



# THE UNIVERSITY OF WESTERN AUSTRALIA

*Graduate School of Education*

## **Doctor of Education (Ed.D.) Research Proposal**

### **EFFECTS OF BIOLOGY-INFUSED DEMONSTRATIONS ON ACHIEVEMENT AND ATTITUDES IN JUNIOR COLLEGE PHYSICS**

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## ABSTRACT

This research will examine the effects of biology-infused physics demonstrations on the achievement and attitudes of junior college (Year 11 and 12) students in Singapore. Within each of two colleges, 120 participants (60 males and 60 females X 60 high and 60 low ability) will be assigned randomly into control and experimental groups (total  $n = 240$ ). In both conditions, students will study two physics units under the constructivist teaching approach of Predict-Observe-Explain (POE). In the experimental group, however, biology-infused physics demonstrations will be used, whilst in the control group, more traditional demonstrations will be used. After two weeks of intensive physics demonstrations as enrichment lessons, these groups will be compared to examine the relative impact of these two approaches on physics achievement and attitudes. Gender and ability level will also be included in the model to determine whether the effects are consistent across these factors.

The outcomes of these two conditions will be assessed using three instruments: a Physics Achievement Test (PAT), a Physics Attitudes Survey (PAS), and an Affective Outcomes Scale (AOS). For data analysis, the statistical methods of Pearson  $r$  and Rasch will be used for the PAT, while factor analysis and MANCOVA will be used for the PAS and AOS. MANCOVA with pretest scores as covariates and Effect Sizes will also be used to study the main effects and interaction effects of the independent variables. This research study will be highly significant in that the findings may have national and international implications for the enhancement of physics education. This teaching-learning approach in infusing biology into physics demonstrations is likely to be the first of its kind in the Singapore context and possibly beyond. This research is also particularly timely, in light of the diminishing enrolments and interest of females in high school physics courses, as well as the reduced levels of physics achievement and attitudes' of females in many countries.

## INTRODUCTION

In Singapore, several important educational initiatives have been introduced in recent years that have direct implications for science education. These include:

- (i) the promotion of interdisciplinary project work in 1999 - this initiative was designed to foster qualities such as curiosity, creativity and enterprise; nurture critical skills for the information age; cultivate habits of self-directed enquiry, and; encourage students to explore the inter-relationships between subject-specific knowledge (Ministry of Education, 1999/2000),
- (ii) the reform of life sciences in 2001 - this was done through a minor revision of syllabus and the production of resource books for primary, secondary and junior colleges which included life sciences activities. This reform was designed to equip students with the knowledge and skills for the growth area of life sciences in the real world, and
- (iii) the introduction of innovation and enterprise in 2003 – this initiative aimed to prepare students for an innovation-driven future by equipping them with a key set of life skills, including a mindset and outlook of creativity, initiative and self-reliance, through the use of specific related learning activities.

Particular interest has been taken recently in the subject area of physics, which is typically characterized by problems of poor student enrolment. Traditionally, physics has been viewed by students as an abstract, ‘elitist’ subject area, and tends not to be preferred by lower-achieving science students (Stepans, 1991). Research has also suggested significant gender differences in preferences for physics at the secondary level. For example, in a study to explore the attitudes and perceptions of Scottish girls and boys towards physics over the age range of 10-18 years old, Reid and Skryabina (2003) reported that twice as many boys as girls were attracted to choose physics at the third year of the secondary school. Harding and Parker (1995) also reported that women are poorly represented in areas of employment that require science-related qualifications, except medicine. For example, in physics courses and examinations at school in England and Wales, girls are under-represented by factors of approximately 1:5 at GSE level, 1:3 at O level and 1:4 at A level. This underrepresentation of girls is then propagated into physics

undergraduate courses (1:8), postgraduate courses (1:10) and professional activity as a physicist (1:20).

Haussler & Hoffmann (2002) cited an international survey by Gardner (1985, 1998) that “many studies repeatedly indicate that students’ interest in physics declines worldwide during Secondary Level 1 and that girls are less interested in physics than boys”. In the case of Germany, the enrolment of female students for physics achievement courses at upper secondary level fell to about 10% (Haussler & Hoffmann, 2002). In this intervention study involving six junior high schools in Germany, the following four different educational measures on intervention were used:

- adapting physics curriculum to interests of girls;
- training teachers in supporting girls to develop positive self-concept;
- splitting classes in half every second lesson and
- teaching girls and boys separately every second lesson.

Studies have also shown that gender differences in attitudes towards science may be discipline-specific. For example, results of the 1999 Third International Mathematics and Science Study (TIMSS) Benchmarking Study indicated significantly greater percentages of boys than girls with positive attitudes towards physics. The reverse, however, was true for the subject area of biology. Studies that have demonstrated relationships between poor engagement and failures to develop basic academic skills (e.g., Mathewson, 1994) highlight the potential significance of such attitudinal problems for physics as a subject area.

### **CONSTRUCTIVISM: THE NEW ORTHODOXY OF SCIENCE TEACHING?**

Many recent efforts to improve student engagement in secondary level science classrooms have been based on applications of constructivist learning principles. *Constructivism* has become the ‘buzz word of the day’ in science education. Since the mid-1980s, constructivism has become an increasingly popular theory of knowledge in the fields of both Mathematics and Science education (Chapman, 2003). As a theory of knowledge, constructivism is founded on the premise that by reflecting on our experiences, we construct our own understanding of the world in which we live. Research interest in constructivist teaching practices has generated a significant body of empirical

data that has contributed to improving teachers' knowledge and understanding of difficulties in the learning of science. The widespread acceptance of constructivism in many parts of the world led Mathews (1993) to label it as "the new orthodoxy of science teaching".

Greer, Hudson, and Wiersma (1999, p.2) argued that, in general, constructivist teaching practices:

- provide learning experiences such as accessing students' prior knowledge, utilizing reflective and relational thinking, and developing big ideas,
- create and capitalize on opportunities for student disequilibrium, misconceptions, and errors so that students are forced to query meaning, and
- provide opportunities for students to verbally interact with others in the pursuit of understanding and growth, enabling students to develop and support their own points of view rather than merely adopt the point of view of others, such as that of the teacher and the text/materials.

## **POTENTIAL BENEFITS OF PHYSICS DEMONSTRATIONS**

Recent increases of interest in the use of physics demonstrations have been prompted, at least in part, by the widespread adoption of constructivist learning approaches across many areas and levels of education. Albert Einstein once asserted that "in the matter of physics, the first lessons should contain nothing but what is experimental and interesting to see. A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds" (cited in Moszkowski, 1970). Clifford and Thomas (1998), who acted as editors of *The Physics Teacher* for many years, noted further in their book *Teaching Introductory Physics*:

The demonstration experiment is one of the most powerful teaching tools that a physics teacher can call on. In a demonstration, an individual, usually the teacher handles objects in a planned way to illustrate or classify the physics to be taught... Teachers often find that returning alumni may say, "I remember when you showed us..." but seldom or never reminisce about a lecture or a film. (p.8).

A search of issues from *The Physics Teacher* (<http://scitation.aip.org/tpt/>) between 1975 to 2004 shows that while several articles have been published on the design and use of physics demonstration experiments as teaching aids, few have examined the effects of these on achievement or affective outcomes in physics. Congruent with the ancient adage

“seeing is believing” (Swartz & Miner, 1998), an effective physics lecture demonstration may foster students’ interest in the topic, as well as slowing the pace of teaching and affording students needed time to organise and digest the ideas presented to them.

Sund and Trowbridge (1973) proposed five types of demonstrations: *teacher* led (the teacher prepares and gives the demonstration), *teacher-student* led (a student assists the teacher in preparing and presenting the demonstration), *student group* led (the teacher acts as an evaluator of the demonstration), *individual student* led (the demonstration is given by a high-status student), and *guest* led (other science teachers or professional scientists are called in to present the demonstration).

Besides their potential motivational advantages, demonstrations may promote a scaffolding dimension in the comprehension and acquisition of abstract physics principles. Physics demonstrations can also promote skills in the use of essential equipment and direct/focus the thinking process by highlighting key concepts effectively.

Although very little research has been conducted on the efficacy of demonstrations on physics achievement, those that have been done generally indicate positive effects. In one recent example, Ciske (2002) examined the effects of student-led demonstrations in a high school physics class in Michigan. The nineteen students in the class were divided into two groups, one group who prepared and performed the physics demonstrations on eleven physics topics and one group who did not prepare and perform but observed the demonstrations. The results showed that the group who prepared and presented the demonstrations performed better on the post-test than the observers.

### **THE PREDICT-OBSERVE-EXPLAIN APPROACH**

One useful structured constructivist teaching strategy which has direct relevance to the use of physics demonstrations is the Predict-Observe-Explain instructional approach (White & Gunstone, 1992). This approach incorporates elements of both teacher-centred and student-centred instruction. Predict-Observe-Explain [POE] (White & Gunstone, 1992) is a powerful strategy to conduct minds-on inquiry based demonstrations. In this approach, the teacher attempts to be a significant part of the learner’s lived experience. This is achieved through facilitating students’ reconstruction of their own knowledge in

inquiry-based lessons by promoting interactions with objects in the environment, and engaging students in higher-level thinking and problem solving (Crawford, 2000).

POE includes the following five stages:

- (i) teachers pose a problem for the students to predict the outcome of a demonstration before it is carried out;
- (ii) teachers ask students (in pairs) to make their personal predictions;
- (iii) students compare their predictions with each other before the conduct of the demonstration;
- (iv) students observe the demonstration as it is being carried out;
- (v) students participate in a discussion facilitated by the teacher for purpose of teaching the correct scientific concepts and remediate any misconceptions.

Watts and Jofili (1998) cited Fox's (1983) seven metaphors of a constructivist teacher which can be achieved through the constructivist POE instruction:

- *Theatrical director* – directs and orchestrates learners' thinking,
- *Tour guide* – guides and chaperones learners,
- *Scaffolder* – provides structure and supports,
- *Provocateur* – challenges and struggles with the learner,
- *Negotiator* – acts as a broker between learner and curriculum,
- *Committee chair* – reconciles, organizes and manages goals and agendas, and
- *Modeller* – shapes and moulds learners' knowledge.

## **WHY USE BIOLOGY EXAMPLES IN PHYSICS DEMONSTRATIONS?**

Though the use of demonstrations at the junior college level in Singapore is already being practiced, these tend to be subject-specific, being largely restricted to physics, chemistry, or biology, with hardly any interdisciplinary demonstrations. One strategy that has some promise for meeting the goals of current educational initiatives within Singapore in the area of physics education is the infusion of biology into physics demonstrations. There are several reasons why infusing biology examples into physics demonstrations may prove to be an effective way of improving both performance and affective outcomes.

First, as indicated, one of the major goals of promoting interdisciplinary project work in science is to encourage students to explore the inter-relationships between

subject-specific knowledge (Ministry of Education, 1999/2000). Scientific theories and models and students' personal theories and models often conflict sharply with one another. The students' personal theories and models may incorporate many "misconceptions" about the way the world works. They are referred to as "misconceptions" or "preconceptions" (Tao, Mak and Chung, 1986). Glynn, Yeany and Britton (1991) noted that students' personal theories and models often work quite well in everyday life. It is only in science classrooms or laboratories that teachers can demonstrate the shortcomings of these misconceptions. Further, however, students tend to 'sectionalise' their personal theories and models in order to protect them from the contradictions they observe in the classroom. Reluctant to give up their preconceptions or even misconceptions, students may prefer to believe that some theories work fine in some contexts, but not in others. Drawing links between different discipline areas in science may be efficient, because it forces students to see that the principles introduced hold across different areas of application.

Second, while physics has been traditionally viewed as a somewhat 'elitist' subject area, biology has not. The gender differences in preferences for science at the secondary level also vary significantly with discipline area. Based on the 1999 TIMSS outcomes, higher percentages of boys demonstrate positive attitudes towards physics, while in biology, the reverse is true. It is possible that by infusing biology into physics demonstrations, and thus associating the two discipline areas, some of the differences previously seen in preferences for physics across ability levels and gender may be reduced.

## **STUDY AIMS**

In general, there is a dearth of research on the efficacy of using demonstrations in the subject area of physics. No research has been located which evaluates the efficacy of infusing examples from other areas such as biology within such demonstrations.

The major goal of this study was to design, develop, and evaluate an innovative teaching-learning approach based on physics demonstrations that infuse biology examples. This approach was designed to improve thinking skills by incorporating the major educational initiatives of innovation, information technology and interdisciplinary project work. The teacher-led physics demonstrations examined in this study are

constructed using commonly available materials and/or equipment (including dataloggers) in the schools. The blueprints of these innovative demonstrations may, therefore, serve as useful educational resources for teachers to replicate within interdisciplinary projects.

The infusion of biology into physics demonstrations refers to the use of biological examples (eg. the human arm) instead of the usual non-biological examples (eg. a seesaw) to illustrate the same physics principles (eg. the principle of moments). In the study, the biology-infused approach will be compared with one that uses only the traditional non-biological examples. The two types of demonstrations will differ only with respect to whether they are infused with biology. Appendix A shows the blueprints (i.e., topic, syllabus outcome and pedagogical design) of four pairs of innovative physics demonstrations with and without the infusion of biology. These have been designed and are currently under further development by the researcher.

Of special interest in the study will be whether the impact of biology-infusion on achievement and attitudes differs across males and females. Increasing female students' physics achievement and attitudes is of particular concern in high schools, in light of research that has indicated reduced levels of interest and enrolments in this subject area (Haussler & Hoffmann, 2002). With the infusion of biology into physics demonstrations, this study will also further examine the performance and attitudinal differences reported previously for males and females in secondary level physics classes (e.g., Gardner, 1985, 1998; Haussler & Hoffmann, 2002).

## **RESEARCH QUESTIONS**

The primary research question to be addressed in the study is: What are the effects of infusing biology examples into physics demonstrations that are based on a constructivist teaching approach? Specific research questions are listed below (corresponding data collection questions are shown in Appendix B):

- (1) What are the effects of using such demonstrations on physics achievement?
- (2) What are the effects of using such demonstrations on physics attitudes?
- (3) Do the effects of using such demonstrations on achievement and attitudes differ across males and females?

(4) Do the effects of using such demonstrations on achievement and attitudes differ across ability levels?

## METHOD

### RESEARCH APPROACH

In the book *Developing Effective Research Proposals*, published in 2000, a central issue in the whole field of empirical social research is the amount of structure and specificity planned into the research study. Studies may vary from tightly pre-planned and pre-structured to almost totally unfolding, with many positions between as shown in Figure 1 showing the continuum of the varying degrees of pre-structuring or unfolding.

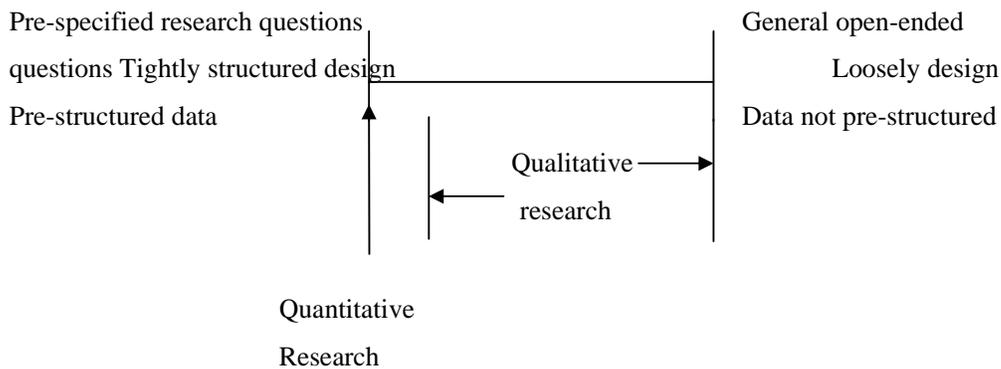


Figure 1: Continuum of the varying degrees of pre-structuring or unfolding  
(From Punch 2000, p.41)

As shown Figure 2, one of the key differences between the two types of research approaches (quantitative and qualitative) is the amount of pre-specified structure in the strategy used. Quantitative research approaches are generally used to address questions of effect (e.g., program evaluation studies). In this light, such studies are usually highly pre-structured, with clear and specific research questions, a clear conceptual framework, a pre-planned design and pre-coded data. On the other hand, qualitative research approaches generally focus on addressing questions of peoples' perspectives. As such, these tend not to rely heavily on pre-structured questions, pre-planned designs and pre-coded data. In light of the fact that the major goal of this study was to evaluate the efficacy of the biology-infused demonstrations on physics achievement and attitudes, a quantitative approach was considered most appropriate.

## **PARTICIPANTS**

The population from which the sample of two colleges will be taken is the fifteen junior colleges in Singapore. These are equivalent in level to Years 11 and 12 in the Australian system. Based on the annual school ranking of the fifteen junior colleges in academic performance, a purposive sampling of two colleges, one among the top five ranked colleges, and one among the bottom five ranked colleges, will be chosen. This is to ensure two groups of highly different ability students for maximum variation in the study.

In the Singapore system, all students receive an aggregate score on which decisions regarding college entry are made. This aggregate score is referred to as the mean L1R5, or the average students' aggregate grades in L1 (English or Higher Mother Tongue) and five relevant subjects for admission to junior college. These scores give an indication of the intake quality of a junior college. The range of mean L1R5 scores is 6 to 20. Students are also assigned a mean subject grade (MSG). For computation of 'A' level subject grades, students are awarded grades A, B, C, D, E, O or F. A grade A is assigned a value of 1, B a value of 2 and so on. The mean subject grade (MSG) of a particular junior college is obtained by adding each of these values for each subject taken and dividing the sum by the total number of subjects taken. The lowest score for MSG is therefore 1 and the highest score is 7.

Table 1 below shows the intake quality of the two participating colleges in the study based on mean L1R5 scores. All colleges are also assigned a ranking position based on mean subject grades from the A level examinations. Table 4 shows the L1R5 scores and rankings for the two selected colleges out of fifteen from 2000 to 2002. As indicated, the mean L1R5 value of College B is almost double that for College A, confirming the large gap in the academic performance of the students in the two colleges. It also indicates that the mean L1R5 values and the ranking positions of the two selected colleges have remained relatively stable across the three years.

Table 1  
Mean L1R5 and Rank Position

Year	College A (Top-5 ranked)		College B (Bottom-5 ranked)	
	Mean L1R5	Rank Position	Mean L1R5	Rank Position
2000	8.5	2	17.2	14
2001	8.3	3	16.4	14
2002	8.5	3	16.3	13

## **RESEARCH DESIGN**

### Independent variables

Type of Demonstration

Ability Level

Gender

### Dependent variables

Physics Achievement

Physics Attitudes

### Independent variables

(1) Type of Demonstration: There will be two levels of this independent variable: physics demonstrations with the infusion of biology, and physics demonstrations without the infusion of biology.

(2) Ability Level: There will be two levels of this variable, based on the mean L1R5 score.

(3) Gender: There will be two levels of this variable (male and female).

### Dependent variables

(1) Physics Achievement: This refers to the scores of the students based on a 30-item, researcher-developed multiple-choice test.

(2) Physics Attitudes: This refers to scores on a researcher-adapted attitude survey comprising 25 statements to examine students' attitudes towards physics.

The study will use an experimental design, with stratified random assignment of participants to conditions. Stratification variables will be gender and ability level. The design used in the study is represented in Figure 2.

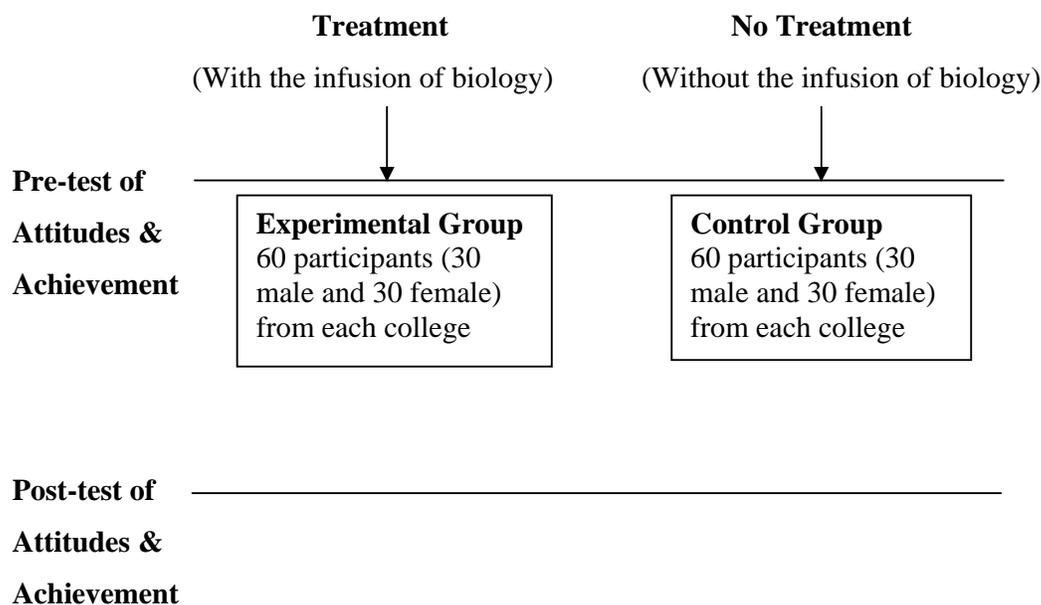


Figure 2. Diagrammatic representation of research design

For colleges A and B, using the mean L1R5 scores in Table 4, 120 first year students enrolled in the same 'A' level physics subject with L1R5 scores of 8 and 16 points will be randomly selected and assigned to either the experimental group or the control group. To examine gender effects, of the 120 students from each college, 60 will be female and 60 will be male. The total number of the participants in the study will be 240.

The following variables will be held constant across the two groups:

- (1) Age: Same age group of 16 year olds junior college students taking the same GCE 'A' Level 9248 physics syllabus
- (2) Gender Composition: Equal number of each gender from each of the two colleges
- (3) Curriculum Content: Same selected topics on Forces, Dynamics, Electric Field, Capacitance and Current Electricity.
- (4) Number of Demonstrations Used: All students will participate in four innovative physics demonstrations. In the experimental group, these will be biology-infused; in

the control, they will be non biology-infused physics demonstrations will be based on the same physics principles in the prescribed syllabus.

- (5) Teaching approach: In both conditions, the same modified Predict-Observe-Explain (POE) strategy will be used. The demonstrations used will be equivalent in terms of (i) the physics principles applied, (ii) application to real-life scenarios, (iii) basic structure and pedagogy, and (iv) difficulty level. The only difference between the conditions will be that the control condition will use traditional, physics-based examples, whereas the experimental condition will use biophysics examples.
- (6) Number of enrichment sessions. In both conditions, students will all receive either two or three enrichment sessions, depending on the constraints of the college timetable.
- (7) Timing of tests: Pre-test to be taken one month before the first lecture to minimise the practice effects. Post-test to be taken immediately on the day after the last lecture.

## **INSTRUMENTS**

### ***Physics Achievement***

To gather data for the evaluation of the effectiveness of two types of physics demonstrations in improving achievement in physics among junior college students in Singapore, a Physics Achievement Test (PAT) is currently under development by the researcher. Appendix C shows two sets of alternate or parallel forms of the PAT that have been developed to be piloted for validity and reliability with the aim of selecting the best items to construct the final PAT. ‘Alternate forms’ are simply different versions of a test that have been constructed so as to be parallel. They are designed to be equivalent with respect to variables such as content and level of difficulty. ‘Parallel forms’ of a test exist when for each form of the test, the means and variances of observed test scores are equal. The format of this final PAT written test will comprise 30 Multiple Choice Questions (MCQ). To ensure a good linkage between the PAT and the two types of physics demonstrations, these 30 MCQs will be divided into the following 3 sections of 10 questions each:

- Section 1 will be based on common background knowledge based on the physics syllabus
- Section 2 will be based on real-life applications which do not involve biology and
- Section 3 will be based on real-life applications which involve biology.

These physics questions will be chosen or modified from previous year questions and established “A” level and university textbooks to test conceptual understanding, thinking skills and application to real life situations. The rationale for choosing questions from past year GCE ‘A’ level examination papers is that these questions are set by an internationally recognised examination board, University of Cambridge-London Examination Syndicate (UCLES).

To ensure content validity in the construction of the MCQ items in the Physics Achievement Test (PAT), the questions have been constructed based on the learning outcomes of the physics topics prescribed in the syllabus. The professional judgement of the senior physics teachers of the two participating colleges as well as content experts from the National Institute of Education will also be sought.

To test for reliability, the ‘parallel-forms’ or ‘alternate-forms’ with a time interval of 1-3 week(s) together with split ordering will be administered to two groups of 20 participants from colleges A and B respectively. The two groups of 20 participants will comprise 10 males and 10 females. These 40 participants from each college will be drawn from the prior batch of Year 1 students to ensure that they have completed the topics covered in the PAT. In addition, the conduct of the pilot study at both the participating colleges will ensure that the succeeding batch of 120 Year 1 students who will participate in the main or actual study have undergone the same instructional programme and college environment. The purpose of the 1-3 week(s) test-retest is to check the instrument’s reliability across time.

### ***General Attitudes Towards Physics***

A modified version from an existing well-established instrument, Test of Science-Related Attitudes questionnaire (TOSRA) (Fraser, 1981; Fisher, Henderson and Fraser, 1995), will be used to assess general attitudes towards physics. The full TOSRA includes items which measure seven distinct facets of science-related attitudes (Social Implications of Science, Attitude towards Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Normality of Scientists, Leisure Interest in Science and Career Interest in Science). In this study, only the Enjoyment of Science Lessons scale will be used, as this is the only subscale deemed to be relevant given the content of the

interventions used. Thus, from the original TOSRA, only seven items will be used. In the scale, the word ‘science’ will be replaced with ‘physics’ to ensure that responses are specific to this subject area. Another change made will be the reduction of the original 5 responses to 4 responses by deleting the ‘not sure’ response for all the seven items. Thus each item will have four-scaled options: SA strongly agree, A agree, D disagree and SD strongly disagree. Appendix D shows the Test of Physics-Related Attitudes (TORPA), which is a modified version of the TOSRA.

### ***Specific Affective Outcomes***

In addition to a measure of general attitudes, a measure will be developed and used to assess students’ specific perceptions of the physics demonstrations. This may provide a more sensitive measure of differences between the two study conditions. Given that there is, at present, no measure that specifically targets responses to science demonstrations, a measure has been constructed by the researcher to assess these. The Affective Outcomes Scale (AOS) constructed (see Appendix E) is designed to reflect students’ responses to the demonstrations used in the study in terms of their utility in terms of (i) facilitating understanding of the subject matter, (ii) enhancing enjoyment and interest in the subject matter, and (iii) emphasising the potential importance of the subject matter.

## **PROCEDURES**

The access to students’ registers will provide the essential data of population size, gender, L1R5 entry scores and subject combinations. For the purpose of the pilot study to test the validity and reliability of the instruments PAT and AOS, the population of the students in each college will be divided into two lists by genders with a range of L1R5 scores for the prior batch of Year 1 students of college A and college B respectively. The required number of 20 male participants and 20 female participants from each college will then be randomly chosen by taking at fixed intervals in the list.

For the actual study involving the 120 succeeding batch of first year students from each college, the population of the students in each college will be divided into two lists by genders with the same L1R5 score of 8 points and 16 points. Based on the pre-test scores, stratified random assignment into the experimental and control groups with equal number of male and female participants will be carried out. An analysis of variance on pretest

scores will be made to ensure that the participants in both the experimental and control groups are not different.

As the pilot study is targeted at the prior batch of Year 1 junior college students, a good period will be before their final examinations sometime in July to August period. For the actual study which is targeted at the succeeding batch of Year 1 junior college students who are new to the lecture tutorial system, it is important for them to get inducted into this mode of learning and to have completed those topics that are selected for this research study before taking the pre-test. A sufficient time lag of a month between conducting the pre-test and the post-test must also be factored in to minimize the practice effect. In the light of the above considerations, a good period for the pre-test would be sometime in November after their promotional examinations or latest early January of the following year. The conduct of the two week intensive physics demonstrations as enrichment lessons can be carried out in February of the following year to be immediately followed by the post-test.

The 'dead' time of the first semester and the early half of the second semester will be used to construct and test the demonstrations followed by a training session to equip the two senior physics teachers from each college on the POE constructivist teaching approach in the conduct of the physics demonstration lectures with and without the infusion of biology. To remove the teacher effect in the study, both the teachers will lecture half of the control group and half of the experimental group.

## **DATA ANALYSIS**

### ***Cognitive Outcomes***

As indicated, the content validity of the two parallel forms of the Physics Achievement Test (PAT) will be evaluated through expert panels. The psychometric properties of the instrument will be further examined and improved through the pilot study conducted in July/August, 2005. On the basis of the 80 students who complete the two parallel forms of the test during this phase, the characteristics of each multiple choice item and the overall structure of the test will be examined using Rasch methods. This process will be used to examine whether any items should be excluded in either of the final forms of the instrument. Based also on the pilot study data, the reliability of the instrument will be

estimated using (i) internal consistency indices within each of the three subdomains, based on Cronbach's alpha, and (ii) test-retest indices, based on the correlation between scores from the first and the second test administrations. If either index suggests a low reliability, the test forms will be reworked prior to use in the final study.

A multivariate analysis of covariance (MANCOVA) will be performed to determine whether there was a significant difference in the post-test achievement of the experimental and control groups. As indicated, half of the participants in each of the colleges will take Form I at pre-test and Form II at post-test, with the remaining half taking the two forms in the reverse order. To ensure that test order does not influence the results, a 2 (condition: experimental versus control) by 2 (college: A versus B) by 2 (test order: Form<sub>I,II</sub> versus Form<sub>II,I</sub>) factorial design will be used in the MANCOVA ( $n = 30$  per cell). If there are no significant interaction effects involving test order, the analysis will be collapsed to a 2 by 2 design. The three dependent measures will be scores for the three subdomains within the tests (common theory, real-life physics-based applications, real-life biophysics-based applications). Pretest scores for the three corresponding subdomains will be entered as covariates to take into account individual differences on the pretest and to reduce within-condition error variance in the posttest scores. All relevant underlying assumptions will be tested prior to conducting the analysis, and all significant MANCOVA outcomes will be accompanied with an index of effect size (the partial  $\eta^2$  statistic) to indicate the percent of variance in scores for which the intervention accounts.

### ***Affective Outcomes***

As indicated, a modified version of the Test of Science-Related Attitudes (TOSRA) will be used both at the pre-test and at the post-test. At post-test, an additional measure (the Affective Outcomes Scale, AOS) will be used to assess students' affective responses specifically to the demonstrations. Given that the AOS cannot be pilot-tested (as it refers specifically to the demonstrations used in the study), a relatively large number of items will be included to allow for some attrition in the analysis stage. To examine the structure of the AOS, post-test scores for the 240 participants will be intercorrelated and subjected to an exploratory factor analysis. Maximum likelihood estimation will be used in the initial extraction of factors, with an oblique rotation (Direct Oblimin) used to enhance

interpretability of the resulting factor loadings. On the basis of this analysis, subscale scores will be formed for the purposes of further analysis.

Following this, a MANCOVA will be performed to determine whether there was a significant difference in the post-test TOSRA and AOS subscale scores of the experimental and control groups. In this case, as there will be no pre-test scores for AOS, the pre-tests for the TOSRA will be used as covariates. Again, all relevant underlying assumptions will be tested prior to conducting the analysis, and all significant MANCOVA outcomes will be accompanied with an index of effect size (the partial  $\eta^2$  statistic).

### **CONSENT AND PARTICIPANTS' PROTECTION**

A formal visit will be made to obtain the support of the principals of the two selected junior colleges for both the pilot study and the actual study. An information sheet and consent letter for Physics Heads and the participating students in this research study will be provided through the principals. No reference will be made to individual results in the analysis of the data. To safeguard the confidentiality of the participating colleges, the names of the colleges will be coded as College A and College B.

### **SIGNIFICANCE**

The outcomes of this study may have national and international implications for the enhancement of physics education through the use of demonstrations. The teaching-learning approach evaluated here is likely to be the first of its kind in the Singapore context and possibly beyond. This research is also particularly timely, in light of the falling enrolment and interest of females in high school physics courses, and the lower physics achievement and attitudes of females in many countries.

At the national level, the introduction of this innovative teaching-learning approach has the potential to (i) contribute to physics education at the junior college, (ii) contribute to the transformation of Singapore schools into thinking schools for the new millennium, and (iii) provide a blueprint for the design and development of customised physics demonstrations that include the infusion of examples from biology. It is hoped that this

blueprint will, in turn, be used as resource to promote meaningful interdisciplinary project work in physics.

In the international context, the research findings on the efficacy of physics demonstrations with the infusion of biology on physics achievement and attitudes could have important implications such as the provision of alternative pathways to the transmission of knowledge as well as the narrowing of the gender gap in physics achievement. This could, in turn, lead to improved attitudes towards physics and improved enrolment of female students in physics courses and physics-related career paths.

## **MAJOR SCHOLARS IN THE FIELD**

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## **TIMELINE**

### **2004**

- Initial Literature Review
- Preparation of Initial Research Proposal
- Identification of the two colleges for research study
- Initial visit to the two colleges for discussion with the principals and physics heads
- Design and development of both types of demonstrations
- Development of Physics Achievement Test (PAT)
- Sourcing of Physics Attitude Scale (PAS)
- Finalising of Research Proposal
- Ongoing literature Review

## **2005**

- Finalising the design and development of the demonstrations
- Finalising the instruments PAT and PAS for piloting
- Final visit to the two colleges for discussion with the principals and physics heads
- Drawing of schedules for the period and duration of the pilot and actual study
- Selection and recruitment of participating teachers and students
- Piloting of instruments PAT and PAS for validity and reliability
- Training of participating teachers in the conduct of the demonstrations
- Finalising the instruments PAT and PAS for actual research study

## **2006**

- Implementation of the demonstration lessons for data collection
- Analysis of data
- Preparation of initial draft of thesis

## **2007**

- Submission of final thesis

## **FACILITIES AND ESTIMATED COSTS**

### **FACILITIES**

Physics Laboratory for the design, development and testing of the demonstrations.  
Lecture theatres of the two participating colleges with audio and visual equipment.

### **ESTIMATED COSTS**

Estimated costs will be approximately \$3000 for the materials in the design and development of the customized demonstrations, token of appreciation for all participants, photocopying of literature readings, achievement test and questionnaire for students.

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