# How Singapore junior college science teachers address curriculum reforms: A theory

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Using grounded theory research methodology, a theory was developed to explain how Singapore junior college science teachers implement educational reforms underpinning the key initiatives of the 'Thinking Schools, Learning Nation' policy. The theory suggests Singapore junior college science teachers 'deal with' implementing curriculum reforms by engaging in a three-stage process of individualised amelioration of teaching and learning. The argument is made that individual amelioration takes place because of an absence of fit between the reform initiatives and the demand on teachers to prioritise preparation of students for national examinations. This paper also discussed the teaching practices of Singapore junior college science teachers with regards to curriculum implementation in light of other scholarly works.

## Introduction

Though our understanding of educational change has improved significantly over the last few decades, educators today are still facing the challenge of effecting successful educational change in schools (Hargreaves, 2005). Notwithstanding the vast collection of empirical studies on change implementation, generalisation and application of research findings from one country to another or from one educational sector to another are problematic and difficult due to diverse social, cultural, economic and political contexts (Fink & Stoll, 2005). More interpretive research is still needed to examine the "dynamics of the interrelationships of the many factors" embedded within the diverse contexts of educational change (Anderson & Helms, 2001, p.12). In light of the aforementioned scholarly advice and concerns, a study was undertaken to examine Singapore junior college science teachers' pedagogical practices in the implementation of curriculum reforms underpinning the 'Thinking Schools, Learning Nation' vision. More than a decade has passed since the unveiling of this new vision for education in Singapore, a nation which places strong emphasis on examination meritocracy for economic success (Zakaria, 2006).

This paper reports a theory developed to explain how Singapore junior college science teachers 'deal with' the teaching of their science subjects under the '2006 revised junior college curriculum'. Scholars on educational change have observed that, internationally, teachers are increasingly being challenged with the responsibility of utilising student-centred pedagogies in the classroom and achieving quality grades in standardised examinations at the same time (see, for example, Towndrow et al., 2010). The theory developed in this study, therefore, has the potential towards advancing educational change literature and furthering educational research.

## Background and context to the study

### New direction for education in Singapore

With the emergence of knowledge-driven economies, the Singapore government recognised the need to re-orient the purpose and practice of teaching and learning in Singapore (Luke et al., 2005; Gopinathan, 2001). Subsequently, the policy of 'Thinking Schools, Learning Nation' was pronounced. The policy aimed to use education to develop students into creative thinkers, life-long learners and leaders of change (Ministry of Education of Singapore, 2006) Two particular expressions of the policy were 'Teach Less, Learn More' and 'Innovation and Enterprise'. These key initiatives emphasised the use of innovative teaching approaches to engage students in their learning (Ministry of Education of Singapore, 2006; Deng & Gopinathan, 2005).

### Junior college education in Singapore

Junior colleges in Singapore were established with the aim of providing a rigorous two-year pre-university education. In Singapore, a junior college is perceived to offer a more direct path towards university education as compared to other post-secondary educational choices (Goh, 2002; Tan & Ho, 2001). Junior colleges adopt a lecture-tutorial system which serves as a gradual introduction to tertiary education and aims to develop independent learning and self-discipline in students. At the end of the two-year course in junior colleges, students sit for the 'General Certificate of Education Advanced Level Examination'. Admission to local universities in Singapore is determined by the grades students obtain in this national examination.

### New demands on Singapore junior college science teachers

Singapore traditionally maintained a teacher-centric approach to education (Tan, C, 2008) and junior college education was not an exception. For junior college science teachers, the new philosophies of 'Thinking Schools, Learning Nation' were presented through the '2006 revised junior college curriculum', which approached reform by seeking to engage teachers as well as students in active learning and in experimenting with new ways of thinking, doing and solving problems (Tan, C, 2006a). Under the new educational paradigm, traditional teaching methods such as 'drill and practice', 'one-size-fits-all' instruction, and providing 'standard formulae and model answers' were regarded as undesirable and were to be discontinued in schools (Contact – The Teachers' Digest Issue 03, October 2005). It was intended that these methods be replaced by 'progressive' pedagogical approaches, such as collaborative learning and differentiated teaching, as well as the use of ICT in teaching and learning. In addition, new science content was introduced into the revised curriculum.

## Overview of the literature

The outcome of the implementation of curriculum initiatives depends on what teachers 'do and think' with regards to these initiatives (Fullan, 2007). In particular, what teachers 'do and think' with regards to putting in practice the intended curriculum initiatives is determined by the challenges teachers encounter during the implementation process as well as the meanings teachers ascribe to the initiatives. The review of literature pertaining to this study is, thus, organised in three parts. The first part discusses the challenges teachers face when implementing educational initiatives. The second part examines the meanings teachers ascribe to intended curriculum initiatives. The third part reports the theoretical propositions asserted by researchers on how teachers implement educational change. These three bodies of literature collectively provided the necessary conceptualisation and contextualisation of this study.

### Challenges teachers face when implementing educational change

*The challenge of acquiring new professional knowledge*

For the successful implementation of curriculum initiatives that espouse 'progressive' pedagogies, teachers need to be proficient in the following three areas of professional knowledge: subject matter content knowledge; pedagogical knowledge; and pedagogical content knowledge (Chen, 2008; Salloum & BouJaoude, 2008). These three forms of knowledge are inter-related, as a good pedagogical content knowledge requires teachers to be strong in their content knowledge and to be able to understand the subject-related learning difficulties students are likely to encounter (Salloum & BouJaoude, 2008). Science teachers strong in their subject matter content knowledge are more effective in promoting higher-order critical thinking skills in their students as the teachers are able to "ask cognitive challenging questions" and "pick up students misconceptions" (Childs & McNicholl, 2007, p.1632).

Conversely, teachers lacking in content knowledge, pedagogical knowledge and pedagogical content knowledge will not be able to promote active learning in classrooms as these teachers are likely to teach by mere repetition and rote memorisation (Johnston & Ahtee, 2006). It has been argued that acquiring new knowledge for innovative science teaching is dependent on personal and institutional factors (Davis, 2003). Therefore, the acquisition of knowledge for effective implementation of educational initiatives may not be a straightforward process.

*The challenge of engaging students*

Teachers also face challenges in achieving active learning amongst students when using 'progressive' teaching techniques. It has been reported that students generally prefer teachers to provide them with facts and knowledge and solutions to problems as they believe that knowledge acquired directly from teachers is 'more trustworthy' vis-à-vis the knowledge learnt through 'collaboration' with their fellow classmates (Baeten et al., 2010; Lewis & Reinders, 2008). Moreover, students accustomed to rote learning often do not appreciate and understand teachers' efforts in promoting active inquiry in the classrooms.

Fear and anxiety in the learning of science may also result in students exhibiting reluctance and resistance towards the use of student-centred learning approaches, and instead rely heavily on teachers to transmit conceptual knowledge. Students generally regard science as a difficult subject to study (Lyons, 2006; Bennett, 2003; Osborne, Simon & Collins, 2003), and it is common to find students exhibiting anxiety towards the learning of science (Udo, Ramsey & Mallow, 2004). The level of students' anxiety in the learning of science is related to their self-efficacy beliefs (Britner & Pajares, 2006; Linnenbrink & Pintrich, 2003), and students are likely to exhibit more enthusiasm participating in student-centred learning activities in the presence of a safe, supportive and caring environment (Rosiek, 2003).

*The challenge of working with insufficient time and limited resources*

Teachers are often confronted with the issues of working with insufficient time and limited resources for teaching new content as well as organising innovative and creative lessons in the classrooms (Cheung, 2008). Such constraints influence teachers' pedagogical choices. For example, in a rush to complete the required syllabus, which is often the primary objective of classroom lessons, teachers are likely to resort to the traditional way of teaching by factual reproduction of concepts and formulae instead of guiding students through inquiry-based learning (Cheung, 2008). In addition to insufficient instructional time, teachers may also experience a lack of time for lesson preparation especially in planning for student-centred activities (Rigano & Ritchie, 2003) as well as ICT learning activities (Bennett, 2003).

### Meanings teachers ascribe towards educational initiatives

*Benefits to teaching and learning*

Teachers are primarily concerned with how the intended educational initiatives improve teaching and learning in the classrooms. Educational initiatives that are perceived to be able to help students attain better results in the examinations are implemented with much enthusiasm by teachers (Churchill & Williamson, 2004; Fishman & Krajcik, 2003). On the other hand, teachers are likely to abort initiatives that they regard as 'threats' to achieving quality academic grades in examinations (Owston, 2007).

Teachers 'forced' to implement initiatives that they believe to be ineffective in enhancing the quality of teaching and learning in the classrooms may exhibit negative feelings of scepticism, frustration and discontent (Bantwini, 2010). Furthermore, teachers are often confronted with other work priorities so that they do not have the opportunity to understand the significance of the initiatives they are implementing (Fullan, 2007), and this contributes to teachers' resistance towards educational change.

*Congruence between educational initiatives and teachers' professional orientations*

Teachers whose professional orientations correlate to the intended educational initiatives are likely to implement these initiatives with great fervour (Watson & Manning, 2008). Congruence between the intended educational initiatives and teachers' professional orientations is perceived as reinforcement to teachers' personal identities (van Veen & Sleegers, 2006). Educational reforms that emphasise inquiry-based learning are fully implemented by teachers possessing a "student-and learning-centred orientation" towards teaching (van Veen & Sleegers, 2006, p.92). However, such reforms are, at best, partially implemented by teachers exhibiting a "teacher- or content-centred orientation" towards teaching (van Veen & Sleegers, 2006, p.92).

*Sense of ownership*

Teachers do not wish to be mere implementers of curriculum initiatives; teachers want to be consulted on the prospective changes to curriculum matters (Evers & Arató, 2004; Salleh, 2003). Teachers' sense of ownership towards curriculum initiatives is therefore critical towards the successful implementation of these initiatives (Evers & Arató, 2004; Vidovich & O'Donoghue, 2003). Elizondo-Montemayor and co-workers (2008) observe that teachers are more engaged and are more successful in implementing curriculum changes when they are involved at the planning stage of the curriculum revisions.

### Theoretical understandings on how teachers implement educational initiatives

In the process of implementing curriculum changes, teachers are likely to make adaptations to the intended initiatives (Churchill & Williamson, 2004). Teachers make adaptations to instructional materials as well as to their teaching practices in order to meet classroom needs (Spektor-Levy, Eylon & Scherz, 2008; Drake & Sherin, 2006). Furthermore, according to Luehman (cited in Barab & Luehman, 2003), the teachers' pattern of adaptation may involve the following steps: identification of classroom needs; assessment of intended initiatives in light of the identified needs; visualisation of the implementation procedures; and finalisation of implementation plans.

Moreover, implementation of educational initiatives proceeds in stages and teachers experience a different set of 'change characteristics' at each stage (Collet, Menlo & Rosenblatt, 2004). Each set of 'change characteristics' is likely to influence teachers' classroom practices.

## The study

### Theoretical framework

The study was developed within the research paradigm of interpretivism and was anchored in the social theory of symbolic interactionism. Symbolic interactionism rests on three basic premises (Blumer, 1969, pp.2–5). The first premise is: "human beings act toward things on the basis of the meanings that the things have for them". The second premise is: "the meaning of such things is derived from, or arises out of, the social interaction that one has with one's fellows". The third premise is "these meanings are handled in, and modified through, an interpretative process used by the person in dealing with the things he [sic] encounters" (ibid., pp2-5) The central research question was: How do Singapore junior college science teachers 'deal with' the teaching of their science subjects under the '2006 revised junior college science curriculum'? The concept of how individuals 'deal with' a particular situation is consistent with the theoretical underpinnings widely articulated within symbolic interactionism (O'Donoghue, 2007). A 'deal with' study is ultimately concerned with revealing the perspectives of the participants with regards to a specific phenomenon and the actions the participants take in light of their perspectives.

### Aims

The research question was pursued by addressing five specific aims which drew on Blumer's three premises of symbolic interactionism. The five specific aims were as follows.

- To examine the intentions of the participants and the reasons behind these intentions with regards to the teaching of their science subjects under the '2006 revised junior college curriculum';
- To examine the strategies adopted by the participants, and the reasons for adopting these strategies, with regards to the teaching of their science subjects under the '2006 revised junior college curriculum';
- To examine the importance of the intentions and strategies to the participants, and the reasons they gave for this importance, with regards to the teaching of their science subjects under the '2006 revised junior college curriculum';
- To examine the outcomes the participants had expected, based on their intentions and strategies, with regards to the teaching of their science subjects under the '2006 revised junior college curriculum'; and
- To examine how the process of action and interaction (with the other stakeholders) impacted/influenced the participants with regards to the teaching of their science subjects under the '2006 revised junior college curriculum'.

Guiding questions, as listed in Appendix A, were constructed to address the specific aims. The guiding questions were not put forth to the participants as phrased, but reworded into conversational data collection questions. The data collection questions were initially general in scope and were restructured when themes were discovered from the interviews.

### Research methodology

Grounded theory (Strauss & Corbin, 1990) was used as the research methodology because grounded theory shares the theoretical foundations contained within symbolic interactionism (O'Donoghue, 2007; Neuman, 2006). Moreover, grounded theory methodology best addressed the research aim of building substantive theory concerning a phenomenon that was oriented towards "action and process" (Strauss & Corbin, 1990, p.38), that is, teachers' implementation of curriculum initiatives. A grounded theory study does not require multi-sites but rather "events and incidents that are indicative" of the phenomena that is being studied (Strauss & Corbin, 1990, p.190). This study was conducted in one government junior college in Singapore.

### Theoretical sampling and selection of participants

There were 43 science teachers teaching in the junior college, of which 18 were physics teachers, 19 were chemistry teachers, and six were biology teachers. The science teachers were deployed according to their subjects of specialisation. All the science teachers were university graduates, majoring in a particular science discipline (that is, physics, chemistry or biology). In addition, each of them had formal training in education and teaching. As a junior college provides a two-year pre-university course, the teachers were further divided into two sections, with each section teaching a particular cohort of students. Thus, at any one particular academic year, one section of teachers would be teaching the 'Year One' students while another section of teachers teaching the 'Year Two' students. The science teachers only taught one science subject, which was their subject of specialisation. Each teacher was given at least three tutorial classes of students and each class consisted of about 25 students.

Theoretical sampling was used in this study. A group of seven science teachers was selected to provide the first set of data. Maximum variation sampling (Mertens, 1998), with variation in the teaching subject, gender and years of teaching experience, was used to select these teachers. A second group of participants comprising five science teachers was then recruited to provide a new set of data to contribute to emerging themes and propositions. The demographics of the 12 teachers are shown in Table 1.

Table 1: Demographics of the research participants

| | Name (pseudonym) | Age | Gender | Years of teaching experience | Teaching subject |
|---|---|---|---|---|---|
| First Group of Science Teachers | Diane | Early 30s | Female | 7 | Physics |
| | Margaret | Late 20s | Female | 6 | |
| | Michael | Late 50s | Male | 25 | |
| | Jane | Late 20s | Female | 1 | Biology |
| | Nancy | Late 20s | Female | 5 | |
| | Martin | Late 20s | Male | 5 | Chemistry |
| | Denise | Mid 20s | Female | 3 | |
| Second Group of Science Teachers | Bert | Late 30s | Male | 12 | Physics |
| | Cindy | Early 20s | Female | 2 | |
| | Sophie | Late 50s | Female | 25 | Chemistry |
| | Marianne | Early 20s | Female | 0.5 | |
| | Melissa | Mid 20s | Female | 4 | Biology |

Having two groups of teachers allowed theoretical sensitivity and theoretical saturation to be established in the study which in turn ensured that the developed theory met demands of being grounded in data, conceptually dense and well integrated (Strauss & Corbin, 1990). It is acknowledged that this was a small-scale study, involving just twelve junior college science teachers in a junior college. However, the participant group was deliberately selected to provide diversity in age and teaching experience and to cover the range of subject areas affected by the revised junior college curriculum. Thus, in these important ways, the sample offered a representation of the body of junior college science teachers in Singapore.

### Data collection and data analysis

The primary sources of data in this study were semi-structured interviews, classroom observations and teachers' record books. The secondary sources of data included official records and public documents such as ministerial releases. Data analysis comprised three major levels of coding, open coding, axial coding and selective coding (Strauss & Corbin, 1990). While coding of the collected data was generally done in stages from open to axial and then to selective, there was interweaving between the three stages. Coding was done directly on the transcripts, field notes and related documents. Memos and diagrams (Strauss & Corbin, 1990) were used in all the three levels of coding.

To illustrate the process of data analysis, samples of the memos and diagrams constructed in this study are provided in Figures 1 to 6.

| Transcript | Coding |
|---|---|
| P: Ok, with regards to teaching to different, to students with different academic background, I actually think that it is more difficult because for example, if you are teaching physics to arts students, we are, we have to make sure that we are aware of their prior knowledge before teaching and we have to take extra effort to do that before we actually carry out our lessons because the class may consist of wider variety of students with different levels of background knowledge. So we have to pitch our lessons accordingly. This is slightly more difficult, as compared to before. | teaching difficulty; professional; students' background; professional; increased workload; class makeup; students' learning; effective teaching; teaching difficulty; addressing situation; |
| I: Have you had any experience in teaching this group of students that are different from the normal group? | |
| P: Yes. I have taught H1 physics to students who mainly doing, who have mainly done combined science before, and as I go along through the lesson, I assume that they know certain concepts but actually, you know, when I actually, proceed say halfway through the lesson and then they tell me that, oh actually teacher, I, we have not learn this. So I actually have to go back and start all over again. This I find is quite difficult. | students' background; learning difficulty; learning difficulty; addressing students' concerns; teaching effectiveness; |

Figure 1: Generation of concepts from interview transcripts

## Study outcome

### The theory

From the analysis of data pertaining to the perspectives and approaches of all the study participants, a theory was developed and this theory was that: Singapore junior college science teachers 'deal with' the teaching of their science subjects under the '2006 revised junior college curriculum' through a three-stage sequence of individualised amelioration of teaching and learning. In the first stage, the science teachers encountered a set of challenges in delivering the revised curriculum according to the prescribed requirements. This set of challenges was conceptualised as shown in Figure 7.

**Category: Teacher's concerns**

Related codes: Preparing students for exams, Helping students, Pitching pace of lessons, Learning outcomes, Students' feedback, Students' reaction

Properties & Dimensions: Scope of concerns (specific ↔ diverse) → specific

Teacher's concerns are mainly centred around helping students learn better.

*Theoretical memo*

While teacher's concerns can be described as narrow in scope, in that the concerns are mainly centred around helping students, there seems to be more than one layer of concerns. One layer is helping students learn the content and apply what they have learnt during examinations. Another layer is helping students acquire a set of analytical skills as life skills. The latter seems to be more important to the teacher. The teacher teaches analytical skills in the form of how to analyse and answer exam questions. She acknowledges that students' priorities are still exams results. The teacher's 'hidden' intention may be different from her 'delivered' intention. The 'delivered' intention could be used to address students' priority which is doing well in examinations. *Addressing students' needs* is a sub-category of this category of *Teacher's Concerns*.

Figure 2: Categorising of concepts during open coding

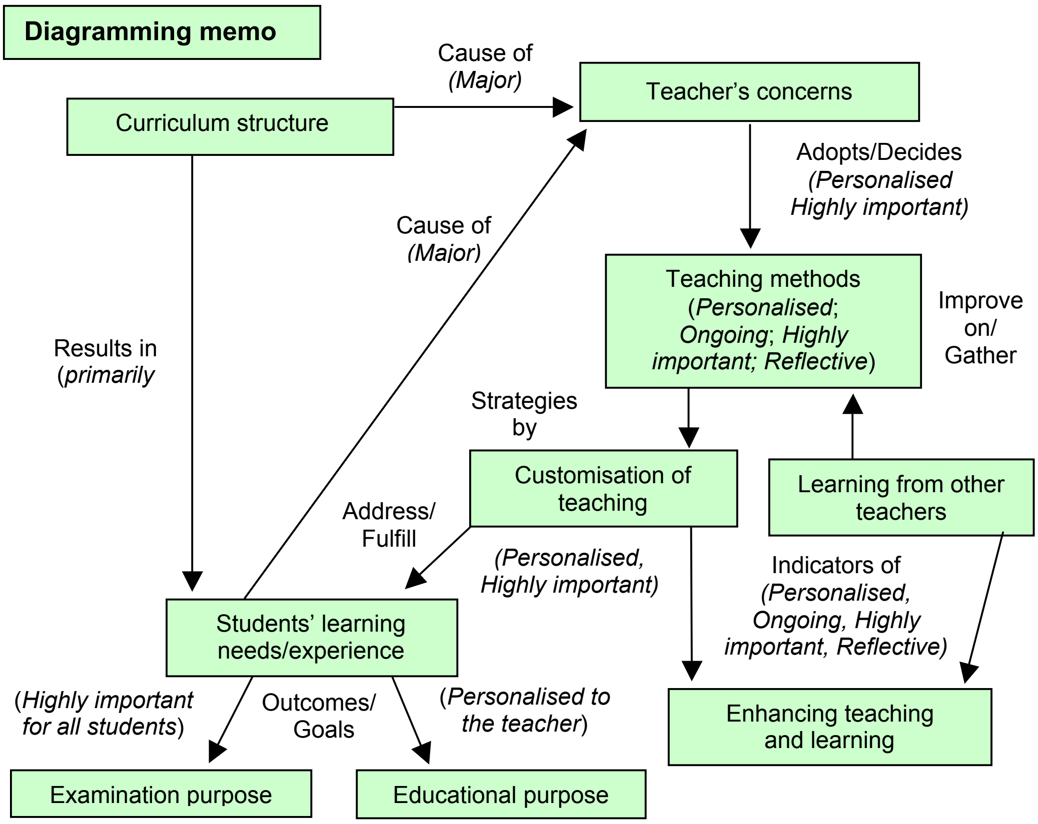


Figure 3: Diagramming memo generated during axial coding

| **Theoretical memo** |
| --- |
| The new curriculum has caused the tutorial time to be shortened. The teacher is concerned about this situation. She also perceives that her students are facing difficulties in coping with the new curriculum due to the reduction in tutorial time. She addresses these situations by making changes to her classroom teaching. The teaching methods she adopts include being more concise during teaching and emphasising the main points in the lessons. The choice of adopting such teaching methods or strategies is a personalised one. The teacher believes this is a way to help her students along their path of learning. This can be described as *customisation of teaching* to address the learning needs of students. There is a strong commitment to help the students.<br><br>*Personalised* here means that the situation the teacher is facing and the ways and strategies she adopts to address the situation is based on her own reflection, personal beliefs and her teaching capacity. While she observes other teachers to gather new teaching methods and strategies, the application of knowledge still occurs in a personalised way to address her own situation.<br><br>The teacher is also concerned about imparting analytical skills in her students which she perceives will be useful in their decision making processes in the future. The new assessment format also demands the students to apply analytical skills. The way the teacher teaches analytical skills is in the form of question-answering techniques. She feels that learning should not be for examination purpose only. However she understands that the students are mainly concerned about examination readiness. Thus she teaches analytical skills through answering tutorial questions. This teacher can be described as teaching for examination purpose as well as educational purpose.<br><br>There is a strong commitment in being an effective teacher for herself and her students. She observes other teachers to improve her teaching skills. *Learning from other teachers* is one way to improve her teaching capacity. She also intends to invite feedback from her students with regards to teaching effectives. In essence there is a sense of enhancing teaching and learning to meet curriculum needs as well as leaning needs for examination purpose and educational purpose. Again this process of enhancing teaching and learning is personalised, ongoing, reflective and highly important to the teacher. |

Figure 4: Theoretical memo generated during axial coding

In this study, it emerged that the science teachers endeavoured to overcome the challenges to achieving their priority objectives by individually adopting measures to improve teaching and learning. This phenomenon constitutes the second stage of the theory. Measures put in practice during this stage can be categorised in terms of ‘knowledge expansion’, ‘resource consolidation’ and ‘pedagogical adaptation’. The science teachers expand their knowledge mainly through consulting reference books, learning from fellow colleagues and attending in-service courses.

In addition, the science teachers consolidate teaching and learning resources through: active referral and utilisation of materials from university-based textbooks and internet portals for teaching content and planning instructional activities; compilation of ‘practice questions’ from past examination papers and examiners’ reports for ‘routine tests’ and tutorials; and by ‘re-fitting’ and ‘re-assembling’ syllabus topics into a ‘coherent’ content. The following remarks by the study participants are presented to support the aforementioned assertions:

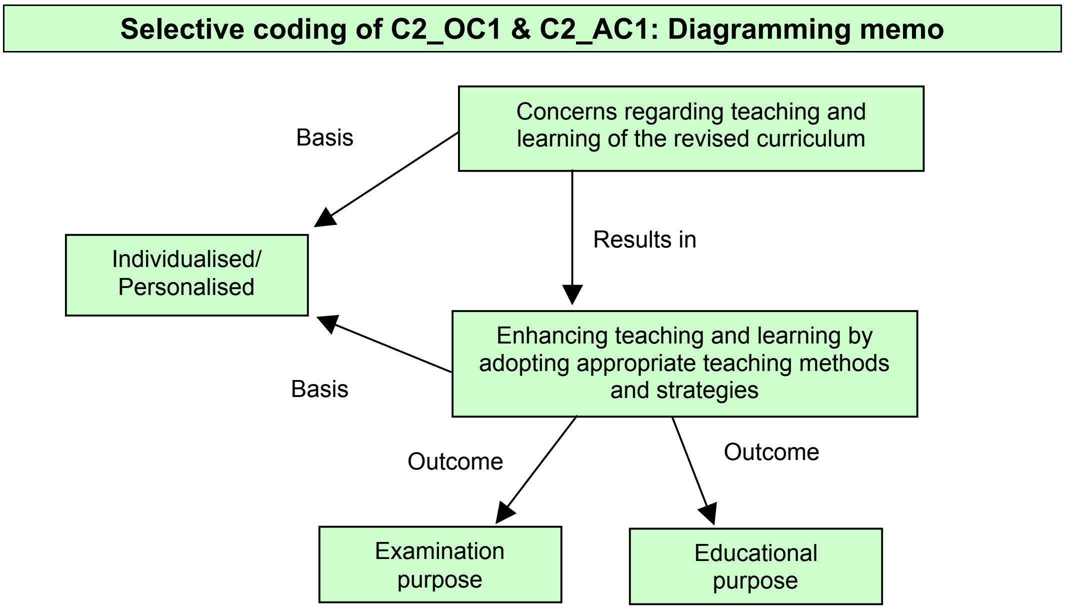


Figure 5: Diagramming memo generated during selective coding

**Theoretical memo (The story)**

The process of teaching the revised curriculum is about enhancing teaching and learning in a way that addresses the students' learning needs. The teacher regards the learning needs as twofold, namely, examination needs and educational needs. She addresses examination needs by strategising the ways which lessons are delivered (e.g. highlighting main points, being more concise and focused). She addresses educational needs by imparting analytical skills through answering tutorial questions. The intentions and actions of the teacher are personally motivated.

It does not mean that there is no motivation to enhance teaching and learning prior to the implementation of the revised curriculum. The implementation has brought about specific challenges and concerns regarding teaching and learning which the teacher intends to address through enhancing the process of teaching and learning by adopting appropriate teaching methods and strategies that are individualised/personalised to herself (i.e. her personal and profession orientation with regards to teaching and learning) and her own students (i.e. to the learning needs of the students; quality and background of students).

Figure 6: Theoretical memo generated during selective coding

> …the first level of things that I will do will be to obviously go for the in-service courses, H2 and H3 courses, which will give me some idea, to some extent, on teaching the new syllabus [sic]. (Diane, Physics teacher)

> I will find 'pictures' and 'diagrams' from books and even 'applets' from the internet to help the students understand the abstract concepts I am teaching. These 'diagrams' and 'applets' help the students to visualise the concepts. (Margaret, Physics teacher)

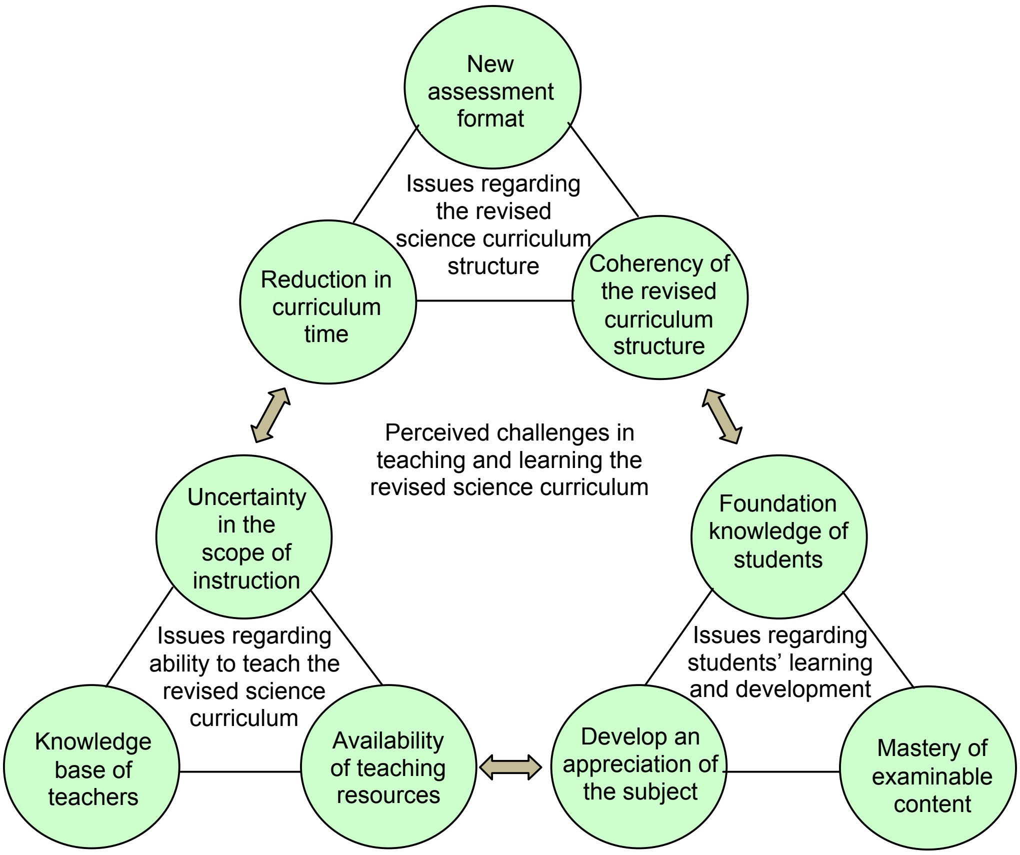


Figure 7: Conceptualisation of challenges encountered by Singapore junior college science teachers

> I just plan according to what I think will help the students in their understanding. It also depends on the students. You can skip certain parts if they know the content, but for the weaker students you have to teach more, sometimes you have to teach what is not in the syllabus to help them understand. (Sophie, Chemistry teacher)

The science teachers also adapt their pedagogical practices in order to teach the revised science curriculum effectively to their students. Examples of these practices include: use of 'conceptual' questions; ICT-based learning; inquiry-based learning; use of 'thinking' questions; 'hands-on' experiential learning; group learning; routine tests; remedial; use of demonstrations; developing skills in answering examination questions; as well as 'Socratic' questioning.

The adapted classroom practices can be described in terms of the roles science teachers assume and the approaches they use to teach their science subjects. The role is of a 'Knowledge-Transmitter' or 'Knowledge-Synthesiser' in the classroom, with delivery of science lessons in a 'teacher-directed' or 'student-directed' manner. These four descriptors further establish four quadrants of pedagogical practice, as shown in Figure

8, which maps the typical classroom practices of science teachers in the teaching and learning of their science subjects under the new revisions.

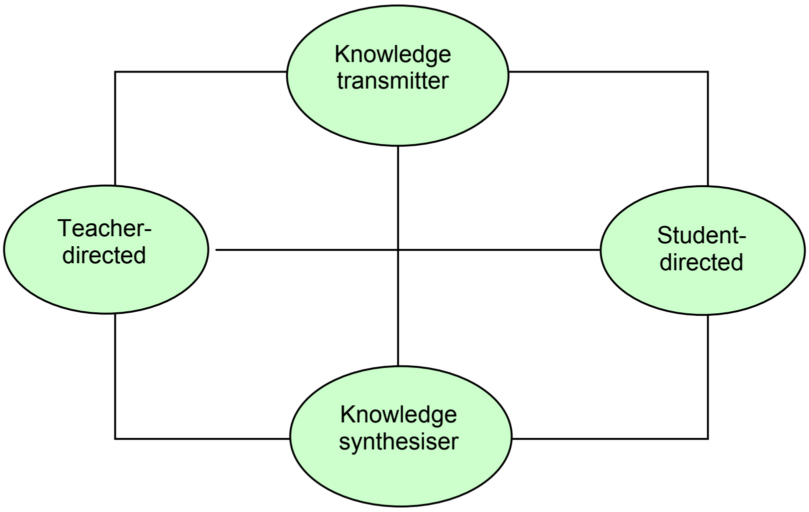


Figure 8: The four quadrants of pedagogical practices

Drawing on study findings, the third stage of the theory proposes that Singapore junior college science teachers individually refine the measures they have adopted to ameliorate the teaching and learning of their science subjects under the revised curriculum. This refinement is accomplished through 'filling up gaps' in the knowledge and materials obtained from the course of knowledge expansion, modifying and filtering teaching materials obtained through resource consolidation and pedagogical re-adaptation within the four quadrants of pedagogical practices. 'Modification' and 'filtration' of teaching resources were necessary so that these consolidated materials were, in the words of the participants, 'at the correct level of study'. The following remark by a study participant is presented to illustrate the process of pedagogical re-adaptation:

> I have a class which is very rowdy. When I first tried to deliver a teacher-centred way of teaching for the difficult topics, it couldn't work. I cannot get the students to focus. So I get them to discuss in groups and I find that they are able to focus better. Therefore I will use this way of teaching for that particular class. (Bert, Physics teacher)

As the science teachers re-adapt their pedagogical practices, they move within a particular quadrant or across quadrants of pedagogical practice depicted in Figure 8.

**Subsidiary propositions**

Subsidiary propositions were developed to support the theory in explicating how the science teachers 'deal with' specific issues that are intricately connected with delivering their science subjects under the revised curriculum.

*Subsidiary proposition one*: Contrary to the emphasis on holistic development of students by the initiatives underpinning the '2006 revised junior college curriculum', junior college science teachers, when delivering their science subjects, focus primarily on teaching students for examinations and developing students' content knowledge.

In support of this proposition, it was determined in the study that in direct contrast to the approaches emphasised by the initiatives underpinning the revised junior college curriculum, participants sought to generate 'recitational' knowledge, that is, the "ability to recite facts on demand, to recognise correct answers on multiple-choice tests, to define terms correctly, and to be good test-takers" (Glasgow and Hicks, 2003, pp.56–57).

*Subsidiary proposition two*: The pedagogical practices of Singapore junior college science teachers in teaching their science subjects are rooted in the 'Expert-Formal Authoritative' instructional approach, and this approach is externally imposed rather than intrinsically motivated.

Notwithstanding the variation in classroom activities during the teaching and learning of the revised science curriculum, study participants consistently grounded their pedagogical practices in the 'Expert-Formal Authority' instructional approach, whereby the teacher assumes a status as an 'expert' knowledge dispenser and maintains a standardised way of knowledge acquisition in the classroom. A description of the 'Expert-Formal Authority' instructional approach and the parallelism between this approach and that of the science teachers' classroom practices is provided in Table 2.

Table 2: Expert-Formal Authoritative teaching approach and Singapore junior college science teachers' teaching approach

| Expert-Formal Authoritative | Singapore junior college science teachers' teaching approach |
|---|---|
| Teacher possesses knowledge and expertise students need | Teacher is the 'undisputed' dispenser of knowledge which the students assimilate |
| Emphasises comprehension of concepts | Emphasises developing students' content knowledge in accordance to examination requirements |
| Gives detailed and succinct answers to assigned tasks | Provides detailed solutions to tutorial and past examinations questions |
| Maintains a standardised way of completing assigned tasks | Maintains a specific way of answering examination questions (so as to meet examiners' expectations) |
| Sets clear goals and objectives | Sets specific academic targets which are measured by a quantitative indicator called 'value-addedness' |

Source: Grasha (2002, 1996)

As explained earlier, 'Pedagogical Adaptation' is one of the key measures the science teachers employ in the second stage of individualised amelioration of teaching and learning. 'Pedagogical Adaptation' further results in establishing four quadrants of pedagogical practices, with each quadrant associating with a particular approach of teaching the science subjects. These four quadrants of pedagogical practices are, however, predicated on the 'Expert-Formal Authoritative' instructional approach.

*Subsidiary proposition three*: Singapore junior college science teachers take measures to build their craft knowledge to teach the revised science curriculum effectively, and this knowledge is made up of two other bodies of knowledge, namely 'subject matter content knowledge' and 'examination matter content knowledge'.

The teacher participants of this study typically recognised a need to acquire new sets of craft knowledge to teach the revised science curriculum, due to changes in the curriculum content and examination format. 'Subject matter content knowledge' refers to the conceptual knowledge of the science subjects the science teachers are teaching, while 'examination matter content knowledge' concerns the type of questions that are likely to be asked in the national examinations as well as the skills to answer these questions to examiners' expectations. A good knowledge in the 'subject matter' and 'examination matter' was perceived by participants as essential towards developing students' content knowledge and 'recitational' knowledge – the knowledge needed to excel in the national examinations.

*Subsidiary proposition four*: Singapore junior college science teachers individually evaluate the measures they have adopted to ameliorate the situation of teaching and learning the science subjects to ensure effectiveness towards developing students' content knowledge and 'recitational' knowledge, and this 'self-evaluation' eventuates in a refinement of the measures in response to actual classroom contexts.

From the study, it was surmised that the measures science teachers adopt in the second stage of individualised amelioration of teaching and learning result from the 'interaction' between the teachers' existing cognitive structures and their individual understanding and interpretation of the teaching and learning situation. The interaction transpires in the form of an individual assessment of teaching effectiveness based on the measures the individual science teachers adopt to overcome the challenges towards preparing students for the national examinations. Teaching effectiveness is evaluated in terms of three components, namely, 'Craft Knowledge', 'Teaching Methods' and 'Teaching Resources'. These three components correlate to the measures the science teachers adopt in the second stage of individualised amelioration of teaching and learning with 'Craft Knowledge' relating to 'Knowledge Expansion'; 'Teaching Resources' to 'Resource Consolidation', and 'Teaching Methods' to 'Pedagogical Adaptation'.

*Subsidiary proposition five*: Teaching and learning of science under the '2006 revised junior college curriculum' happens in the 'Realist' paradigm of education punctuated with 'pockets' of 'Progressivism' pedagogies.

Based on these perspectives and actions of participants in the study, it is reasonable to posit that teaching and learning of the revised science curriculum happens mainly in the 'Realist' paradigm of education. The characteristics of such a paradigm are provided in Table 3.

Table 3: Characteristics of a Realist paradigm of education

| Realist paradigm of education |
|---|
| Emphasis on developing students' reasoning powers and cognitive abilities at the expense of other aspects of students' development. |
| Lesson materials are presented in an orderly and organised manner, and content is based on facts, reason and practical use. |
| Clearly defined criteria in subject-matter are taught to students, and students are formally assessed in standardised achievement tests. |
| The teacher is an expert in the subject; he or she is skilful in explaining the contents to the students and in assessing the students' understanding. |
| Routine tests are used to assess students' progress in learning. |

Source: Tan, C (2006a, 2006b)

As shown in Table 2, Singapore junior college science teachers are likely to adopt the 'Expert-Formal Authoritative' instructional approach when teaching their science subjects under the revised junior college science curriculum. Figure 9 below further amalgamates Tables 2 and 3, and extrapolates the 'Expert-Formal Authoritative' instructional approach to the 'Realist' educational paradigm.

As clearly shown in Figure 9, the individualised amelioration of teaching and learning of the revised curriculum involves the use of the 'Expert-Formal Authoritative' instructional approach, and this approach follows the 'Realist' paradigm of education.

Notwithstanding the dominancy of a 'Realist' educational paradigm in the teaching and learning of science under the revised junior college curriculum, the study found 'pockets' of 'progressive' pedagogy in the teaching and learning of the revised curriculum, albeit confined within the 'Expert-Formal Authoritative' learning environment.

## Discussion

Findings from this study suggest that Singapore junior college science teachers' pedagogical choices seem to support the position adopted by Wu and Huang (2007) that teachers vary their instructional approaches to meet classroom needs. Teachers and students feel comfortable to engage in inquiry-oriented, instructional activities only when the topics that are being learnt can be easily digested by the students. The practice of focusing on developing students' content knowledge and 'recitational' content knowledge by the science teachers in teaching the revised curriculum, as highlighted in the theory, exemplifies what McCain (2005, p.14) means when he asserts that teachers have "little choice but to focus on content delivery" when 'dealing with' a massive curriculum.

Insufficient time and lack of resources are commonly cited by researchers as the major obstacles towards implementing curriculum changes (see, for example, Cheung, 2008; Bennett, 2003). Liew (2005) has called for more research on how teachers 'deal with' these challenges. In respect to this study, science teachers 'deal with' these challenges through 'Pedagogical Adaptation' and 'Resource Consolidation' respectively. In addition, to tailor to the needs of their students, the science teachers are likely to 're-adapt' their pedagogical practices as well as 'modify' and 'filter' the resources they have consolidated.

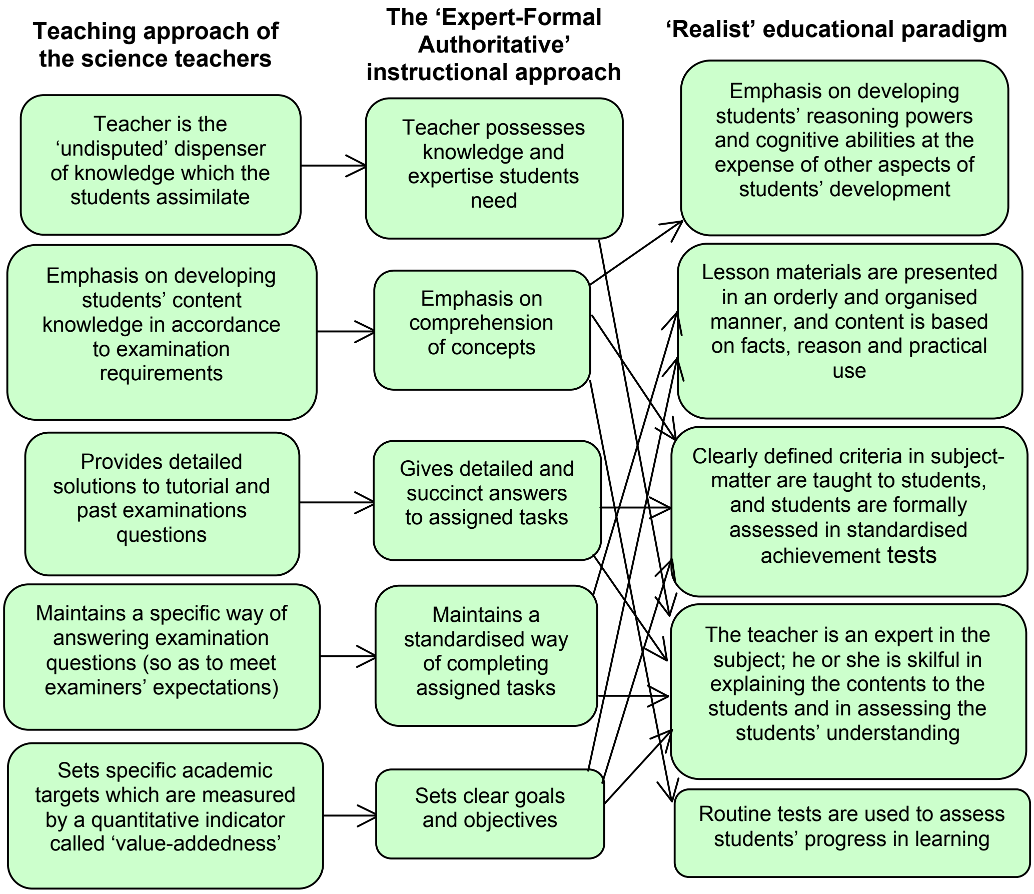


Figure 9: Extrapolation of Singapore junior college science teachers' instructional approach

The theory developed in this study reinforces the position maintained by Shaver and co-workers (2007) that teachers working in high-stakes examination system are ultimately concerned with the impact of educational initiatives on students' academic grades. Findings in this study indicate that initiatives which underpin the new educational framework in Singapore junior colleges, such as 'Teach Less, Learn More' and 'Innovation and Enterprise', are difficult to realise while examination grades continue to serve as the sole determinant of both the teachers' and students' capabilities. These findings support the call (for example, by Tan & Ng, 2005) for attention to be channelled towards broadening the definition of success in college education in Singapore. Students in Singapore junior colleges are still formally assessed by a unilateral written examination system. In addition, the examination is 'episodic', meaning that the examination is performed on a "single occasion" and in a "controlled environment" (Tan, K, 2006, p.118). As the theory that was presented here suggests, such practices induce Singapore junior college science teachers to orient their teaching to 'training' students, through routine tests, for the examinations. Thus, the current examination system is a significant barrier to the adoption of student-centred and inquiry-oriented instructional approaches in the teaching and learning of science in Singapore junior colleges. Policymakers could consider alternative forms of assessment, for example the proposal by local researcher Kelvin Tan (2006) to replace episodic assessment with the portfolio to create 'extended assessment'.

The theory developed in this study does not support the assertion by Smith and Southerland (2007, p.418) that the internally constructed beliefs teachers hold can "override" teaching contexts. On the evidence of the study, it appears that Singapore junior college science teachers' preferred classroom practices are likely to be 'overridden' by the exigency to prepare students for national examinations through the 'traditional' way of 'drill and practice' of 'mock examinations'. Meister (2010) argues for the strong impact of classroom and societal norms on teacher implementation of educational initiatives. This was in evidence in the study. The educational culture and societal expectation on Singapore junior college science teachers to deliver quality examination results undermine their efforts to put in practice initiatives such as 'Teach Less, Learn More' and 'Innovation and Enterprise'.

## Conclusion

Drawing on empirical research, this paper has posited a theory of how junior college science teachers in Singapore 'deal with' educational reforms underpinning the 'Thinking Schools, Learning Nation' vision. Developed through the use of grounded theory research methodology, the theory suggests that the science teachers' pedagogical practices in teaching a new curriculum occur in stages, shifting from problem identification to practice amendment and finally practice refinement, and that individualised amelioration occurs because of contextual realities encountered by the teachers. The argument is that science teachers in Singapore junior colleges are responding to new demands and dictates through a process of individual amelioration of teaching and learning practice. Essentially, they are forced to make practical accommodations when they find new teaching and learning initiatives incompatible with sought outcomes. It also seems very clear that the goals of 'Thinking Schools, Learning Nation' will not be fully achieved within the Singapore junior college system without changes to the status and nature of national examinations.

## Appendix A: Guiding questions for addressing specific aims

This is available in the file http://www.iier.org.au/iier22/lim-appendix.pdf

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