SCIENCE CURRICULUM PROJECT

PROGRESS OF STUDENTS THROUGH THE SCIENCE CURRICULUM: A FOCUS ON MATTER (CHEMISTRY)

STAGE 3, PRE-GRADE 9 REPORT

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EXECUTIVE SUMMARY

This research is designed to examine the implementation of the spiral curriculum structure introduced in the Philippines as part of the K to 12 curriculum reform. The curriculum emphasises the understanding and application of scientific knowledge, the learning of scientific inquiry skills, and the development and demonstration of scientific attitudes and beliefs. The spiral curriculum was initiated with Grade 7 implementation in School Year (SY) 2012/13. In April 2016 this cohort of students became the first to complete the entire new curriculum from Year 7 to Year 10.

Due to the recency of the reform, the influence of its characteristics and design on outcomes is not yet known. How is the curriculum implemented by teachers? Does the teacher's specialisation influence student outcomes? How do other factors such as teacher training, experience, student access to materials, and school size influence student outcomes? How do the students' skills progress as they complete the curriculum? Is spiralling handled differently across year levels?

This research is designed to investigate the progress of students' conceptual knowledge and skills for each unit of Chemistry ("Matter") over the four years of the junior secondary curriculum. Identification of progress is achieved by assessing students in Grades 7–10. Data representing factors presumed to influence student learning outcomes include teacher information, lesson plans, and classroom observations of selected classes.

This report covers the data obtained in order to address the research question:

Do students enter Grade 9 with the level of conceptual knowledge and skills they need in order to engage with the Grade 9 science (chemistry) curriculum?

The report includes analysis of data obtained from a pre-Grade 9 test on chemistry related skills. The pre-Grade 9 test was developed to assess whether students are prepared to access the new curriculum. Students were tested in September 2016, before beginning the chemistry unit "Matter" (which is taught to Grade 9 students during the second quarter of the school year). The results indicate that a sizable proportion of students entering Grade 9 are not well prepared to engage with the conceptual knowledge and skills required by the Grade 9 chemistry curriculum. A larger proportion of students attending science-oriented high schools are well prepared for Grade 9 entry. Details of the knowledge and skills best and least well demonstrated are provided in the report.

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PROJECT INTRODUCTION

Note: This is the same information provided in the reports for Stages 1 and 2 (pre-Grades 7 and 8)

In 2011, the Philippine Department of Education (DepEd) initiated a basic education reform. This reform is known as the K to 12 program. This program covers Kindergarten and 12 years of basic education: six years of primary education, four years of Junior High School, and two years of Senior High School. The rationale for this reform is to provide sufficient time for mastery of concepts and skills, develop lifelong learners, and prepare graduates for tertiary education, middle-level skills development, employment, and entrepreneurship.

In the K to 12 program, a new curriculum for science has been implemented in schools across the country. Through implementation of this curriculum, the aim is to develop scientific literacy among students such that they are able to make judgments and decisions on the applications of scientific knowledge that may have significant impact in everyday life (DepEd, 2013). The new curriculum is designed according to the three domains of learning science: (1) understanding and applying scientific knowledge; (2) performing scientific processes and skills; and (3) developing and demonstrating scientific attitudes and values.

The new curriculum includes statements outlining the progression of science inquiry skills and expectations of the rate at which students will develop these skills, addressing some of the recommendations resulting from a comparison of the Philippines curriculum with those of three other countries (Care & Griffin, 2011). Concepts and skills are presented with increasing levels of complexity from one grade level to another in spiral progression to develop a deeper understanding of core concepts.

DepEd implemented the new curriculum for Grades 1 and 7 (the 2nd year of Elementary School and 1st year Junior High School respectively) in public schools during SY 2012-2013, and it is being progressively introduced in other grade levels. In SY 2014-2015, it was implemented with Grades 3, 7, 8, and 9 respectively. In the SY 2015-2016, the new curriculum for Grades 4 and 10 is implemented in all public elementary and secondary schools.

This project was designed to investigate how students' knowledge of the science content and their inquiry skills develop through the spiral curriculum. Determining what students know and can do at various stages can be used to inform subsequent teaching and assist with future reviews of the science curriculum domains and learner modules. The over-arching goals for the study are outlined below. This report addresses the first goal, with a focus on students entering Grade 9.

1. *investigate the progress of students' knowledge and skills as they complete the spiral science curriculum, with emphasis on whether students have developed the prerequisite knowledge for the next year of study*
2. determine the level of conceptual knowledge and skills students have developed before they enter junior high school
3. determine the level of conceptual knowledge and skills achieved after four years of the spiraling curriculum
4. assess the effect of factors such as previous teacher specialisation, teacher training, experience, student access to materials, school size and school specialisation, on student achievement and curriculum implementation

5. investigate extent to which teachers are implementing science inquiry teaching practices in the Grade 9 Chemistry classroom, where science inquiry is specifically outlined as a content component
6. determine the relationship between teachers' implementation of science inquiry practices and students achievement of science inquiry skills.

PROJECT METHOD

PROJECT PARTICIPANTS

DepEd regular high schools and science-oriented high schools from the National Capital Region (NCR) are targeted in this study, as well as high schools in Regions VI and VII. The science-oriented high schools are of particular interest, in view of the presumption that these schools might have teachers with more expertise in the teaching of science and who might therefore implement the curriculum somewhat differently to teachers within the mainstream. NCR is selected because of its relatively large population and consequent role as education provider for a large number of students with elementary and secondary education. Regions VI and VII (Western and Central Visayas) are selected because of their inclusion within the BEST initiative.

Development phase

As part of the development of the assessment tools for the project, approximately 200 students enrolled in 2-4 schools in the Metro Manila region take each year level test (for Grades 7, 8, 9 and 10) to provide item level data to contribute to the test development. Each grade level test development activity comprises:

a. Curriculum audit: analysis and identification of major themes/skills for analysis
b. Drafting of items
c. Item review and selection of items for pilot test form
d. Administration of items to pilot participants
e. Analysis of pilot quantitative data
f. Finalisation of grade level test.

Research phase cycles

For the research each year, 16 schools are recruited: four in each of Region VI (Western Visayas), Region VII (Central Visayas), NCR, and NCR Science-oriented High Schools. Three sections within each school are selected for participation. The primary activity in each school comprises student assessment. In some schools, classroom observations are to be undertaken across sections. This provides the opportunity to identify the degree of alignment between planned and implemented curriculum and in addition examine the possibility that delivery of the curriculum varies across sections.

PROJECT RESEARCH DESIGN

For the main study, students are tested directly *before* completion of each unit of Chemistry. The rationale for this approach is a focus on depth of student learning, as opposed to knowledge acquisition or surface learning. The approach provides an indication of the skill level of students prior to each relevant quarter, including the level of skill retained from the previous relevant quarter. The skill level is indicative of the knowledge, skills, and understandings retained long-term from previous units of the subject and other sources.

The dependent variable throughout the phases of the study is student outcomes, as measured through tests of chemistry knowledge and skills developed in alignment with the curriculum. Independent variables to explore include – variably across phases – chemistry content delivered, teacher, teacher training, science specialisation, access to materials, class size and school type. Confounding variables include homogeneous/heterogeneous student grouping, socio-economic status (SES), language background, metro/regional/rural location.

Student assessment schedule

The phases of the study are scheduled in order to assess each grade level as it begins the Chemistry quarter, within the shortest amount of time possible in order to expedite feedback of results to DepEd.

Pre7	Jun 2015 before Unit 1, Grade 7 Chemistry (SY2015/2016)
Post7	Grade 7 sub-study end of QTR 1 (SY 2015/16)
Pre8	Nov 2015 before Unit 3, Grade 8 Chemistry (2015/2016)
Pre9	Aug 2016 before Unit 2, Grade 9 Chemistry (2016/2017 school year)
Pre10	Jan 2016 before Unit 4, Grade 10 Chemistry (2015/2016 school year)
Post10	Mar 2016 after Unit 4, Grade 10 Chemistry (2015/2016 school year)

PROJECT INSTRUMENTS

For Students

Tests were developed to assess student learning. Five linked tests were developed in order to locate students on the same scale across the grade levels of interest in the study. The tests of approximately 50 items are linked by sets of common items. The use of common items enables the comparison of student acquisition of skills and knowledge across different grade levels. The process of test development included initial curriculum mapping and development of a test blueprint, item development, item review and selection for a pilot study, analysis of pilot data, and selection of items for the final test form.

The set of chemistry tests for the curriculum study is designed to cover the concept domain (Matter), strands (Properties, Structure and Changes, Inquiry Skills) and sub-strands (see Figure 1). Each strand is not covered in the same proportion across the five tests. This is a consequence of the curriculum design, which the tests reflect. The set of tests for the full study includes:

1. Pre-Grade 7 (Base-Line or Entry Level)
2. Pre-Grade 8
3. Pre-Grade 9
4. Pre-Grade 10
5. Post-Grade 10 (Final)

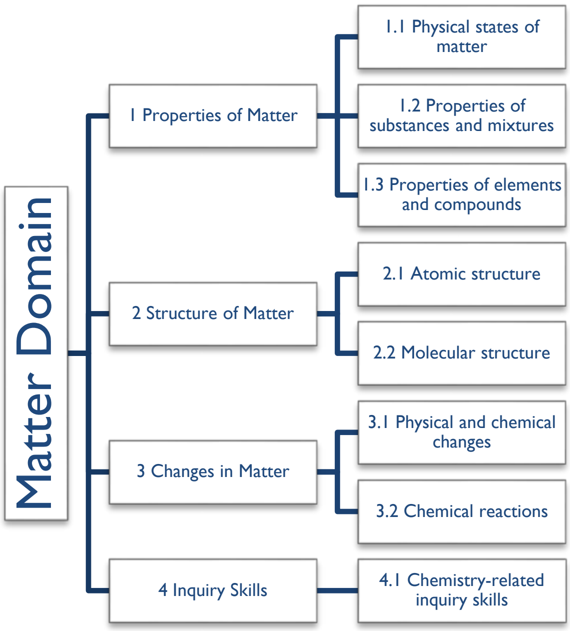

Figure 1. Matter Test Domain Structure

PROJECT PROCEDURES

The main procedures are:

- liaising with DepEd Central and in NCR, Regions VI and VII for the purposes of recruitment
- recruitment within the NCR for the purposes of piloting tests
- fieldwork associated with research data collection from students and schools
- analysis and reporting.

PROJECT DATA ANALYSIS

Student data are collected via pencil and paper tests, with student responses provided on scannable forms. Completed forms are then scanned, and raw data cleaned prior to analysis. All tests are developed and scored on the basis of Item Response Theory. Test results are to be used primarily as an indication of student learning in research reports to be provided to DepEd. In addition, individual class results in aggregated form are provided to participating schools in order to supply teachers with relevant information about student learning levels, and hence the most appropriate levels for teaching and learning interventions. At no point in the study are any individual student scores or grades reported. For school use, student results across descriptive skill levels are provided.

PROJECT INSTRUMENT DEVELOPMENT

The curriculum audit was accomplished in a workshop in March 2015. Participants were six UP NISMED science education specialists, two UP Integrated School science faculty, one science education faculty of the UP College of Education, one ACTRC staff member, and ACTRC's Program Leader for Curriculum. The curriculum audit involved curriculum analysis and identification of concepts and skills for the Grade 7-10 science curriculum. To make the curriculum audit more efficient, two or three experts were grouped to work on each of the grade levels (Grades 7 to 10). The blueprint to structure the development of test items for each grade level was created using the audit information. This included the identification of concepts and skills students need to have in order to access a specific grade level chemistry curriculum.

The blueprint took into account the following questions:

- What strands run through the different grades?
- What is the most communicative terminology to use for these strands?
- What strands appear only at one grade or some grades?
- What is the relative importance of the categories/strands at each grade level?

To articulate the skills integral to each grade level of the curriculum, specific behaviours that a student could demonstrate were identified. Descriptions of behaviours that could be demonstrated in a pen and paper test were written for each statement. Where the same behaviours appear at multiple grade levels, these were noted at each relevant level. The behaviours were also classified as 'essential' or 'advantageous.'

After the two-day workshop on curriculum audit, another two-day workshop on item writing and review took place, focusing on guidelines for writing test items, multiple choice terminology, and multiple choice guidelines. Sample test items were provided. The experts drafted and panelled multiple choice test items. Following Day 1 of this workshop, the blueprint was revised. This involved six steps: (1) the domain (conceptual knowledge and skills), strands, and sub-strands were reviewed; (2) the distinction between essential and the advantageous behaviours was elucidated, insofar as essential behaviours are those that a student needs to have achieved in order to engage with the demand of the (next) year level, while advantageous behaviours are not essential but enhance their progress; (3) capabilities (what we want students to be capable of) were reviewed (added, deleted, modified or moved); (4) indicative behaviours (those behaviours that allow test developers to infer whether students have the capability) were assigned to capabilities; (5) indicative behaviours were reviewed; and (6) indicative behaviours were linked to grade levels. Finally, numbered statements and behaviours were incorporated into the test blueprint.

Multiple-choice test format was selected as the most efficient method of assessing at large scale. The advantages of the format include student familiarity, ease of administration, and cost-effectiveness of scoring.

The item writing responsibilities were shared between team members located in Metro Manila and those in Melbourne. All items were written to the test blueprint. Once each item was written and the skill identified, it underwent a panelling process to enhance item quality. Each item was panelled twice, by team members in each geographical location. This process drew on the expertise of all team members and ensured items adhered to guidelines for best practice in objective item writing and contained language and concepts that were Philippines appropriate.

STAGE 3 METHOD

This stage of the project focuses on the measurement of the understanding and skills of Grade 9 students as they begin the Matter topic in the 2nd Quarter of the school year. The purpose of this measurement is to determine the readiness of the Grade 9 students for the Grade 9 Matter curriculum. The focus of the spiralling curriculum by quarter across grades is shown in Table 1.

Table 1. Curriculum focus by quarter across grades

	G6	G7	G8	G9	G10
1st Quarter	Matter	Matter	Force, Motion & Energy	Living Things and Their Environment	Earth & Space
2nd Quarter	Living Things and Their Environment	Living Things and Their Environment	Earth & Space	Matter	Force, Motion & Energy
3rd Quarter	Force, Motion & Energy	Force, Motion & Energy	Matter	Earth & Space	Living Things and Their Environment
4th Quarter	Earth & Space	Earth & Space	Living Things and Their Environment	Force, Motion & Energy	Matter

PRE-GRADE 9 TEST BLUEPRINT

The blueprint for the pre-Grade 9 test is shown in Table 2. The blueprint includes the prerequisite concepts and skills considered necessary for students to engage in the Grade 9 Matter curriculum. This blueprint is the result of combining the prerequisite concepts and skills determined by the expert panel in March 2015 with additional prerequisites added after the analysis of the pre-Grade 8 test.

Table 2. Blueprint for pre Grade 9 matter test

Strand	Proportion of items	Prerequisite concepts and skills	Curriculum Links (learning competencies unless stated otherwise) *Source for curriculum links: K to 12 Curriculum: Science*
1.1 Physical states of matter	10%	• compare and contrast the arrangement of molecules in gases, liquids, and solids	(Gr 8) explain the properties of solids, liquids, and gases based on the particle nature of matter (Gr 8) explain physical changes in terms of the arrangement and motion of atoms and molecules
1.2 Properties of substances and mixtures	8.3%	• distinguish metals from non-metals based on their properties (such as luster, malleability, ductility, conductivity) • identify whether a mixture is homogeneous or heterogeneous	(Gr 7) describe some properties of metals and non-metals such as luster, malleability, ductility, and conductivity (Gr 6) Content standards: Homogenous and Heterogeneous mixtures - different types and their characteristics
1.3 Properties of elements and compounds	21.7%	• compare elements and compounds in terms of their properties • predict the metallic properties of an element based on its position in the periodic table • describe changes in solid materials when they are bent, pressed, hammered, or cut	(Gr 8) trace the development of the periodic table from observations based on similarities in properties of elements (Gr 8) use the periodic table to predict the chemical behaviour of an element (1 item)
2.1 Atomic structure	18.3%	• identify the charges of protons, neutrons and electrons • identify protons, neutrons and electrons • illustrate using diagrams the interactions between like and unlike charges • describe the forces of attraction between particles • describe the relative sizes of atoms/ions/molecules using familiar objects (e.g. dust, grains) • state the chemical symbol of the first 20 elements • locate the relative positions of electrons, protons, and neutrons • write chemical symbols • recognize particulate nature of matter	(Gr 8) determine the number of protons, neutrons, and electrons in a particular atom
2.2 Molecular structure	8.3%	• identify the components of a molecule • recognize the elements C, N, O and H in a chemical formula • writing chemical formulas	

3.1 Physical and chemical changes	21.7%	• give examples of physical and chemical changes	
3.2 Chemical reactions	0%		
4.1 Chemistry-related inquiry skills (note: many of these skills are assessed in the context of 1.1, 1.2 and 3.1)	11.7%	• observing • inferring • grouping based on a set of properties • recognizing scientific questions • using lab tools and equipment • reading and recording data • describing • identifying similarities and differences • predicting beyond the identified patterns, measurements and observations • recognizing what scientific inquiry skills are • knowing components of scientific investigation • using diagrams to illustrate processes, equipment, observations, science ideas • using models to represent a science idea • identifying patterns • determining whether conclusions follow from results • checking how measurements were made • plotting graphs of two variables • interpreting graphs of two variables • performing basic operations (addition, subtraction, multiplication, division) • converting within a scale of measurement e.g., g to mg, g to kg, mL to L • using ratio and proportion to calculate an unknown quantity • calculating percentages • rounding off • expressing very small or very large numbers using scientific notation • converting between scales of measurement e.g., °C to K	

PILOT SAMPLE AND TEST DEVELOPMENT

For the piloting of the pre-Grade 9 test, N = 223 Grade 9 students from two regular high schools in the Metro Manila region took the test in August 2016. The students in this convenience sample had completed Grade 8 Matter during the previous school year, but had not yet undertaken Grade 9 Matter. The purpose of the pilot was to evaluate the performance of each item and to obtain item characteristics in order to develop a psychometrically sound test. In other words, this process was conducted for test development purposes.

Data from the pilot sample were analysed using the one-parameter simple logistic model (Rasch, 1960). The items were found to fit the model, showing that they measure the same construct and that the spread of the items was appropriate for the student sample. Test items were examined for item fit, discrimination, and difficulty.

From the results of the analysis, 60 items were identified for use in the research test. These items were selected on the basis of sound psychometric qualities and coverage as specified by the test blueprint. Table 3 shows the distribution of the items against the test blueprint and provides a sample of the key concepts and skills tested.

Table 3. Pre-Grade 9 Test Contents

Strand	Number of items	Key concepts/skills
1.1 Physical states of matter	6	Properties and physical states of matter based on the arrangement and interaction of particles; motion of particles in different states and conditions (e.g. change in temperature)
1.2 Properties of substances and mixtures	5	All matter is made up of atoms; examples of mixtures; properties? of solutions due to arrangements? of particles
1.3 Properties of elements and compounds	13	Properties and examples of metals and non-metals; macroscopic properties of elements and compounds; location of elements and prediction of their properties using the periodic table; graphic representations of compounds
2.1 Atomic structure	11	Relative location and size of subatomic particles; number of subatomic particles based on atomic number and atomic mass; interaction of charges
2.2 Molecular structure	5	Elements and subscripts in chemical formulas; composition of compounds
3.1 Physical and chemical changes	13	Motion of particles during phase change; conservation of mass; composition of substance throughout phase change; rearrangement of particles during chemical change; rusting; loss/gain of electrons in ion formation
3.2 Chemical reactions	0	
4.1 Chemistry-related inquiry skills	7	Measurement skills; reading of scales; evidence and inference; conversion of units; use of schematic diagrams; grouping; chemical symbols
Total	60	

The pilot test performed well. The spread of items matched the range of student abilities, providing a reliable tool for the measurement of student abilities. The person-separation reliability of the test was 0.789 (note that this index is comparable to alpha reliability).

RESEARCH SAMPLE

Four schools in Regions VI, three schools in Region VII, one school in NIR and eight schools in NCR were recruited, providing a sample size of 16 schools (the NCR sample was distributed across regular high schools and science-oriented high schools). Three full classes from each school were targeted. Schools were requested to provide classes distributed across sections, in order to ensure a heterogeneous sample of students. For the regular schools in each of the four regions, 1-3 teachers were selected to have their students assessed, providing a total of approximately 10 teachers for Regions VI and NCR, while fewer teachers were selected in schools of Regions VII and NIR. The four science-oriented high schools provided 1-2 teachers per school. In total, N = 1903 Grade 9 students were assessed across 45 different classes, 33 different teachers, and 16 schools in four regions (Table 4).

Table 4. School Participants in the pre-Grade 9 Research Phase

Region	School Type	Schools	No. of Teachers	No. of Classes
Region VI	Regular	A	3	3
		B	2	3
		C	3	3
		D	2	3
Region VII*	Regular	A	3	3
		B	1	3
		C	1	3
		D	1	3
National Capital Region	Regular	A	3	3
		B	3	3
		C	3	3
		D	3	3
	Science-oriented	E	1	2
		F	2	2
		G	1	3
		H	1	2
	TOTAL	**16**	**33**	**45**

*Sample schools in this region include a school from the province of Negros Oriental (formerly in Region VII). The province became part of the newly created Negros Island Region (NIR) through Executive Order (EO) no. 183 issued by former President Benigno S. Aquino III on May 29, 2015.

The sample of students from these classes consisted of more females than males in both regular and science-oriented high schools, and this difference was more pronounced in Regions VI and VII. The specific numbers are provided in Table 5. Enrolment data show a slightly higher proportion of female students within the sample schools when compared to region averages. However, this is insufficient to account for the discrepancy in the research sample. It is hypothesized that attendance patterns may be different between female and male students. Within the science-oriented schools, only the special science classes participated in the study.

Table 5. Distribution of students by region, school type and gender

Region	School Type	Female Students	Male Students	Total
Region VI	Regular	328 (61.1%)	209 (38.9%)	537 (100.0%)
Region VII*	Regular	303 (59.1%)	210 (40.9%)	513 (100.0%)
NIR	Regular	62 (57.4%)	46 (42.6%)	108 (100.0%)
NCR	Regular	306 (55.4%)	246 (44.6%)	552 (100.0%)
	Science-oriented	195 (64.8%)	106 (35.2%)	301 (100.0%)
Total		1132 (59.5%)	771 (40.5%)	1903 (100.0%)

*Sample schools in this region include a school from the province of Negros Oriental (formerly in Region VII). The province became part of the newly created Negros Island Region (NIR) through Executive Order (EO) no. 183 issued by former President Benigno S. Aquino III on May 29, 2015.

STAGE 3 RESULTS

The test data collected from the student sample were calibrated using the one-parameter simple logistic model (Rasch, 1960) and student ability estimates were produced.

There was statistically a significant difference between the performances of male and female students within the science-oriented high school ($t_{(299)} = 4.817$, $p < 0.001$), with male students (mean = 65.70, SD = 8.37) outperforming female students (mean = 61.14 SD = 7.54). In the regular high schools, however, there was no statistically significant difference ($t_{(1600)} = -1.451$, $p = 0.147$) between the performance of male students (mean = 47.24 SD = 8.72) and female students (mean = 47.86 SD = 8.11).

The benefit of Rasch modelling is that the students and items can be placed on the same scale. This enables the comparison of the abilities of students with the difficulties of the concepts and skills assessed by the test. The common logit scale for the pre-Grade 9 test is shown in Figure 2. The representation is known as a variable map and the distribution of students is shown on the left side with students represented by 'X'. The items are shown on the right side with each item shown as a number according to the test order. The logit scale in this map extends from -2 to 2 logits. The most difficult item on the test is shown to be Item 9 and the easiest is shown to be Item 5 (Figure 2).

The relative positions of items and students on the variable map are dictated by the data fit to the Rasch model. When an item is positioned at the same horizontal level as the student, the position indicates that the student has a 50/50 chance of answering that item correctly. When the item numbers are linked with the concept or skill assessed by the item, the horizontal alignment identifies which concepts or skills the aligned students (as represented by 'X's) are ready to learn. For usability, levels containing similar skills are identified, and a level description is written to encapsulate the main ideas that students in each level are ready to learn.

The pre-Grade 9 test conceptually and empirically separates into five levels (A through E). These levels are described in Figure 2.

Levels A to C contain the essential prerequisite concepts and skills for Grade 9 Matter. Some of these concepts and skills were introduced to students in Grade 8 and some were introduced in earlier grades. The level descriptions order these from easiest to most difficult, based on the results of the testing. The students assigned to each level via the analysis are considered "ready to learn" the concepts and skills associated with that level. The levels show that some students have mastered more of the prerequisites than others. For example, students at Level B are ready to learn to attribute differences in states of matter to differences in forces of attraction within matter, while students at Level A are still about to learn to associate arrangements of particles with states of matter. Similarly, students at Level D are beginning to learn to determine the number of subatomic particles given the atomic number and/or atomic mass of an element, while students at Level C are still about to learn to identify subatomic particles based on charge. The level descriptions, however, do not adequately indicate readiness for Grade 9 Chemistry until they are checked against each of the topics to be covered.

There are four content areas covered in Grade 9 Chemistry: electronic structure of matter, chemical bonding, carbon compounds, and mole concept. Each of these content areas has specific essential prerequisite knowledge and skills necessary for students to engage with the topics. The topics on electronic structure of matter require students to have knowledge of the composition of matter. The topics on chemical bonding require students to have knowledge of the physical properties (e.g., metallic/non-metallic) of elements in the periodic table and of charge and interaction of charges. The topics on carbon compounds largely rely on knowledge of covalent bonding, which is covered in the topics on chemical bonding. Lastly, the topics on mole concept require knowledge of the composition of matter and the ability to view matter as consisting of tiny particles.

Level E – Students at this level are starting to use their knowledge of physical states of matter and the periodic table to generalise their understanding and apply it to situations not specifically taught.

Level D – Students at this level are beginning to grasp conservation, recognizing that mass is conserved during physical changes, that chemical changes involve the rearrangement of atoms and that numbers of particles are constant during the mixing of chemicals, even if volume is not. They are learning to link the structure of atoms to the properties of elements (e.g., recognising isotopes and identifying how valence electrons govern the chemical properties or reactivity of elements). They are starting to explain changes in states of matter by reference to changes in kinetic energy and distances between particles.

Level C – Students at this level are beginning to understand the microscopic structures of elements and compounds (molecules, atoms and subatomic particles) and to recognize that the composition of a substance remains the same throughout a physical change. They are learning to use the periodic table to determine the number of protons in an atom and to make predictions about the behavior of elements. They are beginning to use chemical formulas as symbolic representations of substances and to organize ideas by using schematic diagrams. They are learning to recognize common examples of chemical change/reaction.

Level B – Students at this level are starting to attribute differences in states of matter to differences in the forces of attraction between particles. They are learning that protons and electrons have charges that dictate whether the particles attract or repel when placed near each other. Using the periodic table, they are learning to associate the name and symbol of an element with its atomic number and to relate its group number to its physical properties.

Level A – Insufficient evidence.

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Figure 2. Skill level descriptions and Variable map of student and item distribution

Note. X represents 3 students

The level descriptions were compared to the prerequisite concepts and skills for Grade 9, as determined by the expert panel in March 2015 and the Grade 9 Matter curriculum in order to identify which level description could be considered to describe students who were ready to learn the Grade 9 curriculum. Table 6 summarises the outcomes of this comparison.

Table 6. Content areas, concepts and readiness levels

Content Area	Spiralling of Concepts Grade 3 – Grade 10 (Grade 9 Matter)	Readiness level
Electronic Structure	Using their understanding of atomic structure learned in Grade 8, learners describe how ions form. Further, they explain how atoms form bonds (ionic and covalent) with other atoms by the transfer or sharing of electrons.	D
Chemical Bonding	Using their understanding of atomic structure learned in Grade 8, learners describe how atoms can form units called molecules. Learners explain how new compounds are formed in terms of the rearrangement of particles. They also recognize that a wide variety of useful compounds may arise from such rearrangements. They also learn that the forces holding metals together are caused by the attraction between flowing electrons and the positively charged metal ions.	D
Carbon Compounds	Learners explain how covalent bonding in carbon forms a wide variety of carbon compounds.	D
Mole Concept	Recognizing that matter consists of an extremely large number of very small particles, counting these particles is not practical. So, learners are introduced to the unit—mole.	D

Note: The entries in the columns "Content Area" and "Spiralling of Concepts Grade 3 – Grade 10" are obtained from the Curriculum Guide for Science. These concepts will be addressed in Grade 10 Matter.

In order to identify the percentage of students well prepared to engage with the conceptual knowledge and skills required by the Grade 9 Matter curriculum, the distribution of students across the various levels was identified for each school type (Table 7). These data are also shown graphically in Figure 3.

Table 7. Distribution of students across competence levels (A = lowest, E = highest)

	Regular			Science-oriented		
Level	Frequency	Percentage	Cumulative percentage	Frequency	Percentage	Cumulative percentage
E	39	2.4%	100.0%	90	29.9%	100.0%
D	168	10.5%	97.6%	133	44.2%	70.1%
C	354	22.1%	87.1%	63	20.9%	25.9%
B	903	56.4%	65.0%	15	5.0%	5.0%
A	138	8.6%	8.6%	0	0%	0%

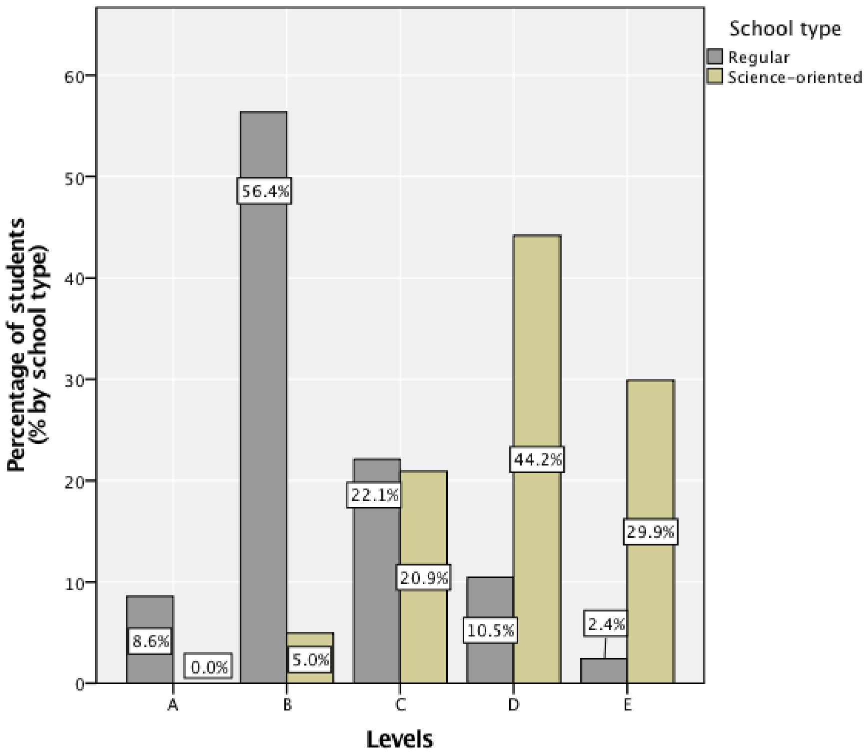

Figure 3. Distribution of Grade 9 students across levels in Regular and Science-oriented High Schools

The data shown in Table 8 indicate that 74% of students at science-oriented high schools and 13% of students at regular high schools (the students at levels D and E) are ready to engage with the conceptual knowledge and skills required by the Grade 9 Matter curriculum. These students are ready to learn what is described in the section on Spiraling of Concepts Grade 3 – Grade 10 of the K to 12

Science Curriculum regarding Properties and Structure of Matter, as presented in Table 6. In the science-oriented high schools, 26% of students are not ready to learn this part of the curriculum. In the regular high schools, the situation is much more serious, with 87% of students not ready to learn this part of the curriculum.

Table 8. Comparison of student readiness for Grades 7 to 9

	Regular High Schools		**Science-oriented High Schools**	
	Ready	Not ready	Ready	Not ready
Pre-Grade 7	619 (39%)	978 (61%)	361 (90%)	39 (10%)
Pre-Grade 8	398 (27%)	1085 (73%)	242 (78%)	72 (22%)
Pre-Grade 9	207(13%)	1395(87%)	223 (74%)	78 (26%)

A comparison of the pre-Grade 9 results with those of earlier grade levels shows that the downwards trend in readiness for students at regular high schools, identified in the pre-Grade 8 results, has continued. There is a significant decrease in the readiness of the students ($\chi 2 = 94.6$, $p < 0.05$). The small change in readiness for students attending science-oriented high schools is not significant, indicating that the decrease in readiness observed for Grades 7 and 8 is not continued for Grade 9 students in these schools.

CONCLUSION

The results of the pre-Grade 9 test show that only 13% of students at regular high schools and 74% of students at science-oriented high schools can be considered ready for the Grade 9 Matter curriculum. A majority of the Grade 9 students at regular high schools (56.4% at Level B) have serious difficulties understanding and applying the assumptions of the particle model of matter, which is part of the Grade 8 curriculum on Matter and an assumed prerequisite for the Grade 9 curriculum. These students are just beginning to ascribe macroscopic properties (differences in states of matter) to submicroscopic properties (differences in the forces of attraction between particles). In contrast, 44.2% of students at the science oriented schools are at Level D, where they are beginning to explain changes in states of matter by reference to changes in kinetic energy and distances between particles, and 29.9% are at Level E, where this knowledge has been mastered. In other words, the majority of students at the science-oriented schools are ready for the Grade 9 curriculum because they have understood the assumptions of the particle model of matter and can relate what is observable at the macroscopic level to the submicroscopic level, i.e., distances between particles. At the regular high schools, based on these results, the majority of the Grade 9 students are functioning at the Grade 8 level of the K to 12 curriculum.

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Science Curriculum Project: progress of students through the science curriculum: a focus on matter (chemistry)

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