Analysis of Results from China Entry in BPhO November 2016

1. Entry

There were 611 candidates in total from 110 schools.

197 female and 414 male students, with 59 schools entering female students, 97 schools entering male students, and 13 schools entering only a single female candidate. Candidates were entered either by their good Physics Bowl score from previous April, or by school recommendation. 393 candidates (139 female and 254 male, ratio 1.83) came from the larger school recommendation, whilst Physics Bowl entry was 218 (58 female and 160 male, ratio 2.76). The female entry is clearly different, with schools boosting the female entry considerably.

Table 1. Entry cohort from schools and through College Bowl.

	Grade 10/ GCSE	Grade 11/ AS	Grade 12/A2	Total
School Recommendation	145	225	23	393
College Bowl	16	153	49	218
Totals	161	378	72	611

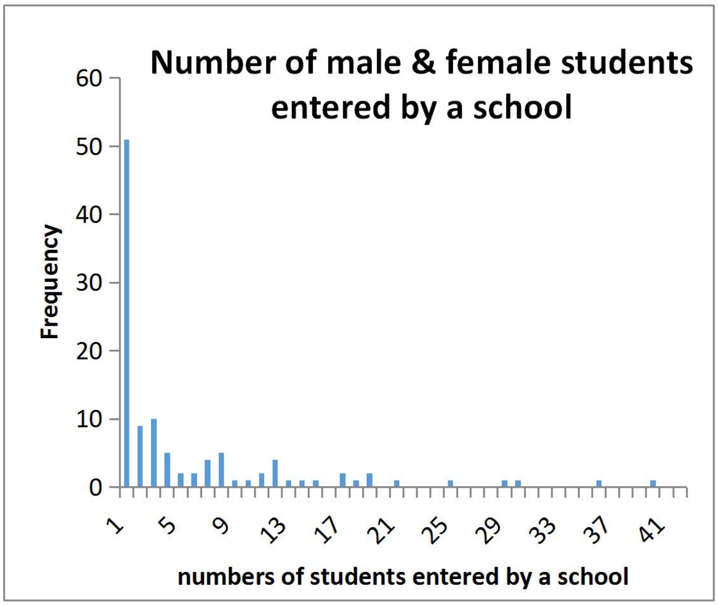


Figure 1. Numbers of candidates entered by each of the 110 schools.

Whilst most schools entered small numbers of candidates (70 schools from the 110 entered one, two or three candidates) with 90 schools entering 1 to 10 candidates, 20 schools decided to enter relatively large groups of students , with the top five schools entering 25, 29, 30, 36 and 40 (male + female) students each. These large entries are mostly via the school recommendation route.

Schools enter candidates for these competitions for several different reasons, and this has to do with the teachers and how they view participation in these demanding exams. Some teachers are cautious about letting their students enter and then obtain few marks and only a Commendation. Others feel that it is in the students' best interests to challenge themselves and strive to compete with the most able students. Then they will learn how to succeed, how they need to push themselves further in the subject, and how to cope if they do not do well.

There is a misconception that achieving a Commendation is a failure. It is important that students do not view their result in such a light. The competition is meant to be a challenge and it is a "risk" to enter such a demanding exam paper knowing that there are questions that may be unfamiliar and that the student may obtain low marks. Without being willing to try something new like this, to challenge themselves against very able physics candidates, students will not learn the key skill of resilience, learning to overcome setbacks, and engage with the subject determined to improve their skills and understanding. These students should be congratulated on taking part and learning from the experience. Doing very well in the competition is very pleasing to the student, but they will learn less from the experience than those students who have to overcome setbacks and have to learn how to improve.

Gaining very low marks is disappointing for a candidate, and although they are not given back the individual marks, they are likely to know that they have performed badly. The role of the teacher is to encourage them to look forwards and not be confounded by a paper that is designed to challenge the strongest students of their age group, or quite possibly students with one or two years more experience in physics education.

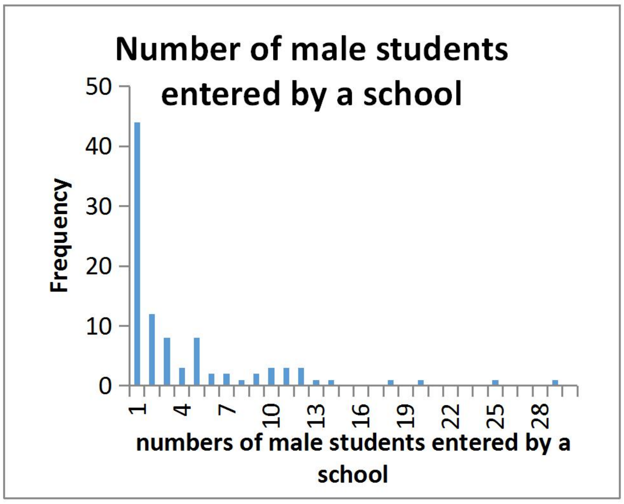


Figure 2. Numbers of male students entered by each school.

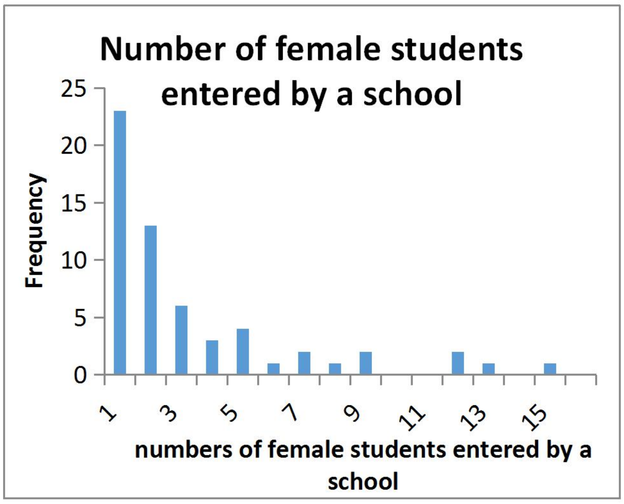


Figure 3. Number of female students entered by each school.

2. Grades

The grade boundaries were set by analysing the results obtained from the 1677 UK entries in the identical competition paper. These boundaries are determined from the numbers of candidates in each medal range, keeping the percentages similar from year to year, with some adjustment for suitable gaps in the distribution of marks. Students are not supplied with their individual marks, but are given the grade boundaries and the award they have achieved. Since there are six categories of award, this gives suitable discrimination in the final awards.

This year's paper was a little easier than those of previous years and consequently there is less discrimination in the marks for the candidates in the Top Gold group. The boundary was lowered from 72/80 of last year to 70/80 in order to ensure that the able candidates were included in the group.

Table 2. Grade Boundaries (determined from the UK results)

Top Gold	70	-	80
Gold	63	-	69
Silver	52	-	62
Bronze I	44	-	51
Bronze II	38	-	43
Commendation	0	-	37

The following analysis of the results is to examine the entry cohort and how they have performed, to see if changes need to be made to the selection procedure, to ask if other students should be encouraged to participate, and to compare the results with the UK cohort. One most obvious point is the number of younger students who have successfully participated compared to the UK entry.

The entry consists of two distinct groups; those who have achieved a strong result in the Physics Bowl competition and those who come from school recommendation. The distribution of results is (not unexpectedly) different for the two groups. The UK distribution is "bell like" although that is entirely school recommendation, with the use of the A2 Challenge Paper as a selection paper, or through knowing the strengths of the candidates from previous years of teaching and participation in Olympiad competitions for younger age groups. Three times as many schools participate (309 compared to 110 for China) with a very similar average entry per school (5.43 UK and 5.55 China).

The effect of the two routes for entry is clearly evident in the distributions below, although it is not necessary to favour one route in preference to the other. Participation provides opportunities for students and there is an ebb and flow of achievement that may favour entering a competition one year and not the next. The medal results for the cohorts can be compared with the UK entry. Numbers and percentages are in Table 2 below. The School Recommendation and the Physics Bowl percentages are calculated for those entries individually. The Physics Bowl results compare favourably with the UK mark distributions, whilst the high end of the school recommendation entry shows a marked drop off in the Gold and Top Gold awards.

Table 3. Medal results for the UK and China's two entry routes.

	UK	China					
	(1677 entries)	School Recommendation	College Bowl	together	School Recommendation %	College Bowl %	Together %
Entry	1677	393	218	611			
Top Gold	4.95%	10	25	35	2.56%	11.47%	5.73%
Gold	5.84%	3	16	19	0.77%	7.34%	3.11%
Silver	13.48%	13	25	38	3.32%	11.47%	6.22%
Bronze I	14.31%	30	28	58	7.67%	12.84%	9.49%
Bronze II	13.42%	23	20	43	5.88%	9.17%	7.04%
(Commendation)	**(48.0%)**	**(314)**	**(104)**	**(418)**	**(79.9%)**	**(47.7%)**	**(68.4%)**
Medal Totals	**52.0%**	**79**	**114**	**193**	**20.2%**	**52.3%**	**31.6%**
Average paper mark	**39.5 (49.4%)**	**24.3**	**40.2**	**30.0**	**30.3%**	**50.2%**	**37.5%**

3. Analysis

There are two different populations in the China entry, with distinct difference. However, looking at the Physics Bowl entry the results are comparable with the UK, except that some of the Golds have been swept up into Top Golds, indicating the strength of these students, selected with a challenging competition, and eager to move to the next stage of physics competitions. These top students may have found the paper not stretching enough to discriminate at this level. This can be seen in Figure 6 below, which is to be compared with the UK distribution of Figure 5. There the distribution tails off at the top whereas the Physics Bowl distribution remains flat. This year's paper did not perhaps have the required demand at the end of each question that has been there in previous years.

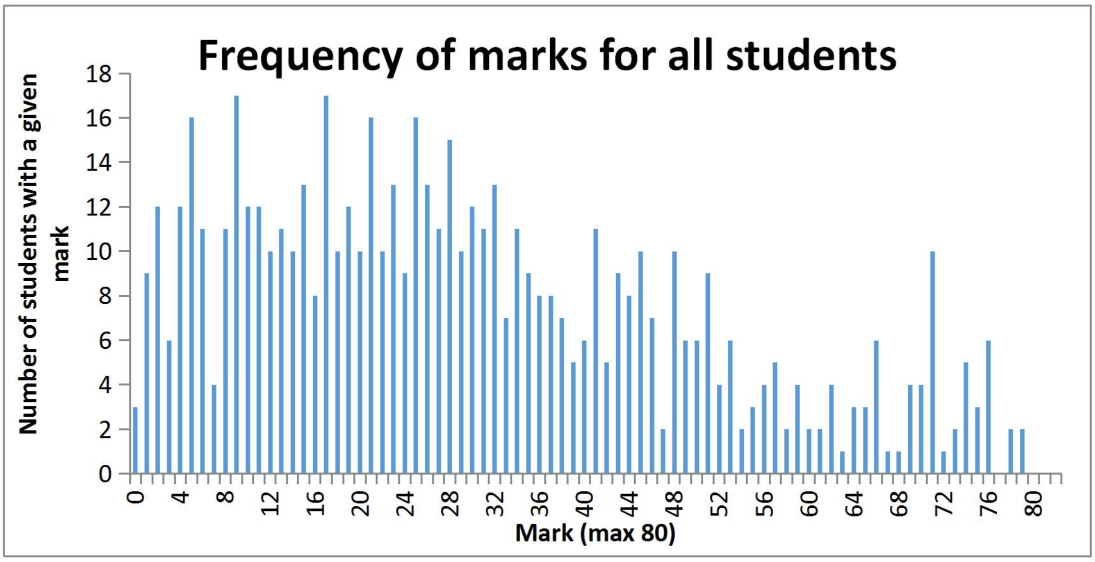


Figure 4. Frequency distribution of marks for the complete entry of 611 students.

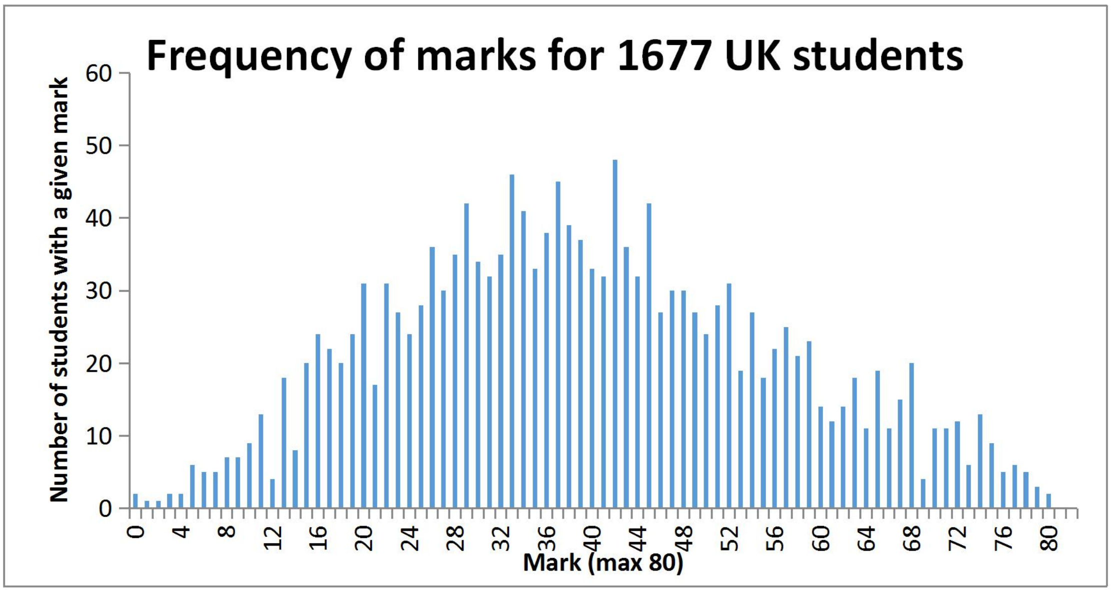


Figure 5. Frequency distribution of marks for UK students.

The distinct distributions for the two cohorts of china's entry are shown in Figures 6 and 7 below. Whilst the entry route is acceptable, it is important that students are not put off by achieving a relatively low mark.

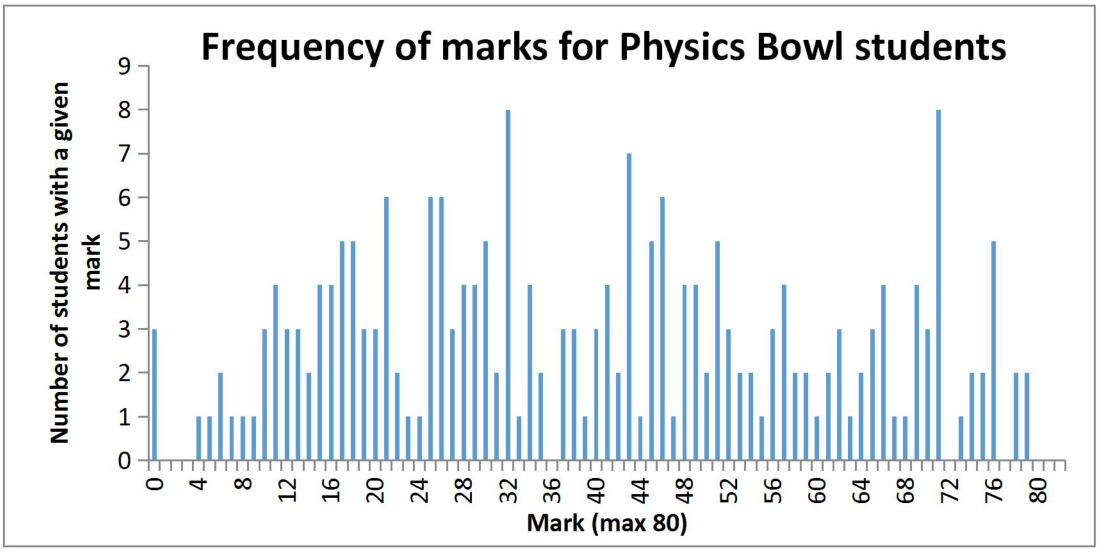


Figure 6. Frequency distribution for 218 "College Bowl" candidates

There are three Physics Bowl students who obtained marks of 22, 23, 27 (out of 40) in the Physics Bowl competition but who achieved zero marks in the BPhO. These three papers were examined and the results are correct. It is not clear why they performed so poorly in the BPhO paper.

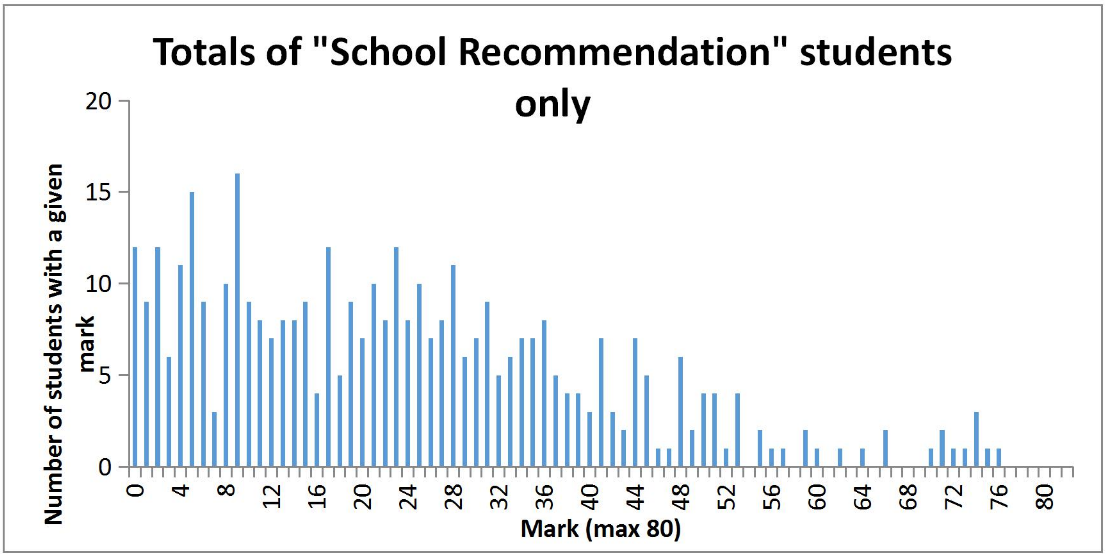


Figure 7. Frequency distribution for 393 "School Recommendation" candidates.

The 218 Physics Bowl candidates clearly have a selection criterion for entry and they would be expected to perform well in the BPhO. There are some very strong candidates recommended by their school s and it might be interesting to see if some of these schools could be encouraged to enter their candidates in to the Physics Bowl next year.

There is a strong correlation between the BPhO and Physics Bowl results, as seen in Figure 9. The three students with zero BPhO marks are clearly apparent in this along the lower border.

Physics Bowl entrants figure well in the medal results and the Top Golds clearly correspond to a high Physics Bowl mark.

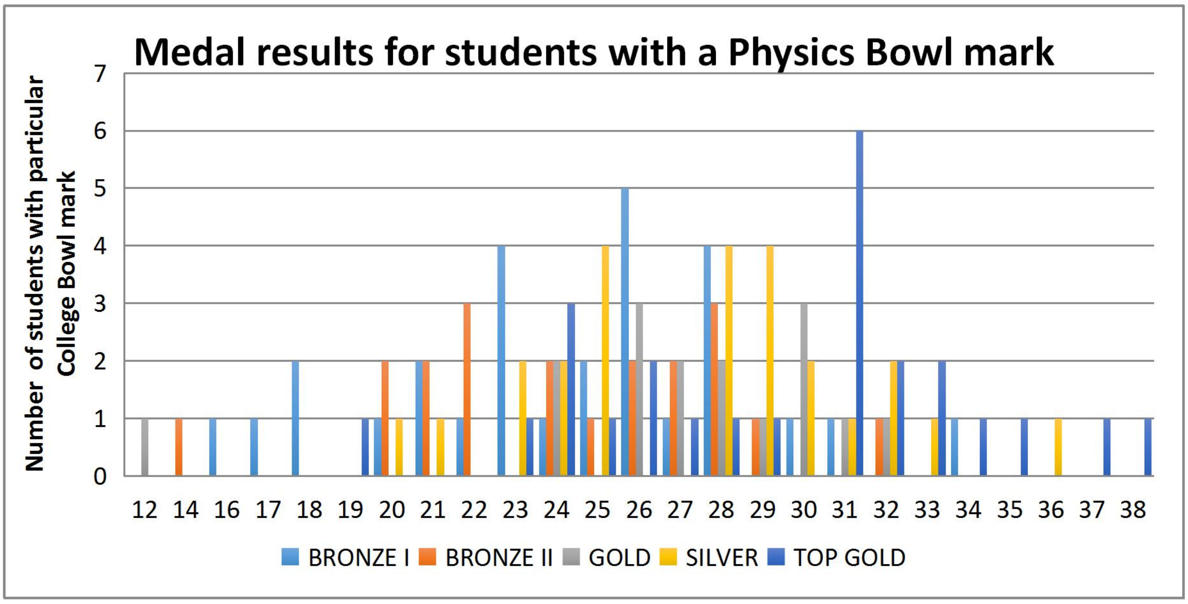


Figure 8. Medal results as a function of Physics Bowl Results.

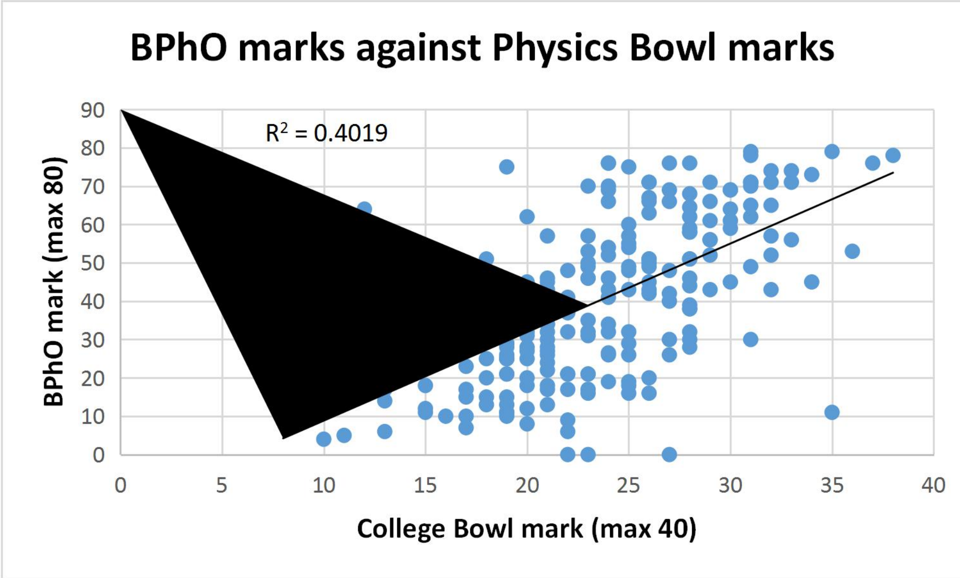


Figure 9. Correlation between BPhO and Physics Bowl results.

In the UK, gender balance is important in physics particularly. The number of girls entered from schools in the Chinese competition appears to be significantly higher than that expected in the UK. Girls figure more in the medals, with the boys dominating the Commendations. It may be that schools are quite selective about entering girls and less so with the boys.

Table 4. Medal results for full entry by gender.

	Gender	Top Gold	Gold	Silver	Bronze I	Bronze II	Total medals	Commendation
Female	197	6	3	12	13	13	47	150
Male	414	29	16	26	45	30	146	268
total	**611**	**35**	**19**	**38**	**58**	**43**	**193**	**418**
Ratio M/F	**2.10**	**4.83**	**5.33**	**2.17**	**3.46**	**2.31**	**3.11**	**1.77**

This gender breakdown is displayed in Figure 10 and the success of the large female entry overall is indicative of a different attitude to physics than in the UK.

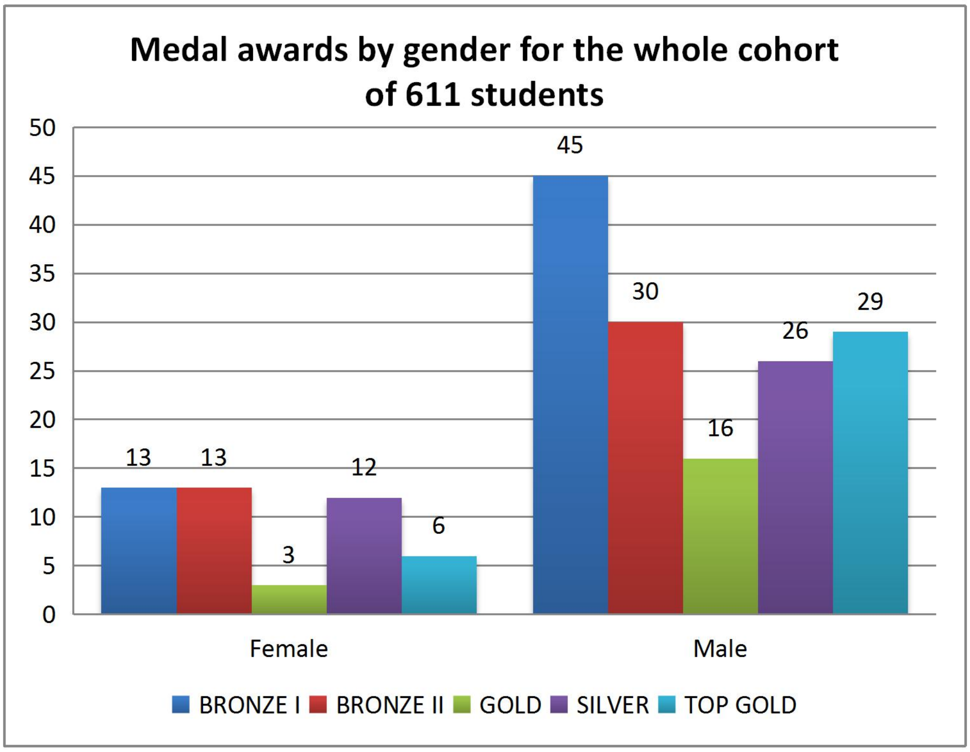


Figure 10. Medals awarded selected by gender

In Table 4 one observes a significant point of interest in the number of students from the two lower years entering. In the UK, only about 10% of the candidates are below the A2 year whereas the Chinese cohort is more evenly balanced between the three years: in fact it is dominated by the two younger year groups, with only 12% of the entry being the A2 year, an unexpectedly small entry. We see that more boys provide these two younger year entries. ThisA2 group is the one for whom the paper is really intended, but it could be that the opportunity to use this result for university application has already passed. Nevertheless, only 12% of the entry being from Grade 12 really is a surprise. Girls form a much greater proportion of the entry at this level.

Table 5. Student entry by gender and by year group.

Year Group	**Grade 10/ GCSE**	**Grade 11/ AS**	**Grade 12/A2**	**Totals**
Female	47	123	27	197
Male	114	255	45	414
Total	**161**	**378**	**72**	**611**
% of entry by year	**26%**	**62%**	**12%**	**100%**
Ratio M/F	**2.43**	**2.07**	**1.67**	**2.10**

A more detailed breakdown of the medals awarded by age and gender is shown in Table 5 below. Younger students in Grade 10 are quite capable of gaining the excellent results, with 4.4% gaining medals, compared to 42% of Grade 11 gaining medals and 7.2% of Grade 12 (a total of 31.6% of the entry received medals).

BPhO British Physics Olympiad

If these percentages of medals awarded are weighted by the percentage of students from each of the three year groups, then the weighted percentages are;

Grade 10 achieving 4.81% of the medals awarded

Grade 11 with 9.28%

Grade 12 with 17.53% (total 31.6%)

So clearly the more advanced students do relatively better, but not so much so given that some of these students have covered two years more of physics. What is surprising is that the GCSE students really can cope so well with the questions on the paper. This would be less so in the UK for such a significant number of students.

Table 6. Medal results by age group showing the relatively strong performance of GCSE entry and the weighted results of each age group.

	Total %	**Top Gold %**	**Gold %**	**Silver %**	**Bronze I %**	**Bronze II %**	**Medals Total %**	**Weighted by entry %**	**Commendation %**
Grade 10/ GCSE	26.35	0.65	0.16	0.98	1.15	1.47	4.42	**4.81**	21.93
Grade 11/ AS	61.87	2.78	1.96	3.93	6.71	4.58	19.97	**9.28**	41.90
Grade 12/A2	11.78	2.29	0.98	1.31	1.64	0.98	7.20	**17.53**	4.58
Totals	100	5.72	3.10	6.22	9.50	7.03	31.6	**31.6**	68.4

The absolute number of medals awarded by age group in Figure 11 shows the same pattern, with a strong performance in the Top Gold. There is a similar shape distribution for all age groups, with a relatively small number of medals for the large entry at GCSE, but showing that there are a small number of students (27) showing an extremely strong performance; these students must be well prepared or working far ahead of the rest of their age group.

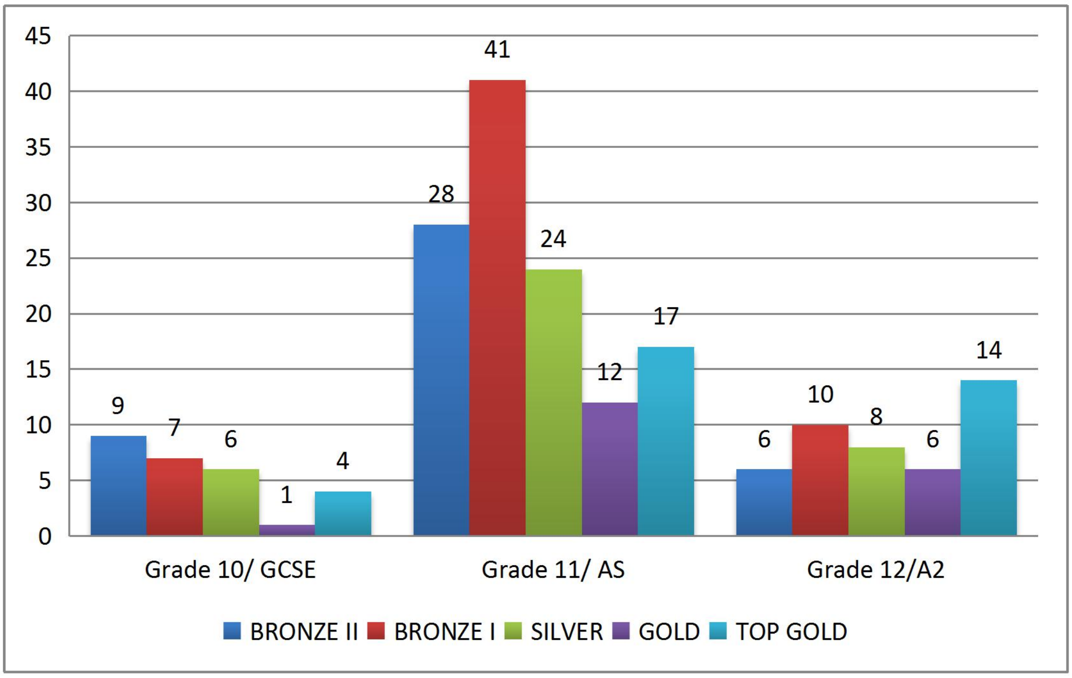


Figure 11. Number of medals by age group, showing a strong performance from a small fraction of the GCSE entry.

Table 6 below shows a more detailed breakdown and one can make the observation that generally there are more Top Golds than Golds awarded, indicating that some students at the top are not being limited by sufficient difficulty at the end of the questions to suppress these very high achievers. This follows on from the relatively flat distribution of the frequency distributions in Figures 4 and 6. The range of marks for Top Gold is 11, Gold 7, Silver 11, Bronze I 7, Bronze II 6, and so a flat distribution would give a number of awards proportional to the mark range for each award.

Table 7. Medals awarded by age group and gender.

	Total	Top Gold	Gold	Silver	Bronze I	Bronze II	Medals Total	Commendation
Female	**197**	**6**	**3**	**12**	**13**	**13**	**47**	**150**
Grade 10/ GCSE	47	0	0	2	0	1	3	44
Grade 11/ AS	123	3	1	8	12	10	34	89
Grade 12/A2	27	3	2	2	1	2	10	17
Male	**414**	**29**	**16**	**26**	**45**	**30**	**146**	**268**
Grade 10/ GCSE	114	4	1	4	7	8	24	90
Grade 11/ AS	255	14	11	16	29	18	88	167
Grade 12/A2	45	11	4	6	9	4	34	11
Totals	**611**	**35**	**19**	**38**	**58**	**43**	**193**	**418**

This data is displayed in the following two charts of Figures 11 and 12. Figure 11 does not include the Commendations which supresses the height of the bars of the other awards. These results are absolute rather than normalised.

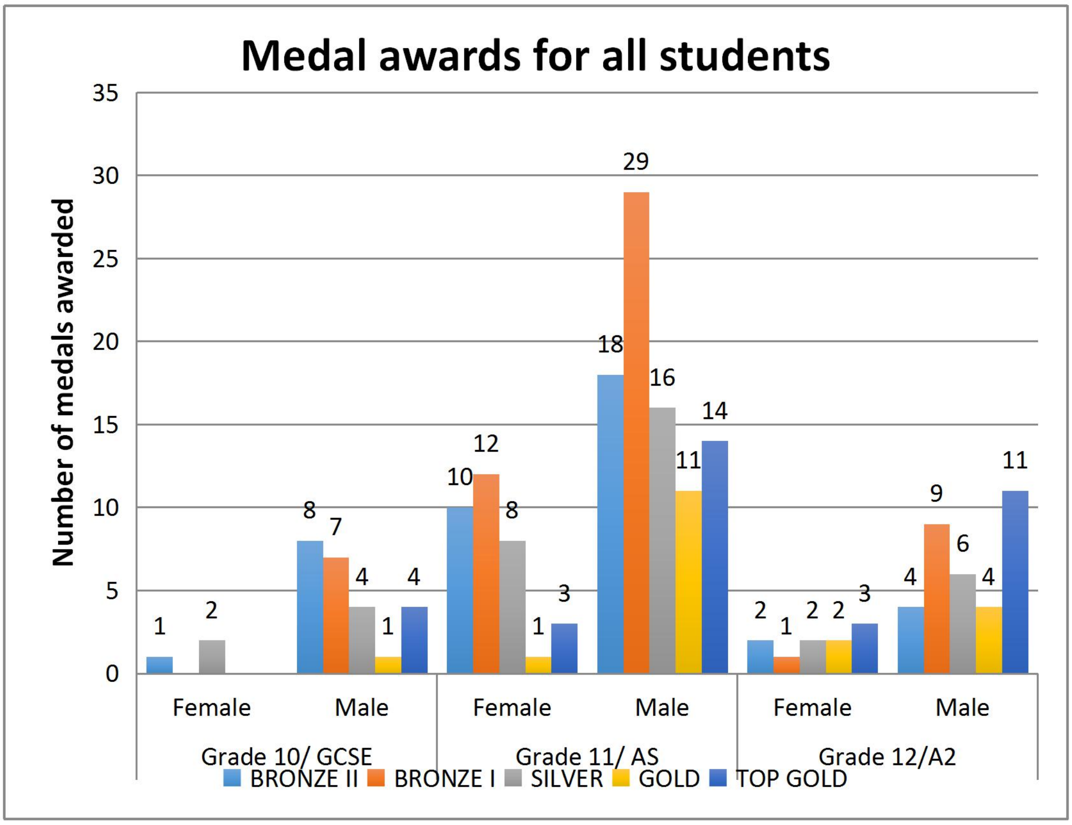


Figure 12. Display of the medals awarded by gender and by year group.

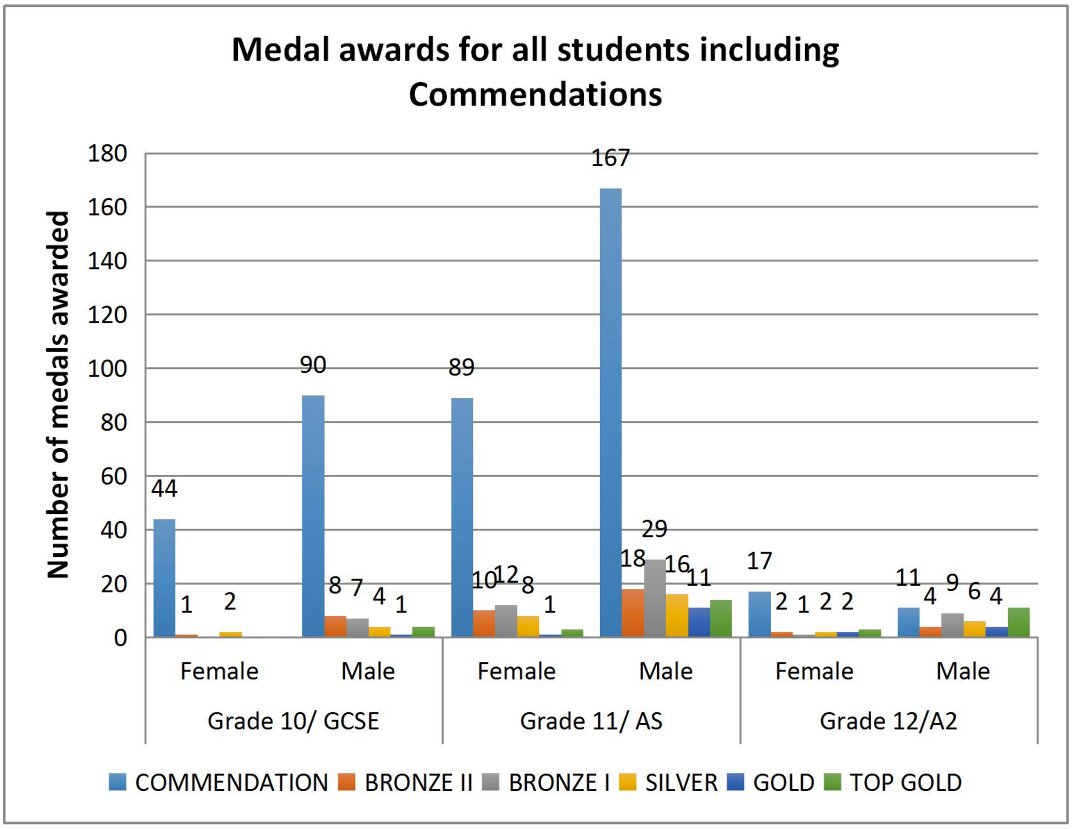


Figure 13. Medal awards or all students, including Commendations.

Table 7 shows as percentages the relative strengths of these year groups, with the figures being scaled to the number of entries in the respective year group. This allows us to see the performance of these students for the three different years. As expected, the Grade 12 students have a stronger performance consistently for all the medals. Again the dip in the number of Golds compared to Top Golds can be seen for all three Grade years.

Table 8. Results by year group normalised to the entry in that year group.

	Total %	Top Gold %	Gold %	Silver %	Bronze I %	Bronze II %	Medals Total %	Commendation %
Grade 10/ GCSE	100.00	2.48	0.62	3.73	4.35	5.59	16.77	83.23
Grade 11/ AS	100.00	4.50	3.17	6.35	10.85	7.41	32.28	67.72
Grade 12/A2	100.00	19.44	8.33	11.11	13.89	8.33	61.11	38.89

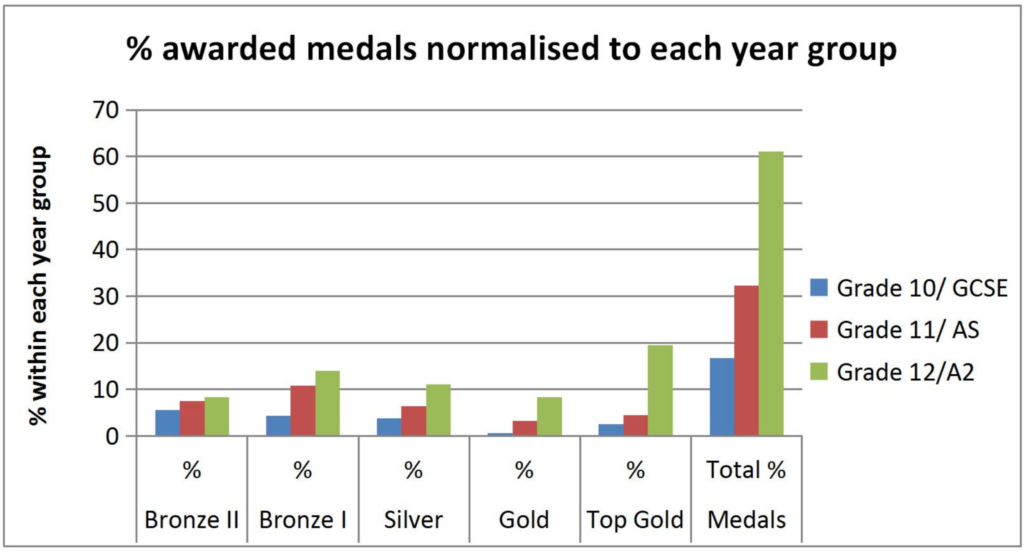


Figure 14. Normalised percentages of medals awarded to the three year groups.

4. Questions

Section 1 of the paper covers a wide variety of topics with short calculation questions. Section 2 consisted of seven long questions from which the candidates had to choose two, but only one of them from questions 5 & 6, which were both on gravity. Students are very particular about the topics they choose to answer questions in. For future years it is important to determine topic areas that are suitable. Clearly, as is seen below, electromagnetism is not popular, although some students are capable of answering question on it.

Most useful here is the topics chosen by the candidates and how successful they were. The three different year groups may well select different questions.

A detailed breakdown of Question 1 is not available.

Table 9. Topics and numbers of questions answered by students.

	Topic	answers	average mark	zeros	UK average
Qu 1	Selection of short questions on may topics	**607**	17.96	4	23.5
Qu 2	Electric circuits, potentials, resistor combinations	**249**	8.50	18	8.05
Qu 3	Two source interference of waves	**122**	9.01	3	9.56
Qu 4	Electrostatic potential's between point charges	**133**	6.56	13	4.89
Qu 5	Gravity and dark matter	**16**	6.00	1	8.55
Qu 6	Gravity and escape velocity	**385**	8.50	13	9.87
Qu 7	Millikan's experiment	**38**	6.35	7	8.79
Qu 8	Electromagnetic induction in a rotating loop	**19**	7.28	1	5.97

Four students obtained zero on Qu 1 and these scripts were specifically checked after results had been entered.

In Section 2 of the paper, 962 questions were attempted (this includes a number of zero marks), compared to 1222 expected if all students had answered two questions from this section. At the lower end of the results, students had often only managed to make a reasonable attempt at one of the questions. 373 students received >0 marks for two questions, 160 received >0 marks for one question (533 students in total).

The question choice is tabulated and displayed below in Table 9 and Figure 15. As might be expected, the A2 candidates were able to select rather more widely, whilst the younger students favoured the very traditional areas of electricity and gravity, in which the questions were rather less adventurous. It is a little disappointing that some of the more interesting questions were not tried by candidates. The average marks do not vary much from question to question so that the difficulty was matched by candidates' knowledge of the topic.

The gender difference was looked at but there was little distinction by gender between the choice of questions from Section 2.

Table 10. Section 2 questions chosen by different year groups.

Year group	Qu 2	Qu 3	Qu 4	Qu 5	Qu 6	Qu 7	Qu 8
Grade 10/ GCSE	64	11	16	2	90	9	5
Grade 11/ AS	160	83	93	11	246	25	11
Grade 12/A2	25	28	24	3	49	4	3
Grand Total	**249**	**122**	**133**	**16**	**385**	**38**	**19**

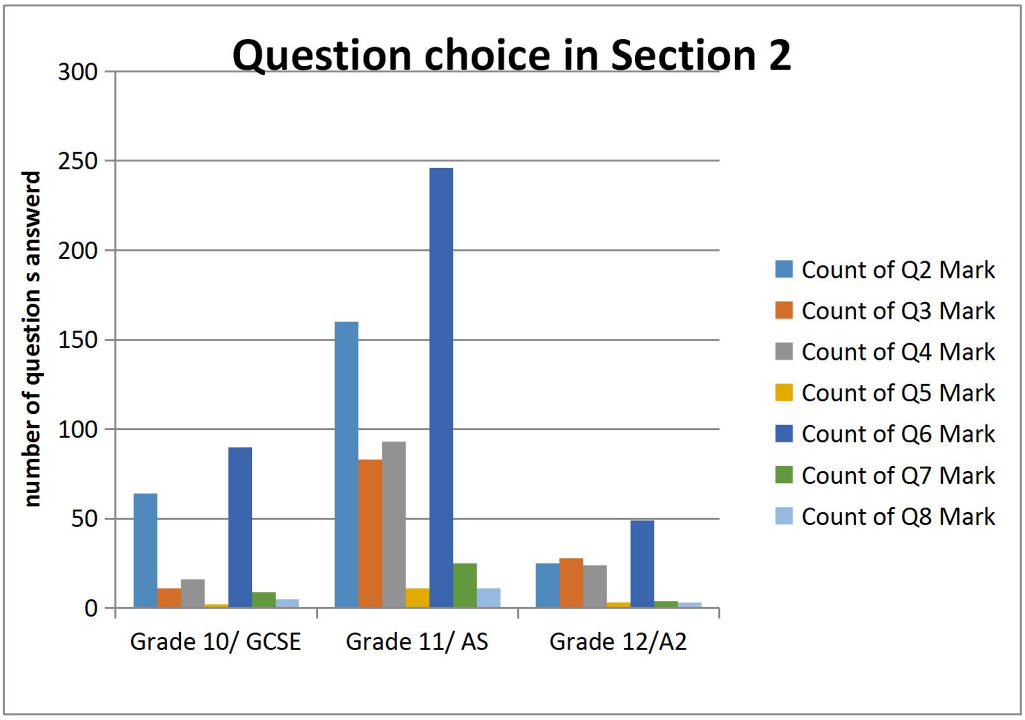


Figure 15. Section 2 questions chosen by different year groups.

The combination of questions chosen is not so vital, here, but it does seem that students who may have done one of the more traditional topic questions in Section 2 (Qu 2 on electricity, Qu 6 on Gravity) might not have always done a second question, whereas those fewer candidates who tried one of the more demanding questions usually did a second question.

The two students who did both Qu 5 and Qu 6 can be seen in table 10 below.

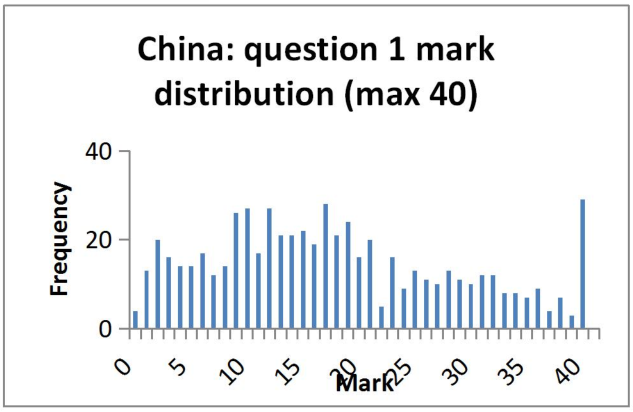
75 students did not obtain a mark for Section 2. There is clearly a number of candidates who were unprepared for the paper with question at this level. It is essential that students have practised on previous papers.

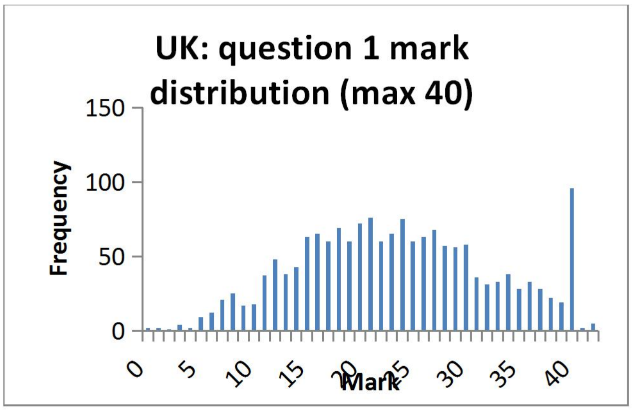
Table 11. Number of 2nd questions chosen when 1st question is known.

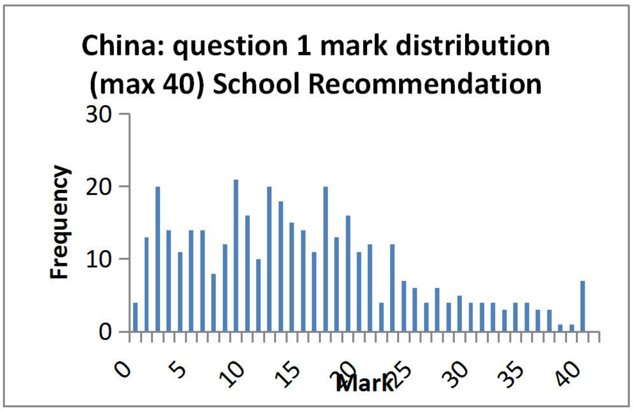
	2nd question chosen is in the same row							No of 2nd questions attempted
1st question chosen Is highlighted	Qu 2	Qu 3	Qu 4	Qu 5	Qu 6	Qu 7	Qu 8	
Qu 2	249	37	24	1	136	5	3	206
Qu 3	37	122	10	2	64	2	3	118
Qu 4	24	10	133	4	81	5	6	130
Qu 5	1	2	4	16	2	3	0	12
Qu 6	136	64	81	2	385	20	7	310
Qu 7	5	2	5	3	20	38	0	35
Qu 8	3	3	6	0	7	0	19	19

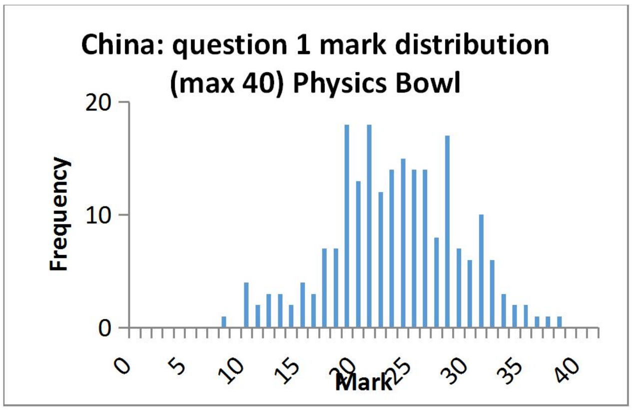
The overall distributions for each question are showing in Figure 16. These indicate a good correspondence between China and the UK students.

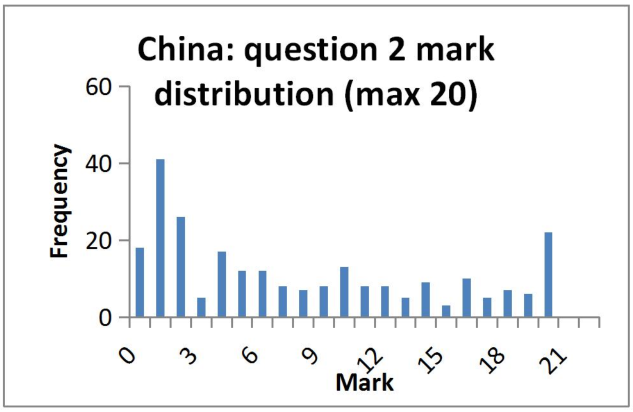
Figure 16 a-r Distributions of marks by question comparing cohorts.

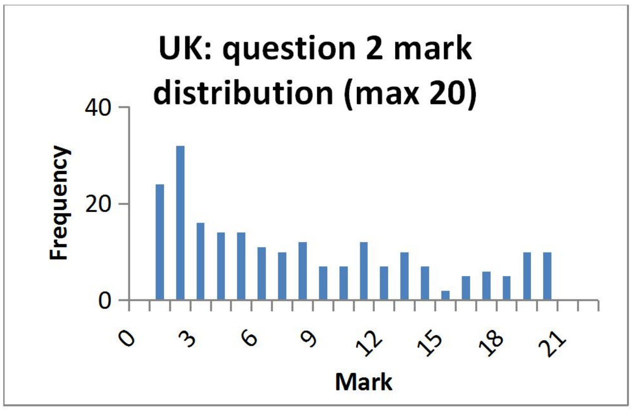


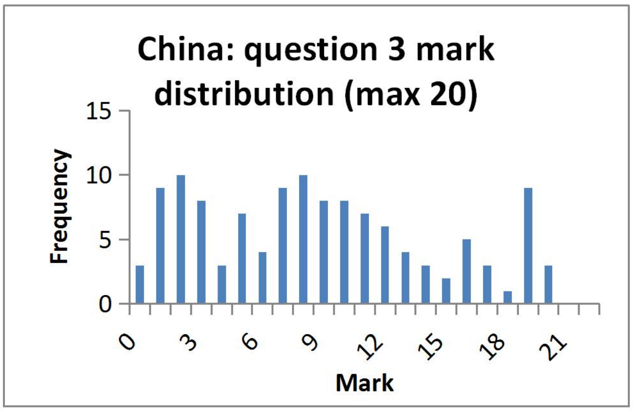











China: question 3 mark distribution (max 20)
Frequency
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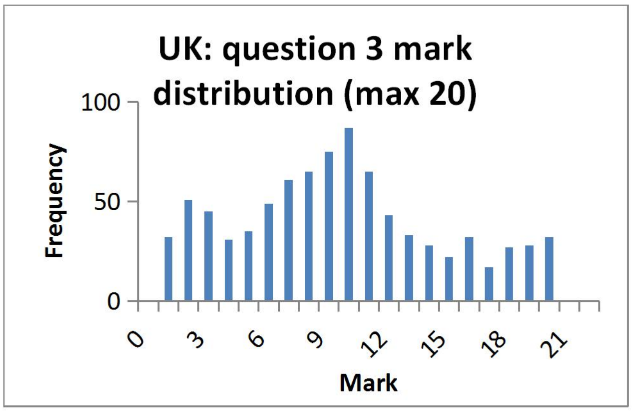
UK: question 3 mark distribution (max 20)
Frequency
0
50
100
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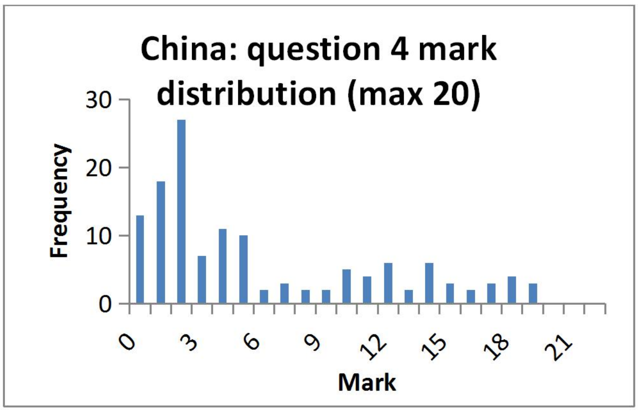
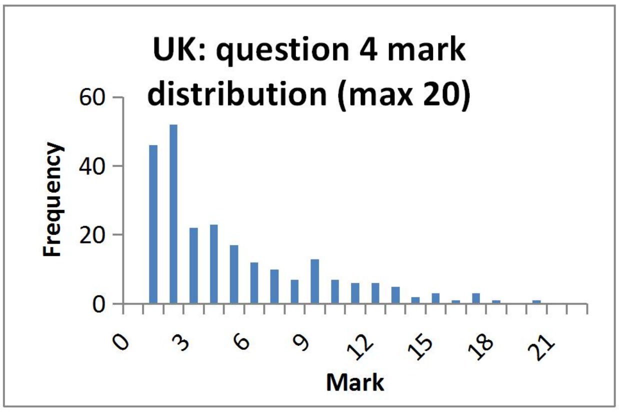
6
9
12
15
18
21
Mark


China: question 4 mark distribution (max 20)
Frequency
0
10
20
30
0
3
6
9
12
15
18
21
Mark


UK: question 4 mark distribution (max 20)
Frequency
0
20
40
60
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3
6
9
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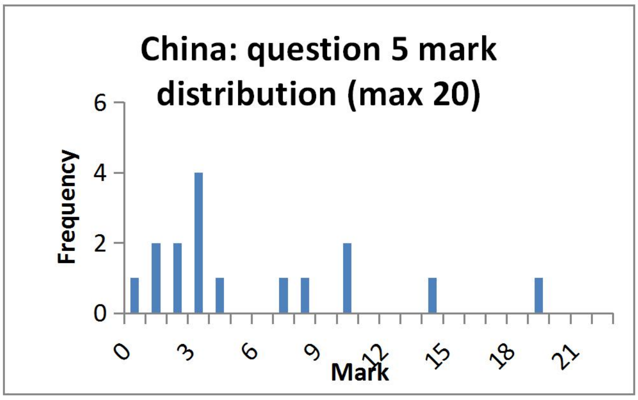
15
18
21
Mark


China: question 5 mark distribution (max 20)
Frequency
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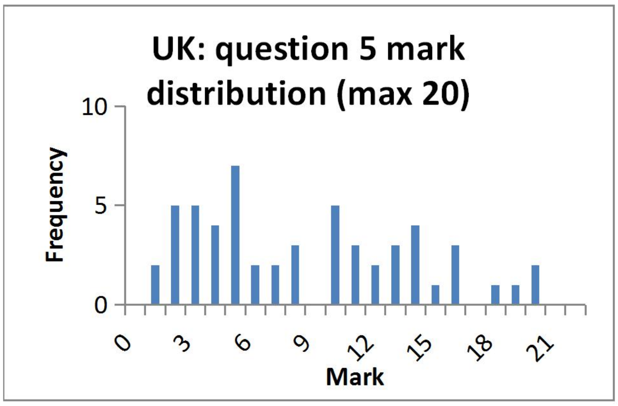
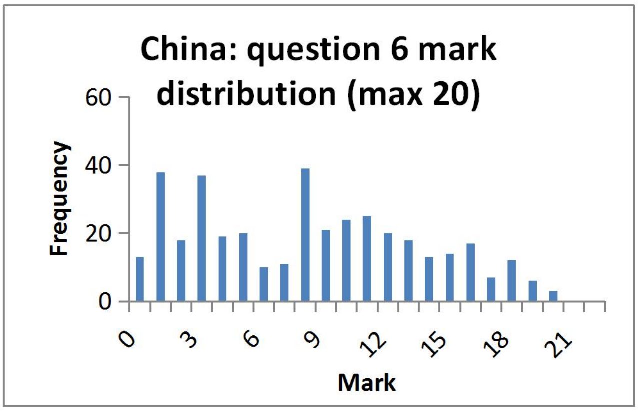
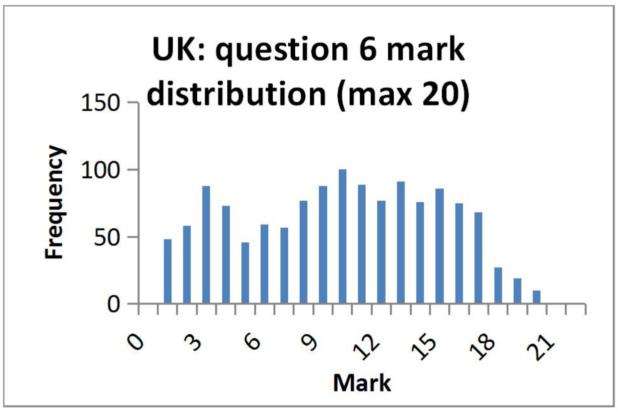
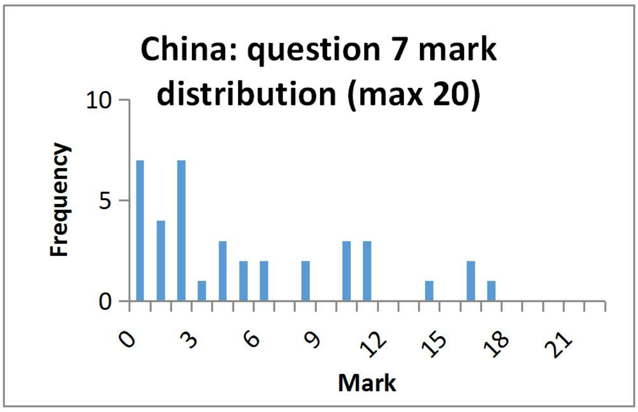
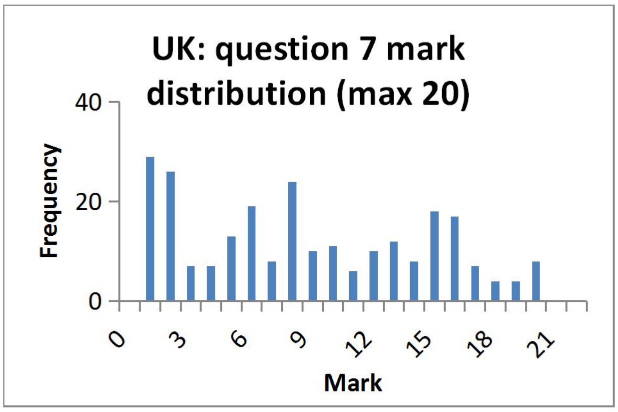
21
Mark

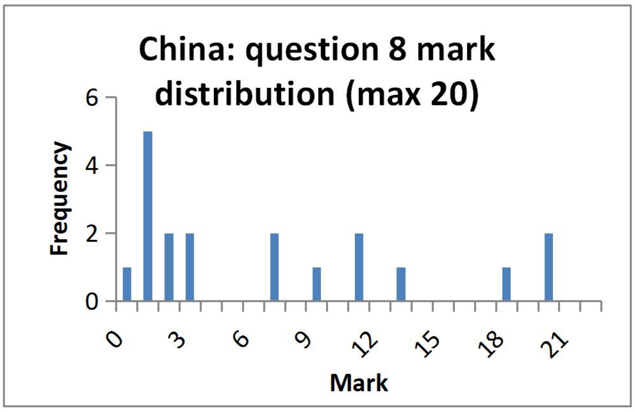

UK: question 5 mark distribution (max 20)
Frequency
0
5
10
0
3
6
9
12
15
18
21
Mark

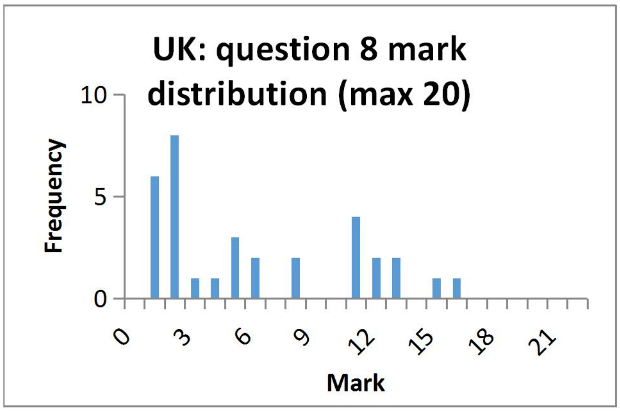

China: question 6 mark distribution (max 20)
Frequency
0
20
40
60
0
3
6
9
12
15
18
21
Mark


UK: question 6 mark distribution (max 20)
Frequency
0
50
100
150
0
3
6
9
12
15
18
21
Mark









5. Conclusion

There are no alarming discrepancies in the results or in the comparison between China and the UK.

1. The UK results compare well with the Physics Bowl selected entry. The averages are similar, as are the distributions. Overall the paper suits both cohorts.

2. There is a cluster of results at the top end of the range for Section 1, indicating that a group of students was able to accomplish every aspect of the question and saturate the marks at the top end. This can be overcome by including more difficult items at the end of each question, or reducing the number of easy questions in this section. This year's paper was thought to be easier than past years. The paper needs an extra level of difficulty.

3. The two lower year groups form the largest entry (88%) and achieved great success. They clearly are at a more advanced stage of knowledge of these topics than equivalent UK students.

4. The two routes of entry through Physics Bowl and School Recommendation seem to work well. However, care must be taken with the weaker students entering by School

Recommendation. A significant number of students failed to make any progress with a second question in Section 2.

5. All the topics seem to be acceptable to the students, though electromagnetism is not popular. Traditional topics will be maintained as the key element of the paper. Two questions were significantly more popular (Qu 2 and Qu 6).

6. Greater discrimination at the top end of the marks is needed.

7. Statistically the experiment seems to have been a success. Feedback from students and their schools would be of interest to see whether the students felt that this was the challenge they expected and wanted. In addition, how does it help them with their physics understanding or university application?

RWH 26th Dec 2016