Development of an instrument to measure physics teachers' views on various aspects of physics.

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Abstract

A survey instrument was developed to capture teachers' views on issues related to various aspects of physics so that it can shed some light on the declining enrolment in Physics at the university level. After expert validation from a panel of reviewers, the instrument was pilot-tested on 35 teachers from secondary schools and junior colleges. This paper discusses the psychometric evaluation of the instrument.

(Key words: teachers' views on physics, survey instrument, declining interest in physics)

Introduction

The problem of declining enrolment in physics is not new for stakeholders in industry, scientific and academic communities. As quoted by Williams et al (2003): *Readers of Physics Education will need no reminder that too few students elect to study physics at A-level and, subsequently, as undergraduates*.

Among the countries facing this problems are England, Wales and Northern Ireland (Assessment and Qualifications Alliance, 2007; Institute of Physics, 2001), Scotland (Scottish Qualifications Authority, 2007), Germany (Tobias & Birrer, 1999), the United States (National Science Foundation, Division of Science Resource Statistics, 2004), Australia (Ian, 2006; Lyons, 2006), Ireland, South Korea, Mexico, Netherlands, and Spain (Organization for Economic Co-operation and Development, 2005 as cited in Barmby and Defty, 2006).

Is physics still a subject deemed to be in the national interest? What would happen to a country if the number of physics graduates produced each year is less than 1% of the total number of graduates? Would this be a threat to economic development?

The existing studies do not capture the viewpoints of physics educators (secondary school and pre-university) in detail on the barriers in the choice of selecting physics at the degree level. A study was found in this aspect but it was not entirely in physics: Woolnough (1993), who investigated teachers' views on why students choose science and engineering.

Literature survey

In conceptualizing the instrument, cognizance was taken of relevant studies in the literature so that appropriate statements can be crafted.

Woolnough (1993) reported that the general consensus among teachers on the factors which encourage students to embark in studying physical sciences are good grades in the subject, relevant extra-curricular activities, ability level, interest and parental influence. Conversely, factors that deter students from doing physical sciences are negative perceptions about job prospects as compared to accountants or business managers, the nature of physics as being a difficult subject, the growing attractiveness of other subjects such as biology and business, and inadequate laboratory facilities.

The commonly cited reasons in the literature associated with the turning off of youngsters from physics/physical science range from the declining interest in the subject among youngsters (e.g. Barmby, Kind & Jones, 2008; George, 2000; 2006; Pell & Jarvis, 2001; Pibun & Baker, 1993; Reid & Skryabina, 2002; Spall, Stanisstreet, Dickson & Boyes, 2004); perception of difficulty of the subject (e.g. Angell, Guttersrud & Henriksen, 2004; Blenkinsop, McCrone, Wade & Morris, 2006; Havard, 1996; Smithers & Robinson, 2008; Woolnough, 1994); irrelevance of the curriculum (e.g. Angell, Guttersrud & Henriksen, 2004; Häussler & Hoffman, 2000; Lyons, 2006); heavy content load of the syllabus (e.g. Williams, Stanisstreet, Spall, Boyes & Dickson, 2003; Woolnough, 1994); and teacher effects (e.g. IOP, 2001; Krogh & Thomsen, 2005; Labudde, 2000; Lee, 2002; Smithers & Robinson, 2008; Smith, 2008; Woolnough, 1994). These are school factors over which teachers have some control and which they could use to positively influence students' decision to study physics /physical science in higher education or choose a physics-based career (Woolnough, 1993). Besides, career aspirations (e.g. Barnes, McInerney & March, 2005; IOP, 2001; Osborne, 2008; Reid & Skryabina, 2002; 2003; Smith, 2008; Stokking; 2000; Tai, Liu, Maltese & Fan, 2006) as well as cultural and social influences (e.g. Hannam, 2008; Lyons, 2006; Støren & Arnesen, 2007; Woolnough, 1994) play important roles in either deterring or encouraging students from physics/ physical science. In spite of the fact that some concurrent factors may be similar in Singapore and in other countries, the results should be interpreted carefully because the emergence of some variables, far from being universal, may prevail only in certain countries.

Methodology

Based on the above framework, items were crafted for the survey form.

An attempt was also made to gather physics educators' views in Singapore regarding the switch-off factors in physics at the tertiary level. Informal discussions were held with a group of physics educators from secondary schools, junior colleges and universities. This is a common practice in developing survey forms (Nardi, 2006).

The preliminary version of the survey instrument comprised 45 statements focusing on teachers' observations on the teaching of physics and 21 statements on teachers' perception of physics in society (Annex A). There are two open-ended questions where teachers can express their views on the issue.

There are fields in the survey form to capture certain details of the school teacher: gender, number of years of teaching experience in physics, qualification, and specialization. The name of the teacher is not requested – this degree of anonymity would encourage frank responses.

The instrument was validated by four expert reviewers from the National Institute of Education in Nanyang Technological University in Singapore before the pilot study. There were several comments and feedback received from the reviewers. The instrument was refined after considering various views of the validators. In the process, new items were added, some items were rephrased, and some were deleted.

Responses to the statements was based on a five-point Likert scale: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. Scoring would be reversed for the negatively worded items before further analysis (Field, 2005). For each item, a high score represents a high level of agreement of the construct being measured.

Sample

The participants in the pilot test were 35 teachers from secondary schools and junior colleges in Singapore. 91.4% were teaching in coeducational schools, 5.7 % in all-boys' schools, and 2.9 % in all-girls' schools. Overall, there are 62.9 % male and 37.1 % female teachers. 65.7 % of the teachers have 2-5 years of teaching experience in physics, 17.1 % have 6-10 years experience, 11.4 % have more than 15 years experience, and 5.7 % have 0-1 year experience in teaching physics. Most of the teachers from these groups are holding Bachelor's degrees (94.3 %); while 5.7 % have Master's degrees. In addition, 65.7% are engineering graduates, 20% are physics graduates, and 8.6% from other specializations.

The samples of physics educators are those who attended two in-service workshops on physics at the National Institute of Education in 2007. They were briefed about the purpose of the study and their assistance was sought for pilot-testing the instrument.

Results and Discussion

The following section examines the psychometric properties of the instrument developed.

An attempt was first made to study the spread of the responses. The purpose was to check whether there were outliers skewing the distribution. Skewness is acceptable within ± 2 to be considered as normal (Keeves, 1997). After finding the outliers, analyses were performed on the data. Among the analyses are internal consistency, reliability (coefficient alpha, α) and item-total correlations. Factor analysis is supposed to be performed; however, due to the small sample size, it will be performed only in the main study.

Scale A: School students and the nature of physics

These items explored students' interest in physics, nature of physics, and perceived difficulty of physics (Annex A).

The values of skewness were within -1.35 to 1.93. After removing the outliers, the item-total correlations among the items improved.

Most of the items met the minimum item-total correlations of 0.30 (Nunnally & Bernstein, 1994). After removing the outliers; only items A1c, A3, and A5 did not meet this requirement.

Reliability values estimated by Cronbach's alpha coefficient before and after removing the outliers from the scale were 0.73 and 0.74. This indicated good reliability (Field, 2005).

Although items A1c, A3, and A5 did not meet the item-total correlation of 0.30, we did not find any problem in the wording and thus we kept these as they served a purpose.

Items A10, A6, and A9 seems to be problematic.

Item A10 was omitted because it appears that this item was not well-defined. There was a need for more specificity in the statement - for example, students lack the mathematics ability to do well in physics. However, since this idea has been subsumed under items A4, Bii13, and Bii15, it was decided to be deleted.

Item A6 also seemed problematic. It was felt that other ways to explicitly measure students' intention to study physics in the future was needed. For example, rather than just frame a statement, it was felt that it is better to solicit the relevant details directly through questions using percentage categories:

Students' intention to study physics in future

1. What percentage of your students do you think will want to choose physics as a subject for study in junior college?

2. What percentage of your students do you think will want to choose physics as their major subject in the university?

3. What percentage of your students do you think will want to choose physics as their minor subject in the university?

4. What percentage of your students do you think will want to choose physics in school as the requirement for other specializations in the university?

5. What percentage of your students do you think will want to choose a career in physics in the future?

The percentages used would be: 0-20%, 21-40%, 41-60%, 61-80%, and 81-100%. As a result, item A6 was deleted and will be replaced by the items above.

It seems that item A9 (Physics puts students off) was not properly defined, for example, in what ways can physics put students off? As a result, it needs to be rephrased or deleted. We decided to delete it since there are other items investigating this idea in terms of mathematical skills (items A4, Bii13, and Bii15) and in terms of conceptual understanding (item Bii12).

Item A8 (Physicists are born) was rephrased to "Physicists are born – not made!) for better comprehension.

In conclusion, two items were deleted from this scale and two were rephrased. 79% of the item-total correlations were above the minimum norm of 0.30.

Scale B: Physics pedagogy in school

There are six sub-scales under this scale: Curriculum, Teaching, Laboratory practice, Extra-curricula activities, and Assessment.

Curriculum

There are 6 items framed on physics curriculum (Annex A).

The Cronbach's alpha reliability coefficient for the raw data here was 0.51. The item-total correlations ranged from 0.07 to 0.71 and a negative item-total correlation index appeared for item Bi1. Attention was given to this item.

After removing the outliers, the alpha coefficient increased to 0.53 and the negative sign on the item-total correlation disappeared. However, the alpha coefficient was still rather low. By removing item Bi1, better results were obtained. The alpha coefficient increased to 0.62 and item-total correlations improved tremendously. Item Bi1 appears to be highly suspect.

In spite of the improvement, item-total correlations for item Bi5 and Bi6 did not meet the minimum recommended value of 0.30. By removing both these items from this sub-scale, the alpha coefficient increased to 0.79; moreover, better results for item-total correlations were obtained.

Therefore, items Bi1, Bi5 and Bi6 were given further attention.

Item Bi1 (The content in the physics syllabus is relevant to students' everyday life) was decided to be deleted. The reason is that there is another similar item probing the relevance of physics to everyday life in A3 (Physics is irrelevant to everyday life). Items Bi5 and Bi6 were kept since no wording problem was found and they were crucial for the study.

In conclusion, one item was deleted and 60% of the item-total correlations were above 0.30.

Teaching
There are 14 items framed on the teaching of physics (Annex A)

When all of the outliers were removed, alpha coefficient increased from 0.60 to 0.64.

Item Bii9, 11, 13, 14, 16, 18, 19, and 20 had a low item-total correlation. Special attention was given to these items.

Item Bii9 (The teaching of physics demands passive reception rather than active involvement by students in the learning process) was rephrased as: "I find that students do not participate actively in the physics lessons". Item Bii11 was also rephrased as: "I find that the traditional way of teaching physics (chalk-and-talk) holds true even today".

Item Bii14 (Just because students are able to pass physics examinations do not mean that they understand physics.) was also rephrased as: "Students are able to pass the physics examinations even without an understanding of physics".

Item Bii 16 - (Incorporating a diversity of resources (e.g. demonstrations, power point presentations, multimedia, etc.) into traditional teaching can make physics more interesting to students.), was suspected to be problematic. The term 'traditional teaching' may not have been well-defined. Hence, the statement was rephrased as: Incorporating a diversity of resources (e.g. demonstrations, power point presentations, multimedia, etc.) into traditional teaching (chalk-and-talk) can make physics more interesting to students.

It appears that teachers are not able to comment on item 19 (Bii19: I find that students enjoy doing homework in physics.) on behalf of students. This question was thus rephrased as: My students find that doing homework in physics is a chore.

Item Bii20 (I find that physics is abstract for students.) does not appear to be well-defined. The statement was rephrased as: "I find that the content in physics is generally abstract for students".

Item Bii 11, 13, 18, and 19 were kept although low item-total correlations were observed.

In conclusion, five items were rephrased and 83% of the item-total correlations were above the minimum norm of 0.30.

Laboratory practice
There are three items framed on physics laboratory practice (Annex A).

The original raw data yielded an alpha coefficient of 0.55. Only item Biii24 did not meet the minimum recommended value of 0.30.

Reliability values before and after removing the outliers from this sub-scale were 0.55 and 0.58.

The moderate alpha coefficient indicated that attention needs to be given to each item in this sub-scale, especially item Biii24.

It appears that item Biii22 (Students find laboratory experiments in physics easy to do) and Biii23 (Students enjoy coming to the laboratory for their practical lessons) were not well-defined. The items, hence, were rephrased as:

Biii22: My students are confident in carrying out the experiments in physics.
Biii23: My students participate actively in laboratory work.

Items Biii21 (The practical work devoted to the content in physics is sufficient) and Biii25 (Laboratory work helps student understand physics better) have been rephrased too:

Biii21: The practical work in the laboratory is sufficiently devoted to the physics content.
Biii25: Students understand the physics content better through laboratory work.

Item Biii24 was kept since no wording problem was found in it.

In conclusion, four items were rephrased and 80% of the item-total correlations were above the acceptable norm. A new item was also added: I believe that the laboratory is a vital part for students in learning physics.

Extra-curricular activities
There are two items which probed about the enrichment programs in learning physics (Annex A). The original raw data yielded an alpha coefficient of 0.74. Both of the items met the minimum norm value of item-total correlation. Thus, no modification was done.

Assessment
There are four items that probed about physics assessment (Annex A).

The raw data yielded an alpha coefficient of 0. 57. No potential outlier was found. Item-total correlation for item Bv31 did not meet the minimum requirement of 0.30. Hence, attention was given to this item.

Item Bv31 was rephrased as: “Students need to memorize a lot to score in physics examination”. Besides, item Bv30 was rephrased to “The questions set in physics examinations are relevant to real world problems”. Item Bii14 (Students are able to pass the physics examinations even without an understanding of physics) was moved to this sub-scale because it is more relevant here.

In conclusion, two items were rephrased and 75% of the item-total correlations were higher than 0.30.

Scale C: Your perception of physics in society
There are 21 items framed about career prospects of physics graduates, market demand, and utility value of physics (Annex A).

The alpha coefficient for the raw data was 0.75.

Items C1, 2, 6, 8, 10, 12, 14, 17, 20, and 21 did not meet the minimum norm value of 0.30, hence, they were given attention.

Attempts to remove potential outliers from the corresponding items yielded a better alpha coefficient: 0.77. The inter-item correlations yielded a slightly better result; most of the items mentioned above still did not meet the minimum norm of 0.30.

It seems that items C6, C8, and C10 were not well-defined and also did not carry much weight towards the purpose of this study. So, they were eliminated from the survey form. However, item C1, 2, 12, 14, 17, 20, and 21 were kept because no wording problem was found on them.

In conclusion, three items were eliminated and 52% of the item-total correlations were above the acceptable norm of 0.30.

Open-ended questions
Most of the teachers provided comments concerning the career prospects and the current demand for physics graduates.

As a result of their comments, two new items have been added in the survey form. They are:

a. Physics graduates have limited job choices.
b. There is less emphasis on hiring physics graduates in industry.

Conclusion
Of the 69 statements in the survey form, 7 items were eliminated either because they were not properly-defined or overlapped with other items. A total of 13 items have been rephrased for better comprehension. Two new items have been added after taking into account the views of teachers.

The refined version of the instrument appears as Annex B.

The initial five response categories (1: Strongly Agree, 2: Agree, 3: Neutral/Not sure, 4: Disagree, 5: Strongly Disagree) were decided to be converted into six response categories besides removing the neutral stand for the main study (1: Strongly Disagree, 2: Disagree, 3: Slightly Disagree, 4: Slightly Agree, 5: Agree, 6: Strongly Agree). The analysis of the pilot test indicated that a good number of teachers tended to choose the neutral stand. The neutral stand was withdrawn and a wider scale was decided as this would enhance the factor structure. Lopez (1996) and Fisher (2000) reported that the option of "Neutral" can provoke irrelevant responses leading to ambiguous category ordering and meaning (cited in Lee & Fisher, 2005).

Each statement is placed in the respective categories of the instrument in the pilot study. It was designed with the intent to help participants focus on issues of importance. It is true that participants may give socially desirable responses according to the respective categories. As stated by Alreck and Settle (1985): "Does the question lead respondents toward a particular answer? If so, the leading phrase must be removed" (p. 114). As a result, each category will be removed in the final version of the instrument for the main study. All items will be grouped by placing items of every sub-scale together so that the respondents do not have a cue as to what is being ascertained. According to Alreck and Settle (1985), each item will not be viewed or evaluated independently if similar items appear in sequence. This approach has been adopted by Young and Brown (1994), as cited in Rijkeboer and Bergh (2006), in developing their Schema-Questionnaire.

The small sample size for the pilot test might have resulted in some unstable observations in the initial version of the instrument. Better results are expected for the main study with more participants.

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ANNEX A

School students and the nature of physics

A1. My students find physics:
a. Difficult.
b. Interesting.
c. Easy.
d. Boring.
e. Fun.

A2. Physics is able to arouse curiosity among students.
A3. Physics is irrelevant to everyday life.
A4. Physics requires mathematical skills to do well.
A5. Physics is only for the brainy students.
A6. Given the choice, students will not want to choose physics as a subject for study in school.
A7. Physics is suitable only for boys.
A8. Physicists are born.
A9. Physics puts students off.
A10. Students lack the ability to do well in physics.

Physics pedagogy in school

Curriculum

B1. The content in the physics syllabus is relevant to students' everyday life.
B2. The syllabus in physics is heavily content-loaded.
B3. Reducing the content in the physics syllabus will lead students to like physics more.
B4. There is too much content to be mastered in physics.
B5. Physics textbooks are able to stimulate students' interest in the learning of physics.
B6. The subject matter in physics textbooks are presented very clearly.

Teaching

B7. Teaching physics is enjoyable.
B8. The classroom environment in schools is conducive for the teaching of physics.
B9. The teaching of physics demands passive reception rather than active involvement by students in the learning process.
B10. I find it difficult to arouse the interest of students in physics.
B11. The traditional way of teaching physics
(chalk-and-talk) holds true even today.
B12. I find that students encounter difficulties in achieving conceptual understanding in physics.
B13. I find that students encounter difficulties in solving quantitative problems in physics.
B14. Just because students are able to pass physics examinations does not mean that they understand physics.
B15. I find that the mathematics used in physics puts students off.
B16. Incorporating a diversity of resources (e.g. demonstrations, power point presentations, multimedia, etc.) into traditional teaching can make physics more interesting to students.
B17. In my physics classes, the boys participate more actively than girls.
B18. In my physics classes, boys do better than girls.
B19. I find that students enjoy doing homework in physics.
B20. I find that physics is abstract for students.

Laboratory practice

B21. The practical work devoted to the content in physics is sufficient.
B22. Students find laboratory experiments in physics easy to do.
B23. Students enjoy coming to the laboratory for their practical lessons
B24. The laboratory is well resourced to support the teaching of physics.
B25. Laboratory work helps students understand physics better.

Extra-curricular activities
B26. Extra-curricular activities in physics are needed to inspire students in the learning of physics.
B27. Extra-curricular activities (for example, collaboration between local engineers and teachers, talks by external speakers, visitations to relevant places like science centers, competitions, etc.) can arouse students' interest in learning physics.

Assessment
B28. Good examination results motivate students in learning physics.
B29. Good examination results enhance students' confidence in learning physics.
B30. The questions set in physics examinations are relevant to real world problem-solving.
B31. The examinations in physics require considerable memorization of content by students.

Your perception of physics in society
C1. Physics is important for society.
C2. Physics leads one to new and exciting jobs.
C3. Physics improves one's career prospects.
C4. Physics provides career opportunities which will bring wealth.
C5. Physics opens up greater opportunities for future careers.
C6. The benefits provided by physics are greater than the harmful effects it has caused.
C7. Physics can help to eradicate poverty in the world.
C8. Physics can solve many problems that the world is facing.
C9. Physics can help the poor.
C10. Physics is the cause of environmental problems.
C11. A country needs physicists to become developed.
C12. Physics provides modest career prospects.
C13. The studying of physics is regarded highly in society.
C14. Physics is able to increase one's appreciation of nature.
C15. Physicists are held in high esteem by society.
C16. Physics graduates have well paid jobs.
C17. Students favor other careers (e.g. Law and Finance) rather than physics-based careers
C18. A career in physics is perceived as being of high status.
C19. Physicists are in demand in today's society.
C20. Admission requirements set by universities for entry into degree programmes in physics are rather high.
C21. The starting salary for physics graduates is high.

ANNEX B

School students and the nature of physics

A1. My students find physics:
a. Difficult.
b. Interesting.
c. Easy.
d. Boring.
e. Fun.

A2. Physics is able to arouse curiosity among students.
A3. Physics is relevant to everyday life.
A4. Physics requires mathematical skills to do well.
A5. Physics is only for the brainy students.
A6. Physicists are born.
A7. Physics is suitable only for boys.

Physics pedagogy in school

Curriculum

B1. The syllabus in physics is heavily content-loaded.
B2. Reducing the content in the physics syllabus will lead students to like physics more.
B3. There is too much content to be mastered in physics.
B4. Physics textbooks are able to stimulate students' interest in the learning of physics.
B5. The subject matter in physics textbooks are presented very clearly.

Teaching

B6. Teaching physics is enjoyable.
B7. The classroom environment in schools is conducive for the teaching of physics.
B8. I find that students do not participate actively in the physics lesson.
B9. I find it difficult to arouse the interest of students in physics.
B10. I find that the traditional way of teaching physics (chalk-and-talk) holds true even today.
B11. I find that students encounter difficulties in achieving conceptual understanding in physics.
B12. I find that students encounter difficulties in solving quantitative problems in physics.
B13. I find that the mathematics used in physics puts students off.
B14. Incorporating a diversity of resources (e.g. demonstrations, power point presentations, multimedia, etc.) into traditional teaching (chalk-and-talk) can make physics more interesting to students.
B15. In my physics classes, the boys participate more actively than girls.
B16. In my physics classes, boys do better than girls.
B17. My students find that doing homework in physics is a chore.
B18. I find that the content in physics is generally abstract for students.

Laboratory practice

B19. The practical work in the physics laboratory is sufficiently devoted to the physics content.
B20. My students are confident in carrying out the experiment in physics.
B21. My students participate actively in laboratory work.
B22. The laboratory is well resourced to support the teaching of physics.
B23. My students understand the physics content better through laboratory work.

Extra-curricular activities

B24. Extra-curricular activities in physics are needed to inspire students in the learning of physics.
B25. Extra-curricular activities (for example, collaboration between local engineers and teachers, talks by external speakers, visitations to relevant places like science centers, competitions, etc.) can arouse students' interest in learning physics.

Assessment

B26. Good examination results motivate students in learning physics.
B27. Good examination results enhance students' confidence in learning physics.
B28. The questions set in physics examinations are relevant to real world problem.
B29. Students need to memorize a lot to score in physics examinations.

B30. Students are able to pass the physics examinations even without an understanding of physics.

Your perception of physics in society
C1. Physics is important for society.
C2. Physics leads one to new and exciting jobs.
C3. Physics improves one's career prospects.
C4. Physics provides career opportunities which will bring wealth.
C5. Physics opens up greater opportunities for future careers.
C6. Physics can help to eradicate poverty in the world.
C7. Physics can help the poor.
C8. A country needs physicists to become developed.
C9. Physics provides modest career prospects.
C10. The studying of physics is regarded highly in society.
C11. Physics is able to increase one's appreciation of nature.
C12. Physicists are held in high esteem by society.
C13. Physics graduates have well paid jobs.
C14. Students favor other careers (e.g. Law and Finance) rather than physics-based careers.
C15. A career in physics is perceived as being of high status.
C16. Physicists are in demand in today's society.
C17. Admission requirements set by universities for entry into degree programs in physics are rather high.
C18. The starting salary for physics graduates is high.
C19. Physics graduates have limited job choices.
C20. There is less emphasis on hiring physics graduates in industry.