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Cognition in 21st century skills: A mixed methods study

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Abstract

The teaching of 21st century skills are essential for student learning in our knowledge driven society. Competencies such as critical and creative thinking and their connection with higher order cognitive processes have received attention within the educational community. Teachers are mandated to teach the content and skills reflected in provincial curriculum documents. These curriculum documents should embody the competencies that educators have identified as been important to student learning. In this mixed method convergent design study, we examine the alignment among the intended curriculum, the enacted curriculum and the assessed curriculum in a Patterns and Relations strand from the Grade 9 Mathematics Program of Studies in order to determine the extent to which teachers are teaching and assessing the competencies reflected in the curriculum documents. Results indicate that learner expectations do not clearly identify the cognitive levels and curriculum alignment of the cognitive levels is low (0.073). Recommendations include a clear connection between curriculum documents and cognitive level processes.

***Keywords*;** cognitive skills, 21st century education, mathematics education, curriculum alignment

1. Introduction

Teaching students to think critically, creatively, and to solve problems is the cornerstone of kindergarten to grade 12 education today. Students have access to powerful learning tools that allow them to locate, acquire, and create knowledge much more quickly than was possible in the past. Educators believe that the development of these skills and learner dispositions are necessary for students to thrive and to be contributing members of society (Kaufman, 2013). The term 21st century skills is generally used to reference the core skills and competencies that students should develop in order to adapt readily to change, think in creative and innovative ways, and become

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lifelong learners in a knowledge based economy (Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M., 2012).).

Provincial Ministries of Education have responsibility for responding accordingly by providing curriculum documents that support teachers in this important work. Curriculum documents, developed for each subject area and at each grade level, are designed to guide teachers in the content to be taught and the skills to be acquired. Values and beliefs guide educators in the creation and development of all curricular documents. Alberta Education's most recent guiding document, "Inspiring Education" (2010) points to the approach that school districts in the province should take. The Inspiring Education report calls for a transformation of education, in which commonly held beliefs are challenged and where new structures and approaches are adopted. In this document, the authors appeal for a transformed education system organized around three key principles: Engaged Thinker, Ethical Citizen, and Entrepreneurial Spirit. According to Alberta Education (2010), an engaged thinker is one who "thinks critically, and makes discoveries; who uses technology to learn, innovate, communicate, and discover; who works with multiple perspectives and disciplines to identify problems and find the best solutions; who communicates these ideas to others; and who, as a life-long learner, adapts to change with an attitude of optimism and hope for the future". An ethical citizen is one who "builds relationships based on humility, fairness and open-mindedness; who demonstrates respect, empathy and compassion; and who through teamwork, collaboration and communication contributes fully to the community and the world". Lastly, a person with an entrepreneurial spirit is one who "creates opportunities and achieves goals through hard work, perseverance and discipline; who strives for excellence and earns success; who explores ideas and challenges the status quo; who is competitive, adaptable and resilient; and who has the confidence to take risks and make bold decisions in the face of adversity". These key principles offer a framework for educational change in the province and are an affirmation of a paradigm shift in how education is enacted in today's classrooms. This new paradigm calls on teachers to move from the dissemination of information and memorization of facts to the development of competencies that assist students in mastering content, while also producing, synthesizing, and evaluating information.

Feedback received through Inspiring Education stakeholder meetings, motivated the Ministry of Education to re-examine their use of the term skills and to adopt a new term, competencies, when referencing skills and behaviors believed to be essential for students to acquire in order to meet the needs of 21st century learning. Accordingly, the term competencies will be utilized in this article to reference 21^{st} century skills when speaking of instruction in school contexts. Competencies such as communication, collaboration, digital literacy and global citizenship, critical thinking, problem solving, creativity, managing information and personal growth and well-being (Alberta Education, 2016) are considered essential "for preparing students to successfully navigate their personal journeys and contribute to family, community and society. Competencies accentuate aspects of learning that apply across all subjects" (Alberta Education, The Guiding Framework, 2016, p. 15). Teachers meet the responsibility for student instruction in these competencies by interpreting and enacting the Programs of Study. It is through the interpretation of these curriculum documents that the transformation of education in the province has the potential to become a reality.

1.1. 21st Century learning

As teacher educators, we have a vested interest in preparing pre-service teachers to become knowledgeable and skilled in the planning, instruction, and assessment of student learning. We are committed to supporting pre-service teachers to become proficient in developing and applying higher order thinking skills among their students and realizing the importance of these competencies for 21st century learning. In assisting pre-service teachers to incorporate 21st century competencies in their teaching, we believe that related strategies in teaching and learning will provide a vehicle for pre-service teachers to realize 21st century competencies in their classrooms. These viewpoints inform our interest in the classroom practice of in-service teachers. Our purpose in this article is to share the results of research measuring the extent to which teachers are teaching at the cognitive level represented in the learner expectations in the Mathematics Program of Studies.

Higher order thinking processes such as critical and creative thinking have received significant attention as essential competencies required for living in the 21st century. These competencies include complex "cognitive processes as reasoning and judgment as well as dispositions of intellectual empathy, fair-mindedness, and persistence" (Schulz & FitzPatrick, 2016). These complex skills are not innate. One main way to acquire them is through education. John Dewey, one of the 20th century's great thinkers and an influential leader in education reform argued that for education to be effective, students should be given learning opportunities that enable them to link present content to their previous experiences and knowledge and understanding. When students are allowed to make judgments and connections in their learning, they are potentially developing the intellectual skills that lead to higher order thinking. As early as 1910, Dewey "introduced the term 'critical thinking' as the name of an educational goal, which he identified with a scientific attitude of mind" (Hitchcock, 2018, History section, para 1). Today in education, the word critical thinking is recognized as a key 21st century skill.

In the learning process there are levels of knowing. These levels of knowing are organized on a continuum from basic to more complex thinking. In 1956, Benjamin Bloom published a taxonomy of educational objectives. A connection was made between higher order thinking and Bloom's cognitive levels (Paul & Elder, 2006). The taxonomy had an impact on teaching practice and continues to influence education today. In 2001, Lorin Anderson, a former student of Bloom's, David Krathwohl and a committee of six other researchers revised this taxonomy and renamed it A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. The nouns that described the levels of thinking were changed to verbs that the committee believed better reflected the actions of thinking. The revised verb forms of the cognitive levels are remembering, understanding, apply, analyzing, evaluating, and creating (Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths, & Wittrock, 2001). The revision of Bloom's original taxonomy provides teachers with an effective framework for the alignment of curriculum learner expectations with appropriate instructional strategies and assessment evidence. These levels of thinking assist teachers to move students from lower order thinking to higher order thinking. Bloom's revised taxonomy provides educators with a common language for describing and teaching 21st century skills.

As stated, the shift to a new learning paradigm is characterized by the term 21st century skills; these competencies are ones that educators believe schools should teach to help students thrive in a world where knowledge is rapidly expanding, technologies are quickly changing, and where diverse communities are more connected than ever. These competencies include: critical thinking and problem solving skills; the capacity to find, analyze, synthesize, and apply knowledge to novel situations; interpersonal skills that allow people to work with others and engage effectively in cross-cultural contexts; self-directional abilities that allow them to manage their own work and complex projects; abilities to competently find resources and use tools; and the capacity to communicate effectively in many ways (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2019).

The definition of 21st century learning is more open to interpretation. However, it is generally acknowledged that learning will be more learner directed, and will offer students the opportunity to manage content, while also thinking critically about new knowledge. Learning will involve collaboration and will require flexibility on the part of teachers to support students who learn in different ways. Thus, "curriculum in the 21st century should focus on the construction of knowledge and encourage students to produce the information that has value or meaning to them in order to develop new skills" (Alismail & McGuire, 2015). The kind of learning that supports "these higher order thinking processes and performance skills is best developed through inquiry and investigation, application of knowledge to new situations and problems, production of ideas and solutions, and collaborative problem-solving" (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2019). These are essential skills for realizing the transformative nature of the framework described by Alberta Education. It is accepted that learning is influenced by brain function (Masson, 2014) and so this knowledge has informed teaching practice. With the advent of technology, neuroscientists have the distinct opportunity to examine a living brain at work in the learning process. As a result, neuroscientists are equipped to inform teachers on effective teaching and learning practices that align with how the brain learns best. For example, neuroscientists tell us that babies have an innate sense of quantity and number line. This information is very useful to mathematics teachers, especially when teaching children counting strategies.

1.2. Examining curriculum and cognitive alignment

There is a global concern that schools do not teach, practice, or nurture innovation and creative thinking in children (Carew & Magsamen, 2010). A nascent field called Neuro-Education has emerged. Its goal is to "blend the collective fields of neuroscience, psychology, cognitive science, and education to create more effective teaching methods and curricula and, ultimately, to inform and transform educational policy". (Carew & Magsamen, 2010). Neuro-Education can play an effective role in supporting teachers in realizing the transformative nature of education as articulated in the three key principles identified in the provincial Inspiring Education (2010) report.

Evidence suggests then that the development of 21st century skills are important for students in becoming engaged and ethical citizens who are able to navigate new societal landscapes. We have posited that education plays a significant role in this shift and that Bloom's revised taxonomy has an important role in assisting educators in realizing this vision. In this article, we share results from a study identifying the cognitive levels represented in a provincial curriculum document and we investigate the extent to which teachers are teaching at the cognitive levels represented. This examination of curriculum alignment can provide an understanding of the extent to which learner expectations, instruction, and assessments are aligned.

In order to provide clarity, we offer the following definitions for the three curricula in education: the intended curriculum, the enacted curriculum, and the assessed curriculum. The intended curriculum consists of the learner expectations provided in the programs of study that specify the content and cognitive skills students are to know and acquire as a result of instruction (Porter & Smithson, 2001). The enacted curriculum refers to the content and cognitive skills taught by teachers and studied by students so as to learn and acquire the intended curriculum (Porter & Smithson, 2001). The assessed curriculum is the collecting of evidence of what students have learned as a result of instruction and their own studies at the end of a unit or block of instruction (Porter & Smithson, 2001).

2. Method

A mixed-method convergent design (Creswell & Clark. 2011) was used to answer the following questions:

1. What are the cognitive levels represented in each of the learner expectations for the Patterns and Relations strand in the Grade 9 Mathematics Program of Studies?
2. To what extent are teachers teaching at the cognitive levels represented in each of the learner expectations for the Patterns and Relations strand in the Grade 9 Mathematics Program of Studies?

The central premise of a mixed methods approach "is that the use of quantitative and qualitative approaches, in combination, provides a better understanding of research problems than either approach alone" (Creswell & Clark, 2011). In our mixed method study, the quantitative and qualitative data complemented each other and provided a valid and sound indication of the degree to which there is alignment with the cognitive level processes in the intended curriculum and teachers' instruction of these cognitive levels (enacted curriculum) as represented for one unit of study in Grade 9 Mathematics.

A convergent design gives equal priority to both the quantitative and qualitative data. However, for this study the data-transformation variant was used (Creswell & Clark, 2011). Through data-transformation, the researchers numerically coded the data thereby facilitating quantitative data analyses. Results from the qualitative data were combined with the quantitative data using direct comparison (Creswell & Clark, 2011). The quantitative data was given priority, while the qualitative data was used to complement or confirm the quantitative data. In order to measure the extent to which teachers are teaching at the cognitive level processes represented in the learner expectations, it was necessary to first identify the cognitive level processes implied in the learner expectations in the Patterns and Relations strand in the grade 9 Mathematics Program of Studies.

2.1. Identification of Cognitive Level Processes

We used the Delphi method (Dalkey, & Helmer, 1963) to identify the cognitive level processes implied in each of the 45 learner expectations for the Pattern and Relations strand in the grade 9 Mathematics Program of Studies. In order to identify the implied cognitive levels in each of the 45 learner expectations, a 2x2 taxonomy table was created that included the 6 cognitive dimensions from Bloom's (Anderson et al, 2001) revised Taxonomy of Educational Objectives to connect learner expectations (Knowledge Dimension) to cognitive level processes.

Knowledge Dimensions	Cognitive Dimensions					
Learner Expectations	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Extend a given graph (extrapolate) to determine the value of an unknown element						
Solve a given linear equation symbolically						
Identify like terms in a given polynomial expression						

Figure 1. 2X2 Taxonomy table with sample learner expectation

A panel of 12 experienced educators with qualifications that included graduate degrees in mathematics education and who were geographically distributed from across the province, were invited to independently place the learner expectations in the cells of the 2 x 2 taxonomy table. Ten educators accepted the invitation to be involved in the process.

The process involved each panel member interpreting and placing each learner expectation in the appropriate cell representing the cognitive dimension. Panel members returned their tables to the researchers, who in turn, determined the proportion of panel members who placed a learner expectation in the same cell in the taxonomy table. The summary of each educator's initial taxonomy table was sent to each educator on the panel separately. Second and third rounds were conducted following the same procedures, and 88% overall agreement was reached. The final placement of each learner expectation within a cognitive level was determined either unanimously or by the majority of the panel members.

2.2. Completion of Delphi Procedure

In most Delphi applications, three rounds of Delphi data collection are sufficient to reach consensus among the judges (Kalaian & Shah, 2006; Yang, 2003). This was also true in this study. The educators completed the placement of the learner expectations in the taxonomy table with at least 80% consensus in the third round for all but six of the 45 learner expectations for the grade 9 Mathematics Patterns and Relations Strand. There were six learner expectations for which consensus could not be reached among the panel members.

2.3. Collecting Information about the Enacted Curriculum

The sample of teachers to determine the enacted curriculum was a convenience sample. Six teachers from a geographically large school district were invited to be part of the study. Five teachers agreed. The instruments used to collect the data from the five teachers are listed in Table 1. The teacher survey, which was based on the Survey of Enacted Curriculum (SEC) model (Porter & Smithson, 2001), consisted of three parts. In Part I, teachers indicated for each learner expectation, whether they provided an opportunity for students to learn the content in the learner expectations, and at what cognitive level process the students were engaged in their learning.

Table 1. Data collection instruments

Intended Curriculum	**Enacted Curriculum**
Taxonomy Table	Teacher Survey

	Classroom Observations
	Teacher Interviews
	Teacher Unit Plans, lesson plans

For example, for the learner expectation, "demonstrate the differences between the exponent and the base by building models of a given power, such as 2^3 and 3^2" (Alberta Education Mathematics Program of Studies, 2007), the teachers were asked to indicate if they taught it and, if so, the level of cognitive complexity the students were engaged in. Part II asked about teachers' practices for planning and teaching. Part III asked about teacher characteristics to allow a description of the sample of teachers. The teacher survey was administered at the end of the Patterns and Relations strand.

Three retired mathematics teachers, and one of the researchers conducted the classroom observations. A checklist was used to record the data during the classroom observations. The researchers conducted a training session outlining the observation process and explained the checklist the observers were to use every time they observed a class. The checklist allowed the observers to record the content of the learner expectations and the cognitive levels that were taught. Each class was observed daily for the duration of the Patterns and Relations strand. The first observation was a warm-up observation during which the teacher and the students had a chance to get used to a visitor in the classroom (Hamre, Pianta, & Chomat-Mooney, 2009). The remaining visits involved making observations. A brief discussion of what was observed for each visit was shared with the teacher in order to make sure that the teacher agreed with what was recorded by the observer for that particular class.

The number of weeks the teachers taught to complete the strand differed widely. One teacher needed seven weeks, one teacher needed eight weeks, another teacher needed 12 weeks, and two teachers needed 10 weeks. Mathematics 9 was taught for five, 40 minute periods per week in two of the schools and seven, 44-minute periods per week in the other schools. Altogether, a total of 238 classroom observations were made. Following completion of the observations, each instructional activity was independently placed in the appropriate cell of the taxonomy table by one of the observers and one researcher.

After completion of the placement of the instructional activities in the taxonomy table, the observed teachers were separately interviewed to discuss the observation data for their classes and what was written in their unit plans and lesson plans. The semi-structured teacher interviews varied from 30 to 60 minutes. The teacher interviews were conducted by the researcher. The interviews were audio recorded, and notes were taken during the interviews. Responses to the interview questions were transcribed with each line being numbered to facilitate retrieving and making quotes and references. The researcher and one of the classroom observers independently coded the transcriptions with the assistance of the written notation of the conversation taken during the interview and guided by the two dimensions in the taxonomy table. For codes that differed, consensus between the two coders was reached through discussion.

3. Data Analysis

The quantitative data from the surveys and qualitative data collected during the classroom observations, the interviews, and the unit plans/lesson plans were merged to obtain a complete view of the enacted curriculum for the Patterns and Relations strand. First, the teacher survey data was matched with the unit plans and lesson plans. Second, data and information from the lesson plans were matched with classroom observations, and the data from the interviews. The results of the final quantitative and qualitative databases were compared using a side-by-side summary table (Creswell & Clark, 2011). The merged data for the enacted curriculum was entered independently into the taxonomy table by the researcher and by one of the classroom observers. There was 96% agreement with the learner expectations and 85.5% agreement with the cognitive levels. The two files were reviewed until 100% agreement was reached.

At this point, three taxonomy tables were created, one for the intended curriculum, one for the enacted curriculum, and one for the assessed curriculum. The base for the index that reflected the overall alignment among the intended, enacted, and assessed curriculum was the total number of items administered at the end of unit assessment. An index was computed for the cognitive processes.

The cognitive process index was the ratio of the total number of teachers who taught the intended cognitive process for a learner expectation (given they assessed the learner expectation at the intended cognitive level) to the total number of items. If the cognitive process index was close to or equaled 1.00, then there was evidence that the teachers enacted the cognitive level represented in the intended curriculum and assessed student knowledge and skill at that cognitive level.

4. Results

4.1. Results of the Delphi Procedure

The final (round three) percentages for each learner expectation are reported in Table 2. As shown, the educators reached 100% consensus on 10 learner expectations, 90% consensus on 23 learner expectations, 80% consensus on six learner expectations, and less than 80% consensus on six learner expectations.

Table 2. Delphi Procedure: Round 3 results

Grade 9 Mathematics Patterns and Relations Strand

LE	1	2	3	4	5	6	7	8	9	10	11	12

DR	*Ap*	*Ap*	*U*	*Ap*	*Ap*	*U*	*Ap*	*Ap*	*U*	*U*	*U*	*U*
%	100	90	100	90	80	100	80	90	90	90	90	90
LE	13	14	15	16	17	18	19	20	21	22	23	24
DR	Ap	U	Ap	U	Ap	Ap	Ap	E	C	C	Ap	U
%	90	80	90	60	90	100	100	90	90	90	100	80
LE	25	26	27	28	29	30	31	32	33	34	35	36
DR	Ap	U	E	Ap	C	Ap	R	U	U	U	U	R
%	90	90	90	90	60	90	70	90	90	80	80	90
LE	37	38	39	40	41	42	43	44	45			
DR	Ap	E	U	U	U	Ap	E	U	U			
%	100	100	90	70	80	90	100	90	70			

Cognitive Process: R – Remember, U – Understand, Ap – Apply, An – Analyze, E – Evaluate, C – Create
DR - Delphi Results
% - Percentage of agreement by the panel of educators

The panel of educators' comments were examined to try to understand their reasons for not reaching consensus on the six learner expectations. The comments revealed a difference on how the panel members interpreted the verbs used in the learner expectation statements. For example, learner expectation 16 asks students to "identify and correct…" Four panel members felt that "correct" is at a higher cognitive level than Understand; one panel member placed it at Apply, one at Analyze, and two at Evaluate. Learner expectation 29 asks students to "Create a concrete model or a pictorial representation …" Four of the panel members believed that the verb create may lead teachers to think that this learner expectation should be placed at a higher cognitive level. However, they felt that it asks students to model which they believed best fit under the Understand dimension. One of the panel members stated, "Just because the indicator has the word 'create' in it, I don't feel that justifies moving it up to the highest level". The remaining six panel members felt that students were asked to create, which indicates a higher order cognitive level. Learner expectations 40 and 45, which required students to "identify errors in a given explanation of the simplification of a polynomial expression" led to different placements. While three panel members indicated the two learner expectations required evaluation and placed them at the fifth cognitive level, Evaluate, seven panel members indicated that "identification of errors…" required interpreting and explaining and placed the two expectations at the second cognitive level, "Understanding".

In summary, the Delphi Procedure identified two learner expectations at the Remembering level, 19 learner expectations at the Understanding level, 17 learner expectations at the Applying level, zero at the Analyzing level, four at the Evaluating level and three at the Creating level, one of which only had 60% agreement by the panel of judges.

4.2. Classroom observer results

With one exception**,** the classroom observations indicated that the five teachers taught all but a few of the 45 Patterns and Relations learner expectations.
There was variability among the cognitive process levels at which the teachers taught the learner expectations for most learner expectations. There were only three learner expectations – 12, 13, and 20 – that all five teachers taught at the same cognitive level and only nine learner expectations that four of the five teachers taught at the same cognitive level. No more than three teachers taught the same cognitive levels for the remaining 33 learner expectations. Clearly, there was unwanted variation in the cognitive processes being taught.

The learner expectations and the cognitive processes taught by the teachers as observed by the classroom observers are reported for each teacher in Table 3.

Table 3. Teacher survey and classroom observations of learner expectations and cognitive process

Teacher A

LE	1	2	3	4	5	6	7	8	9	10	11	12
ClOb	Ap	**U**	Ap	An	An	E	An	**Ap**	Ap	Ap	Ap	Ap
YSur	U	**U**	U	E	Ap	U	Ap	**Ap**	U	An	E	E
LE	13	14	15	16	17	18	19	20	21	22	23	24
ClOb	**Ap**	AP	**Ap**	**An**	An	E	**Ap**	Ap	Ap	An	**Ap**	Ap
TSur	**Ap**	An	**Ap**	**An**	Ap	Ap	**Ap**	E	C	E	**Ap**	An
LE	25	26	27	28	29	30	31	32	33	34	35	36
ClOb	Ap	Ap	E	E	Ap	**Ap**	**Ap**	An	**Ap**	**Ap**	An	**An**
TSur	An	E	An	Ap	An	**Ap**	**Ap**	Ap	**Ap**	**Ap**	Ap	**An**
LE	37	38	39	40	41	42	43	44	45			
ClOb	**Ap**	**An**	**An**	Ap	**Ap**	**Ap**	An	NO	An			
TSur	**Ap**	**An**	**An**	E	**Ap**	**Ap**	Ap	E	E			

Teacher B

LE	1	2	3	4	5	6	7	8	9	10	11	12
ClOb	**Ap**	**Ap**	C	**Ap**	**Ap**	E	An	Ap	E	Ap	E	Ap
TSur	**Ap**	**Ap**	An	**An**	**An**	An	Ap	An	E	An	An	An
LE	13	14	15	16	17	18	19	20	21	22	23	24
ClOb	Ap	Ap	Ap	Ap	Ap	Ap	Ap	**Ap**	Ap	Ap	Ap	Ap
TSur	An	An	E	An	An	An	An	**Ap**	An	An	An	An
LE	25	26	27	28	29	30	31	32	33	34	35	36
ClOb	Ap	Ap	**Ap**	Ap	**Ap**	Ap	Ap	**Ap**	NO	**Ap**	**Ap**	Ap
TSur	An	E	**Ap**	An	**Ap**	An	An	**Ap**	An	**Ap**	**Ap**	An
LE	37	38	39	40	41	42	43	44	45			
ClOb	Ap	Ap	Ap	NO	**Ap**	Ap	U	NO	An			
TSur	An	An	An	An	**Ap**	An	An	E	E			

Teacher C

LE	1	2	3	4	5	6	7	8	9	10	11	12
ClOb	Ap	**U**	Ap	An	An	E	An	**Ap**	Ap	Ap	Ap	Ap
TSur	U	**U**	U	E	Ap	U	Ap	**Ap**	U	An	E	E
LE	13	14	15	16	17	18	19	20	21	22	23	24
ClOb	**Ap**	Ap	**Ap**	**An**	An	E	**Ap**	Ap	Ap	An	**Ap**	Ap
TSur	**Ap**	An	**Ap**	**An**	Ap	Ap	**Ap**	E	C	E	**Ap**	An
LE	25	26	27	28	29	30	31	32	33	34	35	36
ClOb	Ap	Ap	E	E	Ap	**Ap**	**Ap**	An	**Ap**	**Ap**	An	**An**
TSur	An	E	An	Ap	An	**Ap**	**Ap**	Ap	**Ap**	**Ap**	Ap	**An**
LE	37	38	39	40	41	42	43	44	45			
ClOb	**Ap**	Ap	Ap	NO	**Ap**	**Ap**	U	NO	An			
TSur	**Ap**	An	An	E	**Ap**	**Ap**	Ap	E	E			

Teacher D

LE	1	2	3	4	5	6	7	8	9	10	11	12
ClOb	Ap	**U**	Ap	An	An	E	An	**Ap**	Ap	Ap	Ap	Ap
TSur	U	**U**	U	E	Ap	U	Ap	**Ap**	U	An	E	E
LE	13	14	15	16	17	18	19	20	21	22	23	24
ClOb	**Ap**	Ap	**Ap**	**An**	An	E	**Ap**	Ap	Ap	An	**Ap**	Ap
TSur	**Ap**	An	**Ap**	**An**	Ap	Ap	**Ap**	E	C	E	**Ap**	**An**
LE	25	26	27	28	29	30	31	32	33	34	35	36
ClOb	Ap	Ap	E	E	Ap	**Ap**	**Ap**	Ap	**Ap**	**Ap**	An	An
TSur	An	E	An	Ap	An	**Ap**	**Ap**	An	**Ap**	**Ap**	Ap	An
LE	37	38	39	40	41	42	43	44	45			
ClOb	**Ap**	**An**	**An**	Ap	**Ap**	**Ap**	An	NO	An			
TSur	**Ap**	**An**	**An**	E	**Ap**	**Ap**	Ap	E	E			

Teacher E

LE	1	2	3	4	5	6	7	8	9	10	11	12
ClOb	Ap	**U**	Ap	An	An	E	An	**Ap**	Ap	Ap	Ap	Ap
TSur	U	**U**	U	E	Ap	U	Ap	**Ap**	U	An	E	E
LE	13	14	15	16	17	18	19	20	21	22	23	24
ClOb	**Ap**	Ap	**Ap**	**An**	An	E	**Ap**	Ap	Ap	An	**Ap**	Ap
TSur	**Ap**	An	**Ap**	**An**	Ap	Ap	**Ap**	E	C	E	**Ap**	An
LE	25	26	27	28	29	30	31	32	33	34	35	36
ClOb	Ap	Ap	E	E	Ap	**Ap**	**Ap**	An	**Ap**	**Ap**	An	**An**
TSur	An	E	An	Ap	An	**Ap**	**Ap**	Ap	**Ap**	**Ap**	Ap	**An**
LE	37	38	39	40	41	42	43	44	45			
ClOb	**Ap**	**An**	**An**	Ap	**Ap**	**Ap**	An	NO	NO			
TSur	**Ap**	**An**	**An**	E	**Ap**	**Ap**	Ap	E	E			

Notes:
LE – Learner Expectations
Cognitive Process: R – Remember, U – Understand, Ap – Apply, An – Analyze, E – Evaluate, and C – Create
ClOb - Classroom Observations
TSur - Teacher Survey
NO - not observed

Two sets of results are provided for each teacher. The letters in the first row indicate the cognitive process the observers saw being taught for each learner expectation. The letters in the second row indicate the cognitive process the teachers indicated they taught for each learner expectation. For example, for the first learner expectation, "Write an expression representing a given pictorial, oral or written pattern", teachers A (First Panel, Table 3) and B (Second Panel, Table 3) were observed teaching at the Apply cognitive level and teachers C (Third Panel, Table 3), D (Fourth Panel, Table 3), and E (Fifth Panel, Table 3) were observed teaching at the Create cognitive level. The teachers indicated on the survey form that the cognitive process they taught was Understanding, Apply, Understanding, Understanding, and Understanding, respectively. As can be seen, there is agreement between what the observer saw and what the teacher indicated for only Teacher B for the first learner expectation. Agreement data between what the observer identified as to the cognitive level observed and what the teacher identified having taught is bolded in Table 2.

4.3. Teacher interview results

Likewise, as reported by the teachers, there was significant variability among the cognitive levels at which each learner expectation was taught. For example, for the first learner expectation, Teacher A taught it at the cognitive level Understand, Teachers B taught it at the cognitive level Create. There was no learner expectation that five teachers reported having taught at the same cognitive level. There were only seven expectations – 2, 7, 8, 13, 20, 28, and 31 that four of the five teachers taught at the same cognitive level. For the remaining 37 learner expectations, no more than three teachers indicated they taught at the same cognitive level.

During the interviews, teachers were asked what they did to get students to see and understand higher order cognitive processes (for the learner expectations that called for higher thinking). Their answers varied. Teacher A used past Provincial Achievement Test questions to challenge the students. Teacher B expressed her belief that they had covered all the learner expectations but noticed that they tended to stay more at the lower three cognitive levels. Teachers B felt that teaching higher order thinking skills and problem solving presented the greatest challenge. She commented that teachers need to make a conscious effort to teach these higher order thinking skills because students tended to want the answer given to them. It was sometimes easier to cater to the students rather than have them develop their own solutions. The teacher went on to say that it was "a reminder that work needs to be done at the higher cognitive levels". Teacher C taught the students the basic concepts. Then the students went over the material on their own and they decided how it was relevant to them. Teacher D had the students explain their thought processes or had them solve problems on the board and then lead a discussion on why the answer was correct or incorrect. Teacher E stated, "my favorite way is to have students create their own patterns and give these patterns to their peers to solve on the board, and then discuss them as a whole class."

4.4. Cognitive processes

The results for the alignment among the intended, enacted, and assessed curricula for cognitive processes are presented in Table 4.

Table 4. Full curriculum alignment: Cognitive process

LE	Number of Teachers						NA
	0	**1**	**2**	**3**	**4**	**5**	
1		X					
2	X						
3	X						
4	X						
5		X					
6	X						
7	X						
8	X						
9	X						
10							X
11	X						
12	X						
13						X	
14	X						
15		X					
16							X
17	X						
18		X					
19	X						

20	X						
21							X
22							X
23			X				
24							X
25		X					
26							X
27							X
28	X						
29	X						
30	X						
31	X						
32	X						
33							X
34		X					
35		X					
36							X
37	X						
38							X
39	X						
40							X
41	X						

42	X						
43							X
44	X						
45	X						

Note: RS - Rating Scale

0 – No match among the intended, the enacted and the assessed curricula
1 – One teacher Full Curriculum match
2 - Two teachers full Curriculum match
3 - Three teachers full curriculum match
4 - Four teachers full curriculum match
5 - Five teachers full curriculum match
NA - Learner Expectations were not assessed

As shown, one teacher, but not necessarily the same teacher, had full alignment for learner expectations 1, 5, 15, 18, 25, 34, and 35; two teachers had full alignment of learner expectation 23; and all five teachers had full alignment for learner expectation 13. There was no alignment found for the remaining 25 learner expectations. The value of the cognitive process index was 0.073, which indicates that there was low alignment among the intended cognitive processes, enacted, and assessed curricula across the five teachers.

5. Discussion and Recommendations

The Mathematics Program of Studies for grade nine, implemented in 2007, does not clearly identify the cognitive processes necessary to obtain the level of learning intended for each of the learner expectations. Further, teachers tended to concentrate their instruction at the lower cognitive levels. This is not to say that the lower cognitive levels are not important. Indeed, although mathematics concepts may be learned at different cognitive levels, the lower-level cognitive skills are the foundation for the higher order cognitive skills (Kaira, 2010). For example, remembering is an essential skill for problem solving since it taps into long-term memory. The higher-order cognitive processing levels promote transfer of knowledge as opposed to formulaic methods where learners become proficient at substituting numbers into a formula. In the current educational landscape, the value and importance of higher order thinking skills, or 21st century skills are a familiar stance. Wider societal beliefs stress the importance of these skills for economic prosperity and civic engagement. Schools are one of the front-line institutions that are tasked with the responsibility to teach these higher order thinking processes to students.

Ministries of Education provide the curriculum documents to be taught at each grade level. These documents guide teachers in knowing the content areas to be taught. For the grade nine Patterns and Relations strand in the Mathematics Program of Studies, the cognitive processes are not clearly articulated and identified, but are implied and left to the interpretation of the classroom teacher. The Delphi Procedure identified seven higher order cognitive processes from a total of 45 learner expectations. In total, there were six learner expectations in which agreement could not be reached as to the cognitive level represented. Interestingly, interpretations of these six learner expectations by the ten mathematics education experts varied in spite of their expertise in this area. What is needed is a balance in the teaching of the cognitive processes where both lower and higher level cognitive skills are clearly articulated and identified so that there is consistency in how teachers interpret, teach, and assess these competencies.

It is therefore recommended that the Taxonomy for Learning, Teaching, and Assessing: A revision of Bloom's Taxonomy of Educational Objectives (Anderson, et al., 2001) be used to identify the cognitive level for each learner expectation and that the cognitive level for each learner expectation be added to the expectation using the following symbols: R- Remember, U - Understand, Ap - Apply, A - Analyze, E - Evaluate, and C- Create. For example, three learner expectations taken from the Patterns and Relations Strand with the identification of the cognitive complexity that teachers would be required to teach to would appear as follows:

1. Write an expression representing a given pictorial, oral or written pattern. (Ap)
2. Verify the solution of a given linear inequality, using substitution for multiple elements in the solution. (E)
3. Extrapolate the approximate value of one variable from a given graph, given the value of the other variable. (U)

Alignment of learner expectations, instruction, and assessment is an essential principle of systemic and standards-based educational reform. Once cognitive processes are clearly articulated in provincial curriculum documents, then opportunities for the professional development of teachers can be recommended. It is our suggestion that these professional development sessions include opportunities for teachers to enhance their skills in aligning their teaching (enacted curriculum) and assessment practices (assessed curriculum) to the clearly identified cognitive processes within learner expectations (intended curriculum). This would provide teachers the opportunity to analyze their own teaching and assessment practices based on the coherent understanding of the learner expectations. Engaging in professional development in curriculum alignment would assist teachers to know what it is that they are responsible for teaching (content and cognitive processes). In addition, it would assist teachers in making decisions about the use of appropriate teaching strategies; develop relevant assessment items; use the students' assessment data to identify strengths and weaknesses; and adjust instruction accordingly. This practice has the potential to clarify the teaching for teachers and the learning for students (Squires, 2012).

As already noted, the provincial Programs of Study should include a balance of cognitive processes. In our province, the transformative framework for Education, Inspiring Education (2010) was intended as a guiding document for the inclusion of higher order thinking processes referred to as competencies for the 21st century in K-12 education. While much work has been done to connect the Programs of Study to the ideals of the Inspiring Education framework, re-imagined curriculum documents have not yet been realized.

One further recommendation acknowledges the role that teacher education programs play in preparing emerging teachers in how to instruct and assess higher level cognitive processes. Information in Bachelor of Education methodology courses should be provided in that recognize the importance of developing higher order thinking in students. Pedagogical strategies should also be taught to promote learning in this area.

5.1. Limitations of the study

A limitation of this study is that it included one grade and one strand within one subject area. Further research that examines higher order thinking at other grade levels and with other subject areas is suggested. While a small sample size of teachers (5) characterizes the study, the 238 classroom observations add power to the results of the study. Further, the study was conducted in one part of the province and may not generalize to the total population within the province nor across provinces.

6. Conclusion

The results of the study indicate very low curriculum alignment of teachers teaching and assessing at the cognitive levels represented in each of the learner expectations for the Patterns and Relations strand in the Grade 9 Mathematics Program of Studies (0.73). The principle of curriculum alignment is that successful student learning and achievement can be more reliably attained when there is an alignment of (1) learner expectations, (2) instruction in the classroom, and (3) reliable assessment information. But to be most successful, the learner expectations need to clearly identify the cognitive process level that is needed to operate on the mathematical elements for learner expectations. The findings of this study make a contribution toward improving the learning of students with its call to explicitly identify cognitive processes at all levels of learning in curriculum documents. Equally important is that all levels of cognitive processes be included by Ministries of Education who design curricula in order to balance the teaching of cognitive levels of thinking. Additionally, assisting teachers to teach and assess at the cognitive levels represented in the learner expectations as stated in the curriculum documents would help to enhance student learning potential. Clearly, alignment is an essential element in enhancing student understanding.

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