An Exploratory Case Study of Olympiad Students' Attitudes towards and Passion for Science

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Much is known about high school students' attitudes towards science but there is almost no research on what passion for science might look like and how it might be manifested. This exploratory case study took advantage of a unique group of highly gifted science students participating in the Australian Science Olympiad (n=69) to explore their attitudes towards school science and science as presented in the Olympiad summer camp. In particular the role the summer camp might play in igniting the students' passion for science was a focus of the research. Data were collected through a two tiered survey of students' attitudes towards school science, an evaluative survey of the Olympiad summer camp and in-depth interviews with six participants. Findings indicated that Olympiad students generally had positive attitudes towards school science with most selecting science as one of their favourite subjects. However, an underlying ambivalence about school science was noted in the data. In contrast, the Olympiad summer camp transformed students' positive attitudes into passion for science. Seven themes emerged from the data providing a foundation for a model of what academic passion for science looks like.

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There is much in the literature that suggests a strong positive correlation between science achievement and attitudes towards science in high school students (Barrington & Hendricks, 1998; Thomson, 2006). There has, however, been very little exploration of the construct of passion in science education, what passion for science might look like, what ignites students' passion for science and how passion might impact their choices about science subjects and careers in science. The exploratory case study research presented in this paper took advantage of a unique opportunity to work with an extraordinary group of high achieving students, Science Olympiad students, to explore their attitudes towards the science they experience in their regular school settings as well as science as experienced through the enrichment program of the Science Olympiad summer camp. The purposeful selection of the Olympiad students in this case study facilitated the research because "students with a high level of involvement and performance can give us the most insight into passion" (Fredricks, Alfeld & Eccles, 2010, p. 21).

The International Science Olympiads are annual competitions supported by UNESCO for gifted high school students in a number of science subjects including biology, chemistry and physics. Participating countries select high school students on the basis of one or more rounds of examinations often organised through university departments. Teams of three or four students are selected from each country to participate in the international competition. The international Olympiads are rigorous and highly competitive with students undertaking examinations in both theoretical and practical science up to five and six hours duration. The purpose of the Olympiads are to:

> …challenge and stimulate students to expand their talents and to promote their career and to bring together young people from over the world in an open, friendly and peaceful mind (http://www.ibo-info.org)

In the context of this research, we considered the participating cohort of Australian high school Science Olympiad students to be gifted science students because they were successful in a national selective test for the summer camp and hence they have high academic ability as well as highly developed reasoning skills (Gagné, 1985, 1998). The literature reports that gifted students in schools present challenges. They ask difficult questions, become bored quickly, become stressed in unchallenging learning environments and feel isolated among their age peer group (Rogers, 2007; Vitale & Johnson, 1988; Watters & Diezmann, 2003). The sense of being different has led to a reported "mismatch between the curriculum, instruction and learning environment" (Hertberg-Davis & Callahan, 2008, p. 210). Recently, Fredricks, Alfeld and Eccles (2010) reported that in comparison with students who excel in non-academic fields such as music and sport, academically gifted students show little evidence of passion about their field of endeavour. Their research suggested that traditional school settings "dampened their interest" (p. 25) because there was a reported lack of challenge in their regular classes, some teachers lacked enthusiasm, it was not 'cool' to be perceived as smart and the curriculum included content that was of little practical value and relevance to the students' life outside school. One of the implications garnered from Fredricks, Alfeld and Eccles' findings was that by offering "cognitively complex tasks that are both meaningful and challenging" (p. 27) schools are more likely to become places to foster passion in gifted students.

The purpose of this case study was to explore Australian Science Olympiad students' attitudes towards science as delivered in their regular school science classes and science as delivered as part of the Olympiad summer camp enrichment program. In particular, we were interested to see if the Olympiad summer school had any role to play in igniting passion for science in the students beyond what they experience at school?

Conceptual Framework

The purpose of the conceptual framework presented in this section is to categorise and describe concepts relevant to the study and the relationships among them (Rocco & Plakhotnik, 2009). The conceptual framework was initiated with a focus on the two primary concepts of 'attitude' and 'passion' and developed through a review of the literature on students' attitudes and achievement in science, the role of enrichment programs, such as the Olympiad program, on influencing students' attitudes, and also the relevant educational literature related to passion.

Attitudes towards and Passion for Science

Because of the lack of use of the term passion in the science education literature and in an attempt to explore the similarities and differences in the terms attitude and passion we used a dictionary to provide us with contemporary definitions. Attitude is considered to be "the way a person views something or tends to behave towards it, often in an evaluative way" (Wilkes & Krebs, 1988, p. 67). Passion, in contrast, is "a strong affection or enthusiasm for an object, concept, etc." (Wilkes & Krebs, 1988, p. 832). Based on these definitions, both attitude and passion can be considered an emotional response to something (Koballa & Glynn, 2007). Attitudes represent a broad notion of the degree to which a person likes or dislikes something; as such, it encompasses ambivalence whereas passion is a very strong or intense positive emotion about something. Passion can be considered an emotion at the extreme positive end of an attitude continuum. We found an on-line definition of passion useful in that it referred to ideas such as a "compelling feeling or enthusiasm", a "lively or eager interest in an activity," and "enthusiasm toward a subject" that are consistent with a view of passion about an academic field such as science (http://en.wikipedia.org/wiki/Passion_(emotion)) Unlike the concept of passion, attitude is a concept that is well used in the field of science education. In the next section we consider the concept of attitude, in particular the notion of students' attitudes towards science, in more detail.

Attitudes towards Science

In the science education literature Koballa and Glynn (2007) define an attitude as "a general and enduring positive or negative feeling about some person, object, or issue," in this case, science (p. 78). It is important to note that the word 'science' in the phrase, 'attitudes towards science' could refer to several objects including, 'science in school,' 'science in society,' 'scientists,' and/or 'science careers.' In this research the focus was on attitudes towards science as presented as a subject in school and science as presented at the Olympiad summer camp. However, the close association between students' attitudes towards science, their science subject selection and subsequent career choice was recognised by the researchers.

Because students' attitudes are part of the affective domain, they have received much less research attention than the cognitive dimension and, according to Osborne, Simons and Collins (2003), there is much to learn. After a lull in the 1990s, research on students' science related attitudes is receiving increased attention due to the disturbing decreases in science enrolments at the secondary and tertiary levels, particularly in Western counties (Osborne, Simons & Collins, 2003). An international research program that examined student attitudes towards science, the ROSE Project (Relevance of Science Education), revealed a very strong inverse relationship between the level of development of a country and the interest students expressed in learning about science in schools (Sjoberg, 2005). A number of international studies found that although children at the primary level hold positive feelings towards science, attitudes decline with increase in age (George, 2000). Findings of several studies indicate that differences between girls' and boys' attitudes towards science develop during the primary school years (Andre et al., 1999; Jones, Howe & Rua, 2000). Moreover, many studies indicate that girls tend to have less favourable attitudes towards science than boys, and girls' interests are more focussed on the biological than physical sciences (e. g., Sjoberg, 2005).

Attitudes and Achievement in Science

Research has demonstrated a relationship between students' desire to learn science and their academic performance in science (Osborne, Simons & Collins, 2003). For example, results from the Trends in International Mathematics and Science Study (TIMSS) indicated that the degree to which students enjoy learning science has some association with science achievement and it almost certainly has an association with engagement in science leading to continued studies in the area (Thomson, 2006). TIMSS showed that, internationally, in both the Year 4 and Year 8 data, students with more positive attitudes towards science had higher average science achievement than students with medium or low attitudes towards science (Thompson et al., 2008).

Further, it was reported that in Australia, the effect of gender on science achievement is substantially explained by the differences in self-confidence in learning science such that males, with greater average self-confidence, perform better in science (Thompson et al., 2008). The reasons why girls report lower levels of self-efficacy in both science and mathematics and that these persist through university (Enman & Lupart, 2000; Preckel et al., 2008) remain a challenge for educators. Other research has shown similar trends to the TIMSS data with regard to affect and achievement. For example, working with 8th Grade students in Korea, Yoon (2009) found a causal relationship between motivation and cognition in their performance in science inquiry. Caleon and Subramaniam (2008) found a positive correlation between ability and attitudes toward science with 5th Grade boys reporting greater positive attitudes than 5th Grade girls in Singapore. They reported that "intellectual abilities go hand in hand with positive attitudes" (p. 951).

The Role of Enrichment Programs on Students' Attitudes towards Science

Increasingly, science outreach and enrichment programs are deliberately designed to attract high school students into science courses and, ultimately, science careers. Enrichment can provide powerful intellectual stimulation and opportunities to engage with scientists. As such, enrichment programs are designed at "capturing the imagination and creative spark of high school students" (Sikes & Schwartz-Bloom, 2009, p. 83). In some countries, the provision of programs to raise students' interest, participation and achievement in science addresses the concerns of underperformance and attitudes towards science (Watters & Diezmann, 2003). Lee, Matthews and Olszewski-Kubilius (2008), for example, detailed the breadth and scope of programs in the US to both search and provide for the needs of gifted students through testing and enrichment programs ranging from Saturday classes to summer camps. Tytler and Osborne (in press, p. 23) claim that while there is considerable anecdotal evidence that student learning and engagement in science are enhanced by participation in enrichment activities such as the Olympiads, the evidence base remains weak.

It is difficult to tease out the differential impact of a number of factors that can impact on students' attitudes toward science. Students have reported that experiencing an enrichment program provided them with more interesting activities and elicited better study skills and a better work ethic (Hertzog, 2003). The enrichment educational setting also can influence the speed of processing information so that an accelerated approach optimises students' learning (Duan, Shi & Zhou, 2010). The literature also suggests that harnessing both family and teacher support confers synergistic benefits on students participating in enrichment programs (Stake & Mares, 2001). Moreover, the benefits of these programs may be cumulative, so subsequent experience of another enrichment program reinforces previous positive experiences.

Attitudes that reflect personal values towards science seem to be resistant to change in a short period of time (Kotte, 1992; Stake & Mares, 2005). Some studies, however, do report a positive impact of science enrichment programs on students' attitudes towards science. For example, The Launch into Education About Pharmacology (LEAP) program with under-represented minorities in the United States showed that students made considerable "gains in biology and chemistry knowledge and interest in pursuing science" (Sikes & Schwartz-Bloom, 2009, p. 77). It remains to be seen if the positive impact of this program translates into increased enrolment and successful completion at the tertiary level. Stake and Mares (2005) described and demonstrated a 'splashdown effect' where gifted students who have been on a science enrichment program only fully realise the impact of their experience on their confidence and motivation after they return to their home school environments. The splashdown was observed to be greater in students who attended academically weaker schools. Stake and Mares results indicated that the splashdown effect of the enrichment program also led to greater engagement and success in school science. Sustained, positive attitudinal change occurred after students returned to their normal high school setting. Abernathy and Vineyard (2001) reported that students participating in the Science Olympiads in Utah, US, identified the rewards for participating as being fun, learning new things and working with friends. Although the Olympiads are highly competitive, it seems as if the cohort of students studied by Abernathy and Vineyard was intrinsically motivated and, for them, being able to win a prize was more highly valued than pleasing their parents. The purpose of the research presented in this paper was to look beyond attitudes and to explore the construct of passion for science. The next section examines the notion of passion as it relates to the academics in more depth.

Passion for Science

Passion is a concept that has been used in philosophy in a different way to the contemporary definition presented above. In philosophy, as suggested by the Latin origin of the word, passion is associated with a number of strong emotions such as anger, greed and lust. Further, passion has historically had an ambiguous relationship with concepts such as virtue and reason. For example, Aristotle noted a virtuous life was to be imbued with the passion, not devoid of it, and Hume noted that reason is, and ought only to be the slave of the passions (REF Mary). According to these philosophers, therefore, reason alone was not always sufficient to act, and that passion should also be considered a prime mover in bringing about change or transformation (REF Mary). Philosophers such as Spinoza (James, 1997) and Freud (Heller, 2005), in contrast, saw passionate emotions as more powerful than reason and a threat to living a life of reason. In the world of science itself, the paradox in the relationship between science, reason and passion is a conundrum that may have led to some of the major scientific revolutions throughout history including Newton's synthesis between forces and acceleration, Darwin's theory of evolution and Einstein's relativity (Prigogine, 1996).

The concept of passion has mostly been used with regard to educational research in the areas of sport and the arts. For example, Vallerand and colleagues (e.g. Vallerand et al., 2008; Vallerand & Miquelon, 2007) examined passion and performance in sport. They proposed that the concept of passion represents an important source of motivational energy that promotes and supports persistent involvement that in turn enhances performance. “Indeed, being passionate for one’s sport leads individuals to dedicate themselves fully to their sport, thereby allowing them to persist, even in the face of obstacles, and to eventually reach excellence” (Vallerand, et al., 2008, p. 374)

One of the few groups of researchers to consider passion in academic domains is Fredricks and colleagues (Fredricks, Alfeld & Eccles, 2010). In previous research on school engagement (Fredricks, Blumenfeld & Paris, 2004) these researchers concluded that although much has been learned, the potential contribution of the school engagement construct has yet to be realised and they called “for richer characterizations of how students behave, feel and think” (p. 59). Fredricks and colleagues based their work on the proposition that developing a passion towards academic activities is one way to counter youth discontentment with and alienation from schooling. They explored how passion was manifested among 25 high school and college students who had participated in a gifted program in elementary school. They found that passion was more characteristic of those who participated in non-academic activities (i.e. music, sports and the arts) than the academic domains and that standard school classrooms appeared to undercut rather than sustain passion (Fredricks, Alfeld & Eccles, 2010).

Fredricks, Alfeld and Eccles (2010) drew on motivational constructs such as ‘rage to master,’ ‘task value’ ‘intrinsic motivation,’ ‘personal interest’ and ‘achievement goal theory’ to explore what might be considered passion in academic domains. They concluded from the literature that:

> For an activity to become a passion, an individual will perceive the activity as valuable, devote significant time and energy to it, hold mastery goals, choose to engage in challenging tasks, experience positive outcomes during task involvement (i.e. positive emotions, flow and concentration), and incorporate the activity into his or her identity. (p. 20)

To rate students as passionate, Fredricks, Alfeld and Eccles (2010) looked for qualitative differences in the way the youth they interviewed talked about their involvement in the activities in which they were identified as either talented or gifted including sports, music and academic pursuits. These qualitative differences included: "(a) wanting to do the activity all the time and devoting significant time and energy to it, (b) getting completely involved in the activity and experiencing flow, (c) getting emotional release from the activity, and (d) seeing one's identity in terms of the activity" (p. 23). Fredricks, Alfeld and Eccles referred to the work of Csikszentmihalyi, Rathunde and Whalen (1993) to define 'flow' in terms of a rare subjective state when people become so involved in an activity they lose self-consciousness, have intense and focussed concentration and high levels of satisfaction. Identity is a construct that has recently become more prominent in the literature on attitudes towards science. For example, Cleaves (2005) used an identity framework to explain how the self-perceptions of students, including their self perceptions of ability and life aspirations, determined their decisions about whether to select science and mathematics subjects. With regard to interest, Fredricks, Alfeld and Eccles talked about "a willingness to tackle difficult problems, and positive affect and excitement" (p. 19). Emotional release was more strongly associated with passionate students in arts and drama and included feelings of enhanced happiness or escape from feelings of sadness, or from life challenges (Fredricks, Alfeld & Eccles, 2010).

Method

The design of this research was an exploratory case study, an empirical inquiry that investigated Australian Olympiad students' attitudes towards and passion for science within a real-life context (Yin, 2009), the Australian Science Olympiads. The primary purpose for undertaking a case study is to explore the uniqueness and understand the distinctiveness of an individual case (Simons, 2009). "It is through analysis and interpretation of how people think, feel and act" (Simons, 2009, p. 4) that insights and understandings are developed. These features of the case study approach made it particularly appropriate for this exploration of Olympiad students' attitudes towards and passion for science.

As stated earlier, the purpose of this case study was to explore Australian Science Olympiad students' attitudes towards science as delivered in their regular school science classes and science as delivered during the Olympiad summer camp enrichment program. To address the purpose of the research, two research questions were developed:

1. What are Australian Science Olympiad students' attitudes towards school science?
2. What are Australian Science Olympiad students' attitudes towards science as delivered as part of the Science Olympiad summer camp?

Further, the research was underpinned by the proposition (Yin, 2009) that the Olympiad summer camp had a role to play in igniting the participating students' passion for science beyond what was evident in their attitudes towards school science. In the following sections we outline the case study unit of analysis, data collection, data analysis and the trustworthiness of the research.

The Case Study Unit of Analysis: Participants in the Australian Science Olympiads

Yin (2009) explained that a problem for case study research is defining what the 'case' is. In a classic case study, a case is an individual. In this research, however, the case was more like a bounded system or program in a real life context described originally by MacDonald and Walker (1975) and later by Simons (2009) because it was the group of high school students who participated in the Australian Science Olympiad training summer camp in January 2010 at Monash University in Melbourne. The Australian Science Olympiads are well established and send teams of four or five high school students in biology, chemistry and physics to compete in the international program every year. The national program is supported and coordinated by Australian Science Innovations, a non-profit organisation (see: http://www.asi.edu.au). To qualify for a place in the camp, the students must participate in the National Qualifying Examination (NQE) taken in September. The majority of students were prepared for the NQE through participation in a school or university based program of study with a small number self nominating. In all, approximately three thousand students participate in the Australian NQE each year and from this group, the top performing 75 students were invited to the Science Olympiad summer camp in January 2010; 25 students in each science discipline of biology, chemistry and physics. The students came from a range of schools from all over Australia including private and government funded schools as well as schools located in major cities and rural localities. The students in each discipline followed a fixed timetable for the 11 days of the summer camp program. Of the total cohort, 23 biology, 24 chemistry and 22 physics students participated in this research by completing the surveys (Total n=69). Students ranged in age from 15-17 years with most students about to embark on their final year of high school. Table 1 shows the composition of the group of 2010 Olympiad students by gender and subject speciality.

Insert Table 1 about here

The Olympiad summer camp

The 2010 summer camp consisted of activities specifically designed to extend students' understanding and skills in theoretical and practical aspects of one of the disciplines of science. It is an intense experience not just for the long hours engaged in science each day but the range of activities that lie outside the scope of a normal school curriculum. Team selection for places to represent Australia at the International Science Olympiads is based on performance on practical and theory examinations during and after the summer camp. Some Australian universities credit the Olympiad summer camp program, some offer scholarships to team members, and others offer places on a prestigious undergraduate program. It is generally accepted that the level of study for the Olympiad equates to the first year of an undergraduate program in Australia with many components of each program going well beyond the demands of a first year program. (See http://www.youtube.com/watch?v=tgpTqAb9bJU.)

Data Collection

Yin (2009) asserted that a major strength of case study data collection is the opportunity to use different sources of evidence in order to develop converging lines of inquiry. Consistent with Yin's description of a quality case study, data in this research were collected by three methods: 1. A two-tier survey about students' attitudes towards school science; 2. A second survey directly targeting the students' reflections on and perceptions of the Olympiad summer camp; and, 3. In-depth interviews with six summer camp participants. The two-tier survey and interviews provided evidence to answer Research Question 1, the second survey and the interviews provided evidence to answer Research Question 2 and all three methods of data provided evidence that could be used to address the research proposition that the Olympiad summer camp had a role to play in igniting the participating students' passion for science beyond what was evident in their attitudes towards school science. This process is termed "data triangulation" (Yin, 2009, p. 116) which means that data is collected from multiple sources but aimed at converging on or corroborating the same phenomenon, in this case, the Olympiad students' attitudes towards science and their passion for science in the different contexts.

Survey 1: Attitudes towards school science

The two-tiered, pencil and paper survey enabled data to be collected from the majority of the cohort of Olympiad students who participated in the summer camp (n=69). The survey comprised five items that were extracted and adapted from a survey by Bennett and Hogarth (2009), the Attitudes to School Science and Science instrument. A key feature of the instrument is that it collects both descriptive data in the first tier and explanatory data in the second tier. As Bennett and Hogarth point out, "much attitude data are characterized by an emphasis on descriptions of the 'problem', with rather less attention paid to possible explanations" (p. 3). The instrument was based on the approach developed in the Views on Science-Technology-Society (VOSTS) study, undertaken in Canada in the late 1980s (Aikenhead & Ryan, 1992). That is, the developers drew on students' views in its development in order to generate more valid data. The six steps involved in the development and validation of the instrument are reported in Bennett and Hogarth (2005). The instrument was considered suitable for this exploratory study because of the two tiered nature of the items and the generation of both descriptive and explanatory data. Further, Bennett and Hogarth reported their findings from 16 year old students in the UK and this provided baseline data against which the data collected from the 15-17 year old Olympiad students who participated in the research presented in this paper could be compared. An example of one of the items from the survey is shown in Figure 1.

Insert Figure 1 about here

The first four items on the survey were: 1. Science lessons are among my favourite lessons; 2. My current science teacher makes me interested in science; 3. The things we do in science lessons make me interested in science; and, 4. I enjoy reading science textbooks. We altered the fifth item from 'Everybody should study all three sciences until they are 16' (Bennett & Hogarth, 2009) to 'Everybody should study science to Year 12' to better reflect the curricular context in Australia where this research was conducted. Students responded to the survey items in two steps. First they read the statement for each item, decided whether they agreed, neither agreed nor disagreed, or disagreed with the statement and circled the best response for them. Second, they circled all the reasons which applied to them and/or wrote another reason. The five items used the same format except each question had different options for the second tier of responses.

Survey 2: Olympiad evaluation survey

An anonymous, written survey was used to evaluate the Olympiad program that included questions about the academic and social aspects of the summer camp. Surveys were conducted with all students on the final day of the Science Olympiad summer camp. Responses to the four open ended questions listed below were relevant to the research questions and were included in the data analysis:

- What was the easiest part of the academic program?
- What was the hardest part of the academic program?
- What was the best part of the academic program?
- What was the worst part of the academic program?

The Olympiad evaluation survey was not specifically designed to collect data that would address the research questions for this study. Rather, the survey was designed and administered by the people conducting the summer camp with the purpose of gathering feedback to help them reflect on and improve the experiences of the Olympiad students. The independent nature of the Olympiad evaluation survey provided an excellent opportunity to gain insight into the Olympiad students' attitudes about the real-life context (Yin, 2009) of the Olympiad unimpeded by our proposition. This provided a valid source of evidence to converge in a triangulating fashion with the other sources of evidence that were designed and administered by the researchers (Yin, 2009).

Student interviews

In depth interviews were conducted with six of the Science Olympiad 2010 summer school participants. The interview protocol was semi-structured and focused on the students' experiences of science at school and their experience of science at the Science Olympiad summer camp. Comparisons between their experiences of school and summer camp science were explicitly probed as well as the impact the summer camp experience may have had on the way they viewed themselves, how others viewed them and whether the experience had changed their future aspirations. The questions on the interview protocol included the following:

1. Tell me about how you find science at school?
2. Do you find school science interesting?
3. Do you find school science challenging?
4. Do you find school science motivating?
5. Has your Olympiad summer school experience been different from your school science experience? How? (explore such things as curiosity, motivation, drive etc.)
6. Has the Olympiad experience changed your ideas about what you want to do in the future?
7. What have you found out about yourself through the Olympiad experience?
8. Has your view of yourself changed because of the Olympiad experience?
9. What is science to you? Is it a school subject, or is it something different for you?
10. How do you think being on the Olympiad team has changed the way that other people see you?
11. Do you think that representing Australia in the Olympiad has the same meaning as representing Australia in swimming?

Consistent with the research questions, the interview protocol was designed to explore the students' attitudes towards school science and towards science as presented at the Olympiad. The interview protocol did not directly use the word passion or associated words such as passionate in order to allow the students to describe their affective feelings in their own words without deliberately introducing the construct in which the researchers were interested. All interviews were digitally recorded and fully transcribed.

Data Analysis

According to Yin (2009) data analysis consists of examining the evidence to draw empirically based conclusions about the propositions and that every case study should follow a general analytic strategy, defining priorities about what to analyse and why. In this section we outline the methods used to analyse the raw data and how they were brought to bear on the two research questions and the research proposition.

In order to answer Research Question 1, about the Olympiad students' attitudes towards school science, the two tiered surveys were collected, coded and the data entered into SPSS (Statistical Package for the Social Sciences) software. Due to the nature of the data collected from the two tiered survey (Survey 1) and consistent with the research design being an exploratory case study, descriptive statistics were generated to provide broad-brush information about this group of Olympiad students and their attitudes towards science. The data were analysed by first and second level responses. Comparisons were made with the 16 year old students surveyed by Bennett and Hogarth (2005), first by the generation of graphs and visual inspection and then by statistical analysis to provide some basis for making a judgement about the Olympiad students' attitudes towards school science. Bennett and Hogarth surveyed 98 male and female students from four, all-ability (comprehensive) secondary schools in the UK. Two schools were from a city, and the other two were from a town and a semi-rural area. Based on external examinations and tests, three of these students were classified as low ability, 50 as middle ability and 45 as high ability in science. We used a Chi-square test of contingencies to assess whether the Olympiad responses to the survey items could be considered different from those provided by the sample studied by Bennett and Hogarth (2005) (Allen & Bennett, 2008). Qualitative data from the Olympiad students' comments on each of the five questions on the two tier survey were scrutinised for evidence that supported and refuted the general trends evident in the quantitative data and examples selected on this basis to include in this paper.

In order to answer Research Question 2, about the students' attitudes towards science as delivered through the Olympiad summer camp, qualitative data generated by the Olympiad evaluation survey (Survey 2) and the student interviews were subject to a six step analysis process as described by Creswell (2009). The first step of the data analysis involved organising the raw data from the surveys and interviews by transcribing all written and verbal responses from students into word documents. The second step of the data analysis was for the two researchers (the co-authors) to read all the prepared data. In the third step of the analysis, data were coded using a combination of predetermined codes and emerging codes as suggested by Creswell (2009). The four pre-determined codes were a) time, b) involvement, c) emotion, and d) identity that emerged from empirical research conducted by Fredricks, Alfeld and Eccles (2010) to identify students with passion. A description of the codes as used by the researchers in this third step of the analysis process in the current study follows:

a) Time: Wanting to do the activity all the time and devoting significant time and energy to it;
b) Involved: Getting completely involved in the activity and experiencing flow;
c) Emotion: Getting emotional release from the activity; and,
d) Identity: Seeing one's identity in terms of the activity.

Data that supported or refuted the ideas represented by these codes were highlighted by the two researchers independently using colour codes and margin annotations. It was expected that new themes would emerge from the data because these four categories were initially used to describe passion about an 'activity' such as playing a violin or participating in soccer, rather than an academic discipline *per se*.

Step 4 of the data analysis (Creswell, 2009) involved using the codes and annotations on the raw data to generate new themes that better represented the students' reflections on their experiences of the Olympiad summer camp. This step was conducted collaboratively between the two researchers and involved reconciling their independent codes and annotations and generating initial words to describe the new themes. The seven new themes were represented by the following words: immersion, extension, emotion, inclusion, achievement, mastery and identity. Once these themes had been identified, excerpts from both the Olympiad evaluation survey and the student interviews that both confirmed and did not confirm the new themes were electronically rearranged into each theme so that they displayed "multiple perspectives from individuals" and were "supported by diverse quotations and specific evidence" (Creswell, 2009, p. 189). An example of the confirming and disconfirming excerpts coded under the 'extension' theme are shown in Figure 2.

Insert Figure 2 about here

Step 5 of the data analysis (Creswell, 2009) involved constructing the narrative passage to convey the findings and represent the multiple perspectives of the individual Olympiad participants. To do this we underlined key words and phrases in each of the excerpts that had been coded in each theme as illustrated in the extension theme presented in Figure 2. The narrative was then constructed to reflect as succinctly as possible the meaning conveyed by these key words and phrases. In order to limit the quantity of raw data presented in the paper, a small number of quotations were selected to include with each narrative. Words and phrases that were direct quotes from the excerpts were highlighted with double quotation marks in the narrative to give a sense of the students own words. Excerpts that demonstrated how the Olympiad students differentiated school science from their experience of science at the Olympiad summer camp were specifically targeted to include in the findings section of this paper because they would best allow readers to understand the researchers' interpretations with regard to the research proposition.

Finally, Step 6 of the data analysis involved making an interpretation of the data (Creswell, 2009). This involved comparing the findings with information from previous published literature, in particular, the published literature referred to in our conceptual framework. Importantly, this step also involved the generation of a visual representative of the findings as an initial model of passion for science that emerged from this exploratory research. Further, the final step of the data analysis involved a discussion of the meanings and implications that this new model might have for classroom practice and for further research.

Trustworthiness

Creswell (2009) recommends actively incorporating multiple strategies to enhance the accuracy or trustworthiness of findings and suggests eight primary strategies of which we have used three. First we used triangulation (Creswell, 2009) in a multifaceted manner. The three methods of data collection resulted in robust triangulation of both quantitative and qualitative data for each of the research questions. Research question one was addressed by data collected through Survey 1 on students' attitudes towards science as well as the in-depth interviews. Research Question 2 was addressed by data collected through Survey 2, the Science Olympiad summer camp evaluation survey as well as the in-depth interviews. All three methods of data collection resulted in the generation of data that could be brought to bear on the research proposition. Second, the researchers systematically sought both confirming and disconfirming evidence in all the different types of data as is exemplified in Figure 2 where data both confirming and disconfirming the research proposition are presented. Third, the researchers sought to present a detailed or rich and thick description (Merriam, 2009) of the findings to enable the reader to make her or his own conclusions and interpretations with regard to the outcomes of the research. To facilitate this process, a data trail was maintained that allows the original source of the raw data to be traced.

Findings

In this section, the findings from the two tiered survey are presented first and then the findings from the Olympiad summer school evaluation survey and student interviews are presented. Codes in parentheses after student quotes are used as a data trail and represent the data source (S1 – Survey 1; S2 – Survey 2; I - interview), the student identification code (01-69 or anon – anonymous), and the discipline of science the student was involved in during the Olympiad summer camp (B- biology, C - chemistry or P - physics). Hence a code of 'S1/22/B' would indicate the data came from Olympiad student number 22's responses to Survey 1 and that this student was a biology specialist and a code of 'S2anon' indicates the data came from an anonymous respondent to Survey 2.

Research Question 1: Olympiad Students' Attitudes towards School Science

Table 2 presents the Olympiad students' responses to the first tier of items on Survey 1 about their attitudes towards school science in comparison with the 16 year old cohort investigated by Bennett and Hogarth (2005). The chi squared test indicated that on all items, except 'The things we do in lessons make me interested in science' the Olympiad students' responses were significantly more positive when compared with the UK students as reported by Bennett and Hogarth (2005).

Insert Table 2 about here

In response to the statement 'Science lessons are among my favourite lessons' 82.4% of the Olympiad students and only 26.5% of the Bennett and Hogarth (2005) sample agreed (Table 2). Many of the Olympiad students supported their first level choice to this item with more than one explanatory reason resulting in a total of 124 reasons being selected. Almost two thirds of responses indicated the Olympiad students like the topics studied at school and more than a third of responses indicated the Olympiad students found the topics studied at school easy and that they liked discussions. Some of the students wrote comments, for example, "I love all my subjects, science or otherwise" (S1/48/P) that indicated that they may be positive about school and academic pursuits in general. Several students commented that school science lessons are not intellectually stimulating experiences. For example, one student wrote

“I find most of my subjects interesting. I would like to be challenged more” (S1/51/P) and another commented that, “[Science is] easy and oversimplified” (S1/60/P).

While almost 60% of the Olympiad students agreed with the statement that ‘My current science teacher makes me interested in science’ more than 30% selected the neither agree nor disagree option to this item suggesting they were ambivalent or negative with regard to the degree to which their school science teacher makes them interested in science (Table 2). In comparison, only about 30% of the Bennett and Hogarth (2005) sample agreed with this statement (Table 2). Analysis of the second layer of responses showed that the main reason Olympiad students felt their school science teacher makes them interested in science is because he or she is enthusiastic (50%) and the teacher makes them think (35%). For example, one of the students wrote that, “He’s charismatic and a guru” (S1/54/P). In contrast with these opinions, nearly a third of students in total supported their choice of ‘neither agree nor disagree’ to the first layer of this item with the supporting statement: ‘How I feel about science is nothing to do with my science teacher’ which suggests that their positive attitudes towards science are generally independent of their teacher. This idea was supported with several written comments, for example: “If the topic is interesting, I will like it anyway” (S1/30/C); and, “[My teacher] makes me sleep” (S1/63/P).

More than sixty percent of the 69 Olympiad students agreed with the statement that ‘The things we do in science lessons make me interested in science’ (Table 2). In comparison, only 44.3% of the Bennett and Hogarth (2005) sample agreed with this statement (Table 2). This was the only survey item where the two cohorts provided patterns of responses that were not significantly different (Table 2). The Olympiad students provided a total of 179 reasons in the second tier of responses, 45% of which indicated they were interested by the topics they study. fewer students said they were stimulated by putting their own points of view forward (16%) or working in groups on activities (8%). The small number of statements selected to accompany the disagree response to this item about science lessons included doing too much writing or little variety in the lessons. Students further elaborated their reasons: “Sometimes gets boring” (S1/53/P); “Too much basic memorising” (S1/29/C); and “Too simplified, too slow, too formulaic” (S1/64/P).

The Olympiad students responded very positively to the item ‘I enjoy reading science textbooks’ with 70.6% selecting ‘I agree’ (Table 2). In comparison only 25% of the Bennett and Hogarth (2005) sample agreed with the same statement (Table 2). The Olympiad students also selected many reasons (n=179) in the second tier of this item. Nearly one half of the second tier of responses indicated they like finding things out for themselves and, for some, books are a source of information as the following comments illustrate: “To clarify, to see pictures, diagrams … I only like parts of the textbook” (S1/07/B); “Widens knowledge and enjoyable to read about new things outside bubble of school existence” (S1/69/P). Some students expressed being extended though textbooks, “I can read further than my course requires” (S1/29/C). Of the 25% of students who did not enjoy reading science textbooks, some preferred listening to their teacher: “Teachers let you know what you need to know and why” (S1/16/B); others simply didn’t enjoy reading them, “I read but I don’t enjoy” (S1/34/C); and others found textbooks to be limited, “All the textbooks are very restricted. I enjoy normal science books, though” (S1/39/C).

School science is not a compulsory subject from Year 11 in Australia (when students are 15-16 years of age). The survey item, ‘Everyone should study science until the end of Year 12’ was not well endorsed by the Olympiad students with less than a third (31.9%) agreeing with this statement (Table 2). In comparison, 48% of the 16 year old UK students surveyed by Bennett and Hogarth (2005) gave positive responses to this item (Table 2). The Olympiad students selected 129 options on the second explanatory tier of this item. Nearly 40% selected the two responses: ‘People should be allowed to study the subjects they are best at’ and, ‘People should not be pushed into some subjects more than others’. In written comments students further explained their positive responses: “The world is incredibly science based and to move forwards everyone needs a basic understanding of science” (S1/39/C). More ambivalent students wrote: “People should have the choice but be aware of the benefits” (S1/49/P); and, “Being pushed into learning won’t enhance their understanding and acceptance” (S1/07/B). Another student displayed a self-interested reason for his/her negative response, “It makes lessons better for those who enjoy it” (S1/35/C). Recognising that Olympiad students are a self selecting group of highly committed science students, it is a noteworthy finding that they do not advocate science lessons for all.

Research Question 2: Olympiad Students’ Attitudes towards the Science at the Summer Camp

In this section of the findings we present a short description and analysis of each of the seven themes that emerged from the second survey and interview data about the students' reflections on their experiences of science as delivered at the Science Olympiad summer camp. The seven themes are: immersion, extension, emotion, inclusion, achievement, mastery and identity.

Immersion

Olympiad students expressed feelings of being immersed in a challenging environment to learn science, their minds being bathed in knowledge through "absorbing", "revising" and "applying" (I/32/C). They found this immersion stimulating and challenging.

> It's such an incredible experience to learn so much and to be immersed in an environment with so many talented people. You won't forget it! The best thing is not being bored, being around like-minded individuals. (S2/anon)

The students expressed being "driven to study", they loved the fast pace and "intensity" (S2/anon) which was something they "haven't found at school" (I/42/C) and that they had to structure and plan their study time carefully because of the quantity of information and the difficult level at which it was presented. For many of the students, this was the first time they had to "organise myself into like studying" (I/42/C).

The responses from the students indicated that they felt immersed in science and in a learning environment with other like minded people and that this precipitated for them learning of new skills in time management and organisation. Previous research has shown that students who are passionate about sport or the arts devote significant time and energy to their passion and want to do the activity all the time (Fredricks, Alfeld & Eccles, 2010). As a consequence, one of the initial, pre-determined codes for data analysis was 'time', however, the findings indicated that the term 'immersion' was used by the students themselves and was a better descriptor for the theme. While the nature of the Olympiad program was an immersion enrichment program, they identified this aspect of the program as being "incredible" (S2anon) and different to the science they experience at school. There was little evidence of the phenomenon described as 'flow' by Csikszentmihalyi, Rathunde and Whalen (1993) where people lose self awareness while they are involved in the activity, rather, the expressions used by the students conveyed a sense of immersion and fulfilment. The concept of 'flow' or 'being in the zone' is achieved when the level of challenge and skill demanded to execute a task are both high and flow is considered to indicate the most optimal state of intrinsic motivation.

Extension

The students expressed great appreciation at being extended by the Olympiad program beyond what they thought they might be capable of. They said they had not felt such challenge previously and that through the Olympiad program they had gone “beyond” (I/64/P) what they did at school and that this was “rewarding” (I/64/P).

> I realised exactly how much further I'd extended myself than my other classmates and what an excellent program this is. It established a certain thirst for knowledge and appreciation of the intrinsic value of learning that I'm not sure I'd felt before and that I doubt many of my [school] classmates have. It also significantly strengthened my interest in biology, so much so that I think I may have to reconsider my university course aspirations (although I hope that my change in heart is genuine and not a vain effort to relive the excitement of the Olympiad program). (S2/anon)

Students explained that the type of problems they experienced during the Olympiad “stretches you a lot more” (I/39/C), and “the demanding nature of the program” (S2/anon) resulted in “rigorous academic development” (S2/anon). Several students commented that, in comparison, school science was “very bland” (I/06/B), involves “rote learning” (I/64/P) and “churning out formulae” (I/64/P), that they “forget it pretty quickly” (I/64/P), rather than focussing on ”transferable skills” (I/64/P) such as “how to analyse critically” (I/64/P).

The literature supports the notion that interest and engagement will be enhanced when learning tasks have a moderate level of difficulty (Stanley & Baines, 2002). The importance of challenge for cognitive development in the science classroom also is well documented (Shayer & Adey, 2002). Vygotsky’s extensive body of work on the zone of proximal development contends that development within a particular domain is most likely to occur in a zone beyond the current understandings of the student, but not so far ahead that the new learning is beyond them (Tudge, 1990). This body of research supports this theme in association with the concept of passion. It is plausible that school science often does not extend the Olympiad students and hence they are bored. The instruction during the Olympiad summer camp was possibly more within, in Vygotsky’s terms, the zone of proximal development for these students. We contend that this extension has contributed to the precipitation of passion for science for many of these students.

Emotion

Strong emotive words including “love”, “stress”, “fun”, “intensity”, “excitement”, “scary” and “adrenalin rush” were expressed by the students when explaining their Olympiad experiences. “I enjoyed the intensity of the challenge. It was tough, stressful, and very fun. I’m glad I came” (S2/anon).

> It’s really rewarding when you solve a problem that you can’t really do, and it’s almost exciting to think about things at a much higher level, and to be in a room and you’re given these questions. Although it’s a bit scary, you have to try and think about why things are happening. You make the connections and it’s a bit of an adrenalin rush. (I/64/P)

One student explained that while she previously had a “simmering interest” in chemistry and she “liked dabbling in it… being at the Olympiad really made me love chemistry” (I/39/C).

In contrast with the strong emotions expressed by many students, one student expressed confusion and an inability to differentiate between enjoyment and achievement. “I find it really hard to differentiate between what I enjoy and what I do well at… I don’t know whether I just enjoy all of the stuff which I get to do through it” (I/64/P). This same student also commented that school science didn’t motivate him because, “we’re learning it because it’s in the syllabus.”

One of the initial codes used for the data analysis was ‘emotion’ because Fredricks, Alfeld and Eccles (2010) found that students who were passionate about the arts and drama often reported emotional release from participation, students reported feeling happier and escaping from life, but they also expressed love for what they were doing. In this research, participating students did not mention the escaping from life type of emotional release, but they did use emotive words and expressions and reported intense excitement about the science they were involved in during the summer camp.

Inclusion

Students expressed feelings of acceptance, being safe and being with “like-minded people” (S2/anon) while at the Olympiad.

> I feel that I can be more myself around the people that do the Olympiad than everyday people, and everyone seems to be kind of very accepting. Obviously everyone is really smart and they’re not really judgmental or anything like that. It’s kind of quite safe, you don’t have to restrict yourself. (I/05/B)

Their comments portrayed a notion of inclusion, that the Olympiad made them feel part of a group of people who had similar goals and abilities and that they could be who they are without fear of embarrassment or ridicule.

Fredricks, Alfeld and Eccles (2010) reported that youth in extension programs in the sports and arts showed evidence of passion because they were more likely to have supportive peers. Conversely, these researchers found that some students felt that their academic interests were not supported by their peers in school. Gifted or advanced placement programs, however, offered an opportunity for students to be around others who had similar goals and values and supported their academics. The findings from this study supported the idea that feeling passionate about science is enabled by students being part of a group of people with similar feelings.

Achievement

A sense of achievement or “rigorous academic development” (S2/anon) was how several Olympiad students expressed their reflections on their summer school experience. They said it will be an “unforgettable part of my adolescent life” (S2/anon), that it was inspirational and demanding and empowered them by making them feel they can “change the world” (I/11/B).

> The idea that we'd essentially covered a whole year's worth of university level biology in two weeks, without most of us having finished high school biology inspired me. I realised the capabilities of the scholars; not only in terms of the material we'd covered but also in our ability to cope with the intensity of the pace and the demanding nature of the program. These things together left me (and I'm sure the others) with an undeniable sense of achievement. (S2/anon)

Some students felt that this sense of achievement was heightened because other students now “sort of look up to me a bit… they tend to come over and gravitate and ask things” (I/39/C) and that this gave them feelings of pride and a sense of status amongst their peers. They said that their achievement was made public through their Olympiad experience and that their academic achievement had rarely been previously experienced through their high schooling experiences. Similarly, Fredricks, Alfeld and Eccles (2010) noted that a possible explanation for the higher incidence of passion in some youth is that they were more likely to receive frequent public recognition and positive feedback about their ability and for their involvement.

Mastery

The Olympiad students found that the summer camp experience had developed within them a new understanding about learning being something that involves thinking and understanding and that learning is something that they had control over. "We were taught a new way to learn stuff in general" (I/11/B). They found new ways of learning and thinking "I could actually learn this way" (I/11/B) that they had not previously been exposed to and they also associated this with enjoyment.

> It's more about understanding rather than knowing and just memorising. I think I've learnt that, for me, it's so much easier to learn when I'm actually enjoying myself. I think that's the same for a lot of people, and sometimes I don't have to be forced to do work! (I/06/B)

The approach taken to learning during the Olympiad program was contrasted by one student with the approach they had experienced during school science. "We think about what we're doing, whereas at school we just churn out the numbers and we learn no first principles, and I think that's a big problem" (I/64/P). This different approach to learning can be explained by achievement goal theory and the distinction between mastery and performance orientation. A student with a mastery goal orientation focuses on mastering and understanding the task whereas a student with performance goal orientation focuses on performing better than her or his peers (Koballa & Glynn, 2007). Mastery goals are generally associated with more adaptive learning outcomes and it seems that the approach taken at the Olympiad summer camp encouraged this approach and contributed to students becoming passionate about science. These characteristics resonate with reports of "greater affect, potency (i.e., feeling energetic), intrinsic motivation, flow experience, and undivided interest" (Rathunde & Csíkszentmihályi, 2005, p. 341) in middle school students where self direction and intrinsic motivation are highly emphasised.

Identity

There were a number of comments from students who felt that participation in the Olympiad had resulted in them rethinking their career options, for example, from commerce/law, to science (S2/anon), confirming that they wanted to become a scientist (I/64/P), or that they enjoyed the lab work during the Olympiad and that it made them want to become a research scientist (I/11/B).

> I wasn't really sure whether I was good enough to do science, so I guess Olympiad has shown me that I'm at an adequate enough level to pursue it later on. Lots of people already saw me as being into physics… but I guess it's kind of cemented that people view me as that. I don't think it's in a very pejorative way, most of my friends have been really supportive, and that it's really cool. (I/64/P)

One student explained that "I've always been tossing up between doing music and science" but the "Olympiad probably has pushed me a bit more towards science" (I/42/C). Several students made comments such as: "I feel that I can be more myself around the people that do the Olympiad than everyday people" (I/05/B). Another said she, "realised I'm more of a "science-y type person" (I/11/B). These comments reflected the impact the Olympiad summer camp had on the students' sense of personal identity. Identity is a concept that is becoming more prevalent in the published research on students' attitudes and it is now becoming accepted that children's interests and engagement with science will be shaped by their sense of self, how they do and do not see themselves now and in the future (Archer et al., 2010). The findings showed that previously, many of the Olympiad students in this study had not integrated science into how they saw themselves, or who they thought they might become. The Olympiad experience resulted in them becoming comfortable and 'cool' with the idea that science is a part of their personal identity that they may nurture through further study and/or a future career.

Discussion: The Olympiad, Igniting Students' Passion for Science

The findings from this case study showed that the Australian high school students who were selected to participate in the Science Olympiad summer camp in 2010 had generally positive attitudes toward school science and significantly more positive attitudes towards school science compared with students of a similar age from comprehensive high schools in the UK (Bennett & Hogarth, 2005). More than 80% agreed that science lessons are among their favourite lessons, mostly because they like the topics studied at school and they do well in science. Underpinning these positive attitudes, however, was a tone of ambivalence that was indicated in the qualitative data from the surveys and interviews. For example, students commented that they found science at school easy and therefore didn't need to put in extra effort and that they found the nature of school science somewhat restrictive, formulaic, oversimplified and lacking in relevance. These findings resonate with the findings of other research on gifted students for example, Fredricks, Alfeld and Eccles (2010), whose research suggested that traditional school settings "dampened their interest" and tends to undermine rather than support passion about academics (p. 25). The positive attitudes towards science seemed to reflect an importance to the students of being a 'good student' in general rather than any acute interest in, or passion for, science. Fredricks, Alfeld and Eccles (2010) came to the conclusion that "school settings, and especially regular classrooms as compared with gifted and advanced classes, appeared to undermine rather than support passion" (p. 18).

We found that the Olympiad students who participated in this study had positive attitudes towards school science but the passion was lacking. The findings revealed that the Science Olympiad summer camp developed in many of the students something that we feel can be described as academic passion and that it was manifested because of the unique environment of the Olympiad that precipitated for the students feelings of immersion, extension, emotion, inclusion, achievement, mastery and identity, that collectively can be considered to represent what passion for science might look like. Figure 3 provides a schematic representation of the notion of academic passion for science that emerged from the findings of this research.

Insert Figure 3 about here

In contrast with the students' reflections on their school science learning environments, their reflections on science as experienced at the Science Olympiad summer camp is much more in concert with what we described as passion in the introduction to this paper. The themes that emerged from the findings reflect the aspects of the Olympiad summer camp that raised their attitudes toward science from positive to passionate. The students felt completely immersed in learning about science, they were academically extended beyond what they had experienced previously (Tudge, 1990) and the work they did precipitated for them intensely positive emotions about science, for example it gave one person an "adrenalin rush" and made another, "love chemistry". Students spoke of feeling part of a group of like minded people, they felt cared for, included and safe (Fredricks, Alfeld & Eccles, 2010). It has been reported that feelings of alienation, or not being like the other students, are common for gifted students in school environments (Rogers, 2007). Further, the students at the Science Olympiad summer camp had a sense of achievement as a result of participating in the academic activities and they discovered new ways of learning that gave them a sense of mastery (Koballa & Glynn, 2007). Most importantly, the summer camp helped the participating students to rethink their identity and to incorporate notions of being a science person, being proud of being a science person and visualising a future closely aligned with science (Archer et al., 2010). Each of the themes that emerged from the findings were confirmed by the literature as factors that could potentially contribute to passion about an academic domain such as science.

Implications for Practice and Research

The implications of the findings of this study are important for school settings and for informal education or providers of academic enrichment programs. If they want to develop in students a passion for science, then they should explore each of the aspects of academic passion that we have identified in Figure 3 and what they might mean in terms of their program and how these aspects of passion can be encouraged within their participating students. For example, how can a program be developed to give the participating students a feeling that they have been immersed in science and that they are being academically extended beyond where they have been taken previously in their educational experiences? How can the students be enthused about the subject matter to the point where they express emotions such as excitement or love for the subject matter? It is important for education providers to help participating students to feel included, safe and part of a team or group of like minded people where they can be themselves and express their ideas openly. Coupled closely with the notion of extension is achievement. Students need to feel a sense of achievement in order to become passionate about science; they need to feel that they have done something special and outstanding. Further, how can educational programs give students a sense of control of their own learning and provide them with effective ways of learning that are about mastering the concepts rather than doing better than their peers? Finally, to develop passion, a program needs to enable students to incorporate science as part of their identity. A program that brings about passion for science will enable the students to feel comfortable and 'cool' with the idea that they are a 'science-y' person and that they will have a future tied up with this academic field.

The findings also have implications for further research. This study was an exploratory study and the model that emerged from the findings as is presented in Figure 3 is the first description, to our knowledge, of what passion for science might look like. It is important to test this model with further research in different settings and with different students of different ages to see how well the model stands up to empirical testing and to see if modifications and elaborations are needed. For example, a more focussed examination of highly gifted students may reveal whether they are able to achieve a state of 'flow' when "they are doing something that is worth doing for its own sake ... and that they wish to replicate [that specific experiential state] as often as possible" (Csíkszentmihályi & Csíkszentmihályi, 1998, p. 29). The model may also be used as a starting point for the theoretical constructs needed for the development of a survey to measure the degree to which students have passion for science (Fowler, 2009).

Limitations

There are several limitations of this research. As we have previously pointed out, the exploratory nature of the research meant that established methods and instruments were not available for ascertaining students' passion towards science. As a consequence, we used an instrument used to measure students' more general attitudes towards science (Bennett & Hogarth, 2009). Case study design also has limitations. The advantage of limiting the research to a case study of the Olympiad, a group of gifted science students, increased the likelihood of observing passion (Fredricks, Alfield & Eccles, 2010), but also meant that we did not explore passion in other groups of students and in other contexts.

Concluding Comments

The data presented in this paper supported the research proposition. While the Olympiad students had positive attitudes towards science at school, they also reported that they found it somewhat standard and rigid. In comparison, science as experienced at the Olympiad summer camp gave the students a sense of being passionate about science. Coleridge once remarked about science "being necessarily performed with the passion of Hope ...was poetical" (Ferry, 2009 p. 34) and that engaging hearts and minds in and with science continues to be a goal in science education for all.

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	Biology	Chemistry	Physics	Total
Male	11	18	17	46
Female	12	6	5	23
Total	23	24	22	69

Table 1: Composition of the participating Science Olympiad students by speciality and gender

Statement and response	% Olympiad group (n=69)	% Bennett & Hogarth group (n=97)	Chi-square	P value
1. Science lessons are among my favourite lessons				
Agree	82.4	26.5	50.722	<.001
Neither	14.7	49.0		
Disagree	2.9	24.5		
2. My current science teacher makes me interested in science				
Agree	59.4	30.9	19.331	<.001
Neither	31.9	34.0		
Disagree	8.7	35.1		
3. Things we do in lessons make me interested in science				
Agree	60.9	44.3	4.513	Not significant
Neither	26.1	35.1		
Disagree	13.0	20.6		
4. I enjoy reading science textbooks				
Agree	70.6	25.0	33.162	<.001
Neither	4.4	12.5		
Disagree	25.0	62.5		
5. Everybody should study science to Year 12 (this study)				
5. Everybody should study all three sciences until they are 16 (Bennett & Hogarth, 2009)				
Agree	31.9	48.0	4.325	<.05
Neither	18.8	7.1		
Disagree	49.3	44.9		

Table 2: Participating Olympiad students' responses to the first tier of items on the survey about their attitudes toward school science in comparison with data from 16 year old UK students attending comprehensive high schools provided by Bennett and Hogarth (2009)

Figure 1: An example of one of the questions from the survey (Bennett & Hogarth, 2005)

Science lessons are among my favourite lessons

I agree because…		**I neither agree nor disagree because…**		**I disagree because…**	
a	…I like the topics we have studied.	k	…it depends on what we are doing.	p	…I don’t like the topics we have studied.
b	…I find the topics we have studied easy.	l	…science lessons are nothing special.	q	…I find the topics we have studied hard.
c	…I like being able to put my own ideas forward.	m	…I am not really in to being at school.	r	…I don’t like discussions.
d	…I like the discussions we have.			s	…I would prefer to do more practical work.
				t	…what we do is boring.
x	… another reason – please say what.	y	… another reason – please say what.	z	… another reason – please say what.

Figure 2: Examples of excerpts from raw data coded under the theme 'extension'

Source/student code/speciality	Examples of excerpts related to 'extension' theme
	Confirming proposition
Survey 2/anonymous	I realised exactly how much <u>further</u> I'd <u>extended</u> myself than my <u>other classmates</u> and what an excellent program this is. It established a certain thirst for knowledge and appreciation of the intrinsic value of learning that I'm not sure I'd felt before and that I doubt many of my classmates have. It also significantly strengthened my interest in biology, so much so that I think I may have to reconsider my university course aspirations (although I hope that my change in heart is genuine and not a vain effort to relive the excitement of the Olympiad program).
Survey 2/anonymous	Never have I been this <u>extended</u> in my school studies. It's been very rewarding. It was all <u>quite challenging</u>. The best things were the people and the friendships I made.
Interview/64/physics	So I guess I've always been interested in taking it <u>beyond as well</u>, and <u>school doesn't really let me do that</u>, so I guess I have been interested in that for a while, but <u>Olympiad has allowed me</u> to pursue that.
Interview/39/chemistry	I think it really <u>stretches you</u> a lot more, because the <u>type of problems</u> that you get in the Olympiad are <u>really different</u>.
Interview/06/biology	<u>School science is very bland compared to what we do here</u>, so it can be interesting if it's something I haven't learnt before, but generally it's very basic, and not very challenging.
Interview/64/physics	In my units <u>[at school], it doesn't really involve real scientific thinking</u> because we're churning out formulae, we're doing a lot of rote learning, and we're not learning how to analyse critically, and I think that's a really big problem because they're not transferable skills, we're just learning material, and then we forget it pretty quickly.
	Disconfirming proposition
Interview/39/chemistry	I don't know, I really feel like the chemistry, my only motivation is to get a good mark, because I know that I can do it, and I feel like I'd be letting people down if I didn't get a good mark.

Figure 3: A schematic representation of passion for science that emerged from the findings of this research