香港資優教育學苑
The Hong Kong Academy for Gifted Education

RCAGE 18/19

Review of the Impact of International Physics Olympiads (IPhO) Training on Gifted Alumni

1. Background

Academic competitions have long been a channel to provide advanced and challenging learning experiences for gifted students. In Hong Kong, different competitions and the related trainings are recognized as an important part of the off-site provisions for Gifted Education. There are clear evidences showing that Hong Kong students have performed consistently well in several well-renowned international competitions in STEM, for example the International Mathematics Olympiad (IMO), International Junior Science Olympiad (IJSO) and International Physics Olympiads (IPhO) etc. While what they achieved can reflect their excellence in these specific areas, the number of awards was certainly not the sole goal of the training programmes. Besides, since the Hong Kong Olympiad team was composed of a very small group of selected students, their achievement might not be able to reflect the pool of all gifted students who have participated in the related trainings.

This is one of the few studies to examine the impacts of competition-related training programmes on the scientifically gifted students. In this study, we would define the impacts of the training programmes in a broader sense including the following aspects: 1) Science related outcomes (e.g., Interests in Science, Science self-efficacy, and Study and career aspirations); 2) Life-relevant and socio-emotional skills (e.g., Affective & non-cognitive skills, and Social & leadership skills); and 3) Engagement in STEM learning over time, as well as their academic and career choices in STEM-related fields.

2. Method

A retrospective survey was conducted with those alumni who have participated in the competition-related training programmes. For the purpose of capturing the longer-term impacts associated with certain kinds of long-term assessment, retrospective analysis is an alternative approach that has been widely used in several Olympiad studies (e.g. Campbell 1996). In addition, semi-structured interviews were conducted with some respondents of the survey so as to supplement the quantitative data with more in-depth qualitative information.

2.1 Procedures

This study focuses on the training programmes prepared for the International Physics Olympiads (IPhO). Based on the alumni database, all the alumni who have ever joined the IPhO training before 2016/17 were invited to complete the online survey in June 2018. A total of 476 email invitations were sent to those alumni who had valid email address. However, it is estimated that more than 800 of students have joined the IPhO training programmes since the first participation of IPhO of Hong Kong team in 2003. In other words, the population target of the study generally covered 60% of the former participants of IPhO trainings. After the survey, individual interviews were conducted with those respondents who agreed to join the follow-up interviews. The online questionnaire was designed and comprised the following two sections:

Section One

This section focused on the participants' experiences in the training programme and their self-reported impacts on them. Table 1 illustrates the basic framework of the potential outcomes.

Regarding the science-related outcomes, three aspects were identified based on PISA 2015 framework for science (OECD 2017), namely: *Interest in Science*, *Science Self-efficacy*, and *Study & Career Aspirations*. Regarding life-relevant and socio-emotional skills, two aspects were defined in the context of training programmes, namely: *Affective & non-cognitive skills*, and *Social & Leadership skills*. Although these were not explicitly taught in the training programmes, the skills (e.g. self-regulation, persistence and open-mindedness) could be acquired through the serious commitment of the participants and the diversified learning atmosphere.

Table 1 Basic framework of potential outcomes

(i) Science-related outcomes

Aspects	Items	Remarks
Interest in Science	1. Curiosity about the world	Items 4 and 5 were related to the application of science in daily life. Items 6 and 7 were related to the perceived competency in epistemic knowledge and valuing science (OECD 2017)
	2. Interest / passion in science	
	3. Knowledge about science	
Science Self-efficacy	4. Ability to apply science knowledge and skills in everyday life	
	5. Confidence to deal with science-related tasks in the future	
	6. Ability to appreciate the tentative nature of science	
	7. Ability to evaluate 'evidence' and claims in science-related matters	
Study & Career Aspirations	8. Interest in pursuing science-related subjects	
	9. Interest in pursuing science-related careers	

(ii) Life-relevant skills and socio-emotional skills

Aspects	Items	Remarks
Affective & non-cognitive skills	1. Ability to be self-regulated in learning	Related skills: self-regulated, problem-solving, self-management, grit,
	2. Ability to try new methods in solving problems	
	3. Ability to prioritize my work in the busy schedules	

	4. Ability to keep positive emotions towards failures and setbacks	persistence, positive thinking, self-confidence (Kautz, T Heckman 2014)
	5. Ability to recognize my weakness and areas for improvements	
	6. Confidence to overcome difficulties that encountered	
Social & leadership skills	7. Ability to take on a leadership role within the team	Leaderships, communication, collaboration, social awareness
	8. Ability to share my thoughts and ideas with others	
	9. Ability to respect and engage others' opinions	

Section Two

This section was designed to gather information about their engagement in STEM learning over time, as well as their academic and career choices in STEM-related fields. In particular, the participants were asked to provide the following information: Field of study in tertiary education, current and/ or the expected job after their graduation, their involvement in STEM-related activities after the training programmes, and their future plans in STEM-related development (e.g. further studies in STEM-related disciplines).

3. Results

This section consists of two parts. The first part summarizes the findings from the online survey. The second part presents the results from the follow-up interviews.

3.1 Results from the online survey

A total of 34 alumni completed the survey and the overall response rate was 7.1%. Table 2 shows the response rates of the participants by their highest level attended. It is noted that about half of the replies were received from Final Phase's participants, resulting a response rate of 20.5% for this group. The survey sample was biased towards this group of participants. Analysis of the variations across these two groups - Final Phase's participants verse the Non-final Phase's participants - will be carried out with respect to various outcomes in the remainder part of this report.

Table 2 Response rates by the highest level attended

Highest level attended	No. of respondents	No. of survey invitations	Responses rates
Phase I	5	139	3.6%
Phase II	8	167	4.8%
Phase III	5	92	5.4%
Final Phase	16	78	20.5%
Total	**34**	**476**	**7.1%**

Note: A whole series of training programme consists of four phases and different phase tests. Only the top achievers in the phase tests could be promoted to the higher phase of trainings. Enrolment requirements of each phase are described below:

- Phase I: 80-90 top achievers in the Hong Kong Physics Olympiad (HKPhO)
- Phase II: 30 top achievers in Phase I
- Phase III: 15 top achievers in Phase II
- Final Phase: 8 top achievers in Phase III. Toward this end, participants could represent Hong Kong to join IPhO and/or Asian Physics Olympiad (APhO)

3.1.1 Descriptive statistics of the participant' profiles

Table 3 shows the demographic and participation history of the participants. Of all the participants, 85.3% were male. The mean age of participants was 25 years. The youngest group (aged 18-20) contains 35.3% of the sample. The oldest group (aged 31 or above) contains 11.8% of the sample.

Regarding to the participation history, 35.2% of participants were from the 2010 training programmes or before. Besides, about 26.5% of the participants reported that they joined the training programmes more than once. It reflected that some respondents were relatively young (i.e. junior secondary students) in their first participation and they joined again before they left their secondary schools.

Table 3 Descriptive statistics of participant' profiles

	N=34	No.	%
Gender	Male	29	85.3%
	Female	5	14.7%
Current Age	18-20	12	35.3%
	21-23	9	26.5%
	24-26	6	17.6%
	28-30	3	8.8%
	31 or above	4	11.8%
Year of training programmes	2007 or before	6	17.6%
	2008-2010	6	17.6%
	2011-2013	9	26.5%
	2014-2016	13	38.2%
Time(s) to join the programmes	One	25	73.5%
	Two	5	14.7%
	Three or above	4	11.8%

3.1.2 Results of Questionnaires -Section One

As mentioned above, this section's question items focus on the participants' experiences in the training programme. Participants were also asked to rate the impacts of the training programmes.

Reasons of joining the training programmes

With regard to the reasons of joining the training programmes (see Table 4), the three most frequently reported reasons were: “gain new knowledge in science” (91.2%); “join IPhO” (73.5%) and “prepare for my future study in science” (61.8%). In contrast, “My parents wanted me to join” was the least reported reason with only 1 respondent opting this choice. The results reflected the voluntary nature of the respondents and “pleasing others” were clearly not the reasons for their participation.

Table 4 Reasons to join the training programmes

N=34	No.	%
I wanted to gain new knowledge in science	31	91.2%
I wanted to join International Physics Olympiad	25	73.5%
I wanted to prepare for my future study in science	21	61.8%
I wanted to enrich my academic portfolio (e.g. for university application)	14	41.2%
I wanted to prepare for my future career in science	13	38.2%
I wanted to meet students from other schools	9	26.5%
I wanted to study with my friends (many friends joined the programmes)	5	14.7%
My teachers recommended me to join	5	14.7%
I wanted to improve my grades (in school or in public exams)	3	8.8%
My parents wanted me to join	1	2.9%

Memories of the training programmes

The participants were asked to recall specific memories about the programmes. They were asked to pick all those that could be remembered from the list provided. The items included the venues of the programmes (e.g. university campus), the activities in which they engaged (e.g. tutorial sessions, lecture sessions), as well as the people with whom they interacted. For those who had ever represented Hong Kong to join the international competitions, several items related to the competitions were also included.

With respect to the specific memories about the training programmes (see Table 5), “Tutorial sessions” (79.4%) topped the list, followed by “Lecture sessions” (73.5%), “Peers in the programmes” and “Intensive training schedules” (70.6%). Regarding to the specific memories about the international competitions (see Table 6), all the respondents reported that they could remember their “teammates (100%)” even though it was an individual competition.

Table 5 Memories of the training programmes

N=34	No.	%
Tutorial sessions (e.g. group discussions, teaching of tutors)	27	79.4%
Lecture sessions (e.g. teaching of instructors)	25	73.5%
Peers in the programmes (e.g. peers met through the programmes)	24	70.6%
Intensive training schedules (e.g. whole day training, many selection tests)	24	70.6%
Venue of the programmes (e.g. university campus, university laboratory)	21	61.8%
Laboratory sessions (e.g. performed different experiments,)	20	58.8%

Specific science topics/ knowledge	13	38.2%

Table 6 Memories of international competitions

N=16	No.	%
Our teammates	16	100.0%
Host country (e.g. excursions, sightseeing)	14	87.5%
Our leaders	13	81.3%
Theoretical exams	12	75.0%
Experimental exams	12	75.0%
Contestants of other countries	6	37.5%
Lectures / talks held in the competition	3	18.8%

Self-rated value on learning and environmental elements of the training programmes

To understand the value of training programmes and the critical elements that stemmed from in participant's perspective, some learning and environmental elements of the training programmes were identified in the survey. Respondents were asked to rate each statement on a Likert scale (0 = Not Valuable and 3 = Very valuable) or the option of "I don't remember/ I never experienced". For those who had ever represented Hong Kong to join the international competitions, several items related to the international competitions were also included.

From the values of means (see Table 7), "Learned advanced science" was ranked as the highest (M=2.72), followed by "Exposure to various challenging problems" (M=2.44) and "Learned science in ways that different from ordinary schools" (M=2.37). The results suggested that the advanced learning opportunities and exposure to challenging coursework were highly valued by the respondents.

Table 7 Self-rated value on learning and environmental elements of the training programmes

N=34	N	Mean	SD	n^
Learned advanced science that beyond the school curriculum	32	2.72	0.58	2
Exposure to various challenging problems in science	32	2.44	0.84	2
Learned science in ways that different from ordinary schools	32	2.37	0.83	2
Interacted with peers within and out of the lessons	32	2.34	0.97	2
Interacted with instructors/tutors (formal and informal)	33	2.12	0.96	1
Supports from family members, school teachers and friends	31	1.68	1.14	3
Doing scientific investigations on my own	29	1.66	0.77	5

Notes: * 4-point Likert scale (0 = Not valuable to 3 =Very valuable), n^= No. of "I don't remember/ I never experienced"

For the experiences of international competitions (see Table 8), the mean score of "represented Hong Kong to join the international competition" (M=2.87) topped the list as the one with most valuable experience, followed by "Met people from all over the world with the same interest" (M=2.44) and "Competed against other talents from different countries" (M=2.31). It should be noted that all the participants had lasting and detailed memories of international competitions such that none of them chose the option of "I don't remember/ I never experienced".

Table 8 Self-rated value on learning and environmental elements of the international competitions

N=16	N	Mean	SD	n^
Represented Hong Kong to join the international competition(s)	16	2.87	0.34	0
Met people from all over the world with the same interest	16	2.44	0.89	0
Competed against other talents from different countries	16	2.31	0.87	0
Got new insights about science and in other aspects	16	2.19	0.54	0
Accomplished all the exams in the competition(s)	16	1.94	0.77	0

Notes: * 4-point Likert scale (0 = Not valuable to 3 = Very valuable), n= No. of "I don't remember/ I never experienced"

As stated before, since more than 45% of responses in the sample were received from Final Phase's participants, group analysis was carried out between two groups of participants - Final Phase's participants verse the Non-final Phase's participants. Comparison between the two groups (see Table 9) using the Mann-Whitney U-test showed that the score of "Interacted with peers within and out of the lessons" was significantly higher for Final Phase's participants. For the remaining questions, no significant differences were found between the groups. A closer peer relationship of Final Phase's participants was also evident by one response from this group in an open-ended question (i.e. "Any other things you want to share regarding your experience in the programmes"). The respondent wrote "*Playing card games with friends before / after lectures*."

Table 9 Group comparison of self-rated value on learning and environmental elements of the training programmes

	Non-final Phase's participants (N=18)				Final Phase's participants (N=16)			
	N#	Mean	SD	n^	N#	Mean	SD	n^
Learned advanced science that beyond the school curriculum	17	2.71	0.59	1	15	2.73	0.59	1
Exposure to various challenging problems in science	16	2.44	0.89	2	16	2.44	0.81	0
Learned science in ways that different from ordinary schools	17	2.35	0.86	1	15	2.40	0.83	1
Interacted with instructors/tutors (formal and informal)	17	2.06	1.09	1	16	2.19	0.83	0
Interacted with peers within and out of the lessons	17	**1.82**	1.07	1	15	**2.93***	0.26	1
Doing scientific investigations on my own	15	1.67	0.98	3	14	1.64	0.50	2
Supports from family members, school teachers and friends	16	1.38	1.26	2	15	2.00	0.93	1

Notes: * 4-point Likert scale (0 = Not valuable to 3 = very valuable), **p<0.01, N#= No. of Not valuable to Very valuable, n^= No. of "I don't remember/ I never experienced"*

In summary, the participants generally valued the opportunities to learn the advanced sciences with sufficient challenges. However, the value of social interaction and supportive environment were less emphasized by the participants. To understand the reasons behind, the related issues (e.g. interaction and support from various parties) were discussed in the follow-up interviews among five respondents. It was noted that personal interaction and connection were rarely occurred in the tight training schedules. It was reasonable to explain that why these elements were neglected by the participants in general.

Self-reported impacts of the training programmes

This question aimed to explore the impacts of the training programmes based on the participants' assessment. As stated before, two main areas of potential outcomes were defined in the context of training programmes and the results are discussed in the following.

Regarding the science-related outcomes, three aspects were identified, and a set of specific question items was developed (refer to Table 1). Each specific item employs a 4-point Likert-type response format: 0 (No impact at all), 1 (Slight impact), 2 (Moderate impact), 3 (Large impact), and 4 (Very Large impact). The average score of each aspect was then computed, with higher scores indicating greater positive impacts on that aspect.

Descriptive statistics as well as the reliability coefficient of three aspects on science-related outcomes are presented in Table 10. The reliability coefficients of three aspects ranged from 0.79 to 0.85, suggesting the plausible internal consistency. The mean scores of "*Interest in Science*", "*Study and Career Aspirations*" and "*Science Self-efficacy*" were 2.74, 2.41 and 2.32 respectively. The results suggested that the self-reported impacts of science-related aspects ranged from "Moderate" to "Large". Comparison between different aspects using Wilcoxon Signed Rank test showed that score on "*Interest in Science*" was significantly higher than the other two aspects.

Table 10 Descriptive statistics of aspects on science-related outcomes

Science-related outcomes	Reliability coefficient	Range of average score	Mean (N=34)	SD
Interest in Science	0.803	0-4	2.74*	0.74
Study and Career Aspirations	0.851	0-4	2.41	1.00
Science Self-efficacy	0.789	0-4	2.32	0.74

Notes: 4-point Likert-type response format: (0 =No impact at all and 4 =Very Large impact)
**p≤ 0.01 for comparison between aspects using Wilcoxon Signed Rank test*

With respect to the life-relevant and socio-emotional outcomes, two aspects were identified, and a set of specific question items was developed for these two aspects, namely "*Affective & non-*

cognitive skills" and "*Social & Leadership skills*". Participants were asked to rate each item within each aspect in a 4-point Likert-type response format. The average score of two aspects were then calculated for further analysis. Table 11 shows the reliability coefficients and mean scores of these two aspects. The mean score of "*Affective & non-cognitive skills*" was 2.34 while the mean score of "*Social & Leadership skills*" was 1.46. **The mean score of "Social & Leadership skills" was also the lowest amongst all the potential outcomes in the study.**

Table 11 Descriptive statistics of aspects on life-relevant and socio-emotional outcomes

Life-relevant and socio-emotional outcomes	Reliability coefficient	Range of average score	Mean (N=34)	SD
Affective & non-cognitive skills	0.946	0-4	2.34*	1.14
Social & Leadership skills	0.898	0-4	1.46	1.02

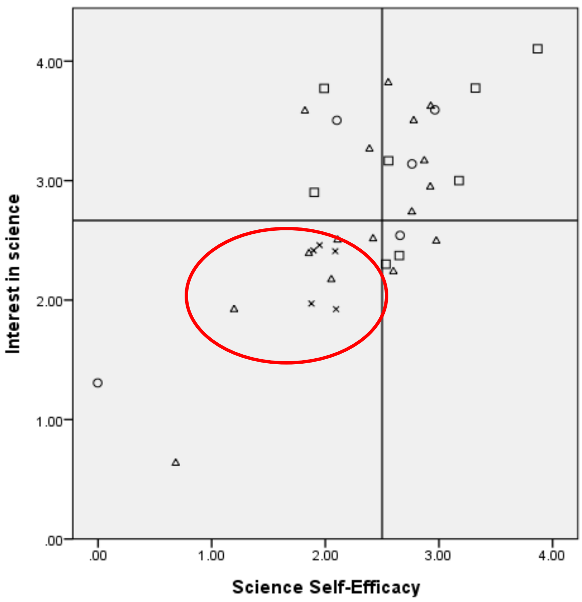
Notes: 4-point Likert-type response format: (0 =No impact at all and 4 =Very Large impact)
$p \leq 0.01$ for comparison between aspects using Wilcoxon signed rank test

Since the training programmes were consisted of several phases (each last for three months), the levels of involvement varied among the respondents. To further explore the relationship between the self-reported impacts and their levels of involvement, the average scores of the five mentioned aspects are plotted among respondents with different levels of involvement (i.e. Phase I, II, III and Final Phase) as below:

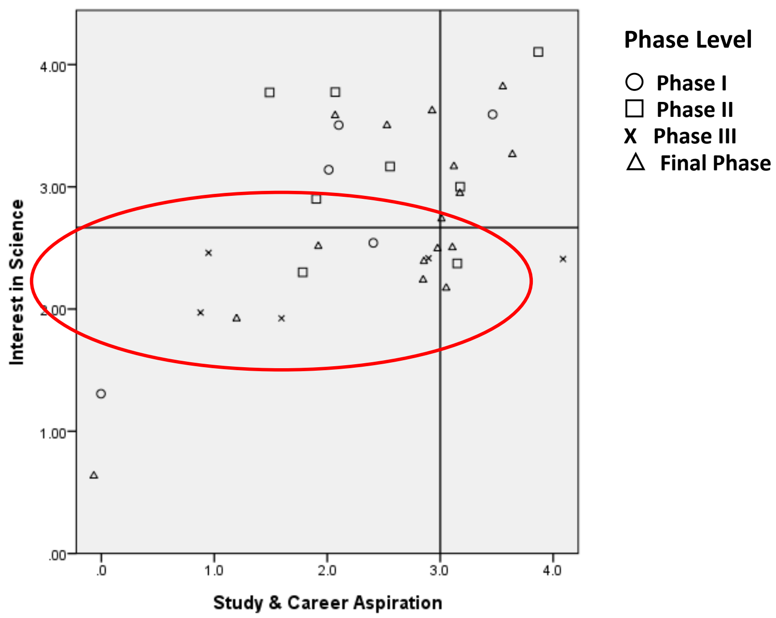
- Graph A: Average scores of "Interest in Science" versus that of "Science Self-efficacy"
- Graph B: Average scores of "Interest in Science" versus that of "Study and Career Aspirations"
- Graph C: Average scores of "Social & Leadership skills" versus that of "Affective & non-cognitive skills"

For each graph, the two lines across the graph indicate the medians of the average scores of the aspects concerned. From the graphs, it is observed that the average scores of five Phase III's participants are all located at the lower-right quadrants of the graphs. The patterns are especially remarkable in Graph C. **The results may reflect the high expectations of those participants (pre-final stage before IPhO) and their self-assessment scores were undermined by their setbacks in the selection process.**

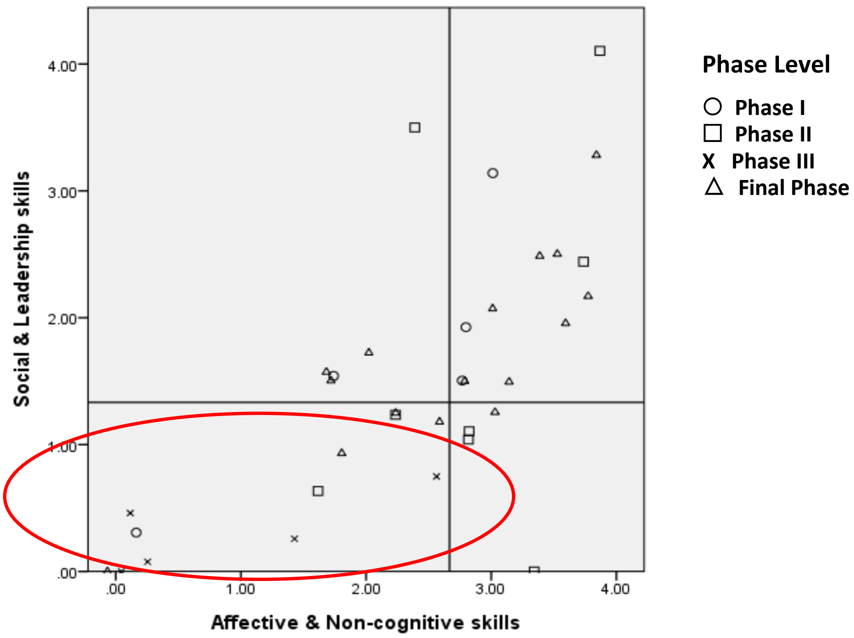
Graph A



Graph B



Graph C



Finally, participants were asked to rate on two pragmatic outcomes (i.e. get a good grade in public exam and admitted in a top-ranked university) and the overall programme impact as a whole in a 4-point Likert scale format. The results are displayed in Table 12. It is noted that the overall programme impact of the training programmes was quite satisfactory. More than 85% of the respondents rated the overall programme impacts as "Moderate" or above.

Table 12 Pragmatic outcomes and overall programme impact

N=34	Mean	SD
To get a good grade in the science subjects (in school/public exams)	1.65	1.39
Admitted in a top-ranked university / my desired major	1.88	1.30
Programme Impact as a whole	2.74	0.93
Overall, how would you rate the impacts of the programmes on you?	**No.**	**%**
No impact at all	0	0
Slight impact	5	14.7
Moderate impact	5	14.7
Large impact	18	52.9
Very Large impact	6	17.6

Note: 4-point Likert-type response format: (0 =No impact at all and 4 =Very Large impact)

Similar to the analysis of the previous questions, group analysis was carried out to compare Final Phase's participants with the Non-final Phase's participants. Table 13 shows that no significant differences were found among the overall programme impact and all the five aspects mentioned above.

Table 13 Average score of different aspects by highest level attended

Average score of different aspects	Non-final Phase's participants (N=18)		Final Phase's participants (N=16)	
	Mean	**SD**	**Mean**	**SD**
Interest in Science	2.78	0.71	2.69	0.78
Study and Career Aspirations	2.25	1.06	2.59	0.93
Science Self-efficacy	2.36	0.82	2.28	0.67
Affective & non-cognitive skills	2.10	1.23	2.60	0.99
Social & Leadership skills	1.30	1.21	1.65	0.74
Overall Programme Impact	2.50	0.99	3.00	0.82

3.1.3 Results of Questionnaires-Section Two

The section below describes the education and career pathways of the participants after their secondary education. Specifically, this section addresses two main questions: 1) Are the participants more likely to pursue STEM-related academic and careers in comparisons to the alumni from Science and/or Mathematic domain in general? 2) Do the participants continue to participate in STEM-related activities after the training programmes?

Academic and Careers Pathways

Among the respondents, 64.7% were full-time students (19 were studying undergraduate programme and 3 were studying doctoral programme), 29.4% were working full-time and 5.9% reported being unemployed at the time of the survey. Among the respondents who had completed the formal education, 1 held sub-degree, 9 held undergraduate degree and 2 held taught master as the final qualification. Regarding to the university attended/attending, 79.4% were studying or graduated from three local universities in Hong Kong (see Table 14), while the remaining respondents reported that they were studying or had studied abroad. Also, it is noted that many of them were admitted in prestigious universities in the United States (e.g., Columbia University, MIT and Princeton University).

Table14 Economic status and place of study of respondents

N=34		No.	%
Current Economic Status	Full-time students		
	-Undergraduate	19	55.9
	-Doctoral Postgraduate	3	8.8
	Sub-total	***22***	***64.7***
	Working full-time (include self-employed)	10	29.4
	Others (e.g. seeking employment)	2	5.9
University attended/ attending	Local university		
	-The University of Hong Kong (HKU)	11	32.4
	-The Chinese University of Hong Kong (CUHK)	11	32.4
	-The Hong Kong University of Science and Technology (HKUST)	5	14.7
	Sub-total	***27***	***79.4***
	University outside Hong Kong	7	20.6

To understand their fields of their studies in tertiary education, the respondents were asked to provide the programme names of their studies. Their answers were then classified according to the "Broad Academic Programme Category" of UGC-funded programmes. Of all respondents, 60.0% majored in science subjects. It was followed by medicine (22.9%), and business (8.6%). As a "baseline", the similar data collected from Alumni Telephone Survey in 2016 are used for comparison. Table 15 shows the undergraduate's majors of 116 alumni from Science and /or Mathematics domain. To facilitate the comparison, the fields of studies among the participants and alumni were further grouped into two major categories: STEM-related and Non-STEM-related. The chi-squares result indicated that a significant difference was found between participants and the alumni Science and /or Mathematics domain (chi-squares = 5.139, p= 0.023). Participants were more likely to major in STEM-related fields.

Table 15 Field of study of participants and alumni (first degree) for comparison

Field of study	Participants in the survey N=34^		Alumni from Sciences and /or Mathematics domain N=116#	
	No.	%	No.	%
STEM-related				
Sciences	21	60.0	29	24.6
Engineering & Technology	2	5.7	23	19.5
Architecture	0	0	3	2.5
Sub-total	***23***	***65.7***	***55***	***46.6***
Non-STEM-related				
Medicine, Dentistry & Health	8	22.9	27	22.9
Business & Management	3	8.6	20	16.9
Social Sciences	0	0	8	6.8
Arts & Humanities	0	0	5	4.2
Education	0	0	2	1.7
Law	1	2.9	1	0.8
Sub-total	***12***	***34.3***	***63***	***53.4***
Total	**35**	**100**	**118**	**100**

Notes: ^1 participant with double-major, #2 alumni with double-major

With respect to the career expectations, the respondents, who were students currently, were asked about their expected jobs after graduation. The respondents could enter any job titles or descriptions in an open-entry field. Also, since the STEM and STEM-related occupations are extensive, the respondents were asked to indicate the STEM-skill requirements of the expected jobs. Similarly, for those who were working full-time, the respondents were asked about the job titles and the STEM-skills requirements of their current occupations (or the most recent occupations for those who are seeking employment). In addition, they were asked to report whether they would remain or advance in their current field of occupation.

Table 16 shows the career expectation and pathways of the respondents. The results are summarized as below:

- Career expectations: Out of the 22 full-time students among the respondents, 7 respondents expected to pursue their careers in scientific research. 6 respondents expected to work as medical doctors or clinical researchers. 5 respondents expected to work as engineers or ICT professional. 2 respondents stated they were still undecided about their future.
- Current occupations: Out of 10 respondents who were working full time at the time of the survey. 3 were professionals in science, engineering or ICT (e.g. software engineer), 2 were health professionals (e.g. nursing), 2 were in the business sector (e.g. banking), 1 respondent was a secondary school teacher and 1 was meteorologist.
- STEM-skills requirements of expected/current/the most recent job: For the expected or the current job nature, 64.7% of respondents expected or the current occupation involves STEM-related skills, 26.5% of respondents expected or the current occupation required intensive skills for innovation and scientific research. Only 3 respondents (8.8%) had left or expected to pursue career outside of STEM-related fields.

- Among 12 respondents who were working full-time or seeking a job, 5 respondents indicated they would not remain or advance in their current fields. Out of them, 1 respondent said that he would leave STEM-related field.

Table 16 Career pathways of the respondents

Field of occupation^ (N= 32)	**No.**	**%**
Scientific research	8	25.0%
Medical doctors or health professionals	8	25.0%
Science, engineering or ICT professionals	8	25.0%
Business	3	9.4%
Education	2	6.3%
Undecided	2	6.3%
Undefined (“Assistant Manager”)	1	3.1%
STEM-skills requirements of expected /current /the most recent job (N=34)	**No.**	**%**
Involves STEM-related skills e.g. engineers, computer programmers	22	64.7
Requires intensive STEM-related skills for innovation and scientific research	9	26.5
Not involve STEM-related skills e.g. lawyers, social workers	3	8.8
Occupation in the long run # (N=12)	**No.**	**%**
Remain or advance in current field	7	58.3
Plan to pursue other fields in the future	5	41.7

Notes: ^ Included expected job (for full-time students) or current job (for respondents who were working full-time), # Respondents who were working full-time or seeking employment

Taken together, the results suggested that the participants were quite likely to purse STEM-related field. However, **some respondents revealed their doubts in career development and the possibility that they can fulfil their potentials under the unclear prospects related to the studying of STEM-related disciplines.** For instance, in an open entry field of the career expectation, one respondent stated that “*Maybe Physicist? Or it is hard and I may give up to find a job*”. The struggle was also evident by one respondent and stated “Robotics / *Data Science, Money, money money, PhD student has been broken and need survival*”.

Engagement in STEM-related activities

To understand the participants’ involvement in STEM-related activities after the training programmes, the respondents were asked about their engagement in STEM-related activities and any plan to pursue study in STEM-related field. Table 17 shows the results of the related questions. 73.5% of the participants reported that they joined the out-of-school learning programmes (e.g. courses, workshop, talks etc) “sometimes” or “often”. Besides, 50% of them reported that they had ever joined the exchange programmes, internship or mentorship in a field related to STEM. Also, 70.6% of the respondents indicated that they planned to pursue further study in STEM-related field in future. In contrast, only 36.6% of the alumni reported that they intended to further study in science from Alumni Telephone Survey in 2016.

Table 17 Engagement in STEM-related activities

<table>
<tr><th colspan="2">Engagement in STEM-related activities after the training (N=34)</th><th>No.</th><th>%</th></tr>
<tr><td colspan="2">STEM-related competitions (school / inter-school / local / international)</td><td>19</td><td>55.9</td></tr>
<tr><td colspan="2">STEM-related exchange tours / Summer camps / Field trips</td><td>11</td><td>32.4</td></tr>
<tr><td colspan="2">STEM-related exchange programmes, internship or mentorship</td><td>17</td><td>50.0</td></tr>
<tr><td rowspan="3">STEM-related Out-of-school learning programmes (e.g. courses, workshop, talks etc)</td><td>Never or hardly ever</td><td>9</td><td>26.5</td></tr>
<tr><td>Sometimes</td><td>18</td><td>52.9</td></tr>
<tr><td>Often</td><td>7</td><td>20.6</td></tr>
<tr><th colspan="2">Further study in STEM-related field (N=34)</th><th>No.</th><th>%</th></tr>
<tr><td colspan="2">Plan to pursue further study in STEM-related field</td><td>24</td><td>70.6</td></tr>
<tr><td colspan="2">No plan to further study in STEM-related field</td><td>10</td><td>29.4</td></tr>
</table>

To summarize, the results indicated that the participants were highly engaged in STEM-related activities after the training programmes. Besides, a majority of the respondents stated that they planned to pursue further study in STEM-related field in future.

3.2 Results from the Follow-up Interviews

After the survey period, follow-up interviews were conducted with those respondents who agreed to join the individual interviews. They were asked to share more about their experiences in the training programmes (and international competitions). Some major questions are shown below:

- What have you learnt from the programmes? What do you appreciate the most and the least?
- Do you think the programme had positive impacts on your future development? If yes, how?
- As a former participant, what would you like to suggest for improvements in the related trainings in the future?

Finally, the follow-up interviews were conducted with five participants. Table 18 shows the demographic information of the participants. Out of the 5 interviewees, 2 of them had ever represented Hong Kong to take part in IPhO.

Table 18 Demographic information of the interviewees

Age	Gender	Current occupation	Highest level attended
25	Female	Dentist	Phase II
32	Male	Secondary school teacher	Final Phase
18	Male	Full-time student	Final Phase
22	Female	Full-time student	Phase III
25	Male	Software developer	Phase II

The interviews were tape-recorded and transcribed for the further analysis. The qualitative data based on the interviews are discussed in the following.

Perceived impacts of the experiences

Regarding the perceived impacts of their experiences, **nearly all participants claimed that they had a stronger interest in science after the training programmes**. The result here was consistent with the similar findings from the survey data. While many participants stated that their general interest in science started at an early stage, their interest increased due to their knowledge gained from the training programmes. For instance, one participant exclaimed:

> "*It is fascinating to learn Physics through mathematical means*".

Some participants stated that the training programmes reinforced their early interest in science. As a result, they opted to study science subjects in universities. For those who had taken part in the national/international competitions, the awards won from the competitions are certainly gave their greatest sense of meaning. One of them expressed:

> "*I was honoured to represent Hong Kong to join IPhO. The medal won helped me to construct my self-identity*".

He continued to explain that his performance in science was already the top within his school and he was less likely to know his capacity without the trainings and the international competitions. In contrast, one participant stated that she wasn't a bright student in her school and the award boosted her confident level. She stated:

> "*I never expected that I had the ability to win an award from the Pan Pearl River Delta Physics Olympiad*. *It increased my self-confidence*".

Interactions with various parties

In relation to the interactions and supportive relationships, most of the participants reported that **they were seldom gave chances to interact with other parties neither during the lectures nor tutorial sessions**. Under this learning environment, the participants were less likely to be motivated to form a closer relationship with peers. **The feelings of alienation and isolation were reported from some of the participants**. On the contrary, the sense of belonging seems easier to develop during the intensive training camp before the international competitions amongst those who represented Hong Kong. For instance, one of these participants said:

> "I *developed great friendships with my teammates. I keep in touch with some of them yet today (from 2003)*".

In fact, the similar result was found in the survey data. It was noted that among all the respondents who had ever represented Hong Kong to join the international competitions, more than two-thirds of them reported that they were still in touch with other participants.

Social and emotional adjustments of competitive environment

The participants were asked to share their views of competitive environment in the training programmes. From their responses, it is observed that most of the participants were generally adjusted well with the competitive process. Specifically, task-oriented competitive behaviours (Udvari & Schneider 2000) were observed, in which the participants were motivated primarily by their desires to improve performance. In contrast, they were less likely to compete to win and to be proven superior to others (i.e. other-referenced competitive behaviour). For instance, one participant expressed his view about the competitive process:

> "*All the participants were the most talented students from different schools and it was no ground for comparison… I just cared my own performance (solve the mathematical problem)*".

Similarly, one participant told his anecdote in the trainings:

> "*I didn't aware that no one finished the assignments except me. Lecturer pointed out this and I was praised by him in the lesson*."

Although "winning" against others might not be the primary source of motivation, the negative emotions associated with failure were inevitable for those participants with intense involvement. Out of the five interviewees, three of them failed to make up the Hong Kong team. Two reported that they could handle the associated negative feelings shortly (e.g. a week). **However, one participant could not help crying when she mentioned that she failed to get the place in the final phase of training**. She stated:

> "*I tried to avoid all the related materials a year as I felt sorrow when I saw all these things*".

She said that she had shared her frustration with one of her school teachers. However, she felt that her school teacher did not understand her.

Improvements and suggestions of the training programmes

For the suggestions and areas of improvement, some participants said that the whole series of the training programme was quite perfect in terms of "training" and preparing the contestants to join the competition. Recommendations for improvement given by the rest of the participants were mainly focused on the pace and the depth of teaching content, for example the fast pace of acceleration, the sources of references and time to upload the course materials. One participant said that it would be desirable if he could sit in the remaining lectures and visit the university laboratories.

In brief, the participants generally reflected the positive attitudes toward their experiences in the training programmes. Instead of referring to accomplishment, most comments reflected the knowledge gained and the growth in scientific interest. However, it is noted that most of the participants attributed the academic gains **but overlooked the non-cognitive benefits that could be acquired through the training programmes**. Also, their responses revealed that the **socio-emotional gains were limited in the absence of the social and supportive environment.**

4. Discussion and Conclusion

The purpose of this study was to investigate the impact of competition-related training programmes on the scientifically gifted students. The findings reflected that the former participants were more likely to purse education and career in STEM-related field in comparison to the alumni from Sciences and/or Mathematics domain in general. Also, the positive impacts to strengthen their interests and knowledge in science were also revealed from participants' own retrospective responses. However, the lack of social interaction and affective supports were revealed. Based on the above findings and observations, the areas of improvement are proposed as follows:

(i) *Enhancement of peer-to-peer interaction.* According to Goldstein and Wagner (1993), a successful training programme should provide opportunities for interaction with equally able and motivated peers. However, the lack of peer interactions was revealed from both the survey and interview data. A peer group or a team of individuals with similar interests can provide social support and foster the social skills of the participants. It is suggested that the more opportunities could be offered for peer-to-peer interaction within the training programmes. For instance, some tutorial sessions could be taken place in a group setting (i.e., work together in small groups or asked to perform group project). In addition, a supportive community could be formed such that closer interpersonal relations could be formed when undertaking informal activities between and outside the lessons. In fact, most of the participants said that they valued the opportunities to socialize and interact with peers with similar interests. They said that they would join and enjoy the time spent if some activities could be held to draw them together.

(ii) *Help or experiences sharing from previous participants*. Besides, since the former participants can better understand the difficulties faced by their fellow participants, a platform could be formed to establish the connection between the current and the former participants. Instead of the formal career guidance activities, personal contact with the former participants could help the students know more the current prospect of STEM-related occupations and a range of career opportunities. Also, the relationship with the former participants may also be one form of socio-emotional supports that enables students to cope with the setbacks during the competitive process.

(iii) *Provision of socio-emotional support*. As far as for the non-cognitive and socio-emotional benefits, the training programmes should give the opportunity to foster the life-relevant skills of the participants that are critical for their future successes. However, all these skills are not an automatic by-product of the academic gains. Affective and emotional programmes, which can help students to identify their virtues and strengthen their resilience, could be considered. Besides, an e-community can be formed to let participants post some positive and supportive feedback regarding the self-improvement and task commitment or vent their frustrations. Moreover, as a safeguard measure, a referral mechanism for handling problematic emotional cases could be established. From the findings, it hints that the ones dropping out from Phase III are more vulnerable.

5. Limitations

Under the voluntary nature of the study, those former participants with positive feelings about the training programme and international competitions were more likely to reply the survey. As a result, the findings here may be subjected to reporting bias.

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