowest mean score, both before and after attendance, was the 'future participation in science' measure. There was an increase for both males and females but not a significant one at the high thresholds we set for this study. Given that around 50% of the students participating were studying or planning to study triple science, this may be a fairly predictable response – in order to study science further and eventually have a career in science, students should be studying triple science to be able to move onto A-level science and beyond in the UK. Many schools now require students to obtain high grades in GCSEs in a particular science subject (triple science route) in order to proceed to A level (post-16) studies. Since this particular measure is more closely related to intentions and behaviour (e.g. I would like to study science at university) rather than feelings (e.g. I look forward to my science lessons) as with other measures, it is less likely to change for the reasons stated, i.e. students have made choices already and these will guide their future study. Therefore, only those studying triple science may have been influenced to change their attitudes to science.

Learning science in school: Scores on this measure were fairly positive (a mean of 3.30 out of 5) and showed a small improvement post-activity (a mean of 3.38 out of 5) but no significant change. This is understandable, as this measure relates specifically to science lessons in school, which a polymer chemistry day is rather different to. The fact that scores on this measure showed a very small increase (and even just the fact that they did not decrease) is positive, as there is always the possibility that attitudes to school science could decrease after seeing how interesting science can be out of the school setting.

Science outside of school: Fairly ambivalent attitudes towards science outside of school were suggested by the average score on this measure (2.72 out of 5) and were not significantly altered after the polymer chemistry day. Items on this scale related to activities such as joining a science club, and visiting science museums, which may seem very different activities to students than those that take place on the polymer chemistry day. It may be that the experience did not increase students' desire to take part in more science related activities outside of school, but it may also be that they would be interested in taking part in activities more similar to those they did on the polymer chemistry day.

Importance of science: The students taking part in the activities tended to think of science as quite important before attending the day, and their opinions did not change significantly after attendance. It may be that their experience confirmed to them their attitudes on the importance of science.

Gender and Attitudes towards Science: The differences between male and female students on the attitudes towards science measure are in line with similar findings from other research into gender and attitudes towards science [e.g. 12, 13]. In the research performed by the authors of the attitudes towards science scale, it was found that there were only a few early differences between the attitudes of boys and girls (with boys scoring slightly higher on almost all measures) during the first year of secondary school (Year 7) but these gender differences became more pronounced between older students (Years 8 and 9). The significant differences observed between males and females on almost all measures in this study appear to support the findings in the research of Kind et al [9].

The results also show that there is no real difference between males and females in terms of the effects of the polymer chemistry day on attitudes towards science. Males and females show a similar pattern,

both show a significant increase in scores on self-concept in science, but not any of the other measures. This is positive, as this (and the enjoyment scores, see later discussion) indicate that this activity is appealing to both males and females. However, given the overall lower attitude scores of female students, it is potentially worth considering whether this could be addressed, possibly with activities designed specifically for females. Interestingly, in a separate event a girls only perfume workshop scored more highly for girls than these polymer workshops, whether this was the result of the subject being more appealing or whether this was due to the fact that it was girls only or a combination of factors is still being investigated.

Enjoyment: Overall scores for enjoyment of the polymer chemistry day were very high with a mean average of 4.30 out of 5. In particular, males attending the activity rated their enjoyment significantly higher than females, which corresponds with their overall tendency to have more positive attitudes towards science than females. It is encouraging that both males and females enjoyed the day's activities. Enjoyment scores were also significantly higher for those students attending who were studying triple science at GCSE. This is unsurprising, since those students wanting to study more science tend to have greater interest in it. What is encouraging is the finding that even those students not studying triple science rated their enjoyment very highly (mean score of 4 out of 5) suggesting that this type of activity appeals to a wider audience than just those with a keen interest in science already. A major reason for these high scores is the congruence between school context and these workshops. Since the workshops were designed by a former secondary school science teacher [3,4] the supporting material was written using scientific language familiar to this age group and the new concepts were linked to those already familiar to this group. The importance of a School Teacher Fellow in this aspect of the study has been noted previously [5].

5. Summary

The evaluation of the polymer chemistry days shows that the activities were enjoyable for students regardless of gender, or whether the student is currently studying triple science. Enjoyment of the day was however rated most highly by males and students studying triple science. Triple science students are expected to have a high interest in such activities, since they have already demonstrated their interest through their subject choice, but the slightly lower enjoyment ratings from females suggests an opportunity to develop more female-focused activities to encourage their interest in the subject of science.

The finding that students' scores of their self-concept in science increased after attending the polymer chemistry day is very a positive result. This suggests that taking part in activities like this one can have a positive effect on students' belief in their own abilities in the science domain. It would be interesting to explore whether this shift in self-concept is sustained over a longer period of time.

6. Limitations

The study could have been improved by moderating when the pre and post questionnaires were given to students. To ensure all students completed both questionnaires, they were administered at the beginning and end of the day spent at the School of Chemistry. Ideally, it would be beneficial to obtain a measure of students' attitude ratings before they get to the day, as this may be more representative of their attitudes towards science than on the day. Responses could have been affected by the fact that they may have felt excited and geared up being on a science trip, or they may have felt they wanted to please the people running the activities. Similarly, responses to the post questionnaire may have been affected by the excitement of the day, or an attempt to please the organisers. The decision to give both questionnaires on the day was taken given the difficulties with administering the questionnaire to students from a number of different schools before they arrive and after they leave Bristol ChemLabS and obtaining a good response rate. Despite this, an interesting difference with attitudes was found, and further research which takes this limitation into account may unearth further interesting findings about the effect of activities like the polymer chemistry day on students' attitudes. In a related study, Gibson & Chase [14] found that the long-term effects of a science-based intervention helped to maintain positive attitudes towards science rather than increase them, whilst those with no intervention tended to show a decrease in positive attitudes towards science over time. These findings indicate that any further research related to this project, looking into long-term attitudinal effects, should also

involve a control group to compare how attitudes may change over time as students progress through their secondary education.

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