INNOVATIVE METHODS IN BOOSTING STUDENTS' PASSION IN THE LEARNING OF SCIENCE

LIM CHER CHUAN

VICTORIA JUNIOR COLLEGE, SINGAPORE

HIGH SCOPE PROGRAM CONFERENCE ON ASIA-PACIFIC SCIENCE EDUCATION 2011

Content

Investing in the Education of Singaporeans 3

Victoria Junior College (VJC): A Premier Institution 5

Disconnect of Science Knowledge with Reality

1. **No Relevance to Real Life Applications** 6
2. **New Science Topics were Difficult** 6
3. **Lack of Science Research Opportunities** 7

Methods Employed to Engage and Sustain Students' Interest

1. **East Zone (EZ) Science and Technology Centre@VJC** 8
    - **Nanotechnology in VJC** 9
    - **Nanotechnology Course Outline** 10
2. **Victoria Science Research Programme** 13

Conclusion 17

References 17

Annex (Worksheets)

- **Introduction to Gold Nanoparticles and Color** **18**
- **Introduction to Aqueous Ferrofluid** **21**
- **Surfactant Monolayer on Silver** **24**

Investing in the Education of Singaporeans

The wealth of a nation lies in its people - their commitment to country and community, their willingness to strive and persevere, their ability to think, achieve and excel. Our future depends on our continually renewing and regenerating our leadership and citizenry, building upon the experience of the past, learning from the circumstances of the present, and preparing for the challenges of the future. How we bring up our young at home and teach them in school will shape Singapore in the next generation.

The Ministry of Education (MOE) in Singapore aims to help our students to discover their own talents, to make the best of these talents and realise their full potential, and to develop a passion for learning that lasts through life.

We have a strong education system. Singapore students aim high and they achieve excellent results, an attribute that is well recognised around the world. We have good schools, with capable school leaders and teachers, and facilities that are amongst the best in the world.

We are building on these strengths as we prepare the next generation of Singaporeans for the future. This is a future that brings tremendous opportunity, especially in Asia, but it will also bring many changes that we cannot foresee today. The task of our schools and tertiary institutions is to give our young the chance to develop the skills, character and values that will enable them to continue to do well and to take Singapore forward in this future.

We have been moving in recent years towards an education system that is more **flexible and diverse**. The aim is to provide students with greater choice to meet their different interests and ways of learning. Being able to choose what and how they learn will encourage them to take greater ownership of their learning. We are also giving our students a more **broad-based education** to ensure their all-round or holistic development, in and out of the classroom.

These approaches in education will allow us to nurture our young with the different skills that they need for the future. We seek to help every child find his own talents, and grow and emerge from school confident of his abilities. We will encourage them to follow their passions, and promote a diversity of talents among them – in academic fields, and in sports and the arts.

We want to nurture young Singaporeans who ask questions and look for answers, and who are willing to think in new ways, solve new problems and create new opportunities for the future. And, equally important, we want to help our young to build up a set of sound values so that they have the strength of character and resilience to deal with life's inevitable setbacks without being unduly discouraged, and so that they have the willingness to work hard to achieve their dreams.

MOE's vision of "Thinking Schools, Learning Nation" describes a nation of thinking and committed citizens capable of meeting the challenges of the future, and an education system geared to the needs of the 21st century. Thinking schools are learning organisations in every sense, where pupils, teachers and principals are always learning and seeking better ways of doing things through participation, creativity and innovation.

This spirit of learning should accompany our students after they leave school, so that they, collectively as a nation, continue to learn throughout life.

Victoria Junior College (VJC): a Premier Institution

VJC is well known in Singapore for its academic excellence, diversified curriculum and ability to produce responsible and global-minded citizens who are leaders in their chosen fields. The school has been consistently producing top quality grades at the annual GCE 'A' Level examinations, but more importantly, have also consistently achieved the MOE's Sustained Achievement Award for Academic Value-Addedness since 2000.

Accolades and awards notwithstanding, the college strongly believes in continuing to provide the freedom, latitude and opportunities for our students to explore and discover who they want to be. As they whet their interests and hone their talents, we help them to go further and dream bigger than they had dared to consider before. We are guided by a set of core values that we want the students to achieve by the they graduate which can be summarized in the following 3 'O's as shown:

Core Values | Character, Compassion, Learning

Core Values | Excellence, Innovation, Partnership

Core Values | Camaraderie

Disconnect of Science Knowledge with Reality

Although math and science have been one of niche area of educations in Singapore, many eventually do not take science related courses when they proceed to higher education. Students are highly proficient to ace their science examinations but unfortunately that passion to do well did not translate to the same passion to learn science. VJC identified the three main problems that students were not interested to learn and explore beyond their content:

1. No Relevance to Real Life Applications

Students often find it hard to understand and fully appreciate the scientific concepts and knowledge as they often cannot see the relevance of what they have been taught to real life. As a result, they sometimes do not find the learning of Science interesting or even useful in lives. In addition, the Science education in Singapore schools is based on syllabuses approved by the Ministry of Education. Schools will follow the syllabuses closely in the teaching of Science to their students and often do not have time to explore beyond the syllabus.

2. New Science Topics were Difficult

Since the beginning of 21st century, there were many new fields of science creating big impacts to the society. Life sciences, nanotechnology and material science became the emerging fields of interest for many people who would want to study in the universities. However as these topics were relatively new, the introductory courses offered by the universities were too difficult for the high school students to comprehend. Students who attended these seminars conducted by the universities academics were often left in a mire load of information that they could not appreciate.

3. Lack of Science Research Opportunities

Students who were interested in science research were generally attached to school teachers who would provide training and research titles for them. The projects offered by teachers lacked depth and relevance to the new fields emerging then. At the same time due to lack of equipments and expertise, many of them faced multiple failures in the experimental attempts. This formed a negative impression of the science research where it is thought to be hard work, boring, mundane and meant for geeks.

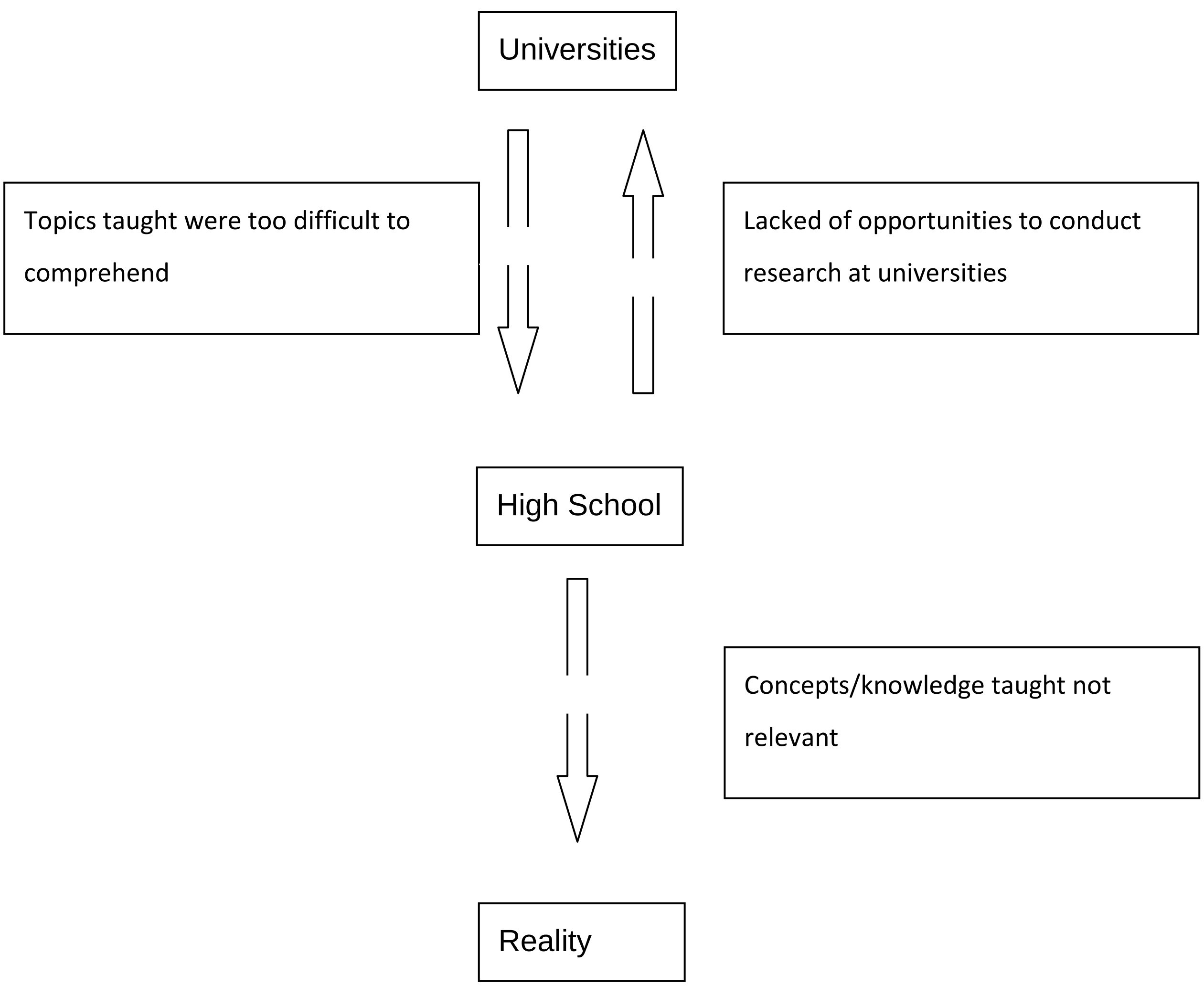


Figure 1. Disconnect of Science Knowledge with Reality

Innovative methods have to be employed to prevent the further downward spiral of the situation where students may eventually lose total interest in their lessons.

Methods Employed to Engage and Sustain Students' Interest

In alignment with the strategic thrusts with MOE and VJC, the science department has been seeking to find new and interesting ways to interest, engage students in their learning and to enhance their abilities in problem-solving. The first approach to be discussed is the setting up of a centre of excellence (COE) in VJC where there will be dedicated resources and funding to implement new methods to engage students. This led to the formation of East Zone Science and Technology Centre@VJC. The second approach is the Victoria Science Research Programme where students interested in research undergo systematic training before they are attached to the various research institutions. These are two of the many approaches used in VJC that will be discussed.

1. East Zone (EZ) Science and Technology Centre@VJC

In 2002, the Zonal Centre for Science & Technology was set up at Victoria Junior College to support the teaching and learning of Science. The key objectives of the Centre are:

- To serve as a Science Hub for schools in the East

- To provide an environment conducive for research-keen students and teachers to explore, learn and share
- To excite and stimulate interest in Science and Technology beyond formal curriculum
- To enhance the capacity of Science teachers in the teaching of Science

The Centre continuously receives strong support from the East Zone with sufficient funding that can allow the teachers with interesting ideas to try out. This eliminates an important hindrance and thus allowing the centre to support teachers to be innovative and test out new ideas. The Centre has since conducted many inquiry-based workshops which are opened to all students studying in primary and secondary schools located in the eastern part of Singapore so as to enthuse them in the learning of Science by exposing them to current and real-life applications of Science. The workshops conducted so far include high-level topics such as Nantoechnology, Photonics, Food chemistry, Forensic chemistry, Design Material Science, Perfume chemistry and Gene amplification. The workshops are designed in such a way so as to allow students to be able to understand these high level topics and learn beyond the formal Science curriculum. At the same time, fun activities are included in the workshops to make the lessons more enjoyable for the students. The teaching materials are also shared with teachers from all schools so that they can conduct the workshops in their own schools for the benefits of more students.

Nanotechnology in VJC

In 2005, nanotechnology was introduced to VJC with the funding from Ministry of Education under School Innovation Fund (SIF). The aim is to educate students and teachers the basic concepts of nanotechnology. This is because nanotechnology has the gaining popularity in terms of research and its applications in Singapore in recent years. In order to align with the learning style of TLLM (Teach Less Learn More), practicals were re-designed in such a way that that would induce their curiosity to learn more about the nature of the experiment and eventually lead on modify the experiment by doing research.

Experiments currently in schools do not have the capability to extend further in scientific research currently done in the world. In order to allow students to learn the skills of research and stay interested in it, practicals have to be conducted in such a way that it can attract their immediate attention. One of the easiest ways is to use the monetary factor. Silver nitrate is widely available in schools and much of it will be thrown way and wasted after the schools' practical examinations. Hence such experiment was conceived to tap the resources available in the schools to teach an interesting and new topic to the students.

The experiment was firstly made to be SPA like (planning) where they had to decide on the procedure to use. Design of the experiment was also done in such a way that their knowledge and technical skills would have to be used effectively in order to maximise the products made by them. As a result, the strength of this programme lies in the ability to infuse both theories and experiments in their learning.

This innovation allows the extensive use inquiry-based-discovery experiments to actively engage the participants in their learning. The use of precious metals during experiment was one of the additional driving forces in their learning. Moreover, these open-ended experiments could expand further into a scientific research, thereby forming a platform toward higher-level learning.

In addition, participants will be interested in things made of silver and gold. Hence experiments to make silver and gold nanoparticles were designed such to attract their interest immediately. With this huge interest in the materials, conduct of the lesson to teach simple principles and concepts was performed and was found that participants were more vocal and active in their learning. The most important factor that would drive the participants to immerse themselves totally in the experiment was that they would get to keep the precious metals that they had made, the amount depending on their skills and knowledge.

At the end of the experiment, further extensions of the experiment leading to meaningful research (that are currently done by researchers today) were offered to the participants. This provided an avenue for the participants to generate ideas to conduct scientific research in the area of nanotechnology.

Nanotechnology Course Outline

Participants (students or teachers) will undergo a one day workshop with the following contents:

- Introduction to Nanotechnology

- Common Methods for Characterization and Demonstration on the Use of Atomic Force Microscopy (AFM)
- Synthesis on Nanoparticles
    - Introduction to Gold Nanoparticles and Color
    - Introduction to Aqueous Ferrofluid
    - Surfactant Monolayer on Silver

The course was designed in a manner to introduce nanotechnology to the participants with no prior knowledge of the topic. During the introduction, participants would take part in a pre-activity game where they would require to form a square using four piece puzzle. A fifth piece was then added to the current 4-piece square to make another square again. The purpose of this pre-activity is to illustrate how nanotechnology (the 5^{th} piece) can fit into the current fields of chemistry, physics, biology and engineering to make a bigger impact.

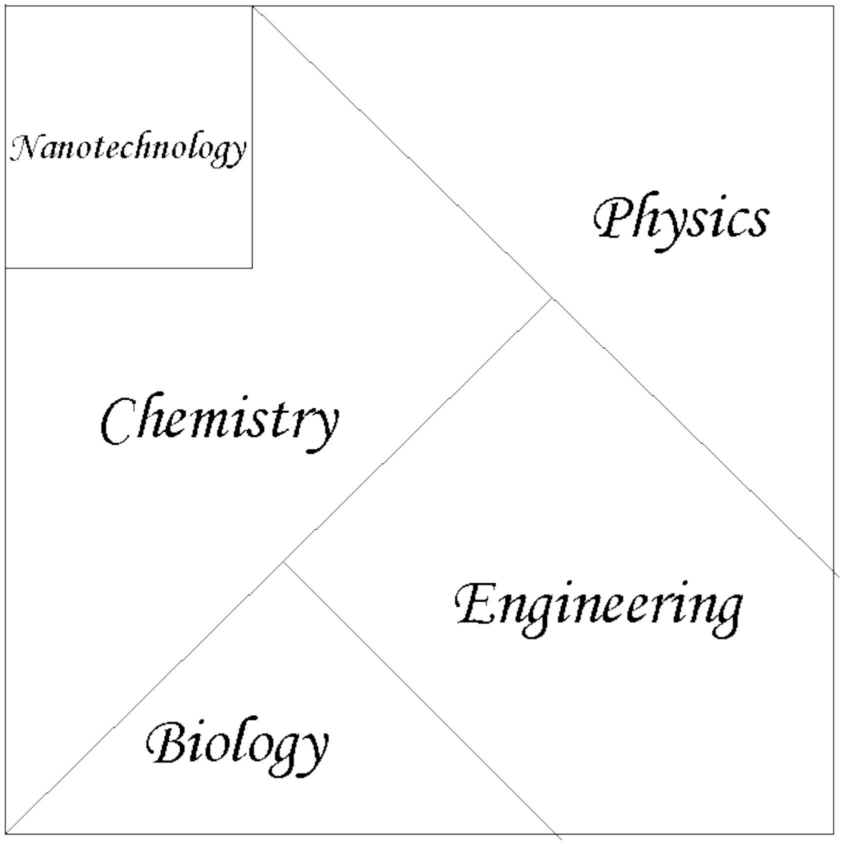


Figure 2. Pre-activity Handouts for the Participants in the Nanotechnology Course

The participants will learn about some basic concepts on nanotechnology and its applications. They will try out the 3 sets of experiments on the synthesis of nanomaterials. Each of these experiments was designed such that it would visually be appealing, open-ended procedures that allow them to modify the experiment so that different results can be obtained. Further extension of the experiment can be done that will lead to experimental research. The detailed worksheets are shown in the annexes.

The programme was conducted with students and eventually with teachers at National level and the response of the workshop was highly positive with many schools (e.g. Victoria School, Bowen Secondary) implemented the workshops for their own students.

This programme hence enabled the teachers to introduce nanotechnology to students and experiments that allow students to excite their interest and learn. At the same time they would realize the applications of the knowledge that they had learnt in schools.

Through the EZ centre, many other programmes were offered to teachers on different topics using similar approaches, These programmes include Food Chemistry, Photonics, Design Material Science, Gene amplification and many others. These programmes give sparks to the teachers' lesson while at the same time enhancing the capabilities and knowledge of the teachers.

2. Victoria Science Research Programme

ViJC has a strong research culture among the science teachers and students and has continuously supported the various research programmes of the Ministry of Education (e.g. Local and Overseas Student Attachment Programmes) and other research initiatives of the local tertiary institutions. With the emerging trends of collaboration with higher learning institutes for research attachments, VJC has been in the frontier to bring about the shift in paradigm to education beyond the four walls of the classroom. As there were many research institutions in Singapore, it would be good for the students to be able to go for research attachments with these institutions so they can gain a deeper insight on the new science research fields. Hence we implemented a Science Research Programme for research-minded students. Collaboration with various institutions was done, leading to the formation of H3-NAV, a tripartite collaboration between National University of Singapore, A*STAR organization and Victoria Junior College.

Together with the establishment of the EZ S&T centre, The Victoria Science Research Programme is intended to:

- Cultivate ingenious instincts and talents in research minded students
- Enthuse students and stimulate their interest in science research beyond formal curriculum

The Victoria Science Research Programme is designed based on a “two-track” system:

1. H3 NUS-A*STAR-VJC (H3 NAV) Science Research
2. Enrichment Science Research (eSR)

Both programmes allow students to learn more about science research of a particular field of interest. However the main difference between the two programmes is the former is an ‘A’ level examinable subject while the latter is an enrichment program.

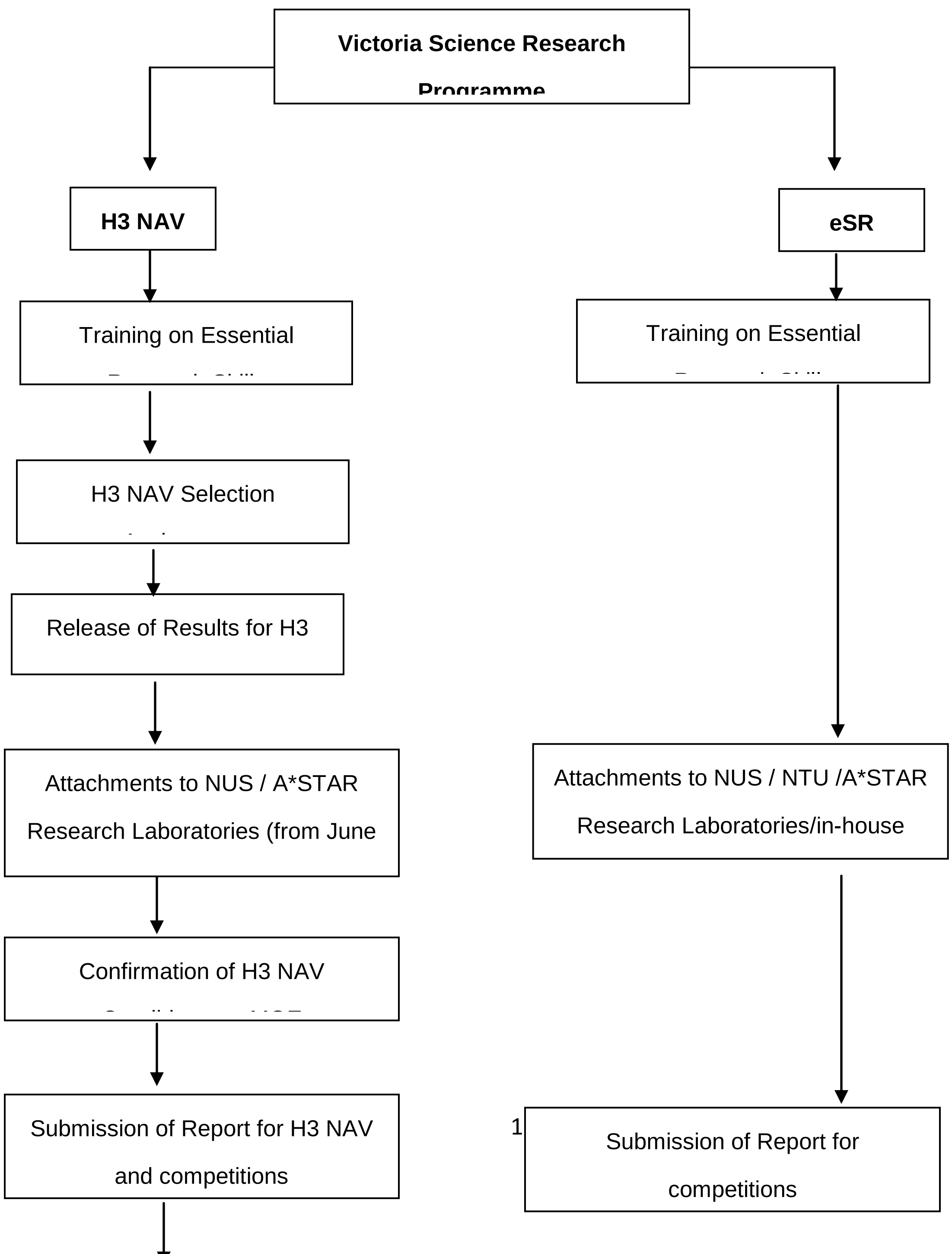


Figure 3. The “TWO TRACK” System of the Programme

In either of the programmes, students will go through a training programme on research methodologies and undertake a research project under the mentorship of a research scientist. All students will receive a comprehensive training on basic research skills. These skills are to better prepare the students for the various phases of research work. A brief insight into the training programme is shown below:

Training Topics
Process of Literature Search How to conduct literature search & understanding journal articles **Writing a Research Proposal**
Research Methodology & Techniques *Experimental Chemistry*

Experimental Biology *Experimental Physics*
Scientific Writing and Oral Presentation

Students first start with training session by being given a series of statements as shown:

- Sleeping less helps me lose weight because I burn more calories staying up through the night
- Green tea will boost my metabolism
- Drinking lots of water will help me lose weight
- Skipping meals is a good way to lose weight
- I should not eat after 8pm
- Don't snack between meals

These are some of the weight loss methods. Fact or Fiction?

These statements were crafted to allow the students to question the factual content which thereby lead to the testing of the hypothesis or assumptions that they have been making. They would realize that in order to verify the content, one has to conduct reasonable amount of reading and determine the information read to be reliable and recent. This hence helps to build the student’s mentality to be inquisitive in nature and constantly testing the hypothesis of the information. The students would then apply the set of skills learnt in the respective areas of research they are assigned to.

During the course of research, the teacher mentor in the school would work closely with the research mentor to ensure that the student could understand the nature of their project and conduct relevant experiments. They would analyse the results obtained together with the teacher and research mentor and find any alternatives that can further reinforce or validate their hypothesis.

At the end of the research programme, the students would take part in the annual Singapore Science and Engineering Fair (SSEF) organized by Singapore Science Centre. They would conduct a poster presentation to various judges and be graded accordingly. The top winners would represent Singapore in the International Science and Engineering Fair.

Many of the students (some with scholarships offered) who had undergone the research programme would continue with the nature of research work at the university level. This programme hence allowed them to gain an advantage compared to others who have no experience in research.

Conclusion

The advances of science and technology have been exponential since the beginning of the 21st century. The amount of information is doubling at the rate of every few years. With the avalanches of information, students will often be overwhelmed and many adopt a passive mode of learning attitude. Transmission of information can no longer be in the traditional mode of blackboard teaching. Engaging them in an innovative manner has been the core objectives for the teachers VJC. With the implementation of programmes through the EZ Science and Technology Centre and Victoria Science Research Programme, the school is able to keep abreast of the relevant teaching pedagogy and engagement of the students. Thus VJC is still one of the premier institutions in Singapore!

References

1. Journal of Chemical Education, http://jchemed.chem.wisc.edu/
2. Ministry of Education, Singapore, http://www.moe.gov.sg/
3. Victoria Junior College, Singapore, http://www.vjc.moe.edu.sg/website/
4. Nanotechnology Now- Current Uses http://www.nanotech-now.com/current-uses.htm
5. Nanotechnology- Project on Emerging Nanotechnologies http://www.nanotechproject.org/

Annex (Worksheets)

VICTORIA JUNIOR COLLEGE

NANOTECHNOLOGY ENRICHMENT WORKSHEET A

INTRODUCTION TO GOLD NANOPARTICLES AND COLOR

Name:____________________________ CT Group:__________

Introduction and Purpose of the Experiment:

The physical and chemical properties of nanoparticles are size dependent over a certain size range specific to the material and property. When a particle of gold metal is similar in size to wavelengths of visible light (400-750 nm), it interacts with light in interesting ways. The color a gold nanoparticle solution depends on the size and shape of the nanoparticles. For example, while a large sample of gold, such as in a jewelry, appears yellow, a solution of nano-sized particles of gold can appear to be a wide variety of colors, depending on the size of the nanoparticle.

In this activity, students follow the process of nanoparticle aggregation by observing the color change of a solution of gold nanoparticles. Students prepared a solution of well-separated, 13 nm-diameter gold particles. A layer of citrate anions adsorbed in nanoparticle's surface produces an electrostatic repulsion that keeps the nanoparticles separated. In this state, the solution absorbs 520 nm (green) light strongly and the solution appears red. When a strong electrolyte is added to the solution, the high concentration of ions screens the repulsive electrostatic forces between nanoparticles. Because the repulsive force is eliminated, the gold nanoparticles aggregate. As the spacing between the nanoparticles decreases to less than their average diameter, the solution absorbs light of longer wavelengths (650 nm). Thus, the solution turns blue. If a larger quantity of the electrolyte is added, large nanoparticle aggregates precipitate out off the solution and solution becomes clear. If a non-or weak electrolyte is added, the electrostatic repulsion between the gold/citrate particles is not disrupted, and the solution remains red.

Precautions:

Gloves should be worn when working with the nanoparticle solution. Rinse used solutions down the sink. If substances other than salt and sugar are added to the nanoparticle solution, dispose of the nanoparticle solution using methods appropriate for solutions containing those substances.

Experiment:

Part A- Preparation of 13nm-Diameter Gold Nanoparticles

1) Pour 20 ml of 1.0 mmol dm^{-3} $HAuCl_4$ solution into a 50-ml beaker. Add a magnetic stir bar. Heat the solution to boiling on a stir/hot plate while stirring with the magnetic stir bar.

2) After the solution begins to boil, add 2 ml of sodium citrate ($Na_3C_6H_5O_7$) solution to the $HAuCl_4$ solution. Continue to boil and stir the solution until it is a deep red color (about 10 min). As the solution boils, add distilled water as needed to keep the total solution volume near 22 ml.

3) When the solution is a deep red color, turn off the hot plate and stirrer. Cool the solution to room temperature before using it in Part B and C.

Part B- Evidence of Formation of Nanoparticles

1) The presence of a colloidal suspension can be detected by the reflection of a laser beam from the particles.

Part C- Nanoparticles As Chemical Selective Sensors

1) Into each of four glass vials or clear, colorless plastic cups, place 4 ml of the gold nanoparticle solution you prepared in Part A.

2) With a dropper, add 5-10 drops, one at a time, of the salt (NaCl) solution to one of the vials. Record your observations. What is happening to the nanoparticles in solution?

3) With a dropper, add 5-10 drops, one at a time, of the sugar (sucrose) solution to one of the vials containing fresh nanoparticle solution. Record your observations.

3) Choose another substance (e.g. vinegar, hydrogen peroxide etc.) to add to the third vial. Before adding the substance, predict whether or not a color change will occur.

4) The effect in part C can be used to detect the binding of biomolecules, such as DNA or antibodies through interaction between complementary strands of DNA link particles. Antibody/antigen pairs are also selectively linked. By modifying the surfaces of the nanoparticles to incorporate these biomolecules, binding events can be detected by a change in solution color.

NOTE: You can keep all the gold nano-solutions at the end of the experiment!

VICTORIA JUNIOR COLLEGE

NANOTECHNOLOGY ENRICHMENT WORKSHEET B

INTRODUCTION TO AQUEOUS FERROFLUID

Name:____________________________ CT Group:__________

Introduction and Purpose of the Experiment:

In recent years, researchers have prepared ferrofluids, which have the fluid properties of a liquid and the magnetic properties of a solid. The ferrofluids actually contain tiny particles (~10 nm diameter) of a magnetic solid suspended in a liquid medium.

Ferrofluids respond to an external magnetic field enabling the solution's location to be controlled through the application of a magnetic field. Fe_3O_4 magnetite nanoparticles can be produced by mixing Fe(II) and Fe(III) salts together in a basic solution.

$$2\,FeCl_3 + FeCl_2 + 8NH_3 + 4H_2O \rightarrow Fe_3O_4 + 8NH_4Cl$$

However, the particles of magnetite must remain small in order to remain suspended in the liquid medium. To keep them small, magnetic and van der Waals interactions must be overcome to prevent the particles from agglomerating. Thermal motion of magnetite particles smaller than ~10 nm in diameter is sufficient to prevent agglomeration due to magnetic interactions. Surfactants too are used to prevent the nanoparticles from approaching one another too closely. Once prepared, ferrofluids have the captivating property of exhibiting “spikes” when placed in the proximity of a strong magnet.

Precautions:

Ferrofluids can be messy. The particular ferrofluid you will prepare will permanently stain almost any fabric. Gloves should be worn when working with the nanoparticle solution

Experiment:

1) Add 8.0 ml of 1 moldm^{-3} $FeCl_3$ and 2.0 ml of 2 moldm^{-3} $FeCl_2$ solution to a 100 ml beaker. Add a magnetic stirring bar and begin stirring.
2) Continue stirring throughout the slow addition over a period of 5 minutes of 50 ml of 1.0 moldm^{-3} aqueous NH_3 solution. After an initial brown precipitate, a black precipitate will form (magnetite). One way to accomplish a slow addition is to drip the ammonia solution from a burette.
3) Turn off the stirrer and immediately use a strong magnet to work the stir bar up the walls of the beaker. Remove the stir bar with a gloved hand before it touches the magnet.
4) Let the magnetite settle, then decant (pour off) and discard the clear liquid without losing a substantial amount of solid. You can speed the settling process by putting a magnet under the container.
5) Transfer the solid to a weighing boat with the aid of a few squirts from a wash bottle.

6) Use a strong magnet to attract the ferrofluid to the bottom of the weighing boat. Pour off and discard as much clear liquid as possible. Rinse again with water from a wash bottle and discard the rinse as before. Repeat the rinsing a third time.
7) Add 1-2 ml of 25% tetramethylammonium hydroxide. Gently stir with a glass rod for at least a minute to suspend the solid in the liquid. Use a strong magnet to attract the ferrofluid to the bottom of the weighing boat. Pour off and discard the dark liquid. Move the strong magnet around and again pour off any liquid.
8) What happens when you move a magnet under the ferrofluid?

Applications of ferrofluid:

There are a whole host of other applications for ferrofluid. Many of these are still at the R&D stage but some have already achieved a degree of commercial success. One of the applications of ferrofluid is to enable audio speakers to function more efficiently, with improved audio response and better power handling. Ferrofluid is roughly 5 times more thermally conductive than the air it displaces from the gap. The fluid provides a much lower thermal resistance between the coil and pole/top plate, lowering the voice coil operating temperature under both transient and steady state conditions. This increases power handling capabilities. Other applications areas in which ferrofluids have been used include material recycling, power and distribution transformers, quiet solenoids, sensors and switches.

VICTORIA JUNIOR COLLEGE

NANOTECHNOLOGY ENRICHMENT WORKSHEET C

SURFACTANT MONOLAYER ON SILVER

Name:_____________________________ CT Group:___________

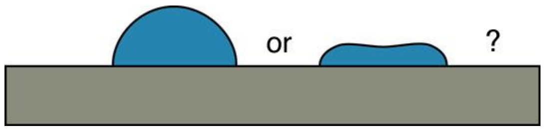
Introduction and Purpose of the Experiment:

Coating silver with a monolayer of surfactant produces a non-polar surface on which water beads up. The surfactant is a long-chain hydrocarbon with a polar head that is attracted to the surface of the silver; thus a surfactant coating is formed on the surface. The long chains of the hydrophobic tails act as a repellent cushion and prevent the close approach of hydrophilic water molecules.

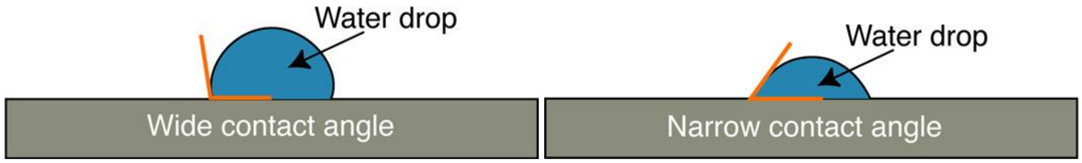
Experiment:

1. Place a clean microscope slide in a Petri dish. Place 8 small drops of a 0.5 mol dm^{-3} glucose solution on the microscope slide.
2. Add 25 small drops of an active silver ion solution to the glucose solution. Gently agitate to mix the solution.
3. Wait several minutes while the solution darkens and a grayish precipitate forms. A silver mirror is also forming on the slide, though it may be obscured by the precipitate.
4. Use water from a wash bottle to wash off the precipitate and reveal the silver mirror. Avoid contact with the solution sinced it will stain your hands.
5. Using a gloved hand, remove the slide from the Petri dish, rinse the silver mirror with water.
6. Wait for the surface to appear dry. Add some water dropwise to the slide.

How attracted are the water drops to the silver? (Like attracts like.) Do water drops on silver spread out or bead up?

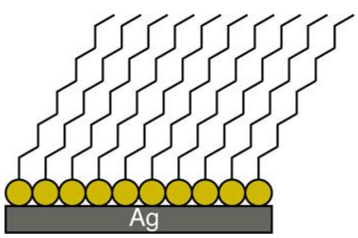


One way to describe this is the contact angle between the drop and the slide. Is the contact angle wide (small attraction to the slide) or narrow (large attraction to the slide)?



7. Cover the silver with a few drops of a long chain of surfactant and wash off the excess surfactants with ethanol.

Allow the surfactant to evaporate, leaving behind a monolayer bound to the silver and the hydrocarbon tails pointing away. This effectively coats the surface with hydrocarbons.



8. Add water as before.

Do water drops on the monolayer coated surface spread out or bead up?

Is the contact angle greater or less than before the alkanethiol was added? Is the water attracted more to the plain glass, to the silver, or to the alkanethiol monolayer-coated silver?

To another slide, add 25 small drops of an active silver ion solution to the surcose solution. Gently agitate to mix the solution. What do you observe?