

Integrating Mathematics in Interdisciplinary Study (IDS)

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Abstract

This paper describes the rationale of designing an interdisciplinary curriculum in Nanyang Girls' High School, Singapore. It focuses on how the Mathematics teachers at the Secondary One level use the Mathematics content of the existing Sec One curriculum and re-engineer it in such a way that different subjects could be linked together through common macro-concepts, thus allowing students to make interdisciplinary connections that stretched their thinking and helped them to understand how combining different subjects together could help them to better understand real world problems that are relevant to their lives.

Keywords: Interdisciplinary, Sustainability, Mathematics, Connections

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Introduction

Faced with the complexities of the 21st century world, Nanyang Girls' High School (NYGH) as a premier education institution in Singapore realised that it must continue to review and update its curriculum in order to ensure relevance and future readiness. Education in NYGH not only shifted towards developing 21st century competencies such as innovation and creativity but there is also an emphasis on the strong NYGH values of diligence, prudence, respectability and simplicity that has stood the test of time for the last 100 years of the school's history. Learning and Thinking takes centre-stage with flexibility and choice being the driving principle for the development of the full potential of our students.

The curriculum team adopted the concept-based curriculum to provide connection between subjects and connection beyond the classrooms to the real world. In January 2016, the concept-based curriculum was introduced to all classes in Secondary One.

The Secondary One Concept-Based Curriculum

A concept-driven curriculum is not new to the school. In 2004 NYGH was one of the first batch of Integrated Programme Schools offering a concept-driven curriculum that focused on mainly content and disciplinary concepts. In the last twelve years, NYGH has tweaked its curriculum to ensure its relevance, including differentiated instruction (2009) and adopting 'agents of change' as an important lag student outcome (2012) to support the school's emphasis in Community Education. The school also adopted the Social Constructivist educational theory which espouses that knowledge is constructed through interaction with others, it emphasises the importance of student's ownership of learning as well as the environment and significant adults in shaping that learning.

Given these key milestones, the new Secondary One curriculum was designed to provide students with a Nanyang experience that is authentic as it engages all the senses and allows the students to create a meaningful, useful and shared outcome. It is personalised, allowing students to exercise choice that would fit their interest and ability. They will be learning knowledge and developing skills and attributes that are relevant for the 21st century world they live in.

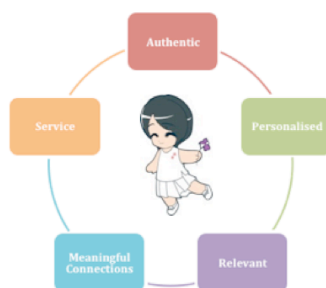


Figure 1: Features of the Nanyang Experience

Students were introduced to Disciplinary Studies such as Mathematics, Geography, History, Biology, Physics, Chemistry and Languages through the use of macro-

concepts or big ideas that cut across the disciplines and micro-concepts that are core to each discipline. Students also experience Interdisciplinary Studies (IDS) that allowed for connections through the use of macro-concepts for a more authentic and real world understanding and application of their learning.

Disciplinary Studies

Disciplinary Studies are designed to provide the rigour and depth. Five macro-concepts or big ideas are featured in the Secondary One Disciplinary Studies. These are evidence, change, communication, model and system. These macro-concepts allow students to go deep into their discipline and through these same concepts, begin to be aware of the connections across disciplines. To enable teachers from each discipline to visualise how the macro-concepts are connected across disciplines, a mapping of these macro-concepts is done. At Secondary One, much of the students' ability to see connection depends on their teacher's ability to facilitate the development of this understanding. New Unit plans were crafted using either the concept-based approach or the UbD approach. These Unit plans detailed how macro- and micro-concepts were unpacked within each discipline and given a specific knowledge and skills focus.

Interdisciplinary Studies

The Interdisciplinary Studies (IDS) has been designed to provide breadth and application. The IDS modules are designed to enable students to begin to deliberate and solve real world problems using the knowledge, skills and thinking taught in various disciplines/subjects from languages and the humanities to mathematics, science, art and music. This is part of the NYGH's total curriculum and instructional experience which is rigorous and enriched. At the same time, it provides students with an experience that is authentic, personalised and relevant. It also enables students to make meaningful connections, think and create for the good of the community.

IDS is also designed using the marco-concept of 'sustainability' and supported by 'model' and 'system'. At Secondary One, students explore the idea of sustainable living focusing on two basic human needs of food and shelter. Titled 'Garden to Table' and 'The Built Environment', these IDS modules moved beyond disciplines and embrace authenticity, allow students to empathise and establish connections with the public, the world of work and the environment or community. It also requires them to think innovatively and creatively using Design Thinking as a scaffold and process guide.

A scenario is given to help students contextualise how they should think about their IDS and what they need to do. The scenario is set in the future in the year 2036. The details of the scenario are shown below.

Scenario

The year is 2036, Nanyang Girls' High School is the first school to be awarded the Urban Redevelopment Authority's sustainable living award.

As the winner of this award, the school has to organise an exposition to

communicate its winning ideas to the general public. Your group has been selected to present its winning project at the exposition.

The two IDS modules are exclusive but yet interconnected. See the details of the IDS modules in the table below.

Sustainability				
IDS modules	Title	Interdisciplinary Connections	Macro-concepts	Enduring Questions
Module 1	Garden to Table	<ul style="list-style-type: none"> • Food Studies • Geography of food Science of horticulture and population growth, Nutrients, Fertilisers <ul style="list-style-type: none"> • History of agriculture Maths – graphs and statistics • EL & CL – Communication and culture • Maker education 	System	How can we improve food security for the future?
Module 2	The Built Environment	<ul style="list-style-type: none"> • Architecture • History of architecture Mathematics - geometry <ul style="list-style-type: none"> • Science of architecture Geography – settlements and urbanisation Aesthetics – acoustic and building materials • EL & CL – Communication • Maker education 	Model	How can humans and nature live in harmony?

Table 1: Interdisciplinary Studies Modules in Secondary One 2016

Students will work on these IDS in groups made up of no more than 5 students depending on the total within the class.

An online learning community (OLC) was created as a one-stop station for critical and supplementary learning resources that will help students cope and extend their learning across multiple disciplines. This community serves as a blended learning environment supporting students' learning in both online and physical environments, pooling together collective knowledge and facilitate learning and communication among the Secondary One students.

Nurturing Critical Thinking

The new concept-based curriculum also seeks to nurture Critical Thinking as an important competency that our students must develop to understand and manage the 21st century. Teachers introduced the following strategies to encourage and nurture critical thinking.

Elements of Thought	Intellectual Standards	Habits of Mind
<p>Purpose What am I trying to accomplish? What is my central aim? My purpose?</p> <p>Information What information am I using in coming to this conclusion? What experience have I had to support this claim? What information do I need to settle the question?</p> <p>Inferences / Conclusions How did I reach this conclusion? Is there another way to interpret the information?</p> <p>Concepts What is the main idea here? How could I explain this idea?</p> <p>Assumptions What am I taking for granted? What assumption(s) has led me to this conclusion?</p> <p>Implications /Consequences If someone accepted my position, what would be the implication(s)? What am I implying?</p> <p>Points of View From what point of view am I looking at this issue? Is there another point of view that I should consider?</p> <p>Questions</p>	<p>Clarity Could you elaborate further? Could you give me an example?</p> <p>Accuracy How could we verify or test this? How could we find out if this is true?</p> <p>Precision Could you give me more details? Could you be more specific?</p> <p>Relevance How does that help us with this issue? How does that relate to the problem?</p> <p>Depth What are some of the complexities of this question? What factors make this a difficult problem?</p> <p>Breadth Do we need to consider another point of view? Do we need to look at this from another perspective?</p> <p>Logic Does what you say follow from the evidence? Does this all make sense together?</p> <p>Significance Is this the most important problem to consider? Is this the central idea to focus on?</p>	<p>Persisting Thinking and Communicating with Clarity and Precision Managing Impulsivity Gathering Data Through All Senses Listening with Empathy and Understanding Creating, Imagining and Innovating Thinking Flexibly Responding with Wonderment and Awe Thinking About Thinking (Metacognition) Taking Responsible Risks Striving for Accuracy and Precision Finding Humour Questioning and Posing Problems Thinking Independently Applying Past Knowledge to New Situations Remaining Open to Continuous Learning</p>

Elements of Thought	Intellectual Standards	Habits of Mind
What question(s) am I raising? What question(s) am I addressing?	Fairness Am I sympathetically representing the viewpoints of others? Do I have a vested interest in this issue?	

Table 2: Critical Thinking Table

Mathematics Literacy and Interdisciplinary Connections

As a discipline, mathematics is an expression of the human mind that reflects the basic elements of logic and intuition, analysis and construction, generality and individuality. In NYGH, the mission of the Mathematics Department is to nurture and enable students to:

- be a critical thinker and innovative problem solver who communicates her reasoning and collaborates with others;
- connect ideas within mathematics and between mathematics and other disciplines through applications of mathematics;
- and foster interest in mathematics, and appreciate the beauty of mathematics.

A concept-based curriculum thus means developing deep mathematical conceptual understanding in the students. This requires students to understand key ideas (by being helped to draw inferences about those ideas) and that they grasp the heuristic value of those ideas. Students are thus better able to use key mathematical ideas strategically to solve problems, especially non-routine contextual problems

In other words, students demonstrate understanding of

- which mathematical ideas are key, and why they are important;
- which ideas are useful in a particular context for problem solving;
- why and how key ideas aid in problem solving;
- how an idea or procedure is mathematically defensible;
- how to flexibly adapt and transfer previous experiences to new problems.

Integrating Mathematics in IDS

As mentioned earlier, the IDS is designed using the macro-concept of ‘sustainability’ and students explore the idea of sustainable living focusing on two basic human needs of food and shelter.

Months before the implementation of the IDS, teachers teaching the Secondary One level met on a regular basis to share with one another their schemes of work and discuss areas of collaboration. The core team comprising teacher representative from each discipline planning the IDS set up a connection matrix for each of the two modules. All teachers teaching that level could then contribute their ideas based on specific domains and concepts in each of these modules. This allowed teachers in each discipline to have knowledge of what the other disciplines were covering. They

could then continue sharing ideas and brainstorming on possible connections with another discipline without having to meet physically. In subsequent meetings, teachers met up in smaller groups to plan lessons related to these connections.

In the planning of the mathematics programme to support the IDS and the macro-concept 'sustainability', the team of mathematics teachers referred to the connection matrix and designed the curriculum to help students see the connections and relevance of mathematics with the other disciplines. This would then help the students see that mathematics is alive and everywhere.

The mathematics teachers planned the programme in order to promote the development of the mathematical skills within the context of teaching about global issues, sustainability and its connections to the other disciplines.

It is important that the students can see the link between the sustainability issues they had uncovered through the two IDS modules and the mathematical skills they were learning in the classroom.

Besides imparting mathematical skills, the programme hopes to address the environmental, economic and social dimensions. In the brainstorming of their various winning ideas, students make sustainable living choices which will have future environmental, economic and social impacts.

Garden to Table (Food)

Students were shown that the increase in world population followed an exponential growth rate due to the advancement in agriculture. This was an issue that was also being discussed in history when students explored the topic of agricultural revolution in early human history. The growth rate in the last century however did not follow a similar pattern, with the annual world population growth rate peaking in 1962 and coming down to almost half since then. This introduction of the history of the world population gives students a better understanding of the reasons behind its increase and also allows the students to see the connection between mathematics and history.

The statistical information on the world population and growth rates was represented graphically and students were able to use their mathematical skill of interpreting graphical information in an authentic situation. They were also better able to identify the misrepresentations that some of these graphs actually represented. They were able to transfer the knowledge of what they had learnt in Statistics to the current context.

Students were asked to find the annual percentage growth rates in Singapore across the different decades from 1970. This allowed them to understand the decrease in the growth rate despite the increase in population. The lesson also raised their awareness of the difference in growth rates between developed and developing countries.

Students were introduced to the concept of interpolation and extrapolation in graphs in order to estimate the values between and beyond the given data. This allowed them to understand how the prediction of population data may have been estimated.

Students were introduced to the various ways of measuring the growth of a plant. This enables the students to measure and record the growth of the plants that they had

decided to grow as part of the IDS. Many of the groups have included community gardens and vertical gardens into the new school building as one of the ways of promoting sustainable living. A learning journey to the community gardens in Singapore also allowed them to understand how the community was currently promoting sustainable living and also understand the difficulties and challenges faced in doing so.

Teachers also made references to My Healthy Plate, a visual guide designed by the Health Promotion Board of Singapore to enable Singaporeans to create balanced and healthy meals. This had been introduced to the students in Food Studies previously. In using this, the concept of proportion was highlighted when students looked at the proportion of nutrients they had consumed in a typical day. This reinforced the idea of having a healthy and balanced diet.

Apart from just teaching students the mathematical skills, teachers also touched on the concepts of food supply and food security, issues that were also discussed in geography.

The concern was that as the rate of growth of world food production had slowed down, the world food production may not be able to keep up with the expected increase in population. This was linked to the Malthusian Theory that their Geography teachers had shared with them. A graphical representation of this was shared so that they were better able to understand this theory better.

The uneven distribution of food supplies, across developed and developing countries, has also led to other social issues – hunger and malnutrition vs obesity and food wastage. Students were asked to complete a reflection of how they could contribute towards managing this dilemma.

With all these information provided to them, the students moved from understanding world issues to thinking of solutions that will contribute towards a positive change in school and in the community. Being aware of the effort put in into growing and cultivating the food that they have on their plates, which foods are healthy and the importance of food security will ensure that they make healthy and sustainable decisions for themselves and the world.

Built Environment (Shelter)

Real-world examples of symmetry in architecture were shown to the students. This enabled them to identify the symmetry in their school building and also build in these ideas and designs into their winning project.

In building their model, students had to take into consideration the scale used. A learning journey to the Urban Redevelopment Authority (URA) in Singapore gave them a better understanding of Singapore's effort in promoting sustainable living. They were also exposed to the scale used in models displayed at URA and models of the school building displayed in school. Some groups referred to these scales when building their own model. The students had learnt how to build models using recycled materials in their Art lessons.

In Mensuration, students studied the different Geometric shapes and concepts related to their area and volume. They applied these concepts in the alternative assessment when they had to calculate the area of different materials used in the construction of their model. A further extension in this assessment was to use the scale in their model to calculate the actual area of the school building. Students were also asked to comment on how they had ensured that their measurements and solutions were reasonable and realistic. They also had to specify all assumptions they had made in this task.

Conclusions

Through the use of the IDS, the students are better able to use their mathematical concepts strategically to solve the problem posed to them. This developed their mathematical skills within the context of teaching about global issues, sustainability and its connections to the other disciplines. It allowed students to make interdisciplinary connections that stretched their thinking and helped them to realise how they could better understand real world problems and find creative solutions by combining the key ideas and understanding gleaned from different disciplines. This makes learning of any discipline truly meaningful and thus Mathematics is no longer that abstract after all.

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