

SCIENCE CURRICULUM PROJECT

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

STAGE 2 PRE-GRADE 8 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. By the end of SY 2015/16, this cohort of students will be the first to have completed the full 7 – 10 new curriculum.

Due to the recency of the reform, the influence of its characteristics and design on outcomes is not yet unknown. 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 spiraling 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 8 with the level of conceptual knowledge and skills they need in order to engage with the Grade 8 science (chemistry) curriculum?

The report includes analysis of data obtained from a pre-Grade 8 test on chemistry related skills. The pre-Grade 8 test was developed to assess if students are appropriately prepared to access the new curriculum. Students were tested in November 2015, before beginning the chemistry unit "Matter" (which is taught to Grade 8 students during the third quarter of the school year). The student results indicate that the sample assessed was distributed normally across the test. Although this demonstrates that the test itself is well-targeted for the population, the results also indicate that a sizeable proportion of students entering Grade 8 is not well-prepared to engage with the conceptual knowledge and skills required by the Grade 8 chemistry curriculum. A larger proportion of students attending science-oriented high schools is well-prepared for Grade 8 entry. Details of those knowledge and skills best and least well demonstrated are provided in the report.

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SECTION I: PROJECT INTRODUCTION

Note: This is the same information given in Report 1 (Pre-Grade 7)

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 8.

1. *investigate the progress of students' knowledge and skills as they complete the spiral science curriculum, with emphasis on whether students have developed the pre-requisite 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 7 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 relatively 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 are developed to assess student learning. Five linked tests are 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 includes 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)

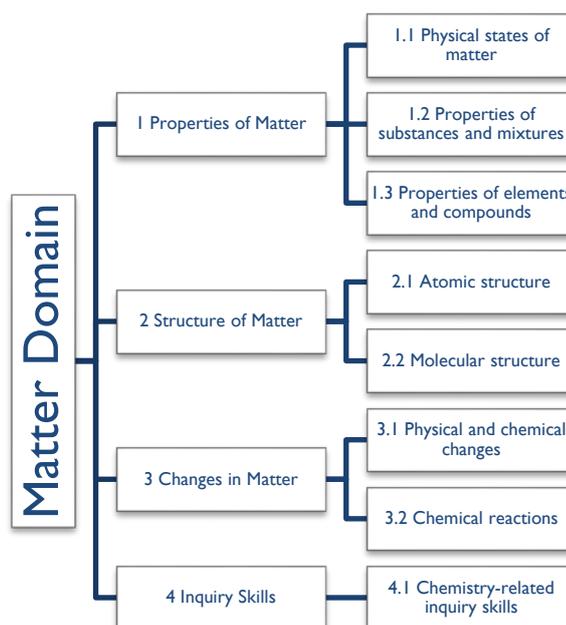


Figure 1. Matter Test Domain Structure

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 2 METHOD

This stage of the project focuses on the measurement of the understanding and skills of Grade 8 students as they begin the Matter topic in the 3rd Quarter of the school year. The purpose of this measurement is to determine the readiness of the Grade 8 students for the Grade 8 Matter curriculum.

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

The blueprint for the Pre-Grade 8 test is shown in Table 2. The blueprint includes the pre-requisite concepts and skills considered necessary for students to engage in the Grade 8 Matter curriculum. This blueprint is the combination of the pre-requisite concepts and skills determined by the expert panel in March 2015 and additional pre-requisites added after the analysis of the Pre-Grade 7 test.

Table 2. Blueprint for pre Grade 8 matter test

Strand	Proportion of items	Pre-requisite concepts and skills	Curriculum Links (learning competencies unless stated otherwise) <i>Source for curriculum links: K to 12 Curriculum: Science</i>
1.1 Physical states of matter	5%	<ul style="list-style-type: none"> give examples of solids, liquids and gases distinguish solids, liquids and gases based on their observable properties (shape, volume, ease of flow) 	(Gr3) describe different objects based on their characteristics (e.g., shape, weight, volume, ease of flow) (Gr3) classify objects and materials as solid, liquid, and gas based on some observable characteristics
1.2 Properties of substances and mixtures	20%	<ul style="list-style-type: none"> identify whether a mixture is homogeneous or heterogeneous design a method that can separate components of a mixture distinguish mixtures from substances based on their properties Interpret pH Comprehend key terms associated with solutions 	(Gr6) describe the appearance and uses of uniform and non-uniform mixtures (Gr6) enumerate techniques in separating mixtures such as decantation, evaporation, filtering, sieving, and using magnet (Gr7) distinguish mixtures from substances based on a set of properties (Gr7) (Content standard) demonstrate understanding of the common properties of acidic and basic mixtures (Gr7) investigate properties of unsaturated or saturated solutions
1.3 Properties of elements and compounds	20%	<ul style="list-style-type: none"> identify common elements and compounds distinguish elements from compounds based on their properties distinguish metals from non-metals based on their properties (such as luster, malleability, ductility, conductivity) 	(Gr7) recognize that substances are classified into elements and compounds (Gr7) describe some properties of metals and non-metals such as luster, malleability, ductility, and conductivity
2.1 Atomic structure	5%	<ul style="list-style-type: none"> recognize the elements C, N, O and H in a chemical formula state the chemical symbol of the first 20 elements 	(Gr7) (Performance standard) make a chart, poster, or multimedia presentation of common elements showing their names, symbols, and uses
2.2 Molecular structure	5%	<ul style="list-style-type: none"> recognize structure of water molecule given its diagram recognize that matter consists of smaller (invisible) particles given a concrete sample of matter 	While not linked to standards for earlier grade levels, this knowledge would be advantageous and could be learned from non-curricular sources.
3.1 Physical and chemical changes	10%	<ul style="list-style-type: none"> predict the phase changes that may happen when heat is applied 	(Gr4) describe changes in properties of materials when exposed to certain conditions such as temperature or when mixed with other materials

		<ul style="list-style-type: none"> • recognize changes in state (melting, freezing, etc.) • recognize that some metals rust • recognize the dissolving process • give examples of physical and chemical changes 	<p>(Gr5) investigate changes that happen in materials under the following conditions:</p> <p>(a) presence or lack of oxygen; and</p> <p>(b) application of heat</p> <p>(Gr7) (Content standard) demonstrate understanding of some important properties of solutions</p> <p>2002 Basic Education Curriculum, Gr5 competencies- 1) Show that physical change may take place in materials; show that materials may change in size, shape, volume or phase; observe that no new material is formed when physical change takes place</p> <p>2) Show how chemical changes take place in materials (e.g., cooking, rusting, burning, decaying/rotting, ripening of fruits); observe that a new material is formed when chemical change takes place and that the product of chemical change cannot be brought back to its original form.</p>
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)	35%	<ul style="list-style-type: none"> • observing • inferring • grouping based on a set of properties • describing • identifying similarities and differences • predicting beyond the identified patterns, measurements and observations • using diagrams to illustrate processes, equipment, observations, science ideas • using models to represent a science idea • writing chemical symbols • identifying patterns • determining whether conclusions follow from results • interpreting graphs of two variables 	<p>(Gr4-6) (Key Stage Standards) at the end of Grade 6, the learners should have developed the essential skills of scientific inquiry- designing simple investigations, using appropriate procedure, materials and tools to gather evidence, observing patterns, determining relationships, drawing conclusions based on evidence, and communicating ideas in varied ways to make meaning of the observations and/or changes that occur in the environment.</p>

PRE-GRADE 8 PILOT SAMPLE

For the piloting of the pre-Grade 8 test, N = 526 Grade 8 students from four regular high schools in the Metro Manila region took the test in August 2015. The students in this convenience sample had completed Grade 7 Matter during the previous school year, but had not yet undertaken Grade 8 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 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, 52 items were identified for use in the final 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 key concepts and skills tested.

Table 3. Pre-Grade 8 Test Contents

Strand	Number of items	Key concepts/skills
1.1 Physical states of matter	2	Properties and examples of solids, liquids and gases
1.2 Properties of substances and mixtures	11	Separation techniques; properties and examples of mixtures; properties of substances with different pH values, terminology of solutions
1.3 Properties of elements and compounds	10	Properties and examples of metals and non-metals; macroscopic properties of elements and compounds; graphic representations of compounds
2.1 Atomic structure	3	Chemical symbols; relative size of particles
2.2 Molecular structure	3	Particulate nature of matter
3.1 Physical and chemical changes	5	Phase changes; rusting
3.2 Chemical reactions	0	NA
4.1 Chemistry-related inquiry skills	18	Measuring skills; reading scales; evidence and inference; scientific method, including control of variables; interpreting data tables; graphing; percentage composition; links between purpose of experiment and variables.
Total	52	

The 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 0.815 (note, this index is comparable to alpha reliability and is well within the acceptable range.)

SECTION 3: RESEARCH PRE-GRADE 8

CHARACTERISTICS OF THE PRE-8 SAMPLE

Four schools in each of Regions VI and VII, 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). Twelve full classes from each of the regions were targeted. Schools were requested to provide classes distributed across sections, in order to ensure a heterogeneous sample. For the regular schools in each of the three regions, 2-3 teachers were selected to have their students assessed, providing a total of approximately 10 teachers for each region. The four science-oriented high schools provided one teacher per school. In total, N = 1798 Grade 8 students were assessed across 45 different classes, 34 different teachers, and 16 schools in three regions (Table 4).

Table 4. Test Set-up for Pre-grade 8 Research Phase

Region	School Type	Schools	No. of Teachers	No. of Classes
Region VI	Regular	A	3	3
		B	3	3
		C	2	3
		D	3	3
Region VII	Regular	A	3	3
		B	1	3
		C	2	3
		D	3	3
NCR	Regular	A	3	3
		B	2	3
		C	2	3
		D	3	3
	Special science	E	1	2
		F	1	2
		G	1	3
		H	1	2

The sample of students from these classes consisted of more females than males in both regular and science-oriented high schools, and especially within Regions VI and VII. The specific numbers are provided in Table 5. Enrolment data shows a slightly higher proportion of female students within our sample schools when compared to region averages, however, this is insufficient to account for the discrepancy. It is hypothesized that attendance patterns may vary across 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	Gender not specified	Total
Region VI	Regular	300	180	1	481
Region VII	Regular	275	187	1	463
NCR	Regular	302	236	1	539
	Science-oriented	203	111	0	314
Total		1080	714	3	1797

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

Analysis showed there was no statistically significant difference between the performance of male and female students within regular schools. There was, however, a statistically significant difference ($t(312) = 4.8, p=0.000$) between the genders within science-oriented high schools, where male students (mean = 62.83, SD = 9.38) outperformed their female classmates (mean = 58.12, SD = 7.67).

The benefit of Rasch modelling is that the students and items can be placed on the same scale. This enables the comparison of students with the concepts and skills assessed by the test. The common logit scale for the pre-Grade 8 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 and each item is shown as a number according to the test order. The logit scale in this map extends from -2.5 to 2 logits. The most difficult item on the test is shown to be Item 5, and the easiest is shown to be Item 11 (Figure 2).

The relative positions of items and students are dictated by the data fit to the Rasch model. When an item is positioned at the same horizontal level as the student, 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 written to encapsulate the main ideas that students in each level are ready to learn.

The pre-Grade 8 test conceptually and empirically separates into four levels (A through D). These levels are described in Figure 2.

Levels A to D contain the pre-requisite concepts and skills for Grade 8 Matter. Some of these concepts and skills were introduced to students in Grade 7 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 pre-requisites than others. For example, students at Level A are ready to learn the macroscopic properties of solids, liquids and gases. This concept was introduced prior to Grade 7, but experiences during Grade 7 Matter could also improve students' understanding of this concept. Nevertheless, the students at this level have not yet mastered the concept and still require further instruction in it. As the Grade 8 Matter curriculum assumes that students already understand this concept, students at Level A do not have the pre-requisites required for Grade 8. The same is true of students at Level B.

Students at Levels C and D are ready to learn the Grade 8 Matter curriculum, based on the concepts and skills identified by the expert panel. For example, students at Level C are 'starting to use scientific terminology to describe microscopic particles (atom, molecule, compound, element, mixture, proton, electron, neutron)'. As the topics within Grade 8 Matter include the particle nature of matter and atomic structure, these students can be considered ready to learn the topic. But a vast majority of students are not yet ready to learn these fundamental concepts, which are essential in understanding chemical reactions and the quantitative explanations of chemical changes that will form part of their experience in Grades 9 and 10.

<p>Level D – Students at this level are starting to interpret pH scales to make inferences about acidity/basicity. They are beginning to make deductions based on their understanding of scientific terminology (element, compound, mixture, density). They are starting to recognize that gases are compressible.</p>
<p>Level C – Students at this level are starting to use the appropriate scientific terminology to distinguish between sub-microscopic particles (atom, molecule, compound, element, mixture, proton, electron, neutron). They are learning to use chemical symbols and to connect the position of an element on the periodic table with its classification as a metal/non-metal. They are beginning to make inferences from experimental data presented in tables and graphs in order to identify trends and explanations and to draw conclusions.</p>
<p>Level B – Students at this level are beginning to recognize the particulate nature of matter, e.g. that ice and water are the same substance with different arrangements of particles. They are learning to use scientific terminology to describe the properties of metals and non-metals (malleable, ductile, brittle) and recognize that heating causes expansion. Students are starting to read instruments accurately, convert between different units of measurement, choose the correct scale for accurate measurement, and link given graphs and diagrams with written descriptions.</p>
<p>Level A – Students at this level are learning the macroscopic properties of solids, liquids and gases. They are beginning to classify metals and non-metals based on their properties; that metals conduct heat; that non-metals are not attracted by magnets. Students are starting to use data in tabulated form.</p>

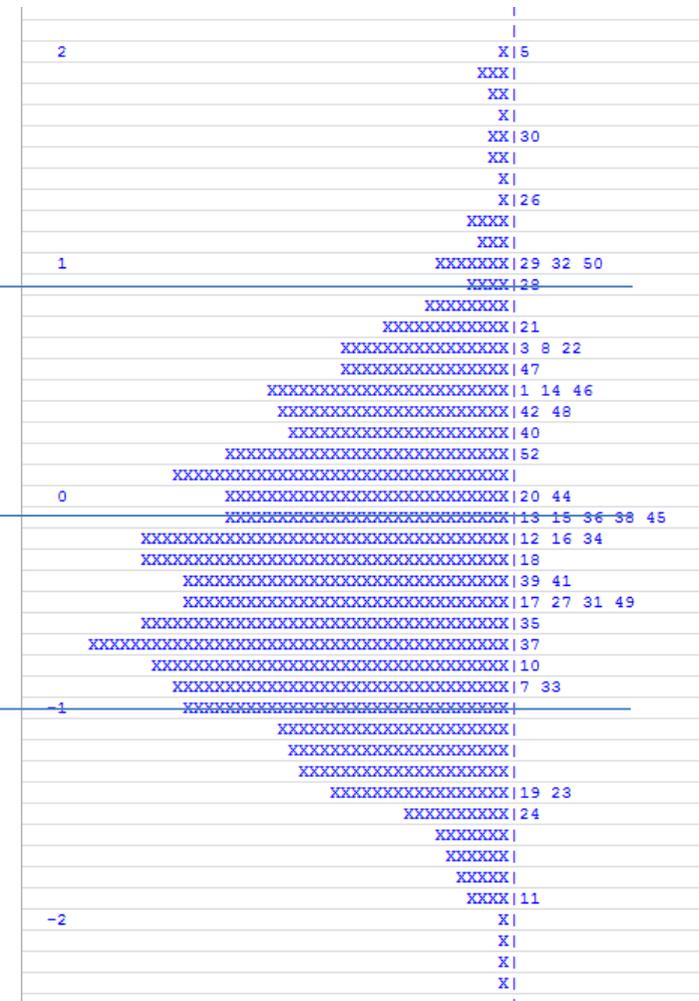


Figure 2. Skill level descriptions and Variable map of student and item distribution

Note. X represents 2.6 students

In order to identify the percentage of students well prepared to engage with the conceptual knowledge and skills required by the Grade 8 Matter curriculum, the distribution of students across the various levels was identified for each school type (Table 6). These data are also shown graphically in Figure 3.

Table 6. Distribution of students across competence levels (A = lowest, D = highest)

	Regular			Science-oriented High Schools		
Level	Frequency	Percentage	Cumulative percentage	Frequency	Percentage	Cumulative percentage
D	54	3.6%	100.0%	72	22.9%	100.0%
C	344	23.2%	96.4%	170	54.1%	77.1%
B	625	42.1%	73.2%	70	22.3%	22.9%
A	460	31.0%	31.0%	2	0.6%	0.6%

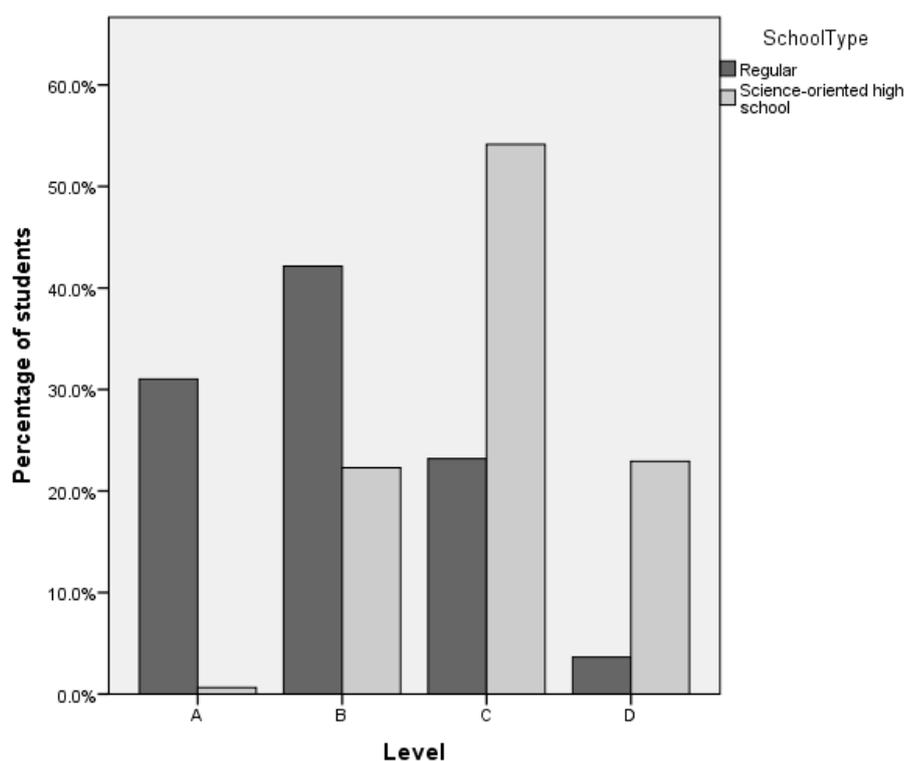


Figure 3. Distribution of Pre-Grade 8 students across levels in REGULAR and Science-oriented High Schools

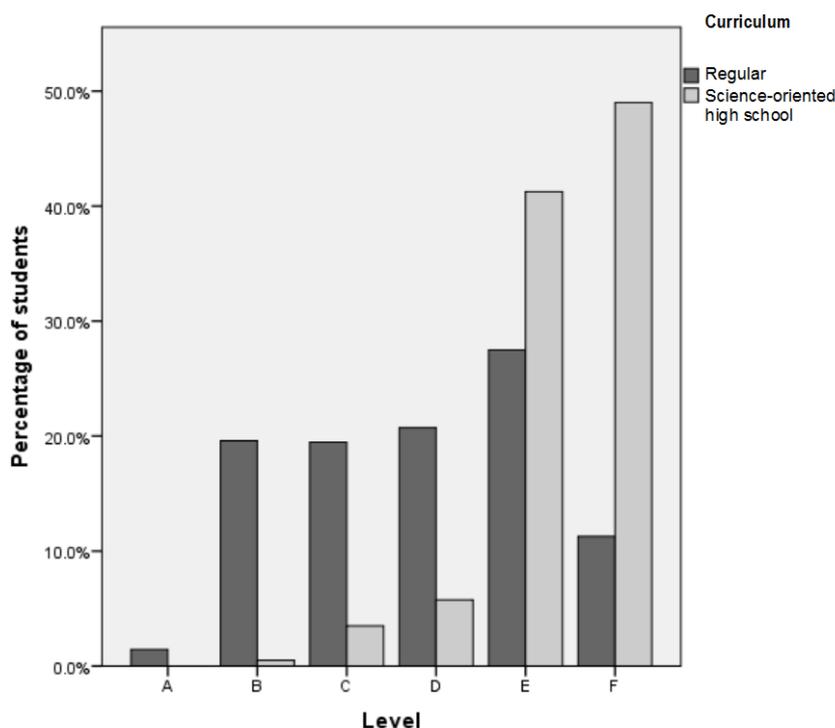


Figure 4. Distribution of Pre-Grade 7 students across levels in REGULAR and Science-oriented High Schools

These data indicate that 78% of students at science-oriented high schools and 27% of the regular high school students are ready to engage with the conceptual knowledge and skills required by the Grade 8 Matter curriculum (those at levels C and D). In effect, this group of students is ready to learn what is stated in the section on Spiraling of Concepts Grade 3 – Grade 10 of the K to 12 Science Curriculum regarding Properties and Structure of Matter: “Using models, learners learn that matter is made up of particles, the smallest of which is the atom. These particles are too small to be seen through a microscope. The properties of materials that have observed in earlier grades can now be explained by the type of particles involved and the attraction between these particles.” This suggests that approximately one fifth of students at science-oriented high schools would find it difficult to manage the Grade 8 Matter curriculum. In regular high schools the situation is much more serious, with over two thirds of students starting the Matter quarter without the required prior learning.

Table 7. Comparison of student readiness for Grade 7 and Grade 8.

	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%)

When these findings are compared to the findings of the Pre-Grade 7 stage of this research (refer to Report 1), shown in Table 7, it can be seen that a greater proportion of Grade 8 students are not ready for the curriculum. The data for regular high school students show 27% of students can be considered ready for Grade 8, down from 39% for Grade 7 students. The trend is the same for students from science-oriented high schools where 78% of students are ready for Grade 8, down from 90% for Grade 7 students. This is a significant decrease in readiness for the students at both regular and science-oriented high schools ($\chi^2 = 49.4$, $p < 0.05$ and $\chi^2 = 23.3$, $p < 0.05$, respectively).

CONCLUSION

The decrease in readiness from Grade 7 to Grade 8 indicates that the student performance is not simply due to the curriculum and instruction of previous grades. It suggests that the pace of the curriculum is such that students cannot keep up, given their current access to teaching and resources. Research in chemistry education (Harrison & Treagust, 2002; Lee, et. al., 1993; Nakhleh, 1992; Novick, S. & Nussbaum, J. 1981) has established the difficulty of moving between the macroscopic and the submicroscopic levels of descriptions of atomic particles. In part, this may be attributed to students having a number of intuitive thoughts about matter and the changes it undergoes (Nakleh, M., Samarapungavan, A., & Saglam, Y., 2005; Skamp, 2009) which require re-situating. The competence levels identified by this research project could help inform the improvement of both curriculum and teaching in the future to better support students to make the transition from the macroscopic to the submicroscopic conception of matter. Matching of the curriculum to the prerequisite concepts and skills attained by most students would better place the students to achieve the learning competencies for the given grade level. The implementation of teaching activities in Grade 7 that specifically address the typical stages of development exhibited by the research cohort would provide students with specific scaffolding to support their development. It is to be hoped that such changes would ease the transition from macroscopic to submicroscopic conceptions of matter.

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

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