Success in Grade 9 Applied Mathematics Courses

Alison Macaulay

Abstract Streaming—the practice of sorting students into ability groups or streams—is a common practice in many jurisdictions around the world, and often favoured for mathematics classrooms. Research has established, however, that streaming leads to lower outcomes for those students who are placed in the lowest streams (or tracks). This paper begins with a discussion of the literature on streaming, highlighting the issues that contribute to the disparity in student achievement.

The paper then moves in to a discussion of streaming in the province of Ontario, Canada where grade 9 students who take the lower—or Applied mathematics course—are more likely to not reach the provincial standard on the provincial assessment than they are to reach it. The paper highlights findings from case study research of four Ontario schools that have bucked this trend and can boast strong, or unusual, performance for all of their grade 9 mathematics students, regardless of course selection. The research is distilled into ten recommendations for Applied mathematics classroom settings.

This paper offers practical advice for teachers who aim to create mathematics learning environments where all students can thrive.

Keywords Applied mathematics · Streaming · Tracking · Effective mathematics teaching

This chapter describes some of the outcomes of recent research around best practices in non-university stream classes at the grade 9 level. These best practices are described based on data collected from Ontario schools which showed strong scores, or unusual growth, on provincial assessment scores in Grade 9 Applied mathematics.[1] Based on this research, recommendations for teachers are described.

[1] See McDougall and Ferguson (Part II this volume, para. 1) for a discussion of two of the possible Ontario pathways (Academic and Applied).

A. Macaulay (✉)
University of Toronto/OISE (alumni), Toronto, ON, Canada
e-mail: alison.macaulay@utoronto.ca

A. Kajander et al. (eds.), *Teaching and Learning Secondary School Mathematics*, Advances in Mathematics Education,
https://doi.org/10.1007/978-3-319-92390-1_15

The practice of separating grade 9 students into different levels of courses, referred to as streaming, will be discussed first.

Streaming

In many jurisdictions, students will be streamed at some point during their secondary schooling, usually at the grade 9 or 10 level. This process involves sorting and grouping students into different courses, based on their perceived ability, for the purpose of instruction (Oakes 1985). The typical rationale for streaming is an efficiency argument (Van Houtte 2004)—presumably when students are placed in homogeneous classes or groupings, teachers can adapt the materials, level, and pace of instruction to better meet the needs and cognitive level of individual students. This thinking implies a fixed mindset towards mathematics learning and a belief that students have relatively static levels of ability and should therefore be taught accordingly (Boaler et al. 2000). It is worth noting here that mathematics teachers are more likely to support streaming than are teachers from any other discipline (Talbert 1995). In Ontario, for example, for students to switch from the Applied (non-university mathematics/science stream) pathway to the Academic (university) pathway, they must take a transfer course. No other discipline has this requirement. This fact, in and of itself, is worthy of reflection.

Although streaming mathematics courses is prevalent in Canadian and North American secondary schools, the practice is not supported by research. In fact, researchers have demonstrated that when they control for ability level and socioeconomic status, being in the top stream accelerates achievement and being in the low stream significantly reduces achievement, especially for mathematics (EQAO 2012; Gamoran and Berends 1987; Hamlin and Cameron 2015; Slavin 1990). Furthermore, the achievement between students in the high and low streams becomes more and more unequal over time (Gamoran 2002), resulting in gaps that inevitably widen as students progress through the grades. In the province of Ontario, for example, there is a solid decade of provincial assessment data that shows students in the higher stream of grade 9 mathematics are twice as likely as their counterparts in the lower stream to reach the level of achievement that the Ontario Ministry of Education has set as "the provincial standard" on the provincial assessment, which is equivalent to a "B." There is also a solid base of evidence that demonstrates poor, working-class, and minority students are disproportionately labeled as slow learners in elementary schools and assigned to the lowest streams in secondary schools (People for Education 2013). For example, there are about four times as many students with special needs in the Applied stream of grade 9 mathematics in Ontario. To make matters worse, there is a third and even "lower" stream in Ontario, which is exempted from the provincial assessment altogether. This indicates that by default, most at-risk students are streamed into the "lower" and less academic streams, making them especially vulnerable to under-achieving in mathematics.

In Ontario, the curriculum is structured around pathways, which are linked to post-secondary destinations. The Academic courses have been designed to prepare students for university, while the Applied courses have been designed for students who plan to go to college or directly to the workplace. Perhaps because of a bias that most teachers have (being university-educated themselves), the Applied course is often viewed as being less rigorous, and “basic.” This is certainly not the intent of the curriculum, but nonetheless, students often get labelled as Applied kids and often students are counselled to “move down to Applied” if they show any sign of struggle in the Academic course.

Many researchers have shed light on why it is that streaming—whatever you call it, or how you package it—actually derails student performance. They have found, quite simply, that students in the lower streams have less opportunity to learn than their peers in higher streams. For example, Oakes (1982, 1986) established that students in high stream classes have a more rigorous curriculum, higher quality instruction, and lessons that engage higher-level thinking skills. Moreover, teachers place more emphasis on reasoning and inquiry skills in the more academic streams. In contrast, instruction in lower stream classrooms has been found to be more fragmented with an emphasis on isolated bits of information, instead of sustained inquiry (Hattie 2002). As such, students in lower stream settings are more likely to be subject to drill-and-practice activities that focus on memorization. This emphasis arises because there is often a perception amongst mathematics teachers that students cannot engage in problem solving and higher order thinking until they have “the basics” mastered. The inquiry focus of Ontario’s curriculum, for example, is often relegated to “Problem Solving Fridays” or End of Unit tasks, instead of being the mainstay of teaching that the curriculum calls for.

Gamoran, Nystrand, Berends and LePore (1995) found that questioning patterns differ significantly in the different streams. For example, students in lower stream classes will answer five times more multiple-choice, true/false, and fill-in-the-blank style questions than those in higher streams (Gamoran and Mare 1989). Consequently, these students have much lower expectations placed on them and they are not expected to be critical thinkers (Callahan 2005). They are very likely, therefore, to spend their time reading textbooks and filling in worksheets (Gamoran et al. 1995). This lack of opportunity to learn challenging mathematics contributes to the gap in performance between streams (Balfanz and Byrnes 2006). This situation also becomes an issue of institutionalized expectations, or lack of them, the consequence of which is a demoralizing and demotivating setting for the children who end up in the lowest streams (Rubin 2008).

As might be expected, studies have also suggested that streaming has a negative effect on the attitudes, self-esteem, and motivation of students that are placed in the lower-ability groups (Berry et al. 2002; Callahan 2005). Students internalize labels, become alienated and develop anti-school attitudes that put them at risk of delinquency, dropping out, and other social problems (Ireson et al. 2002; Slavin 1990).

What Can Teachers Do?

In view of this evidence, it can reasonably be argued that the very nature of streaming can set up teachers, and their students, for low outcomes and levels of success. Notwithstanding this fact, many secondary school teachers will find themselves working within a streamed environment at some stage of their career. The question, then, is what teachers can do to optimize teaching and learning in low stream settings.

Through my own research, I conducted case studies of Ontario schools that have been extremely successful on the provincial assessment for grade 9 mathematics, in both the Applied and Academic courses. Specifically, my research was concerned with discerning the practices that are effective in supporting student achievement and success in the Applied level course. I have distilled my findings into ten powerful and promising practices that appear to have supported high levels of mathematics learning for students in low stream environments.

1. Have and hold high expectations for students in Applied classrooms.

As was discussed, sorting and sifting students into streams assumes that there are students that are more and less able to undertake study in the discipline. A by-product of this approach is that teachers, and even students, develop mindsets about what students are and are not capable of, depending on the stream in which they are placed. In some classrooms, students in lower streams are assigned less complex and low-demand tasks because the assumption is that they are not capable of higher level thinking. In the high performing schools that I studied, I found that quite the opposite was true of the classrooms that I visited. These schools were chosen as case studies because they consistently—over 5 years—performed above the provincial average, for both the Academic and Applied courses on the provincial mathematics assessment. Over this time, these schools also had a performance gap between the two courses that was smaller than the provincial gap. Given the scope of my research, I did not study low achieving schools, so I cannot comment on what may or may not be happening in those environments. What I am able to report, however, is what was common to four schools that have had outstanding success with provincial assessment results in grade 9 mathematics.

In order to determine what kind of thinking was being required of students in the high achieving, and lower-streamed, classrooms, I used a taxonomy to analyze the level of work that the students had been assigned during my classroom visits. This taxonomy, developed for The International Mathematics and Science Study (TIMSS), distinguishes the cognitive dimensions of a task by specifying the thinking processes that are needed to successfully complete it:

> The first domain, *knowing*, covers the facts, concepts, and procedures students need to know, while the second, *applying*, focuses on the ability of students to apply knowledge and conceptual understanding to solve problems or answer questions. The third domain, *reasoning*, goes beyond the solution of routine problems to encompass unfamiliar situations, complex contexts, and multi-step problems. (Grønmo et al. 2013, p. 24)

Fig. 1 Cognitive Skills. From "TIMSS 2015 Assessment Frameworks," by TIMSS & PIRLS, http://timssandpirls.bc.edu/timss2015/downloads/T15_Frameworks_Full_Book.pdf, pp. 25–27. Copyright 2013 by the International Association for the Evaluation of Educational Achievement

Cognitive Skill	Associated Verbs
Knowing	Recall Recognize Classify/Order Compute Retrieve Measure
Applying	Determine Represent/Model Implement
Reasoning	Analyze Integrate/Synthesize Evaluate Draw Conclusions Generalize Justify

These dimensions are further articulated by verbs that can be associated with mathematical tasks, as outlined in Fig. 1. I found that without exception, the level of work assigned in the case study classrooms reached the highest cognitive level of reasoning. The students were being asked to do more than carry out mathematical procedures; they were asked to apply them in novel contexts and then reason about the results.

It is also worth mentioning here that oftentimes teachers, with all of the best intentions, will scaffold more complex tasks for students that they perceive to have weak abilities. The problem with this is that by overly scaffolding these kinds of tasks, the thinking is actually being done for the students. If you think of the brain as a muscle, then it actually needs to be exercised in order to grow. If students are never given the opportunity to think, then they will not expand their capacity to think. Saying this, it is important that teachers set their students up for success by creating the conditions that will help them to engage in the thinking and subsequent learning.

An effective strategy to engage students in thinking and problem solving is to be open to a wide variety of approaches. In my study, teachers reported that students in Applied classrooms are less formulaic in their thinking and approach problems more creatively. It is very critical to play to this strength by accepting a wide variety of strategies and methods, even if they do not "look pretty" or follow conventional formats. This is actually more helpful to students in the long run because they will be better equipped to solve problems intuitively, instead of relying on formulas that they may or may not remember correctly.

The descriptions of the remaining practices will provide more direction on how to best support thinking mathematics classrooms.

2. Build confidence and efficacy for students.

Typically, students in the lower streams have lower levels of confidence and efficacy when it comes to mathematics. At the very least, the nature of the streaming process has signaled to them that they are not capable of higher levels of mathematics. My research of low stream classrooms revealed that teachers in these settings find many of their students to be disenfranchised, and even traumatized, by their prior experience of mathematics. These students express strong sentiments about not liking mathematics, not being good at mathematics, and not seeing how mathematics matters to them. For many, their history with mathematics education has not been very positive. Many of them have experienced mathematics as working in isolation on drill and practice activities to build their skills. As such, the teachers reported that one of their first goals was to help students to repair their relationship with mathematics and the damage caused by the perceived stereotype of what it says about you if you are a student in Applied mathematics. To do so, they worked to quickly foster a feeling of success and comfort in the classroom. An important strategy was to begin the course in areas that students traditionally do well in, such as measurement or geometry. This got students off to a strong start in the course and helped to build their confidence and efficacy—their belief that they were capable of doing mathematics.

It is also important to value the learning and strengths that students bring to the classroom. Recognizing that the students are not blank slates is imperative, and so too is activating their prior knowledge so that they understand what they are learning now is simply building on what they already know. It is always a good idea for teachers to peruse the prescribed curriculum for the grade that precedes the one they are teaching. This will help them to understand the mathematical content and skills that students should already have been exposed to. This, in turn, will provide insight into how new learning might be anchored by prior knowledge and experience. By way of example, one of the expectations in the Ontario Grade 9 Applied mathematics course is that students "construct table of values and graphs to represent linear relations derived from descriptions of realistic situations" (Ontario Ministry of Education 2005, p. 42). If teachers look at the curriculum that precedes grade 9, they will see that students actually began recording patterns on a table of values in grade 5 and plotting them graphically using ordered pairs in grade 6. By grade 7, students represent and describe linear growing patterns algebraically and in grade 8 they use algebraic equations to describe linear patterns. Therefore, to treat this expectation as brand new learning can be a great dis-service, and even monotonous, to the students. Using diagnostic tasks is a great way for teachers to see who has mastered certain skills, who might need support, etc. for the upcoming learning.

3. Capitalize on the social nature of adolescents.

Research has demonstrated that learning and making sense of mathematics is a social enterprise (Kilpatrick et al. 2001; Newman and Holzman 1996; Sfard et al. 1998; Spillane 2000). Therefore, using collaborative grouping in Applied classrooms is an important strategy, especially given the social nature of adolescents. Working within these supportive structures, students can together investigate mathematical concepts and solve mathematical problems. In collaborative groups, students become resources for one another's learning, allowing individuals to go beyond what they might be able to do on their own.

It is important to recognize that students in lower streams might not necessarily have experience in working this way during mathematics class. Many of them may be more accustomed to working alone, doing different mathematics than the rest of their classmates. Some of them might not be comfortable with sharing their thinking with others because they may not have a history of being called upon to do so. As such, it is important to support students in working collaboratively with one another. This involves making the classroom a supportive space where students know that it is okay to make mistakes and in fact, learn from doing so. Getting students comfortable to work in these ways will require persistence and support on the part of the teacher. A good strategy that I have observed to get students to work collaboratively is "Think—Pair—Share." Here, after assigning a task or problem, the teacher gives students a couple of minutes of individual think time to reflect and strategize. Then, students are paired with a partner to share their thinking. This sharing gives all students an opportunity to rehearse and refine the articulation of their thinking. From here, students can then be assigned to larger groupings, if desired. With this approach, all students will come to class discussions with their own ideas, or are the very least, an idea from their partner.

The teachers that I observed through my research also embedded clear accountability structures. They would precisely articulate their expectations for the students: e.g., "There are ten minutes left and then I want to hear from each group what you found out."

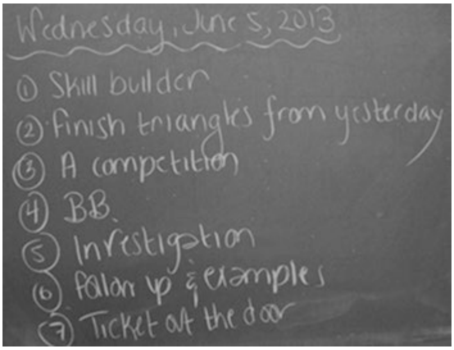
4. Use a variety of resources that engage students in active and hands-on learning.

In the classrooms that I studied, teachers did not limit the learning experience for their students to a textbook. Instead, they used a variety of resources that both met the needs and interests of their students and provided opportunities for active, hands-on, and experiential learning. A popular resource was the Ministry of Education's TIPS for Revised Mathematics, or TIPS4RM, which is freely available at www.edugains.ca on the mathematics homepage. This resource provides three-part lessons designed to address the expectations outlined in the Ontario mathematics curriculum. These lessons can be used as is, or modified by the teacher to meet the needs of his or her students.

I found that the teachers also offered open access to mathematical thinking tools such as manipulatives, calculators, and pencils, and expected students to use them to show and explain their thinking. They also made widespread use of instructional technologies, such as interactive whiteboards, that help students to conceptualize and connect mathematical ideas.

The teacher talk around the use of manipulatives and technology positioned both as being tools for thinking, which can actually help the students to think through a problem. In essence, these tools allow students to engage in "doing mathematics" in the way that mathematicians would (OME 2005). The general sentiment was that these tools are especially important in Applied classrooms because the courses have been designed to be very "hands on" and appeal to the concept that students learn by doing. In this sense, manipulatives and other concrete materials can act both as a hook and a support to doing the mathematics. The importance of meaning-making

Fig. 2 Sample 75 minute lesson agenda



needs to be underscored here. Oftentimes teaching in lower streams will default to a skills approach and a focus on "the basics." When students learn skills in isolation and out of context, they are hard pressed to use those skills appropriately in any meaningful way. In order to learn to think mathematically, students need to do more than rehearse someone else's mathematics. They must be engaged in the mathematical enterprise, which involves problem solving, making conjectures, reasoning, reflecting, connecting ideas and communicating thinking.

It is also important to point out that there is not a long history of manipulative use in secondary schools. Teachers in these settings will often forgo their use altogether (Kajander and Zuke 2007; Suurtamm and Graves 2007). In this sense, new teaching graduates have an important role in trail-blazing innovative ways of learning for both students and teachers. Support for the use of manipulatives can be found on Ontario's Edugains website at http://www.edugains.ca/newsite/math/manipulative_use.html.

5. Maintain a rigorous pace.

In the case study classrooms that I studied, I was struck by the rigorous nature of the lessons that I observed. In all cases, the teachers had chunked their lessons into 10–15-min learning episodes with a short mid-lesson break where students could get up, move around, and re-focus their energies. Figure 2 illustrates the agenda for one such lesson.

This lesson design is in fact supported by brain science (Sousa 2006). Neuroscientists have discovered that our working memory is where we build, take apart, and rework ideas that will eventually be discarded or put into our long-term memory. Researchers have established that working memory is capable of handling only a few items at a time. This implies that depth of learning over breadth of learning should be considered in lesson design.

Brain research has also established that a newly learned idea is likely to fade from working memory and be discarded unless something else is done with it. Any new learning, therefore, is best retained when students have adequate opportunity to re-process it. Therefore, different experiences within a lesson will reinforce new learning, increasing the chance that it will be put into long term memory.

Researchers have also determined that the capacity to process new learning is also time bound and is about 10 to 20 min for the adolescent learner. This means that an adolescent can process an item in working memory for 10 to 20 min before fatigue or boredom sets in. In order for the adolescent to continue to focus, there needs to be a change in how he or she is dealing with the item. In teaching terms, this means the need for different learning experiences within the same lesson, as illustrated by the different activities outlined in Fig. 2.

6. Provide a rich learning environment in Applied classrooms.

A rich learning environment must attend to the emotional, as well as academic needs of the students. As previously discussed, it is important that the classroom be a supportive space that is respectful of all learners. It is important that all thinking is valued and that all students feel that they have a voice. Again, this may require persistence on the part of the teacher who may, for example, need to help students understand how to respectfully disagree with one another by offering an opposing line of thinking. For more on how to build a "Math Talk" community, refer to Bruce's research monograph (2007) on student interaction in the mathematics classroom.

Expectations should be set high and clearly communicated to students in applied classrooms. The use of a lesson agenda, as illustrated in Fig. 2, is a great way to inform students of what will be happening during the lesson and also signals high expectations. Providing frequent prompts is also helpful: e.g., "In five minutes I want to hear from each group what strategy you used to solve the problem."

It is also important that the classroom space reflect that this is a place of learning. One observation that I have made in Ontario schools is that there is often very little posted in secondary classrooms. Teachers tell me that this is because they regularly have to share classroom spaces; teachers will not necessarily have their own classrooms, and instead move from room to room throughout the day. This practice is not very supportive of students, however, especially when they are coming from very rich classroom spaces in elementary school. Having established this, the case study classroom spaces that I visited for my study were not typical.

In these classrooms, a clear account of the mathematics content that had been covered during the course was evident by just looking at the walls. There were a variety of teacher, student, and co-created visuals including charts and word walls, that provided both an anchor to and record of student learning. These records of learning can be extremely helpful to students who may have poor organizational and note taking skills because they can refer back to them when needed or prompted. Having student work posted is also beneficial because it allows students to see the variety of ways in which others approached a problem.

7. Skill building in context.

A common practice in mathematics classrooms is to begin the school year or semester with a review of material that was covered in the previous grade or course. Some teachers will devote several weeks to this review. Teachers in my study did not favour this practice. Instead, they preferred to work review of skills into their lessons, on an as needed basis. Figure 2 demonstrates, for example, how one teacher began her lesson with a skill building activity. On this particular day, students practiced the skill of mentally multiplying. For example, 18×6 is the same as $2 \times 9 \times 6$ or 2×54, which is equal to 108. This skill would come in handy later in the lesson when students were conducting an investigation of the sum of the interior angles of a polygon [$S = (n-2) \times 180°$]. In this way, practicing the skill was purposeful, relevant, and seamless to instruction.

8. Provide samples of what good work looks like and engage students in self- and peer-assessment.

There is more and more research that demonstrates that self-regulation and the monitoring of one's own learning has a huge impact on student achievement (OME 2010). When students understand the criteria for success, they are better positioned to actually be successful. Therefore, developing, or co-constructing success criteria can be an important strategy in Applied classrooms. It is also important to help students monitor their own progress in meeting the criteria by having them reflect on their own work to assess their progress. Providing models of good work can facilitate this process. Similarly, when students help peers to assess their work, they become more adept at articulating the criteria and operationalizing it in their own work.

When getting started, a teacher may want to look to outside sources for examples of criteria and student exemplars, such as those based on Ontario's provincial assessment, available at http://www.eqao.com/en/assessments/grade-9-math/Pages/example-assessment-materials-2015.aspx. Over time, though, teachers should strive to collect their own student samples, based on tasks that can be used again in subsequent years.

9. Provide students with frequent, oral, and descriptive feedback.

In my research of Applied classrooms, I heard repeatedly from the teachers that it is important to monitor the progress of each and every student and to connect with students on an individual basis to provide them with oral and descriptive feedback that can move their learning forward. Teachers would accomplish this in a variety of ways. For example, many of the teachers used some kind of exit strategy such as a "Ticket out the door" where students would independently answer a question related to the day's lesson. This allowed teachers to immediately target those students who may be having difficulty by providing remediation during the next lesson, or facilitating peer support by pairing someone who was struggling with a concept with someone who had mastered it.

A really important strategy for all of the case study teachers was to monitor students when they were at work during the classroom activities. As students were involved in investigations, for instance, the teacher would move about the room engaging in conversations and observations of students as they were at work. Interacting with students in this way gives teachers a much better sense of what students are thinking than can be surmised by simply looking at a piece of written work. It is during these kinds of interactions that the teacher can gather more qualitative descriptions of what it is that students can do, where they struggle, and what might be next steps for their learning.

10. Foster productive dispositions around mathematics by sharing the wonder and beauty of the discipline.

As was discussed previously, oftentimes students in Applied settings have been traumatized by their experience of mathematics. Couple this with the damage caused by the stereotype associated with lower stream classes, and it is not hard to understand why students in Applied classrooms may not come to the class with the most positive of attitudes. It is very important to be mindful of this and to understand that an essential part of the work with these students will be to help them to build a positive relationship with mathematics and to begin to see themselves as capable and competent. The strategies discussed thus far will help.

Sharing the love and joy of mathematics is also imperative. Mathematics is an elegant, creative, and beautiful enterprise and too often students do not witness this in their experience of school mathematics. Bringing interesting mathematics puzzles, anecdotes, and stories of mathematical interest and application to the students helps them to develop a more robust appreciation of what mathematics is, the often-compelling history behind it, and the importance of it to daily life and living. Enthusiasm is contagious and when teachers are truly passionate about their discipline, students perk up and take notice.

An example might be the illustration of how the Fibonacci sequence and Golden Ratio, are reflected in nature. Doing a simple internet search will result in many examples that can be shared with students, such as flower petals; pinecones; fruits and vegetables such as apples, cauliflower, and pineapples; tree branches; galaxies, animal bodies; and hurricanes. Good sources for these kinds of materials are the Illuminations page on the NCTM website at illuminations@nctm.org or the enriching mathematics activities found on the NRICH website at http://nrich.maths.org/frontpage. Investigating famous mathematics thinkers and writers such as Martin Gardner will also yield many great mathematical ideas to share with students.

In closing, it is vital that teachers think very carefully about the context in which he or she is teaching. An important part of this requires understanding the learner and what we can do to best support them in our teaching practice.

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Additional Suggestions for Further Reading

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