

FLIPPING LEARNING

THE SCIENCE CLASSROOM

EXPLORING MERITS, ISSUES AND PEDAGOGY

By Wan Ng

Educators are continually being challenged to think about how best to integrate digital technologies meaningfully and effectively in their classrooms. A current trend in educational technology which has the potential to enable this in a pragmatic manner is the flipped classroom concept. This paper aims to explore the idea in Science teaching and learning, and examine its merits, issues and pedagogical implications.

INTRODUCTION

The affordances of digital technologies that support science knowledge acquisition and inquiry-based learning are well documented (e.g. Kim & Hannafin 2011; Ng, 2012a). Extrinsicly, digital technologies provide: (a) science resources that enable highly interactive experiences, including providing rich feedback to engage students with learning; (b) tools for facilitating data collection and analysis; (c) tools for communicating and collaborating; and (d) tools for creating in order to demonstrate what has been learned (Webb, 2005). Intrinsicly, digital technologies are motivating influences for learning with young people who are familiar and comfortable with their uses (Hsi, 2007; Ito et al., 2008; Ng, 2012b).

Other motivational aspects include the enabling capacity of digital technology to facilitate students' self-management of learning to foster cognitive development, cater for learning style preferences through the multimodal affordances of digital technology, and enable students to relate science to real-life experiences through simulations or contextual learning activities (Ng & Nguyen, 2006; Webb, 2005).

The self-management of learning through digital technologies, as alluded to in the above paragraph, allows for students' self-paced and self-directed learning. However, in technology-enhanced learning environments, scaffolding of the learning by the teacher is still crucial to gain maximum benefits for the students (Kim & Hannafin,



2011; Ng, 2012b; Raes, Schellens, De Wever & Vanderhoven, 2012; Webb, 2005). In the traditional classroom, teachers attend to content and its delivery during school time and assign homework tasks that reinforce students' understanding of the concepts taught in class. In a flipped classroom learning model, the teaching in the classroom is reversed with homework (Bergmann & Sams, 2012; Hamdan, McKnight, McKnight & Srfstrom, 2013).

In order to teach the content 'at home', teachers could video record themselves teaching or create recordings of screencasts of the teaching such as explaining and showing derivations of formula in physics or illustrations in biology on the screen. Screencast software such as Jing, Camstudio, Camtasia, Community Clips and ShowMe are cost-free applications that capture and record the computer screen output and the accompanying audio narration. These screencasts are instructional videos that can be uploaded to the internet, for example, to iTunes and YouTube and broadcast to an audience. In schools, the instructional videos could be uploaded to the school's learning management system such as Edmodo or Moodle, where students are able to access them and download to view at home.

Alternatively, the teacher could make use of science instructional videos that are already freely available on the internet, for example, from YouTube, the Khan Academy, ShowMe or university websites (such as MIT). Instructional videos that are accessible from the internet will be referred to as 'vodcasts' (video podcasts) for the rest of this article. The idea of vodcasts is that students view and listen to the teaching in informal learning settings that are outside the classroom in preparation for the activities that are planned for them in the formal classroom setting in the next session of the course or subject.

The argument for flipping the classroom in this way is to enable the more passive aspect of learning (the consuming of information conveyed by the teacher) to be carried out at home so that classroom time is reserved for more interactive activities and problem-solving tasks that build on the learning

conducted at home. The interactive classroom activities include providing help to the students on an individual needs basis by the teacher and/or peers and engaging students in small group collaborative tasks. Flipping the classroom in this manner, where students learn the science content in their own informal time and space, means that the teacher will need to ensure that all students have access to technology and the internet at home.

THEORETICAL UNDERPINNINGS FOR FLIPPING TEACHING AND LEARNING

The flipped classroom, also known as the inverted classroom (Lage, Platt & Treglia, 2000), is blended learning that uses both online and face-to-face modes of learning.

The practice of flipping the classroom is not new. Teachers have been practicing varying degrees of flipping the classroom as one of their teaching strategies for a long time. For example, getting students to read relevant articles online or research for information at home in preparation for the activities in the next lesson. But a consistent approach in which the teaching is done at home via technology is advocated by the flipped classroom concept.

As technology evolves to be more user-friendly, teachers are able to video record, audio record or create screencasts of their teaching and upload to a platform for student access prior to class sessions. With the ownership of smartphones and tablets on the rise (BBC, 2008; Griffith, 2013; Sherman, 2013; Whitney, 2009) and with BBC online (2008) reporting that mobile net users are getting younger, access to these prerecorded teaching technologies in the students' own space and time are becoming easier and would enhance flipped classroom learning.

The research into the pedagogy and impact of flipping the classroom is still in its early days. Hence empirically based evidence of the practice and its impact is quite limited.

The general theoretical underpinning for flipping the classroom in the literature (e.g. Berrett, 2012; Flumerfelt & Green, 2013; Frydenberg, 2013; Marcey & Brint 2012; Talbert, 2012) is in the use of videos to shift students' direct and passive learning in traditional and lecture-style, large group teaching to individual learning spaces outside the classroom. In the formal classroom space, students would focus on and engage in activities that foster deeper understanding and higher-order thinking through discussion, practical work and problem-solving tasks that they do individually or collaboratively in small groups.



In order to solve problems, the students would need to have a level of mastery of the concepts involved and would be required to draw on the knowledge gained through viewing the videos at home. Hence the design of the 'homework-teaching' resources would require careful consideration to ensure that the content is sufficiently well explained and illustrated so that students across a range of abilities are able to grasp the concepts that need to be learnt. However, individual students would have the opportunity to clarify concepts taught in the vodcasts that they are unsure of with the teacher in the classroom. Hence, the teacher takes on the role of a facilitator or mentor, guiding the learning with the online resources and providing individual

assistance in class by moving around the room and providing explanations, additional information and assistance to the students on a needs basis. By paying more attention to individual students, the teacher is also able to assess and gauge where each is at in their understanding of the content taught. This type of student-centred learning, enabled by flipping the classroom, is supported by practitioners who reported on student gains in their trials (see next section: [the] 'Impact of flipped classroom on learning').

Learning theories supporting the flipped learning concept are the cognitive constructivist learning theory (Bruner, 1966) and the social-constructivist learning theory of Vygotsky (1978). Constructivist theory posits that meaningful learning can only take place when the learner is actively interacting with the learning materials and engaged in the learning process. Students engaged in a flipped classroom pedagogy will be actively constructing understanding when viewing video content at home and making sense of it.

Central to Vygotsky's learning theory is the role of others (for example, teachers, peers and parents) in mediating the student's access to new experiences and knowledge. A difference between cognitive and social constructivism is that in the former the teacher plays a limited role, whereas in the latter the role of the teacher is active and involved in helping students grasp concepts by further discussing, scaffolding and encouraging engagement with assigned activities. The student-centred feature of flipped learning means that students are actively engaging in their learning; taking responsibility for and having ownership of their own learning. This active, self-directed approach to learning using technology increases students' engagement and promotes better learning outcomes (Michael, 2006; Ng, 2008).

In their review on flipped learning, Hamdan et al. (2013) reported on key features for effective flipped classroom practice that were identified by Pearson & The Flipped Learning Network (2013). These features were described as the four pillars of FLIP.



1. **Flexible environment:** The informal flipped learning allows for flexible individual learning in his/her own space and time. Flipped classrooms allow for a variety of learning modes and may involve group work, independent study and research and evaluation. In-class time may be somewhat chaotic and noisy compared with the quiet, passive behaviour during a traditional lecture. In addition, the pace of learning and assessment in flipped classrooms is flexible, catering to students' learning abilities. In this regard, it allows for some differentiation of the content. Weaker students are assisted to cover the mandatory objectives while higher-ability students could extend their learning with more open, inquiry-based and problem-solving tasks.
2. **Learning culture:** Flipped learning requires a shift in learning culture, from teacher-centred to student-centred approaches of instruction where "students move from being the product of teaching to the centre of learning, and where they are actively involved in knowledge formation through opportunities to participate in and evaluate their learning in a manner that is personally meaningful" (Hamdan et al., 2013, p.5).
3. **Intentional content:** Teachers need to evaluate the content that they require their students to learn at home and the activities to adopt for active learning in the classroom. Active learning activities could include peer instruction, peer presentation, peer review, problem-based learning or individual research.
4. **Professional educator:** Flipped professional educators are required to decide on when and how to shift group-based, direct instruction to the individual student's learning space as well as how to maximise the face-to-face interactions between teacher and students. They are required to continually monitor their students and assess their work, providing the students with relevant

feedback where appropriate. Hence, they are required to design appropriate assessment procedures that objectively measure understanding in a way that is meaningful for both the students and the teacher. Professional educators take on a visible guiding role in the classroom, are tolerant of classroom noise and disorder and are reflective practitioners.

IMPACT OF FLIPPED CLASSROOM ON LEARNING

While the concept of the flipped classroom is gaining more prominence, particularly in technology-enabled learning and teaching circles and on blog sites, empirical evidence, based on rigorous methods of investigating the impact of flipping the classroom, is still scant. Reports of case studies appear to indicate that the flipped classroom pedagogy has positive impact on students' learning in the Science, Technology, Engineering and Mathematics (STEM) subjects (Herreid & Schiller, 2013).

At the school level, case studies reported by Hamdan et al. (2013) showed that in one school, the Mathematics teachers found an increase in student engagement that exceeded expectations after flipping their Mathematics classroom. They found that nearly three-quarters (73.8%) of students passed the state Mathematics test, which was more than double the performance from just three years earlier.

Another case study indicated that the Year 9 failure rates dropped by as much as 31% for Mathematics and 22% for Science as a result of flipping the classroom (Green, 2012). In another study, Flumerfelt and Green (2013) worked with a group of 23 at-risk students using the flipped classroom approach and found that the students increased their online engagement and homework rates from 75% to 100%. Students' successes also increased by 11% in the flipped class compared with the control class.

In a Physics class, Brunsell & Horejsi (2013) reported that the class teacher

prepared 16 videos teaching about magnetic fields and implemented the flipped classroom process. Survey and interview data found that the students responded positively to the new format, indicating that they liked watching the videos and being able to rewind them. Ninety-six percent of the students indicated that they received the time and assistance needed from the teacher in this new format. Two-thirds of the students indicated the value of learning from their peers in the interactive classroom time. While there were issues, such as some students not pre-viewing the videos at home, there was a level of success in the learning outcomes as indicated in the unit test scores that was equal or better than scores in previous years.

In higher education, Marcey and Brint (2012) investigated the flipped classroom concept with a group of undergraduate Biology students through cinematic lectures and the inverted-class pedagogy. Their results showed that in comparison with a 'control' group of traditionally taught students, there were statistically significant differences in learning outcomes with the flipped class students performing better on all the tests and quizzes. Frydenberg (2013) reported on the implementation of the flipped classroom pedagogy in a first-year introductory information technology course, focusing on how the flipped strategies facilitated students' experiences learning about Excel concepts. The students' responses indicated that the flipped instructional methods captured their interests, challenged their thinking and contributed to their learning.

In another study, Papadopoulos, Santiago-Román and Portela (2010) developed, implemented and assessed an inverted classroom model for an engineering Statistics course. Their model consisted of a set of pre-lecture modules and exercises online, a lecture that responded to the students' experiences in the pre-lecture activities and a problem-solving session after each lecture. The survey results showed that there was general endorsement of the inverted class model with 81% of the

student group preferring the inverted format over the traditional method of teaching. Test scores revealed that the inverted group performed significantly higher than the control group.

MERITS AND ISSUES OF FLIPPING THE CLASSROOM

There are many merits of a flipped classroom pedagogy.

1. Self-directed learning where students are able to learn independently and at their own pace, rewinding instructional videos as often as is necessary to understand the content delivered. This is particularly important for students learning novel and abstract concepts in Science and for weaker students who do not have to keep up with the in-class explanation pace of the teacher, which is usually directed at the middle ability group of students (Ng, 2008). Regular formative assessment such as online quizzes with automatic feedback will be necessary for the students and teacher to monitor the learning progress.
2. Self-paced learning progress where students who have been absent are able to catch up with the online materials uploaded by the teacher onto the school's learning management system.
3. The teacher is able to differentiate the curriculum to cater for the different abilities by preparing a sequence of multimedia resources, including extension work for the high ability students.
4. There is more contact time for the teacher with the students, answering individual questions and providing frequent feedback. The teacher is able to develop a better relationship with the students as well as a better understanding of their difficulties.
5. Students are able to maximise class time on collaborative work with peers and develop better peer relationships through teamwork and problem-solving tasks.



6. There is more time and opportunity for hands-on activities and laboratory work in which scientific equipment is only available in the classroom.
7. The method promotes thinking inside and outside the classroom.
8. Students are motivated to learn through technology and are actively involved in the learning process.
9. For the younger students, parents are better able to understand what their children are learning through the vodcasts and become involved.
10. Teachers at a school teaching the same topic and year level can share the task of creating the instructional videos to be shared across classes.

The issues associated with the flipped classroom pedagogy include the following aspects.

1. Not all students do their homework, and sometimes parents do not support homework for their children, which will pose more challenges for the teacher.
2. More technology-based homework means more screen time for the students, which could impact on health.
3. The preparation of vodcasts could be time consuming and requires the teacher to have a good understanding of the video-recording or screencast software, its editing features and how best to integrate the content into producing the vodcasts.
4. Where not all students have access to technology, teachers will need to ensure that they can access it, for example, a loan to them from the institution's repository of mobile devices.

FLIPPING THE CLASSROOM: AN EXAMPLE OF PEDAGOGY AND IMPLEMENTATION

Appendix 1 shows an example of the pedagogy of flipping the classroom for Year 9 students, with learning outcomes

related to the Australian Curriculum: Science. The subject of nanotechnology is chosen because it is topical and interdisciplinary. The focus, however, of this flipped classroom pedagogy is more on developing students' scientific inquiry skills and understanding of science as a human endeavour—these learning outcomes need to be explicitly assessed according to the Australian Curriculum: Science. Some integration of chemistry and physics content matter is necessary to complete this nanotechnology module.

The instructional sequence as shown in Appendix 1 would require the teacher to produce several vodcasts. While there are many videos available on the internet, it is important that the teacher is present in some of the instructional videos that the students have to view in order to stay connected with them and build a better relationship.

The preparation of instructional videos could be time consuming. Depending on how involved the teacher wants the instructions to be, it could mean preparing a script and/or presentation to speak to and collecting images and links to be embedded in the videos. The use of MovieMaker or iMovie software could enhance the quality of the videos created. The videos could be re-used so the initial input of time and energy is a worthwhile investment.

Instructional materials for students to use at home do not always have to be videos, although the visual and multimedia effects are more interesting and motivating. The instruction materials could be an audio file. For example, a short audio recorded explanation (5–10 minutes) of hydrophobic nano-coating or an interview with a nano-scientist. Audio files could be uploaded onto iTunes or the school's learning management system for students to download onto their iPods or other smart devices.

Audio and video files for students to view at home should not be longer than 15 minutes and could be accompanied by a few questions that the students prepare answers to for discussion in the next lesson. The deployment of

the instructional materials should be structured and placed in an orderly manner on the school's learning management system.

A flipped classroom allows students to work at their own pace. For the weaker students, interactions with the teacher and peers in class time would provide the help required to progress their understanding relatively smoothly. For the higher-ability students, extension work that takes them further in their learning could also be prepared in advance. The following are examples of such work.

1. Learn more advanced content such as the science behind a nanosensor. These students could then work in groups, or individually, to design a nanosensor that could detect and treat cancer or detect bacteria in water systems.
2. Explore Richard Feynman's 'marvellous biological system' idea as the origin for the concept of nanotechnology. Explore 'cells': what do they do; what do they have inside them; how the extremely tiny (and invisible) 'things' inside cells keep the whole body working.
3. Find out about the people listed and create a digital story using MovieMaker, iMovie or Photostory software: Norio Taniguchi, Eric Drexler, Gerd Binnig and Heinrich Rohrer, Gerd Binnig, Calvin Quate and Christoph Gerber. Share the story with the class on VoiceThread (which is a protected site).



"As technology evolves to be more user-friendly, teachers are able to video record, audio record or create screencasts of their teaching and upload to a platform for student access prior to class sessions."

4. Research the people connected with nanotechnology and the work they have done: Richard Feynman, William McLellan, Tom Newman, Gordon Moore, Norio Taniguchi, Tuomo Suntola, Eric Drexler, Richard Jones, Donald Huffman and Wolfgang Kraetschmer, Suomo Iijima, Richard Smalley, Gerd Binnig and Heinrich Rohrer, and Gerd Binnig, Calvin Quate and Christoph Gerber. Construct a timeline on the historical aspects of nanotechnology research. Use HistoryPin or other timeline software to do this.

CONCLUSION

While the argument of the flipped classroom is not new, a contributing factor to the increase in interest of the concept is the evolution of technology and the one-to-one affordability of mobile technology.

The flipped way of learning is essentially blended learning that is enhanced by mobile technology that provides continuity between formal-informal learning. A consistent approach is required in which class time is devoted to problem-solving tasks, interactions between peers in group work and the provision of assistance to individuals with difficulties. Regular monitoring of students' understanding of the content taught is necessary through discussions and short quizzes.

By enabling students to take responsibility of their learning, they develop better critical-thinking skills rather than wait for the teacher to give them the 'right' answer. For some students this could be challenging, but the instructional resources are readily available for the students to look over again if necessary and individual assistance is readily available.

As policy makers and schools are increasingly focusing on one-to-one access to technology and bring-your-own-device, its



use to support flipped learning is ideal. However, flipping the classroom would require careful planning and flexibility on the teacher's part if (s)he wishes to adopt the strategy successfully in the classroom.

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APPENDIX 1: AN EXAMPLE OF FLIPPED CLASSROOM PEDAGOGY

The focus of the module is on developing students' scientific skills and understanding of science as a human endeavour through investigating the topical area of nanotechnology

AUSTRALIAN CURRICULUM: SCIENCE DESCRIPTORS

OBJECTIVES 1: Probe for prior knowledge and 2: Introduce nano-technology with the aim of motivating and stimulating interest

Lesson 1. In class:

Probe: (i) what students know: open class discussions about the meaning of nanotechnology (ii) small group discussions of stimulus statements e.g. from Jones, Falvo, Taylor & Broadwell (2007).

Examples include:

- there are currently biological nanomachines that naturally exist in your body;
- NASA plans to build a space elevator that would use carbon nanotubes to move materials from Earth to outer space;
- self-cleaning toilets are now available; these toilets are made with nanotechnology that keeps the porcelain clean;
- through nanotechnology, steaks can be made atom-by-atom such that cows are no longer needed to produce the meat.

Pre-test on 'size matters' on SurveyMonkey; students access and complete on smartphone, tablet or desktop.

1. How big is a nanometre compared to a metre? List one object that is nanosized, one that is smaller, and one that is larger but still not visible to the naked eye.
2. Name two properties that can differ for nanosized objects and much larger objects of the same substance. For each property, give a specific example.
3. Describe two reasons why properties of nanosized objects are sometimes different than those of the same substance at the bulk scale.
4. What do we mean when we talk about "seeing" at the nanoscale?
5. Choose one technology for seeing at the nanoscale and briefly explain how it works.
6. Describe one application (or potential application) of nanoscience and its possible effects on society.

(source for questions: <http://www.ck12.org/book/NanoSense-Student-Materials/r1/section/1.1/>)

Science Inquiry Skills

(AC SIS164) Formulate questions or hypotheses that can be investigated scientifically

Science as Human Endeavour

(ACSHE161) Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating new career opportunities

(ACSHE228) The values and needs of contemporary society can influence the focus of scientific research

OBJECTIVE 3: Students to have a sense of the smallness of 'nano'

Outside class (homework):

Conceptualise nanotechnology and its scale at the nanometre level:

View teacher's short (2-3 mins) introductory vodcast about scale. Undertake exercises at <http://tinyurl.com/Isoaxqt> and watch YouTube video at <http://tinyurl.com/n5nhqsg> or at <http://tinyurl.com/mukvjk>

Science Inquiry Skills

(AC SIS169) Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies



Lesson 2. In class:

Discussion: Draw out what students have learnt from the homework tasks; may need to have a class definition of nanotechnology.

Conduct a practical activity that sorts a wide variety of materials into km, m, cm, mm and nm groups to get a sense of dimensions. Students work in small groups to come up with 5–6 images for each scale and present to class for verification.

Teacher creates a nanotechnology folder in Dropbox or Google Drive and shares with class. Teacher creates subfolders for 'size of objects' for students to place images in sub-subfolders of 'km-sized objects'; 'm-sized objects' etc.

Students start keeping a glossary of terms encountered on the topic in Word or Pages on their laptops or a note-taking app e.g. EverNote for smartphone and for tablet (Pages for Apple devices, or Kingsoft Office for Android devices).

(AC SIS171) Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

OBJECTIVE 4: Students to understand that properties change with size and structure

Outside class (homework):

Revise atoms and molecules: teacher-created vodcast for students to view at home.

Install Jmol Molecular Visualization app for laptop and Android devices or Ball & Stick app for Apple devices. Explore different structures e.g. water, ethanol, glucose etc.

Properties change with structure: Find images for the structures of diamond, graphite, bucky ball and nanotube—these are all made of carbon atoms but are arranged differently and demonstrate different properties, hence different uses.

Create a folder for nanotechnology in Dropbox and save images.

Science Understanding

(ACSSU177) All matter is made of atoms which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms

(ACSSU182) Energy transfer through different mediums can be explained using wave and particle models

Lesson 3. In class:

Discuss the materials and research on the internet for information on (i) their uses and (ii) how the shape and arrangement of atoms fit the use.

Construct a table in a word processor—insert images and describe structure and uses.

Construct (physically) a paper bucky ball with template at <http://invention.smithsonian.org/centerpieces/ilives/kroto/buckyball.pdf>

Outside class (homework):

Read about nano particles and sunscreen at www.cancer.org.au/preventing-cancer/sun-protection/nanoparticles-and-sunscreen.html

Science Inquiry Skills

(AC SIS164) Formulate questions or hypotheses that can be investigated scientifically

(AC SIS165) Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods

Lessons 4 and 5. In class:

Properties change with size of materials. Use sunscreen as example. View titanium oxide and zinc oxide on the molecular visualisation apps.

Students conduct experiment on nano sunscreen experiment. In groups of two, investigate and compare the differences between zinc cream that stays white when applied with nano-sunscreen which is transparent when applied. Use UV sensitive beads to investigate which materials, e.g. paper, cloth, aluminium foil, students' sunglasses, plastic, cellophane, face foundation etc. will block out UV rays better. Include testing different brands of sunscreen. Video

(AC SIS166) Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data

record or take photos of experimental results to be included into report. Write report of the investigation using a word template that the teacher has created.

Outside class (homework):

View teacher's vodcast on the electromagnetic spectrum (10–15 mins).

Lesson 6. In class:

Relate the electromagnetic spectrum and how colours are seen to the nano sunscreen experiment. Learn about UVA, UVB and UVC and why they are harmful. Students write a short essay on this and upload to ePortfolio.

Students undertake set problems relating to electromagnetic spectrum and undertake an online quiz to reflect on understanding at the end of the period.

(AC SIS169) Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies

(AC SIS171) Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

(AC SIS174) Communicate scientific ideas and information for a particular purpose, including constructing evidence based arguments and using appropriate scientific language, conventions and representations

Objective 5: Students to know about the development of instrumentations (microscopy) in advancing nanotechnology research

Outside class:

View teacher's vodcast (5–10 mins) on an overview of the evolution of microscopy from the magnifying glass to the light microscopy (compound microscope) to electron microscopy (scanning tunnelling microscope) to the atomic force microscope. The latter two enable nanoscale imaging.

Lessons 7 and 8. In class:

Students work in teams to research further and create a presentation (using PowerPoint on PCs, Keynote for Apple devices or SoftMaker Presentations Mobile for Android devices) or a Prezi presentation or a glog (online poster at gloster.com) on the different microscopes, with each student in the team taking responsibility for one type of equipment. (Note: Android devices do not support Prezi so students will need to create a PowerPoint or use laptop/desktop to create the Prezi.)

Students complete presentation, share drafts with members of their team for comments and upload the final presentation to a designated space created by the teacher so that all presentations are accessible by all members of the class.

Each team of students will peer review two other teams' presentations, based on a class-negotiated set of criteria.

Science as a Human Endeavour

(AC SHE157) Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community

(AC SHE158) Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries



Outside class (homework):

Peers review the presentations and make comments for discussion with the rest of the team in the next lesson.

Lesson 9. In class:

Team members get together to assess the other teams' presentations and justify their comments. Submit evaluations to the teacher. The teacher will provide general feedback on the task in the next class.

Objective 6: Students understand the applications of nanotechnology in their everyday lives

Outside class (homework):

Students learn about the applications of nanotechnology by researching online artificially synthesised miniature 'things' that could work inside cells e.g. nanobots to detect and treat cancer and useful things outside the body for our day-to-day living e.g. self-cleaning glass; anti-bacterial bench top or food containers; anti-odour and stain-resistant clothing, cleaner water, bandaids delivering drugs (hence no injections) and nanodiamonds (4 nm).

Lesson 10. In class:

What are the implications of producing things that are really, really small? Students to discuss and debate pros and cons for nanotechnology in our lives. Examples of issues that are debatable are:

- job losses if window cleaners are not needed with self-cleaning glass;
- use of silver nanoparticles as anti-microbial agent;
- use of nanoparticles in cosmetics and sunscreen and whether these particles are small enough to get into cells to cause harm.

An informed understanding of these issues is necessary, hence wide reading and research is important to appreciate both sides of the argument. Students work in pairs to present their case to the class.

Science Inquiry Skills

(AC SIS172) Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems

Science as a Human Endeavour

(ACSHE160) People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions

(ACSHE161) Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating new career opportunities

(ACSHE228) The values and needs of contemporary society can influence the focus of scientific research