Changing attitudes to learning physics through participation in the Victorian Young Physicists' Tournament

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Abstract.

In this paper, we report on attitudinal studies of students, and their teachers, competing in the Victorian Young Physicists' Tournament (VYPT), using the Colorado Learning Attitudes about Science Survey (CLASS).

The VYPT is a physics competition for senior high school physics students. Student teams conduct long-term independent investigations into various topics and then on the day of the tournament present and defend their research with other teams. The whole process is intended to be a realistic reflection of science in practice: starting from an interesting observation, studies are conducted to investigate it, and then the results and conclusions are reported to and critiqued by peers.

We hypothesised that after participating in the VYPT, students will have a more positive attitude towards scientific enquiry and learning physics in particular.

Using the CLASS instrument, we compared students' attitudes towards learning physics before, immediately after, and 6 months after the tournament. We also examined the data to see whether there was any link between students' and teachers' responses.

The survey results suggest that the students that compete in the tournament are exceptional, scoring near the top of the scale of 'expert-like' views on all three occasions the survey was administered. This ceiling effect, combined with the low response rate and completion rate, meant that we were unable to draw more meaningful conclusions about the effect of participation in the tournament on attitudes towards physics. Two findings are of interest however. Firstly, from matching up sets of responses from individual students and teachers at different times, we verified the reliability of the survey instrument. Secondly, there was one exception to the general observation that the survey completion rate (the fraction of survey questions that were answered) was relatively stable for both students and teachers across the different times the survey was completed. The survey completion rate for female students on the post-test was markedly lower than that of any other cohort at any other occasion. One possible interpretation is that completion rate is a proxy for confidence, and that for some reason female students were less confident on the post-test.

Introduction

A decline in the numbers of students enrolling in science subjects in the post compulsory years of school has been noted for some time (Ainley et al. 2008). This decline has implications for Australia's future supply of science teachers, engineers, and other professionals whose work requires a sound scientific understanding (Office of the Chief Scientist 2012). It also raises questions about the quality of science teaching in schools (e.g. Goodrum et al. 2012), given negative experiences in science classrooms have been found to discourage students from enrolling in tertiary science, technology, engineering and mathematics courses (Universities Australia 2012).

Consistent with the above findings, research indicates students typically find science classes to be uninteresting, irrelevant and difficult, and underpinned by a teacher-centred, transmissive pedagogy (Lyons 2006). The approach focuses on facts and definitions, and includes 'recipe-based' laboratory

work which involves following detailed instructions to obtain an already known result (Goodrum et al. 2012). Such teaching is common in all the sciences, including physics.

Yet school science curricula commonly aim to engender students' interest in science, develop their scientific literacy, and provide them with a solid foundation for science related careers (e.g. VCAA 2008; ACARA n.d.). Concerns these aims are not being met led Tytler (2007), in a major report on science education in Australia, to assert the need for "[p]edagogy … [that is] more varied, more supportive of students' agency through more open tasks, increased discussion and negotiation of ideas" (p 62). This requires changing teachers' beliefs about science and learning science and involves moving away from the teaching practices described earlier towards approaches that encourage problem solving and engagement with science ideas, and that reflect science as a human endeavour (Tytler et al. 2008).

The Victorian Young Physicists' Tournament

Participation in the Victorian Young Physicists' Tournament (VYPT) offers students an experience of physics consistent with the humanistic perspective of science envisaged above. The VYPT is an extra-curricular competition for senior secondary students. Student teams spend months in preparation, conducting investigations into a short-list of topics. Investigations are open-ended and student-driven, and typically prompted by a one-sentence starter (e.g. investigate the phenomenon of how a small ball dropped together with a basketball is propelled much higher than its starting height). The student teams independently investigate the phenomenon, exploring its aspects while perhaps making some simplifying assumptions, and reach some level of understanding. On the day of the tournament, the student teams engage in a Round-Robin of 'Physics Phytes'. These are analogous to a debate for there are two teams competing in each Physics Phyte that take turns speaking to the audience. However, unlike a debate, these encounters are not adversarial, but collegial and constructive. Roles rotate throughout the tournament but in each 'Phyte' one team presents and defends their investigations and analysis, and the other team offers constructive critique. The presenting team is judged by the quality of their research and presentation, and how they respond to the other team's questions. The opposing team is judged for appropriately recognising the presenting team's good work, and their insight in asking probing questions and challenging the presenting team's assumptions.

The long-term open-ended nature of the investigation is intended to more accurately reflect the 'real-world' practice of scientific investigation than the practical activities typically conducted within a single school lesson, with their short time-scale and necessarily more closed nature. Coupled with the constructive exchange of scientific ideas that takes place during the Physics Phytes, we hypothesized that the combined experience would positively affect participants' attitudes towards learning physics and offered the following three research questions:

1. Does participation in the Young Physicists' Tournament affect students' attitudes towards learning physics?
2. Are any changes in students' attitudes sustained over time?
3. How are students' attitudes related to their teachers' attitudes?

Attitudes towards science

But how to measure participants' attitudes towards physics? And are they important?

Osborne et al. (2003) reviewed over 40 years of research literature to argue for the societal importance of studying attitudes towards science. They contrasted the increasingly recognised cultural and economic significance of scientific knowledge with widespread scientific illiteracy and falling enrolments in post-compulsory science education. In particular, they advocated a research focus on aspects of the classroom environment and types of activities that make science engaging for school students.

Attitudes towards science are established early in a student's education (e.g. Milner-Bolotin et al. 2011; Wulf et al. 2010) and there is correlation, if not causation, between student attitudes towards science and student achievement (Milner-Bolotin et al. 2011). Studying whether the innovative, unconventional experience of the VYPT can affect student attitudes towards science is thus important.

Numerous survey instruments have been developed to measure the attitudes of respondents towards different aspects of science. For example, the "Derived chemistry anxiety rating scale" (Eddy 2000) was adapted to show lecturing leads to greater anxiety about learning chemistry. Similar instruments include the "Epistemological beliefs assessment for physical science" survey (Duncan et al. 2012), "Views of the Nature of Science" survey (Otero et al. 2008), and the "Maryland Physics Expectations" (MPEX) survey (Redish et al. 1997).

This study used the "Colorado Learning Attitudes about Science Survey" (CLASS) instrument (Adams et al. 2006). Although at 42 items it is somewhat longer than other comparable instruments, and therefore runs a greater risk of participant drop-out (Hoerger, 2010), it has several important advantages. It is appropriate for use with both teachers and students at different levels because it was written using language appropriate "to a wide variety of physics courses and to be meaningful for students who have not taken physics" (Otero et al. 2008, p. 020104-3). Rather than pre-conceived categories not subsequently validated in analysis of survey responses (like the MPEX survey), with the CLASS survey exploratory factor analysis was used to identify item categories which were subsequently validated through interviews and further statistical analysis (Sawtelle et al. 2009). Question wordings were revised to ensure each question had "only one interpretation for both novices and experts" (Sawtelle et al. 2009, p. 023101-1). The CLASS instrument has been further validated by findings that CLASS scores are highly correlated with self-reported interest in learning physics (Perkins et al. 2006), and with Force Concept Inventory performance (Milner-Bolotin et al. 2011). Typically, studying introductory physics leads to more negative attitudes towards physics (Otero et al. 2008).

Study design

The CLASS instrument was used in a pre/post/retention study design to measure student and teacher attitudes towards physics at different points before and after the VYPT tournament (Figure 1).

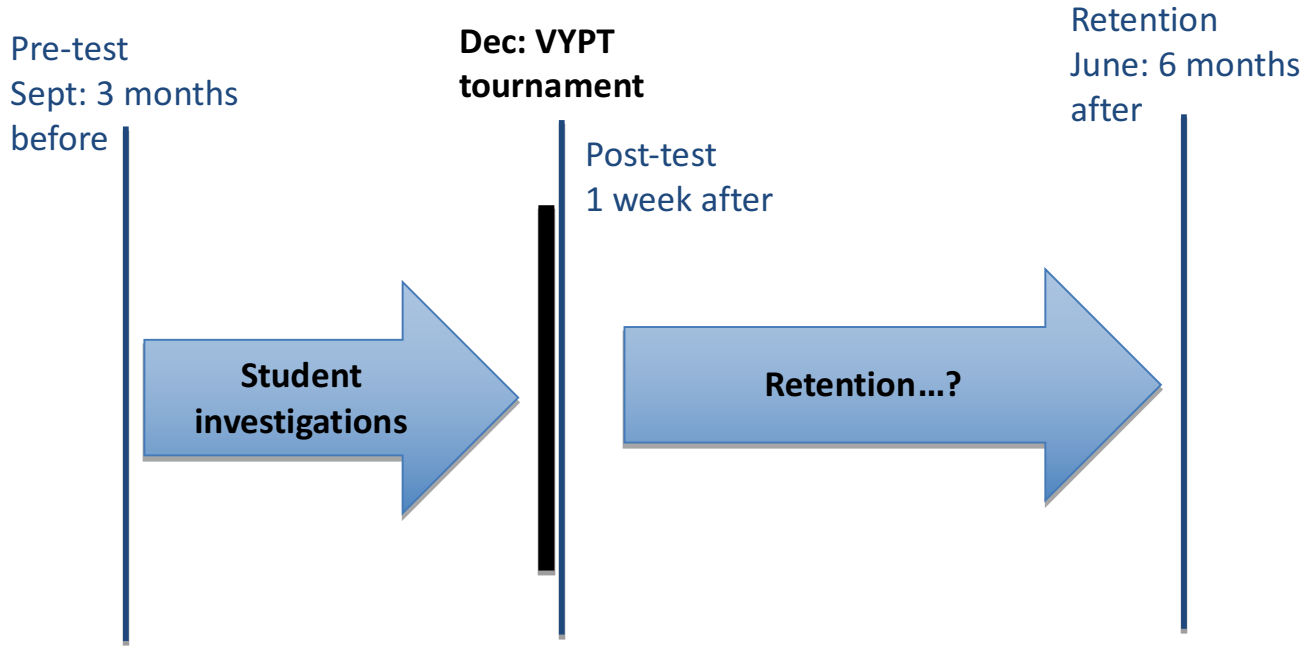

Figure 1 - Pre / post / retention study design

Results and Discussion

Students and teachers were recruited from participants of the 2012 and 2013 VYPT. The aggregate responses over the two years are shown below in Table 1:

Table 1 - Numbers of responses at different administrations of the survey

Responses	Pre-test	Post-test	Retention-test
Students	6	19	17
Teachers	1	7	4

Unfortunately, this very low response rate precluded meaningful comparisons across all three survey administrations. No one student or teacher completed the survey at all three times. In contrast, other studies that have used a similar methodology of matching responses before and after some intervention have achieved matched response rates of 40-70% (Adams, Perkins et al. 2006; Gray, Adams et al. 2008; Milner-Bolotin, Antimirova et al. 2011). However, the high response rates of these studies were achieved where the survey was promoted and/or completed in class, in one case for course credit. This points to the difficulty of attaining comparably high response rates when the researchers are not in the classroom with the students.

In this study, as the retention test was completed from 6-8 months after the tournament, and the pre- and post-tests were both completed within a 3-month period, the data were instead analysed longitudinally. This was done by pooling the pre- and post-test data and comparing this with the retention test data that was collected much later (Table 2).

Table 2 - Pooling data to make longitudinal comparisons

Responses	Pooled pre- and post-test	Retention-test	*Subset who responded to both*
Students	25	17	*10*
Teachers	8	4	*4*

High reliability of attitudinal instrument

For the 14 respondents who completed the survey twice, the intervening time-period varied from 5 to 9 months (except for one teacher who participated in the tournament both years that data was collected, for whom there was an 18-month period between the two times they completed the survey). Across this time span, the survey results showed a high reliability (Table 3).

Table 3 – Reliability of survey responses from matched respondents

	Number	Correlation between pre/post-test and retention-test
Students	10	0.96
Teachers	4	1.0

Exceptional nature of VYPT participating students

The students' responses were remarkable in two ways. Firstly in how they corresponded very strongly to expert-like views, and secondly in how decisive the students were in answering.

One way of analysing CLASS survey data is to calculate the percentage of responses that align with the expert view. Typical first-year university physics students have about 60% of their responses align with the expert view, whereas the students in this study were around the 90% mark (Table 4).

It seems that there is an extremely strong self-selection bias for students who elect to take part in the VYPT and the extensive independent preparation this entails. However, this means that the CLASS

survey does not offer much scope for observing significant changes in attitudes because the students were already scoring near the top of the scale in the pre-test.

Table 4 - Proportion of expert-like views in this and comparable studies

	Cohort	% expert-view
This study	Pre-test (N=25)	89
	Post-test (N=17)	91
	Teachers pre-test (N=8)	97
Reference studies	*1st yr physics students (Adams, Perkins et al. 2006)*	*65*
	Top decile of 1st yr students (Gray, Adams et al. 2008)	*80*
	1st yr Canadian physics students (Milner-Bolotin, Antimirova et al. 2011)	*56*

Another remarkable feature of students' responses was the exclusive use of the extreme response categories. The CLASS survey is presented as a set of statements to which participants respond on a 5-step Likert-scale from Strongly Disagree to Strongly Agree. The five levels of response allow for some nuance of meaning, yet the students in this study used only the ends of the scale (Table 5). Perhaps this decisiveness is an indicator of their strong sense of self-efficacy regarding science.

Table 5 - Distribution of students' Likert-scale responses

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
273	0	0	0	418

Low completion rate

In addition to the low response rate mentioned earlier, the completion rate was also low – around 30% in the different cohorts. Curiously, it was not just the first 30% of questions that were answered, but rather that answers were scattered throughout the pool of questions. Furthermore, under the original criterion imposed by the developers of the CLASS instrument that sets of survey responses in which more than 4 questions were skipped would be excluded from analysis, none of our sets of responses would be accepted (Adams et al. 2006). The highest completion rate of any one survey attempt in our data was 67%, which translates to 14 skipped questions.

Even amongst the low completion rates observed between the different cohorts, there was one outlier - highlighted below in Table 6.

Table 6 - Proportion of expert views and completion rates in different cohorts

Pooled responses	**Pre-/post-test**		**Retention-test**	
	% expert-view	Completion rate	% expert-view	Completion rate
Teachers (N=8, 4)	**96%**	**34%**	**96%**	**39%**
Boys (N=14, 8)	**87%**	**27%**	**91%**	**32%**
Girls (N=10, 8)	**93%**	**29%**	**87%**	**14%**

One possible interpretation of this disparity is that completion rate is a proxy for confidence. Perhaps the low completion rate of the female students on the retention-test is indicative of a reduction in confidence. This seems plausible given the higher completion rate of teachers and the expectation that they would be answering the survey questions with greater confidence.

Conclusion

The Victorian Young Physicists' Tournament certainly attracts high-caliber students. Although the CLASS survey has established reliability and validity, it is perhaps not sufficiently nuanced to distinguish meaningful attitudinal shifts in this group as they were already scoring at expert-like levels from the beginning. A concern, however, is the low response rate and low completion rate observed in this study. Whether or not the conjectured relationship between completion rate and confidence is realistic, improving the survey response rate and completion rate in studies of this type is necessary for a rigorous statistical analysis.

References

ACARA. (n.d.). "The Australian curriculum v3.0 Science: Rational." Retrieved 11 July, 2012, from http://www.australiancurriculum.edu.au/Science/Rationale.

Adams, W.K., et al. (2006). "New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey." Physical Review Special Topics - Physics Education Research **2**(1): 010101.

Ainley, J., et al. (2008). Participation in science, mathematics and technology in Australia, ACER Research Monograph 63. Camberwell, Victoria, Australian Council for Educational Research.

Duncan, D.K., et al. (2012). "Improving Student Attitudes about Learning Science and Student Scientific Reasoning Skills." Astronomy Education Review **11**(1): 010102-010111.

Eddy, R.M. (2000). "Chemophobia in the college classroom: Extent, sources, and student characteristics." J. Chem. Educ **77**(4): 514.

Goodrum, D., et al. (2012). The Status and Quality of Year 11 and 12 Science in Australian Schools. Canberra, Australian Academy of Science.

Gray, K., et al. (2008). "Students know what physicists believe, but they don't agree: A study using the CLASS survey." Physical Review Special Topics - Physics Education Research **4**(2).

Hoerger, M. (2010). "Participant Dropout as a Function of Survey Length in Internet-Mediated University Studies: Implications for Study Design and Voluntary Participation in Psychological Research." CyberPsychology, Behavior & Social Networking **13**(6): 697-700. doi:10.1089/cyber.2009.0445

Milner-Bolotin, M., et al. (2011). "Attitudes about Science and Conceptual Physics Learning in University Introductory Physics Courses." Physical Review Special Topics - Physics Education Research **7**(2): 020107-020101-020107-020109.

Office of the Chief Scientist (2012). Health of Australian Science. Canberra, Australian Government.

Osborne, J., et al. (2003). "Attitudes towards science: a review of the literature and its implications." International journal of science education **25**(9): 1049-1079.

Otero, V. et al. (2008). "Attitudinal gains across multiple universities using the Physics and Everyday Thinking curriculum." Physical Review Special Topics - Physics Education Research **4**(2).

Perkins, K. K., et al. (2006). "Towards characterizing the relationship between students' interest in and their beliefs about physics." AIP Conference Proceedings **818**(1): 137-140.

Redish, E. F., et al. (1997). "The distribution and change of student expectations in introductory physics." AIP Conference Proceedings **399**(1): 689-697.

Sawtelle, V., et al. (2009). "Validation study of the Colorado Learning Attitudes about Science Survey at a Hispanic-serving institution." Physical Review Special Topics - Physics Education Research **5**(2).

Tytler, R. (2007) "Re-Imagining science education: Engaging students in science for Australia's future." Australian Education Review.

Tytler, R., et al. (2008). Opening Up Pathways: engagement in STEM across the primary–secondary school transition. Canberra, Australian Department of Education, Employment and Workplace Relations.

Universities Australia (2012). STEM and non-STEM First Year Students. Canberra, Universities Australia.

VCAA (Victorian Curriculum and Assessment Authority) (2008). Physics Victorian Certificate of Education Study Design. East Melbourne, Victoria, Victorian Curriculum and Assessment Authority.

Wulf, R., et al. (2010). "Impact of Informal Science Education on Children's Attitudes About Science." AIP Conference Proceedings **1289**(1): 337-340.