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# From the Editor

*Monica Chahal*

> I have no special talents. I am only passionately curious.
>
> *Albert Einstein*

I hope that your summer has been filled with sunshine and joy and that you enjoyed your well-deserved break. Welcome back to a new academic year. It's funny how in June the summer seems so far away, yet come September the summer seemed to fly by. But what September brings is the chance for a fresh start with fresh faces. The possibilities at this time of year are unlimited.

This year the Science Council is hosting another joint conference with the Mathematics Council, with the theme "Geeks Unite 2.0." Are we not all geeks at heart? I chose to open with the quotation from Einstein because, to me, passionate curiosity is the realm of the geek. As educators, we are questioners, cross-examiners, inquirers and planners. How many of us find conversations revolving around climate change, redox reactions, stoichiometry or collision equations exciting? I'd conjecture that many of us do. But we don't stop there. The questions then become about pedagogy and praxis. How do you teach single-replacement reactions? What is the best way to assess the nitrogen cycle? Is there a better way to describe buoyancy or electric current? And who do we talk to? Our peers, our coteachers, our colleagues and our friends. So, come join us in Edmonton this October and share your ideas, pose your questions, and help us create an invigorating and exciting conference experience.

In line with our conference theme, this issue of the *Alberta Science Education Journal* opens with an article that expertly illustrates the many connections between math and science education. Simply put, Ellen Watson asks how we should be teaching math. Her answer: in conjunction with science. She aims to answer the long-asked question about mathematics: "Why do we need to learn this?" While her article is primarily anecdotal, it provides tangible examples from her personal and teaching experiences that illustrate how integrating high school math with physics would benefit students. Only a real geek would find the solution to this question of why we teach math in the study of decibels or projectile motion. For her, the answer is simple—contextual mathematics.

Latika Raisinghani's article explores the notion that cultural diversity, while at times a strength, can also be a challenge. Her qualitative study of science and math teachers in a school district in western Canada is explored through the discourse of critical multicultural education and provides an interesting perspective from an insider/outsider—one that may cause a few of us to reconsider how we interact with our culturally diverse students.

Erica Alexander, Richard Pardo, Susan Lindsay and Carol Rees's article describes the DRiVe Inquiry Framework. One of the authors states, "This model has changed the way I think about teaching and how my students feel about learning." Is that not what we all desire? The article stemmed from the experiences of teachers who were asked to teach a more open-ended style of science inquiry and were concerned about how to do so successfully. What is great about this article is that it provides readers with a detailed example from a Grade 7/8 combined class in which students are testing pop bottle water filters. This article provides us geeks with something tangible to bring into our classrooms.

The inner geek in Saiqa Azam hopes to answer the question, How do we better prepare our elementary teachers to become better science teachers? To answer this, she proposes a unique model for improving elementary teacher education programs and professional development for inservice elementary teachers with regard to scientific pedagogical content knowledge (PCK). In her proposal, she highlights not only research in the field but also why this research is pivotal for those teaching science in Alberta schools.

Also in this issue, we have added a new feature—a book review. Kerry Rose reviews *Small Teaching: Everyday Lessons from the Science of Learning*, by James M Lang (Jossey-Bass, 2016). For her, this book is great not only because of its useful examples but also because the author uses rich storytelling—again, only a geek would find a book about teaching fascinating.

If you would like to review a book or have a book of interest for one of your colleagues to review, or if you have any other suggestions for the journal, please let me know. I can be reached at atascjournaleditor@gmail.com.

I hope you find some inspiration for your upcoming school year from these articles.

# Why Teach High School Mathematics? Integrating Mathematics with Other School Subjects

*Ellen Watson*

## *Abstract*

Mathematics students often ask, "Why do I need to know this?" Teachers may provide answers loosely related to professions or, perhaps, reasoning skills. Is this enough? Considering the social, traditional and contextual reasons for teaching mathematics in schools, organizing information into separate subjects is no longer feasible in our fractal and complexity-based thinking culture. To better suit our complex society, this author proposes that mathematics be taught in conjunction with science courses, particularly physics at the secondary level. This collaboration may provide a better response to why one learns mathematics by concretizing abstract mathematics in the context of science.

As a high school mathematics teacher, I was often asked, "Why do we need to learn this?" This (somewhat tiring) question is an important one for mathematics educators to consider. Why do we need to teach mathematics? Is it because we always have? According to Robitaille and Dirks (1982), formal mathematics education has become a familiar tradition. Interestingly, this sentiment is still alive today. We teach mathematics because we always have, yet there are many other reasons to teach mathematics.

I am sure that most secondary school mathematics educators would agree with me when I assert that everyone needs to have some understanding of mathematics, whether for simple estimation or for complex calculation in their daily lives. This need highlights the importance of including instruction in the nature of mathematics—those ideas, principles and characteristics central to knowing in mathematics (Garegae 2016; Robitaille and Dirks 1982). However, while mathematical knowing must be taught, this knowing can be interpreted in a number of ways. These interpretations, based on teacher, societal and contextual beliefs, influence the curriculum as presented in our classrooms (Garegae 2016). We, as mathematics teachers, hold deeply rooted beliefs about mathematics and education (Foster 2013), and I wonder if those beliefs are enough reason to maintain mathematics as a separate course.

Curriculum documents, which our courses are based on, are often written with a particular curriculum emphasis. According to Roberts (1982), a curriculum emphasis offers students strong messages *about* a subject rather than *within* the subject. All agents involved in curriculum development and delivery have beliefs about what should be emphasized in the classroom. These emphases may be based on career decisions, personal beliefs or even an agent's own interest in the subject. As teachers, we must recognize our curriculum emphases to uncover our reasons for teaching mathematics.

I am well aware of my curriculum emphasis in mathematics. One reason to learn mathematics is for scientific exploration,[1] particularly at the high school level. This view is supported by Project 2061 (1989), which claims that "because mathematics plays such a central role in modern culture, some basic understanding of the nature of mathematics is requisite for scientific literacy." Through mathematics, we are able to better explain science, specifically physics.

Originally developed through philosophy, mathematics comes to life when applied within physics. For example, "the ancient doctrine of the conic sections, which for 2000 years was an object of mere curious speculation, in the hands of Newton, became an efficient means of unfolding the planetary motions" ("Use of Mathematics in the Sciences" 1852).

With these applicable examples in mind, I claim that we teach students mathematics as a tool with which to explore our physical universe. Physics and mathematics, together, explain and quantify nature. Science is used to search for, describe and explain patterns in nature, while mathematics quantifies those patterns (So 2013). As the conceptualization of mathematics is central to explanation in physics (Brahmia 2014), it seems logical to teach the two together. The interrelated nature of the two subjects is undeniable, yet we teach them separately in schools.

Why is mathematics taught as a separate subject in schools? Arguably, mathematics is a language, one in which our students need to be well versed (Riccomini et al 2015). If we were to integrate mathematics across all subjects, like language skills are reinforced in all courses, we may see deeper mathematical comprehension in our students (Freudenthal 1973; Phillips et al 2009). Mathematical skills are used in a variety of subjects, including graphical interpretation in the sciences and history, ratio and proportion in art and physical education, and spatial reasoning in the practical and applied arts. It is time for mathematics to take on a more central role in our secondary school curricula, potentially one in which it is embedded across courses.

Many subject areas use some aspect of mathematics, but the subject with which we could best begin this transition is high school physics. With the question of why we teach math in mind, I propose that we combine physics with senior mathematics courses to best serve our students and show them one reason to learn mathematics.

## Emphasizing Mathematics in Physics Class

In my experience, students have difficulty seeing mathematics beyond the mathematics classroom. My students often seemed to have forgotten the concepts I had taught them in Mathematics 10 when I taught them the next semester in Science 10. It may be that they had difficulty translating the concepts they had learned through abstract explanations in math class to the concrete applications in science.

Perhaps the elementary curriculum, with its built-in thematic and integrative approach to subjects, makes clearer connections with concrete concepts (such as using fractions to show the parts of something) and mental strategies for mathematics operations (such as adding objects to find a total). As students progress in their mathematics education, these connections become increasingly difficult for them to perceive. Concepts become more abstract, and applications are less readily accessible. This is made even more difficult by the fact that the mathematical skills required for many physics concepts are taught in mathematics courses designed for older students (Brahmia 2014). For example, the concept of waves is often taught in science or physics courses well before the trigonometric ratios required to interpret wave behaviour are taught in mathematics courses; the same can also be seen with the concept of light intensity, which is taught in science well before logarithms are taught in mathematics. This mismatch in sequencing can make it difficult for students to connect mathematics and science concepts.

Students need to be aware of why they are learning a subject. According to O'Brien (1973), and echoing the ideas of Dewey (1916), we must consider the usefulness of the subject in the life of the child. A recent study conducted by Mahaffy et al (2017) found that students were more interested and motivated to learn when encountering science in a context-rich course.

While we cannot possibly predict the future usefulness of mathematics for each student, I contend that we can show students useful meaning through the lens of contextual mathematics in terms of physics. Physics is made up of both conceptual, qualitative understandings and mathematical explanation (Elby 2011; Hammer 1994). In senior physics courses, we are often reiterating, or pre-emptively teaching, a lot of the content taught in mathematics courses, and mathematics courses often use physics examples in their textbooks (Brahmia 2014). As an example, in a 30-level mathematics textbook I use, a question asks students to explain the reflection of a sound wave in terms of its sinusoidal wave function. The question uses two paragraphs to explain the physical phenomenon before asking students to simply interpret a wave function based on their understanding of sine waves. This question could be so much more, if only the teacher were able to address the physics as well as the mathematics. Not only is mathematics for physics contextual, but it can also provide clearly unified information about the workings of the world.

Contextual mathematics, such as mathematics that is integrated with physics education (among other subjects), may unify these subjects while addressing miscommunication between teachers of the subjects. According to Freudenthal (1973), physical science teachers want mathematics curriculum to prepare students for their subjects, yet because of mistrust, they de-mathematize their subjects. I have many colleagues who teach science but not mathematics, and they are not always sure what students have learned in mathematics before entering physics courses; hence, it is easier to teach the physics using the least complex math possible. For example, wave motion *can* be taught without an understanding of trigonometric functions (and, admittedly, it is simpler), but if these concepts are taught together, students are offered an opportunity to better understand *both* concepts. In addition, the de-mathematization of the physics classroom neglects to show students how physics experts use mathematical ideas to reason about the physical world (Brahmia 2014). If physics concepts and the required mathematics concepts were taught in parallel, students may develop a better conceptual understanding of mathematics, as is required by experts, and the mistrust between the teachers of physics and mathematics might be eliminated.

However, even when we include mathematics instruction in our physics courses, are students readily making the connections between the two subjects? In my experience, no. Students still see mathematics and physics as separate subjects with little cross-pollination, and therein lies the problem. To remedy this lack of connection between subjects, I propose that we teach the two subjects as they have evolved—together. For example, consider the origins of what is now known as calculus. Ideas in calculus, such as derivatives, were discussed before Isaac Newton contributed to the field, but Newton is considered to be a father of modern calculus. Newton came to these ideas as an extension of his work with physics, particularly optics and motion. It was through a need in physics that this "new" mathematics was derived. Mathematics and physics are based on interdependent ways of knowing (So 2013). The interconnectedness of mathematics and physics provides one more argument for the teaching of mathematics with physics courses. Mathematics is more than a tool; it is a way of understanding physics.

## Creating a Context

I vividly recall the first time I *truly* understood the process of integration. After studying calculus through formal instruction for two years, I was able to complete the process of integration quite easily for most problems presented in class or in the textbook. However, I did not truly understand why I would ever need to integrate until I *used* the process.

I am forever grateful for the demonstration shown to me late in my second year of studying physics. The professor showed the class a circle and asked us to find its area; he then placed the circle on the end of a Slinky and wrapped it into a circular tube, showing us what we were calculating when we integrated our circle's area to create a solenoid. This demonstration was not particularly groundbreaking, yet integration finally made sense. Never in my mathematics courses had I been given such a clear explanation. Using mathematics in a science-based context offered me a deeper understanding of integration than I had ever been offered through any formalized calculus instruction.

Physics experts use conceptual mathematics and mathematical reasoning to predict and explain physical phenomena (Brahmia 2014); unfortunately, secondary physics and mathematics curricula rarely integrate these two subjects in such a way. In high school math courses, at least those I have experienced, mathematical concepts are often introduced with few connections drawn to concrete real-world examples. These theoretical introductions can be frustrating for students (Freudenthal 1973; Swanson and Williams 2014). A lack of concrete mathematics instruction may also hinder students' learning. Meaningful, context-based mathematics requires students to think and is far more beneficial than rote recall (Jones, Jones and Vermette 2009). Moreover, using contextual mathematics develops better understanding of mathematical ideas than does the use of unfamiliar abstractions (Cohen 1990).

Personally, I was more engaged and more keen to learn mathematics when I knew of applications of the concepts. For example, I still recall an instructor telling us about the importance of the radius of a tire in its relation to angular speed. He had tires put on his truck that had slightly too large a radius and, consequently, his speedometer, which read revolutions and not distance travelled, neglected to inform him of his true speed; the police, however, were able to tell him that true speed when they pulled him over. Whether this story was true does not really matter; it was a contextual example that illustrated the concept in a tangible way, and I still remember the effects of radius on circumference and angular speed today. The need for contextual mathematics is also shown in my personal encounter with real-world integration and the solenoid calculations. Teaching mathematics outside of the abstract and inside of its useful applications showcases the mathematical reasoning required by experts in physics.

Contextual mathematics education allows learners to access and connect information to real-world scientific concepts. Concept development is enhanced by real-world investigations (DeHaan 2005; Mahaffy et al 2017). As teaching mathematics with physics reflects the way both subjects were derived (So 2013), the use of investigations in class could help contextualize the understanding of both subjects. For example, the concept of decibels as related to sound intensity provides an excellent space to explore and explain the rules of logarithms in a physically relevant situation. An investigation on the topic of decibels could use the mathematics of logarithms to explore (and visualize) the physics of sound intensity. Scientific concepts can be better understood by using mathematics to represent scientific phenomena (So 2013). Our students need to be given contextually relevant opportunities, such as investigations of sound intensity, to formulate deep physics and mathematical understanding.

There are those who will argue that mathematics *is* taught contextually through word problems. However, research has shown that students react negatively to mathematics where the real world is simulated through contrived word problems (Usiskin 1997). Contextual mathematics, as I am urging teachers to consider, should not be confused with artificial word problems; contextual mathematics is rooted in real-world exploration and understanding. True real-world investigations drive students to search for connections and generalizations to mathematics (Burrill 1997). Contextual mathematics can provide students with the drive to deepen their understanding of physics, but this depth of comprehension is not easily achieved through unrealistic word problems (as described by Usiskin 1997). Contextual mathematics can be used to investigate physics and provides more than mere practice of mathematical skills through solving a word problem. A contextually rich mathematics curriculum, grounded in scientific exploration of the physical world, may encourage students to seek and explore connections between physics and mathematics.

## Integrating Information

Integration of mathematics and science content is key to an understanding of physics-based, contextual mathematics. Mathematics, as with other subjects, must be taught as coherent material, not in isolated pieces (Freudenthal 1973; Schmidt, Houang and Cogan 2004). I contend that this coherence can be extended to physics and mathematics as integrated material since the two subjects both emerged from philosophy and evolved in parallel; physicists created new mathematics as it was needed, and as mathematicians furthered mathematical understandings, physics applied those understandings. As an example, two high school courses that could be logically combined are senior physics and calculus. In this classroom, students would learn basic calculus and physics concepts side by side, which could promote the unification of the two subjects through exploration.

Combining physics and calculus into one class may give students a better comprehension of both subjects. As Marrongelle (2004, 260) writes, "Concretizing the abstract field of calculus with the use of encounter-able physics helps students struggling with math to develop useful reasoning skills, and students struggling with physics to develop explanation skills."

As previously discussed, mathematics, particularly calculus, may appear abstract if taught in isolation from its applications; the concrete nature of high school physics offers a grounded plane for calculus concepts to be developed. According to Sokolowski (2012), mathematics gains thought-provoking problems from science; I think any education in the sciences, such as physics, should be thought-provoking. A teacher of combined physics and calculus curricula could teach students some basic calculus concepts and help them develop an *understanding* of the mathematics through applying mathematics to solve provocative questions in physics.

For example, in physics, students convert from position–time graphs to velocity–time graphs to acceleration–time graphs. In my experience, teaching these graphs and conversions without calculus is an exercise that is both tedious and time-consuming, with little gain toward an understanding of the concepts themselves. When I am lucky enough to have a class with many students who are enrolled in calculus while taking physics, I can extend my lessons from the required area and tangent line slope calculations to some basic integration and derivative applications.

When I can teach these graphical conversions using calculus, it is extremely powerful for students, as they are able to *use* calculus and better comprehend what the calculations are telling them about movement. Unfortunately, also in my experience, when students take calculus and physics in separate semesters, despite being taught similar processes in different courses, many students fail to make the connection between the two subjects. If we fully integrated the content from these two courses, calculus concepts may appear less abstract while promoting deep exploration of position, velocity and acceleration in kinematics.

Integration of mathematics and physics allows teachers to show the deep connections between mathematics and physics, which may allow students to explore both subjects with more independence. Mathematics and physics are entwined; "[mathematics] is the *soul* of science" ("Use of Mathematics in the Sciences" 1852). It is important that we show these two subjects as being connected, but it would be even better if physics and mathematics were integrated at a level that knowledge from one subject *informed* the development of knowledge from the other subject. Knowledge of the interconnections of the subjects offers students the opportunity to deeply study problems with more independence (Marrongelle, Black and Meredith 2003). If understanding mathematics can inform an understanding of physics, and vice versa, students may be able to be more independent in their exploration of both physics and mathematics. For example, if students learned quadratic equations connected with the concept of projectile motion, they may become more confident in analyzing projectile motion and better able to recognize reasons for learning the mathematics of the parabola. In my experience, physics students often struggle with the concept of time in the mathematics of projectiles, presumably because they are analyzing two dimensions simultaneously. If they were able to investigate projectile motion using a single approach, of quadratic equations, this may enable them to better comprehend the relationship between time and both the x and y dimensions, while also giving meaning to quadratic equations and parabolic graphs. Students should be exposed to, and explicitly shown, the interconnectedness of these subjects, as well as given the chance to use the connections among integrated curricula to fully explore both physics and mathematics.

Along with gained independence, combining physics and mathematics curricula in secondary school may also enhance student enthusiasm for and interest in these often difficult subjects. Students must develop the ability to interpret abstract mathematics in order to understand and solve physics problems (Marrongelle 2004). In the rare semesters when I was able to teach some calculus in my physics course, or use the quadratic formula to solve a particularly sticky projectile problem, I can remember those students with a proclivity for science and mathematics lighting up. They were learning *why* they had learned those mathematical concepts and delighted at the chance to apply their mathematics knowledge. Physics provides avenues for students to understand the physical world, and mathematics provides avenues for students to interpret relationships and patterns found in the physical world. Since learners are inspired and motivated by integrated curricula and contextual learning (Frykholm and Glasson 2005; Mahaffy et al 2017), understanding physics may serve as an incentive to further their mathematical understanding. Learners' desire to interpret the scientific world may provoke them to deeply analyze the mathematics required to understand the physics.

Finally, while independence and motivation are products of integrating curricula, the most powerful product is understanding. "Students often drop out of science majors because they have not been prepared for the level of understanding required in mathematics and sciences" (Drew 2011). Perhaps we are losing physics majors because, as Brahmia (2014, 37) claims, "students are not taught to mathematize in the context of physics, even though reasoning in physics is based on a conceptual understanding of the mathematics used." Are students *prepared* to undertake postsecondary physics courses without this mathematization? While this is troubling, Schwols and Miller (2012) explain that science instruction, such as within a physics course, can move mathematics learning from lower levels of understanding (such as retrieval, comprehension and analysis) to knowledge use, metacognition and beyond. Combining secondary school subjects could develop the levels of understanding necessary in order to succeed in postsecondary science, consequently equipping future science majors better than our current, separated curricula does. Hence, integrating mathematics and physics curricula is not merely a good idea but imperative for deeper understanding and use of physics and mathematics in our students' future careers.

## Mathematics Emphasis in Physics Courses

Robitaille and Dirks (1982) explain three models of mathematics emphasis in curricula: applied mathematics, pure mathematics and basic mathematics. The integrated mathematics curriculum proposed here may appear to align solely with applied mathematics; however, according to these authors, "no mathematics curriculum would likely be based exclusively on any one of the three models" (p 12). Admittedly, teaching mathematics within physics focuses significantly on the application of mathematics, but to apply mathematical concepts requires an understanding of pure mathematics (rooted in logic), applied mathematics (contextual and with a real-world focus) and basic mathematics (arising from sociological factors, such as the STEM [science, technology, engineering and mathematics] movement). Applied mathematics is obviously central to the proposed integrated courses of physics and mathematics, but these courses would also require basic mathematics through the instruction of many skills used in the physical world and the showcasing of society's need for mathematics. As one example of teaching basic mathematics, a physics teacher could incorporate data interpretation exercises in which students justify their agreement or disagreement with the use of nuclear technology. But what about pure mathematics?

The reader may not see room in this curriculum to explore pure mathematics; I disagree. Mathematics should be first studied (and conceptualized) in its pure form and then applied to physics. Consider the decibels activity previously described. The activity is designed to promote exploration of the concept of sound intensity through application of the mathematics of logarithms. However, the logarithmic knowledge needed would be best introduced through pure mathematics. After being exposed to the abstract ideas of exponential functions with mathematical theory, students could investigate inverses and develop the logarithm as an inverse function of the exponential. Finally, the logarithmic nature of the decibel scale could be explored through the use of scientific conceptual activity using the mathematics encountered. This activity may seem like a lengthy process merely to learn about the decibel scale, but it offers students the *why* of mathematics within science instead of merely the *how* of mathematics for science.

# Can It Be That Easy?

I am proposing that mathematics be taught as a tool used to interpret the world but taught contextually in secondary courses. The best place to initiate this integration may be uniting the instruction of secondary mathematics and physics courses. Yet while integrating these courses seems both intuitive and sound to me, the truth is that education is a system with many variables that influence any changes; hence, it is important to recognize, and highlight, the barriers one may encounter when introducing integrated curricula into this system.

## Teaching Two Subjects at Once

With two curriculum documents for two separate courses, an integrated mathematics and physics course would contain a lot of content to be covered. In Canada, we have provincially mandated curricula that we are required to teach; this means that teachers cannot simply choose to teach those concepts that are easily integrated.

Admittedly, if the course selections for integration are made properly, there will be an intentional overlap of concepts, and a teacher will gain some time in those areas. However, other concepts may not be so simple. For example, while quadratic functions may nicely describe projectile motion in a frictionless system (with no wind resistance), we do not live in a frictionless reality. Does the teacher then have to teach component analysis anyway to introduce wind resistance? The larger question to consider here is, How is a teacher to cover those concepts that do not connect as readily across the two curricula?

I do not have an answer to this question, but I suspect that it will be informed by teachers' beliefs about the subjects being taught. One's perceptions and beliefs influence how one reads a situation or a document (Barnes, Bloor and Henry 1996). Hence, teachers' beliefs deeply influence their interpretation of curriculum. When it comes to those concepts that are not as easily integrated, a teacher will make decisions about how deeply to cover a concept based on many factors, including assessment, what the teacher feels that the students need to know for the course and what will support the students in their future learning. Should a teacher take on the task of integrating two established courses, there will be some difficult pedagogical choices to be made in order to ensure that both curriculum documents are satisfied.

## Fluency in Both Subjects

Another aspect to consider is the fluency of the teacher in both subjects, as well as the teacher's orientation and emphasis in both subjects. I am lucky to be well versed in both mathematics and physics; hence, teaching a course integrating the two subjects seems intuitive to me. This is not the case for all teachers, and lack of fluency can deeply affect how content is portrayed.

For example, Saskatchewan no longer offers chemistry and physics as separate courses at the Grade 11 level; these courses have been replaced by one Physical Sciences 20 course. However, Physical Sciences 20 is taught by a single instructor. According to a colleague, who is versed in both chemistry and physics and who is substitute teaching in Saskatchewan schools, it is usually a chemistry-focused person who is teaching this course, and the physics content is often taught as disconnected activities. Students in one course were examining wave motion as it is applied to light and sound, but they had no instruction in wave motion as a concept on its own. They were struggling with what they were seeing in their labs without this background. My colleague spent some time explaining waves and wave motion to students, at a very basic level, and they were then able to better understand the activity. Not all students have access to an instructor versed in both subjects, particularly in integrated courses. If this is the case, the instructor may focus more on the quality of instruction in one subject over another. If one subject is focused on and the other is neglected, is this really an integrated course?

Unfortunately, because of curricular and time constraints, as well as the fact that not all teachers are versed in mathematics, teachers are forced to limit the integration of mathematics with their courses to only what is necessary. If teachers were prepared to fully integrate mathematics, our students may finally reach the goal of "seeing the world with math" (Hung 1997, 312). Yet teaching mathematics requires an awareness of what mathematics encompasses (Freudenthal 1973; Robitaille and Dirks 1982).

Most preservice teacher programs require prospective secondary teachers to declare a major and a minor. Preservice teachers are then versed in instruction in their major and minor through courses in these subjects, as well as courses in the instruction of these subjects. This system prepares teachers to be well versed enough to potentially integrate two subject streams, but the subject streams are unique to each teacher. Hence, while it is feasible for me to integrate physics and mathematics, it may be feasible for another teacher to integrate history and mathematics, based on his or her education.

Perhaps the decision about which courses to integrate would be most appropriately made at the school level, rather than at the provincial level, based on the personnel to which a school has access. Hence, while I am proposing that mathematics be integrated with all subjects at some point, this may require changes to the way in which we prepare our preservice teachers. All teachers would need to be fluent in mathematics and the nature of mathematics instruction to successfully integrate mathematics with courses across the curriculum. This is no small undertaking.

## Inertia and Educational Change

A mentor of mine often says, "There is an inertia required for any educational change." He means that there is a tendency to teach the same and to avoid change until enough change has occurred to get things moving. This would be the same for any teacher implementing an integrated course.

For example, five years ago I proposed a combined physics and calculus course in my school. While this integrated course excited many students, many opted to take the traditional offerings of these courses. Some reasons given for choosing the traditional offerings were as follows: "I thought it would be hard having both classes together," "I'm not sure I can handle both classes" and "I may want to drop one but not the other." Students had trouble seeing the benefits of integrated courses, such as fewer assignments with more depth and having a single teacher communicate both subjects. The traditional was safe, so the courses remained unchanged. However, two years later, in the wake of the rise of interdisciplinary education discussions, a combined course of Science 10 and Mathematics 10 was created at the school. The school also now offers a media studies course that integrates Media Studies 20, English 20 and History 20. The force to begin the acceleration of an integrated courses movement began with my course introduction, and with some inertial change, integrated courses made their way into the school.

Educational change is not easy or quick, especially when it comes from the teachers within the system (Fullan 2016). Teachers will run into bureaucratic systems, student excuses, refuge in the traditional and challenge from the opposition. A recent example of this difficulty is the new mathematics curriculum in western Canada. While research shows that students develop deeper understanding of mathematics through exploration, there are those who call for a return to rote mathematics (Vashchyshyn and Chernoff 2017). However, despite this outcry against the new mathematics, I saw a significant increase in physics understanding from students who studied the new mathematics curriculum. The new curriculum, in my opinion, does a better job of teaching students to conceptualize mathematics, a skill vital to success in physics (Brahmia 2014). Students are better able to apply mathematical reasoning and interpret physical relationships. I cannot empirically claim that it is the new curriculum that has taught these skills, but I have noticed a difference.

Hence, for those who want to integrate courses, to introduce change into a system with long-standing tradition, it may be a long and difficult road, but it also may provide immense rewards in terms of student understanding.

## Concluding Thoughts

Mathematics is a deeply philosophical subject with many interpretations, but to some, the true purpose of mathematics education lies in its application, including its application to science, particularly physics. Physics provides a grounded and contextual foundation for the instruction and exploration of mathematics. Through this contextual foundation, learners can easily manoeuvre between the fraternal realms of physics and mathematics. Mathematical knowledge should be integrated with conceptual understandings of physics, as well as other subjects, not taught as a separate tool. If concepts are successfully integrated, mathematics moves from procedural knowledge to comprehension.

I propose that we begin integrating mathematics instruction with our physics courses by offering two existing courses in parallel, as in the example provided of senior physics and calculus. Mathematics and physics have evolved as subjects together; perhaps we should redesign our secondary courses to better reveal and make use of the interconnectedness of these subjects. One way to achieve this is the integration of mathematics and physics courses in secondary schools.

## Note

1. Of course, science cannot be the only subject to integrate mathematics concepts. While this article proposes that we integrate mathematics courses with science, this would also mean integrating various aspects of mathematics with other subjects.

## References


Barnes, B, D Bloor and J Henry. 1996. *Scientific Knowledge: A Sociological Analysis.* Chicago: University of Chicago Press.

Brahmia, S M. 2014. "Mathematization in Introductory Physics." PhD dissertation, Rutgers University. Also available at https://rucore.libraries.rutgers.edu/rutgers-lib/45215/PDF/1/play/ (accessed July 18, 2018).

Burrill, G. 1997. "Choices and Challenges." *Mathematics Teaching in the Middle School* 3, no 1 (September): 92–96.

Cohen, D K. 1990. "A Revolution in One Classroom: The Case of Mrs. Oublier." *Educational Evaluation and Policy Analysis* 12, no 3 (Fall): 311–29.

DeHaan, R L. 2005. "The Impending Revolution in Undergraduate Science Education." *Journal of Science Education and Technology* 14, no 2 (June): 253–69.

Dewey, J. 1916. *Democracy and Education: An Introduction to the Philosophy of Education.* New York: Macmillan.

Drew, C. 2011. "Why Science Majors Change Their Minds (It's Just So Darn Hard)." *New York Times,* November 4. Also available at www.nytimes.com/2011/11/06/education/edlife/why-science-majors-change-their-mind-its-just-so-darn-hard.html (accessed July 25, 2018).

Elby, A. 2011. "Getting Started with Research on Epistemologies and Expectations." In *Getting Started in Physics Education Research,* vol 2 of *Reviews in Physics Education Research,* ed C Henderson and K A Harper, 1–33. Also available at www.per-central.org/items/detail.cfm?ID=10578 (accessed July 25, 2018).

Foster, C. 2013. *The Essential Guide to Secondary Mathematics: Successful and Enjoyable Teaching and Learning.* Abingdon, UK: Routledge.

Freudenthal, H. 1973. "Use and Aim of Mathematics Instruction." Chapter 4 in *Mathematics as an Educational Task*. Dordrecht, Netherlands: Reidel.

Frykholm, J, and G Glasson. 2005. "Connecting Science and Mathematics Instruction: Pedagogical Context Knowledge for Teachers." *School Science and Mathematics* 105, no 3 (March): 127–41.

Fullan, M. 2016. *The New Meaning of Educational Change.* 5th ed. New York: Teachers College Press.

Garegae, K G. 2016. "Teachers' Professed Beliefs About the Nature of Mathematics, Its Teaching and Learning: Inconsistencies Among Data from Different Instruments."

*Philosophy of Mathematics Education Journal* 30 (October). https://socialsciences.exeter.ac.uk/education/research/centres/stem/publications/pmej/pome30/index.html (accessed August 17, 2018).

Hammer, D. 1994. "Epistemological Beliefs in Introductory Physics." *Cognition and Instruction* 12, no 2: 151–83.

Hung, D W L. 1997. "Meanings, Contexts, and Mathematical Thinking: The Meaning-Context Model." *Journal of Mathematical Behavior* 16, no 4: 311–24.

Jones, J L, K A Jones and P J Vermette. 2009. "Teaching Mathematics Understandings for Transfer." *Teaching Mathematics and Its Applications* 28, no 3 (September): 145–49.

Mahaffy, P G, T A Holme, L Martin-Visscher, B E Martin, A Versprille, M Kirchhoff, L McKenzie and M Towns. 2017. "Beyond 'Inert' Ideas to Teaching General Chemistry from Rich Contexts: Visualizing the Chemistry of Climate Change (VC3)." *Journal of Chemical Education* 94, no 8 (August): 1027–35.

Marrongelle, K A. 2004. "How Students Use Physics to Reason About Calculus Tasks." *School Science and Mathematics* 104, no 6 (October): 258–72.

Marrongelle, K, K Black and D Meredith. 2003. "Studio Calculus and Physics: Interdisciplinary Mathematics with Active Learning." In *Integrated Mathematics: Choices and Challenges,* ed S A McGraw, 103–16. Reston, Va: National Council of Teachers of Mathematics.

O'Brien, T C. 1973. "Why Teach Mathematics?" *Elementary School Journal* 73, no 5 (February): 258–68.

Phillips, D C K, M E Bardsley, T Bach and K Gibb-Brown. 2009. "'But I Teach Math!' The Journey of Middle School Mathematics Teachers and Literacy Coaches Learning to Integrate Literacy Strategies into the Math Instruction." *Education* 129, no 3 (Spring): 467–72.

Project 2061. 1989. *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology.* Washington, DC: American Association for the Advancement of Science. Also available at www.project2061.org/publications/sfaa/online/sfaatoc.htm (accessed July 25, 2018).

Riccomini, P J, G W Smith, E M Hughes and K M Fries. 2015. "The Language of Mathematics: The Importance of Teaching and Learning Mathematical Vocabulary." *Reading and Writing Quarterly* 31, no 3: 235–52.

Roberts, D A. 1982. "Developing the Concept of 'Curriculum Emphases' in Science Education." *Science Education* 66, no 2 (April): 243–60.

Robitaille, D, and M Dirks. 1982. "Models for the Mathematics Curriculum." *For the Learning of Mathematics* 2, no 3: 3–20. Also available at https://flm-journal.org/Articles/49AD035443452EC49BFF1FFBE32341.pdf (accessed July 25, 2018).

Schmidt, W, R Houang and L Cogan. 2004. "A Coherent Curriculum: The Case of Mathematics." *Journal of Direct Instruction* 4, no 1 (Winter): 13–28. Also available at www.nifdi.org/research/journal-of-di/volume-4-no-1-winter-2004/454-a-coherent-curriculum-the-case-of-mathematics (accessed July 25, 2018).

Schwols, A, and K B Miller. 2012. "Identifying Mathematics Content and Integrating It into Science Instruction." *Science Scope* 36, no 1 (September): 48–52.

So, W W. 2013. "Connecting Mathematics in Primary Science Inquiry Projects." *International Journal of Science and Mathematics Education* 11, no 2 (April): 385–406.

Sokolowski, A. 2012. "Enhancing Interpretation of Natural Phenomena Through a Mathematical Apparatus: A Proposal of an Interactive Unit in Optics." *International Journal for Mathematics Teaching and Learning* (March). www.cimt.org.uk/journal/sokolowski.pdf (accessed July 25, 2018).

Swanson, D, and J Williams. 2014. "Making Abstract Mathematics Concrete In and Out of School." *Educational Studies in Mathematics* 86, no 2 (June): 193–209. Also available at https://link.springer.com/content/pdf/10.1007%2Fs10649-014-9536-4.pdf (accessed July 25, 2018).

"Use of Mathematics in the Sciences." 1852. *Farmer and Mechanic and American Cabinet* 10, no 13 (March 27).

Usiskin, Z. 1997. "Applications in the Secondary School Mathematics Curriculum: A Generation of Change." *American Journal of Education* 106, no 1 (November): 62–84.

Vashchyshyn, I, and E J Chernoff. 2017. "Sick of Viral Math." *Math Horizons* 25, no 1: 33–34. Also available at https://horizonsaftermath.blogspot.com/2017/08/sick-of-viral-math.html (accessed August 17, 2018).

# Teachers' Perspectives on Cultural Diversity and Gendered Cultural Practices in Science and Mathematics Classrooms

*Latika Raisinghani*

## *Abstract*

This case study employed phenomenographic methods to investigate K–12 teachers' perspectives on cultural diversity in their science and mathematics classrooms in western Canada. The investigation involved individual teacher interviews and informal observations of teachers' classrooms. The data corpus was analyzed using critical and transformative multicultural education perspectives, complemented with the notion of culturally responsive teaching. The key findings included teachers' recognition that cultural diversity is both a strength and a challenge and their experiences of confronting gendered cultural practices. These findings illustrate the complexities involved in teaching science and mathematics to culturally diverse students. Therefore, this study highlights the need for increased teacher support to promote (trans-multi)cultural understandings that could facilitate culturally diverse students' learning of science and mathematics in diversity-rich elementary and secondary classrooms in Canada.

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This article reports on teachers' perspectives on cultural diversity in their science and mathematics classrooms and the challenges they have experienced with regard to gendered cultural practices.

The study draws from a larger case study conducted in a large urban city in western Canada. The key focus of the larger qualitative inquiry was to investigate teachers' perspectives on the effect of students' cultural diversity on their science and mathematics teaching.[1] It also explored teachers' perspectives on and understandings about culturally responsive teaching as a viable strategy for teaching science and mathematics in diversity-rich classrooms.

My interest in this research stems from my own experiences as a student, teacher and teacher educator in multiple cultural contexts, including India, Micronesia and Canada. My passion for understanding and responding to students' cultural diversity is driven by my experiences of witnessing many culturally diverse students feeling deprived and alienated in classrooms where science and mathematics were taught as neutral, fact-based bodies of knowledge (Raisinghani 2016). Therefore, in my teaching and research, I am committed to finding ways to help teachers create responsive educational experiences for culturally diverse students in their science and mathematics classrooms.

The terms *culture* and *cultural diversity* can be interpreted in different ways in different socio-political-cultural contexts. I perceive culture as a dynamic, complex, learned way of life, which continually evolves as one interacts with others (Bhabha 1994; Goodenough 1976). It is simultaneously constructed by and contributes to the construction of temporal politics and the distribution of social power in society (Banks 2010; Bhabha 1994). Culture comprises patterns of behaviour, values, beliefs, attitudes, modes of thinking and meaning making, customs, traditions and heritages, as well as other aspects of one's identity, experiences, perspectives and mode of being (Gay 2013). Cultural diversity is an encompassing aspect of one's cultural identity, which is influenced by but is not limited to one's designation of race and ethnicity, religious affiliation, family structure, home and community background, socioeconomic status, languages, values, norms, gender, sexual orientation, learning styles, exceptionalities, and other associated special needs and characteristics (Horowitz, Darling-Hammond and Bransford 2005; Lee 2010). Hence, I consider students' cultural diversity to include all the cultural experiences diverse students bring into schools. I recognize that cultural diversity and classroom practices for responding to cultural diversity are continually evolving even as I write this article.

I view teachers' perspectives as the world views or paradigms through which they see their world and make sense of it (Kuhn 1970). Perspectives inform one's thoughts and actions and, at the same time, are informed by one's understanding of one's world and how one gives meaning to it (Danesh 2011). Therefore, I acknowledge that the participating teachers' perspectives in this study were informed by their varied experiences in teaching science and mathematics to students of diverse cultural backgrounds in the contexts of their own cultural-diversity-rich classrooms. Additionally, their perspectives were shaped by their beliefs about teaching, science and mathematics, cultural diversity, and culturally responsive teaching.

Furthermore, considering the qualitative nature of this case study, I am aware of the complexities and associated power dynamics inherent in my engagement in this research as an insider/outsider. As Merriam et al (2001, 411) note, "The insider's strengths become an outsider's weaknesses and vice-versa." I had certain privileges, as well as limitations, while engaging with the teachers in this research. My more than 14 years of experience as a science teacher and a teacher educator, as well as my involvement as a parent in the schooling of my two daughters, who were students at the participating elementary and secondary schools, gave me the privilege of being an insider in this research. However, my involvement in doctoral studies (as well as teaching at a large research university in Canada), my upbringing as a heterosexual female, my prior educational experiences in India, my following of the Hindu religion and its vegetarian diet (and, thus, being unable to join teachers in their lunch), and my perceived status as a visible minority and an English as a second language (ESL) learner in Canadian educational settings made me an outsider in this research.

In this article, I focus on only one of the key themes that emerged from the larger case study and share teachers' perspectives on students' cultural diversity and the challenges they experienced with regard to gendered cultural practices in their science and mathematics classrooms. I first discuss the background, rationale and theoretical framework of the study. I then briefly share the methodology and methods. Next, I present the findings, which are followed by the discussion. I conclude by sharing the implications of the findings, as well as the limitations of this study.

## Background, Rationale and Theoretical Framework

The presence of more than 200 ethnic groups, with immigrants accounting for 20.6 per cent of the Canadian population, makes cultural diversity a central characteristic of life in Canada and multicultural education an essential requirement in Canadian classrooms (Freiler et al 2012; Statistics Canada 2013). Student populations are increasingly becoming culturally diverse in urban centres across Canada, and many teachers have identified dealing with cultural diversity as a key challenge in their classrooms (Canadian Teachers' Federation 2012). According to social capital theorist Putnam (2007), ethnocultural diversity reduces social solidarity as it produces fear and prevents people from associating with others. Hence, it is not surprising that student diversity produces significant concern among Canadian teachers, who find themselves in need of acquiring highly specific skills to address and manage diversity in their classrooms (Allan 2012).

Almost five decades after the nation's multiculturalism policy was established in 1971, the issues of educational equity and equality remain unresolved in Canada (Ghosh and Abdi 2013; Ghosh and Galczynski 2014). For instance, Aboriginal people raise concerns that the policy has ignored Canada's Indigenous population,[2] as it does not recognize their historical relationship with the land and their inherent treaty rights (Battiste 2009; Kovach 2009; Smith 2012), while the province of Quebec, in spite of the recognition of French as an official language, criticizes an "equalizing multiculturalism" for francophones' lost cultural hegemony (Moodley 1999, 140). Some European ethnics, especially Ukrainians, have questioned the success of a policy promoting cultural preservation without linguistic preservation (Moodley 1995). The increasing number of immigrants from visible minorities adds another dimension to Canadian multiculturalism and demands critical scrutiny of multiculturalism in the current Canadian context (Fleras 2009; Ghosh and Galczynski 2014). Rather than demanding a critical examination of dominant discourses that deeply influence school and classroom culture, this apolitical view of multicultural education neglects multiplicity of identities, presents culture as a static artifact and emphasizes difference (Ghosh and Abdi 2013).

Because it emphasizes knowing the Other only through "celebration" (Kirova 2008, 107) in the form of "holidays and heroes" (Nieto 1995, 196) and the four Ds—dialect, "dress, dance, diet" (Levin 2009, 124), such multicultural education is disconnected from the lives of students, teachers and the community (Nieto 2000, 9). The racism that can be embedded in schools (Ghosh 2008) perpetuates standardized whiteness as the norm and subjugates other cultures as inferior or primitive (Giroux 2001, 2005; hooks 1994). As a result, schools are increasingly becoming sites of isolation and social injustice because they are poorly equipped to deal with existing student diversity (Berry 2013; Levine-Rasky 2006; Zine 2006).

The lack of federal control over education and the absence of meaningful key directions has resulted in various manifestations of multicultural education across Canadian provinces, which often fail to ensure just and equitable multicultural education (Kirova 2008). As noted by Ghosh and Abdi (2013, 45), the clause for education in the 1971 multiculturalism policy is vague, as it "ignores ethnic, racial and socio-economic differences, depoliticizes culture, and legitimizes a Eurocentric view of the world." Stripped of their political content, both multicultural and intercultural education programs, as practised in anglophone and francophone parts of Canada, continue to reproduce dominant Eurocentric culture. Even though these programs are transitioning from accommodation to integration of Other(ed) cultural ways of knowing, the education in Canada is "still based on unequal relations between the anglophones and the allophones, and the francophones and the allophones" (p 137). For example, by framing Canadian national identity within the English–French bilingual language discourse, this multicultural policy officializes English and/or French as the sole mode of instruction in Canadian classrooms and, thereby, disenfranchises Other(ed) cultural languages and ways of knowing (Henry 2017). Complicating the notions of culture and cultural diversity in Canada, these contested interpretations of multiculturalism and multicultural education, along with the increasing diversity of the country, make it more imperative for teachers to be well prepared to serve their culturally diverse student populations.

Indeed, substantial efforts are needed to provide ongoing professional development and support to help prepare teachers to deal with the complexity of socio-political-cultural dynamics inherent in today's diversity-rich classrooms. Traditionally, few teacher education programs prepared teachers to teach effectively in diversity-rich classrooms (Cornbleth 2008; Ladson-Billings 2001; Obidah and Teel 2001; Teel and Obidah 2008). Tremendous ambiguity about multicultural education and how it should look in teacher education programs has resulted in theoretical, fragmented and contested discourse of multicultural education, which addresses diversity in a "tokenistic" way (Gill and Chalmers 2007, 552). Many of these programs have historically been suffused in deficit-based theories, which promote negative assumptions about diverse student populations by classifying students from non-dominant groups as genetically or culturally inferior (Bennett 2012; Egbo 2009; Nieto 2000). An unfortunate consequence of such teacher training is reflected in teachers' standardized norms of classroom participation and mainstream expectations, which are often incompatible with students' cultural understandings (Ghosh and Galczynski 2014; Lee 2001).

According to Howe (2014), while the core of teacher education programs in Canada has remained unaltered, a lot has changed in recent years. There has been a recent surge in adapting teacher education programs in North America to have a greater focus on diversity and multicultural education in their coursework for preservice teachers (Van Nuland 2011). However, how effectively such understandings are implicated in teaching practices has yet to be explored fully (Kahn, Lindstrom and Murray 2014). Moreover, while provincial governments usually provide financial support for teacher training, these supports are often provided at the graduate level (Darling-Hammond 2017). I wonder how many teachers get the opportunity to pursue graduate studies. Of the ten teacher participants in this study, only two had a master's degree in education.

One could argue that Canadian teachers have many opportunities for ongoing professional training, but increasing student diversity, along with shrinking budgets and the implementation of specific curricular initiatives without appropriate teacher support, puts teachers under increasing pressure to "make do with less while achieving more" (Howe 2014, 597). This is evident in the concerns of many British Columbia teachers, who feel overwhelmed and unprepared to integrate Aboriginal knowledges as per the redesigned British Columbia curriculum (Arnold 2018; British Columbia Teachers' Federation 2017).[3] Previous studies in other Canadian provinces, such as Manitoba and Saskatchewan (Kanu 2011), suggest that these situations are illustrative of quandaries faced by teachers in the wider Canadian context.

Despite the initiatives that have attempted to advance the indigenization and decolonization of curriculum in various Canadian provinces (Aikenhead 2006; Aikenhead and Elliott 2010; Aikenhead and Michell 2011; Nicol, Archibald and Baker 2010, 2013; Snively and Corsiglia 2001; Snively and Williams 2006), teachers have been largely unsuccessful in transforming the traditional curricular and pedagogical strategies of teaching science and mathematics into inclusive practices that are culturally responsive (Egbo 2009; Ghosh and Galczynski 2014; Kanu 2011). Consequently, students may not see any relevance in learning these subjects. Cultural conflicts between school science and mathematics and students' perceptions of these subjects may lead to student disengagement and even affect students' attitudes about pursuing further education and future careers in these areas (Bishop 1994; Ezeife 2002, 2003; Snively and Williams 2016).

Science in particular has continued to develop and perpetuate "scientific racism" (Hodson 1999, 230) by legitimizing discrimination and institutional injustices through stereotypical and prejudiced attitudes toward minority groups (Ghosh and Galczynski 2014). Since the 17th century, Eurocentric science, or Western modern science (WMS), has had a monopoly on what is legitimated as scientific knowledge and whose knowledge gets known (Aikenhead and Elliott 2010; Ezeife 2002). Claiming to be a neutral, or value-free, intellectual activity, WMS continues to generate Western colonial perspectives and, thereby, to devalue and disrespect the "cultural capital" (Giroux 2001, 239) and "funds of knowledge" (Nashon and Anderson 2013, 403) of many culturally diverse students (Ahlquist and Kailin 2003; Raisinghani 2016). An example of this can be seen in contemporary classrooms, where science is often taught as Eurocentric canonical knowledge devoid of any cultural connections (Aikenhead and Elliott 2010; Brown and Crippen 2017).

A significant consequence of such acultural practices is reflected in the continued low enrolment of Aboriginal students in higher-level science and mathematics courses in high school, and their subsequent low participation in related postsecondary programs and careers in Canada (British Columbia Ministry of Education 2016; Kim 2017; Snively and Williams 2006). According to Kim (2017), science remains "inaccessible and culturally irrelevant for most of the aboriginal students" in Canadian classrooms. Moreover, in many sociocultural contexts, WMS is continually translated and taught as a gendered practice of "white male science," which further contributes to discriminatory injustices toward minority groups (Snively and Corsiglia 2001, 9).

Research demonstrates that teachers' beliefs and attitudes about student diversity, as well as about specific subject areas, are inherently interlinked with their pedagogical practices and classroom environments (Gay 2010a, 2013; Kahn, Lindstrom and Murray 2014). Considering the important role teachers play in shaping the learning experiences of their students (Brown and Crippen 2017; Gay 2003), investigating teachers' perspectives in cultural-diversity-rich science and mathematics classrooms has been the key focus of this research.

Various studies have investigated teachers' perspectives on cultural diversity and culturally responsive teaching in different contexts (Atwater et al 2010; Daniel 2016; Howe 2014; Kahn, Lindstrom and Murray 2014; McGee 2014; Nieto 2003, 2005; Obidah and Teel 2001; Rasmussen and Bayer 2014; Sleeter 2001, 2008; Sleeter and Cornbleth 2011; Teel and Obidah 2008). However, most of these studies have focused on preservice teachers, and very few studies have reported on inservice teachers' perspectives and culturally responsive teaching in urban Canadian contexts (Henry 2017). More Canadian-based research is needed because there is a strong American influence on Canadian teacher education research and practice (Van Nuland 2011).

Hence, to add to this knowledge base, this study employed critical and transformational multicultural education perspectives (Keating 2007; Nieto 2000), as well as Gay's (2010b) notion of culturally responsive teaching, to investigate teachers' perspectives. To give authenticity and ownership of learning to culturally diverse learners, there is a need for comprehensive societal and educational change that can help eliminate the social, political and economic inequalities rampant in society at large (Gay 2010b; Ghosh and Abdi 2013; Nieto 2001). Critical multicultural education is one attempt to bring such changes by ensuring equity and excellence for all learners (Ghosh and Galczynski 2014;

May and Sleeter 2010). As a "mirror image" of critical pedagogy (Nieto 2000, 317), critical multicultural education questions these notions of "white supremacy" (Gillborn 2005, 490–92) and serves as a form of resistance to oppression, which is inherent in dominant modes of schooling (Nieto and Bode 2010). It emphasizes a structural analysis of institutionalized inequities by situating culture in the context of unequal power relations inherent in everyday lived interactions, and examining how these power relations contribute toward the dynamic evolution of culture and "a fluidity of identity depending on context" (Sleeter 2012, 572).

The connectionist approach of transformational multiculturalism takes these understandings further (Keating 2007). By exploring the reciprocal, uneven movements by which people, traditions and cultural knowledge are altered through their complicated interactions with each other, transformational multiculturalism recognizes that "[Canadian] culture has always been multicultural" (p 15). Translated into classroom instruction, transformational multiculturalism attempts to bring change through recursive transcultural dialogues that initiate individual self-reflection and communal communications that do not ignore the differences. These dialogues generate complex commonalities among differences to destabilize the rigid binary boundaries that divide us as Us/Others based on race, culture, ethnicity, gender, class, sexual identity, re(li)gion, (dis)ability and exceptionalities (Keating 2007).

Emphasizing that culture plays an important role in how students receive and interpret knowledge, culturally responsive teaching serves as a "power pedagogy" (Gay 2010b, 8). By recognizing students' cultural diversity as a strength and incorporating it into daily teaching, culturally responsive teaching validates cultural ways of knowing and makes learning relevant and meaningful for diverse students. The core elements of culturally responsive teaching—namely, the cultural knowledge base of teachers, cultural relevance, cultural caring and building a learning community, cross-cultural communications, and cultural congruity in classroom instruction—allow teachers to understand the dynamics of culture and diversity (Gay 2010b). Operationalizing these core elements in the contexts of their classrooms and communities may help teachers in promoting equity and excellence for all students, who are increasingly becoming culturally, ethnically, socially and linguistically diverse.

# Methodology and Methods

This qualitative case study (Stake 1995) employed a purposeful sampling technique (Merriam 1998) to recruit 10 teachers who were all involved in teaching science or mathematics to elementary and secondary students during the 2014/15 school year.

The teachers' self-reported teaching experience ranged from 5 to 30 years and their ages from 25 to 65 years. Out of these teachers, six were teaching at the elementary level, and the remaining four were secondary teachers. Seven of the teachers self-identified as female (four elementary and three secondary teachers), and the other three self-identified as male (two elementary and one secondary teacher). All the teachers had a bachelor's degree in education and provincial certification for teaching in British Columbia public schools. Among the elementary teachers, two female teachers also had a master's degree in education, and one male teacher had a diploma in education. Eight of the teachers acknowledged their white, Canadian identity. One of the remaining two teachers self-identified as an Indo-Canadian born in Canada, and the other teacher self-identified as a Chinese Canadian who immigrated to Canada in the early 2000s.

The average number of students in the elementary classrooms was 24–30, whereas all the secondary classrooms had 28–30 students. The teachers reported that students in their classrooms represented at least 10–12 nationalities, and more than half of those students spoke English as a second language. They reported that the socioeconomic status of their students varied, as some came from highly influential families who owned houses in the schools' neighbourhoods while many others were children of parents who were themselves students, studying at the nearby university.

Data for this study were collected by phenomenographic methods, primarily semistructured interviews with the teachers and field notes collected during informal classroom observations. The teachers were all interviewed twice—before and after four informal observations of their science and mathematics classrooms. The specific days for interviews and observations were determined based on each teacher's availability and preference.

The collected data were analyzed by transcribing recorded interviews and field notes to generate thick descriptions and identify emergent themes by reviewing transcripts for meaning units, and by examining the similarities and differences between teachers' experiences of cultural diversity (Collier-Reed and Ingerman 2013; Miles and Huberman 1994). Phenomenography acknowledges that a phenomenon can be experienced in a variety of ways and that people might make sense of the same phenomenon in distinctly different ways (Marton 1981, 1986). Using a phenomenographic approach allowed me to get the unique perspectives of these teachers, who might have experienced differently the phenomena of cultural diversity in the specific contexts of their own science and mathematics classrooms.

# Findings

During their interviews, the participating teachers identified student cultural diversity as both a strength and a challenge.[4] They acknowledged that cultural diversity helped them in promoting all students' learning in their science and mathematics classrooms and broadened their own cultural understanding. They also identified gendered cultural practices as a key challenge they experienced in their cultural-diversity-rich classrooms.

## Cultural Diversity Enables Collaborative Student Learning and Reflective Teaching

The teachers shared that they used students' diverse cultural backgrounds to invite multiple ways of knowing in their classrooms. They also considered students' cultural diversity as a criterion while forming student groups, as well as for enabling collaborative peer learning, in their science and mathematics classrooms. Many of them recognized cultural diversity as a "gift," as exhibited in John's statement:

> Having the diverse [student] population I feel can make the classroom a lot more exciting, but . . . sometimes the conversations we have [are] not all physics. . . . I do have people sharing their own experiences of culture. . . . Part of teaching in a classroom [is] to realize that you are not just teaching a subject; you are teaching a group of students who have lots of experiences to share . . . of learning in a different culture. . . . Cultural diversity is a gift, and sometimes you can find the correlations and links between [students'] cultural experiences and what you are teaching. (John, interview session 1)

John's efforts to acknowledge the cultural knowledges and ways of knowing of diverse students were also evident in his day-to-day teaching, as noted during my informal observations of his classroom. Following is a vignette of what I observed in one of his physics classes:

> After a brief greeting and collection of upcoming field trip forms, John asked students to begin working on their assigned experiments (which, I noticed, were related with series and parallel circuits, conservation of momentum and Archimedes' principle). The students started working in groups of four or five (it seems that the groups were preformed). John walked around and asked students probing questions and answered their questions if they had any.
>
> As he walked to the student group working on Archimedes' principle, he noticed that the students had eliminated their first reading while doing calculations. He said, "I learned something new! Can you tell me the reason why you did not want to use your first reading?" He listened carefully to their responses and asked them further questions to guide their thinking but did not directly point out that they were mistakenly committing a procedural error.
>
> Later, during the five-minute brief follow-up as the class finished, I asked John why, rather than pointing out to the students their mistake directly, he had spent more time in getting them to come to realize it. And he said that he wants to acknowledge students' prior understandings.
>
> "Sometimes, I just watch and wait to see why the students have performed this action. I want the students to explain the reason to me. They might have learned something differently in their culture, in their country previously or might have abstract ideas that they are not able to turn into concrete things. So, I often also try to group the students based on their abilities. The brightest students might not be apt in using hands-on, and there are students who are skilled in performing the practical tasks of the lab but struggle in connecting these with the abstract ideas." (field notes, John's Physics 11 class)

Thus, in addition to acknowledging students' prior cultural understandings in his teaching, John also tried to respond to student diversity by identifying the strengths of individual students and using those strengths to support their own and their peers' learning.

Similarly, Ashley shared how the different learning experiences of students from diverse cultural backgrounds helped promote collaborative learning in her Chemistry 11 classroom:

> Because you know all these different countries that the kids are coming from, their schooling is very different as far as what they are learning at different grade levels. So often in a class you'd get, for example, [the] kids who really excel in math so then when you are in chemistry and you are doing sort of like the math-focused part of chemistry, that's where those kids can now become helpers to other kids in class who haven't done that kind of math yet. So that's where the kids can start helping each other, because they had experiences of learning things at a different time. (Ashley, interview session 2)

In the same vein, Callum expressed how having culturally diverse students in his combined Grade 3/4 classroom had broadened his cultural understandings and helped him in not making stereotypical or generalized assumptions about other cultures:

> I see cultural diversity is a positive thing because it helps you to question things or challenge things. It's just easy to make assumptions about things when everybody thinks the same way. . . . When you see the kids in Asia all learning times tables in Grade 2, it makes you understand that it's not a hardship and it's very helpful. In every culture there is good and bad, and it helps you. If you only grew up in one culture, then you don't [understand other cultural perspectives]. It's very easy to just make assumptions and not understand. Assumptions like that's how it's done or that's the only right way or that's the best way of doing it. (Callum, interview session 2, part 2)

## Experiences of Confronting Gendered Cultural Practices

In contrast to the above instances, the teachers also shared situations where they found themselves challenged and their teaching practices questioned because of the diverse cultural backgrounds of their students. A key challenge experienced by these teachers was gendered cultural practices.

The perspectives shared by the participating teachers indicated how they had to deal with the gendered cultural practices brought into their science and mathematics classrooms by culturally diverse students. An example of such an experience was shared by Louise, who felt her authority as a teacher frequently questioned by a male student in her combined kindergarten and Grade 1 classroom:

> I am sensitive to gender as well. You know, I am not using phrases like "boys and girls" and, you know, making those differences so . . . . There is this student and his sister in my class. . . . I have seen [their] parents; they treat him like a "prince" (*making a hand gesture to indicate that the word* prince *is in quotation marks*). When they come to pick [up] their children after school, I have seen [them] always letting him take the front seat, and the sister never gets a chance. [In the classroom] I had to correct and tell this student, "I am your teacher here, and I am telling you that you are going to finish cleaning up your desk. You used colours to draw animals [in your science worksheet]. You have to do your part, not your sister." (Louise, interview session 1)

According to Louise, this male student expected his sister to clean up after him in the classroom because that was most likely what was encouraged in his home environment. Louise felt that this male student disregarded her instructions and did not respect her position as teacher, solely because she was female.

A situation encountered by Callum was much more complex. This teacher shared his dilemma of being in a difficult situation in which he had to teach a female student whose parents did not want her to be in a male teacher's classroom:

> I have one girl in my classroom, and her parents they never told me that it's culture. . . . They were upset that [their daughter] had a man teacher, and it's even worse if I touch. You know, when they solve a [math] problem, you just give a pat on their shoulder. And it's a way of having a positive contact with the kids. . . . But this girl had a taboo. She was always quiet, so I went near her desk and put my hand on her shoulder like this (*demonstrating the placement of his hand*) and asked if she need[ed] my help. And I touch kids sometimes in this way, right? I wish they had told me at the beginning of the year, so I would have known. The dad told me a couple of months earlier that they never wanted their daughter to be placed in a male teacher's classroom. . . . I [then] let her work alone. (Callum, interview session 1)

Meera, who taught at the secondary level, also experienced gendered cultural practices in her Grade 9 science classroom. One of her female students shared that she felt neglected and rejected in her home because, culturally, her family preferred male children. The following excerpt from Meera's interview relates what happened:

> We are learning about human embryology, artificial reproductive technologies and genetics. [The students] are very interested, and they want to know about all the different types of prenatal testing and . . ., you know, what if people are choosing not to have girls instead of boys? . . . One student in my class told [us during the class discussion that] her grandparents don't like her because she was a girl and her parents don't have any other kids, and they are always complaining about her being a girl and not being [a boy,] not keeping their family name. So that was something interesting that she told me. (Meera, interview session 2)

## Discussion

As evident in the findings, teachers described the cultural diversity of their student populations as both a strength and a challenge. The teachers also shared challenges associated with gendered cultural practices in their science and mathematics classrooms.

Interestingly, addressing the issue of cultural diversity has been an exclusive goal of multicultural education in Canada (Joshee et al 2016). By 2031, foreign-born people will make up 25–28 per cent of the total population, and more than 55 per cent of the people living in large cities in Canada will be either immigrants or Canadian-born children of immigrants (Morency, Malenfant and MacIsaac 2017). Canada's increasing ethnocultural diversity makes it imperative for teachers to be well prepared to serve their culturally diverse student populations.

Since the publication of Rosenthal and Jacobson's (1968, 1992) classic study *Pygmalion in the Classroom,* an extensive body of research has indicated that teachers can develop differential expectations of their students, which may lead to differential treatment (McKown and Weinstein 2002). Research suggests that teachers' beliefs and attitudes about various dimensions of their students' cultural diversity greatly influence their instructional behaviours and students' achievements (Gay 2010a; Rubie-Davies, Hattie and Hamilton 2006). Thus, the participating teachers' identification of cultural diversity as a strength and a challenge in this study has implications for their teaching and for their culturally diverse students' learning.

Students' ethnicity, race, socioeconomic status and gender, as well as their work habits and confidence (as perceived by teachers), serve as key variables that shape teachers' expectations regarding the intellectual performance of these students (Timmermans, de Boer and van der Werf 2016). Often translated into students' perception, appraisal and confirmation in the form of their classroom behaviours and achievements, these differing teacher expectations and treatments can differentially affect the members of different student groups and aggravate the achievement gaps for students from different cultural backgrounds by favouring dominant groups (Hughes, Gleason and Zhang 2005; McKown and Weinstein 2002). Hence, it is encouraging that the perspectives of most of the teachers in this study indicated that they held high expectations for all their students, regardless of cultural background. The teachers valued cultural diversity as a gift and acknowledged that having culturally diverse students in their classrooms created more opportunities for them to make learning science and mathematics more exciting.

The immigrant status of students is another key variable that affects teacher–student interactions. When it comes to nonimmigrant students, teachers tend to hold high expectations for students of higher socioeconomic status. Conversely, teachers' expectations of immigrant students seem to be low, regardless of socioeconomic status. This differing teacher expectation makes it harder for immigrant students to show their abilities and receive adequate encouragement and support from teachers (Tobisch and Dresel 2017). However, this did not seem to be the case in this study. The perspectives of the participating teachers indicated that although they were aware of the immigrant statuses and socioeconomic statuses of their students, these factors did not influence their teaching practices in their science and mathematics classrooms. As evident in the excerpts from the interviews with John and Ashley, these teachers seemed to be more inclined to acknowledge and consider the diversity of the prior learning experiences their culturally diverse students brought into their classrooms. The actions of these teachers, as indicated in the findings, demonstrated their willingness to broaden their cultural knowledge base and build cultural congruence in their science and mathematics classrooms, which are two of the core elements of culturally responsive teaching (Gay 2002, 2010b).

Additionally, the teachers strove to include cultural relevance, another core element of culturally responsive teaching, by connecting the learning of specific science and mathematics concepts with the diverse cultural experiences students brought with them. As reflected in the teachers' perspectives, having culturally diverse students with varied prior learning experiences helped the teachers create diverse collaborative learning groups in their science and mathematics classrooms. The teachers' efforts to recognize and value their diverse students' strengths and use those strengths to support students' learning reflected their cultural caring and respect for students' diversity (Nieto 2000; Nieto and Bode 2010). By creating opportunities for their students to work in strength-focused collaborative groups, these teachers tried to create communal learning spaces that were conducive for promoting learning among students from diverse cultural backgrounds (Gay 2010b). Facilitating students' learning in collaborative group settings may also enable transcultural dialogues that allow diverse students to see the connections among their differences (Keating 2007).

According to Gay (2003), the journey to become a culturally responsive educator begins by acknowledging one's own biases. As evident in the excerpt from Callum's interview, the participating teachers in this study were reflective about their own biases and stereotypical understandings. Their acknowledgement that having culturally diverse students in their classrooms helped them broaden their own cultural understandings demonstrated their critical consciousness, cultural sensibility, and personal and professional self-awareness (Gay 2010b).

However, it is important to mention that these were self-reported attitudes. As noted by van den Bergh et al (2010), there is no correlation between teachers' self-reported prejudiced attitude measures and their expectations and the achievements of culturally diverse students. The authors were able to explain the differing academic achievement of culturally diverse students through implicit measures of teachers' prejudice as manifested through their expectations. Thus, in spite of a self-reported awareness of their prejudices and biases, the teachers in this study may still have held implicit biases, which could be associated with the challenges of the gendered cultural practices they experienced in their diversity-rich classrooms.

Issues related to gendered social roles and gendered perceptions of identity resulting in differing teacher–student relationships and student achievement have been studied previously (Else-Quest, Mineo and Higgins 2013; Grant and Sleeter 2010; Riley 2014; Robinson-Cimpian et al 2014). The complexities inherent in differing cultural expectations regarding gendered social roles and expectations based on the gendered identities of culturally diverse students posed challenges for the teachers in their science and mathematics classrooms. As evident in the excerpt from Louise's interview, the participating teachers faced situations in which they had to correct the behaviour of male students in their classrooms and remind them that they had "to do [their] part" and not expect their sisters or other female students to clean up after them. Louise reported that because she was female, it was harder for her to maintain her authority as a teacher in her combined kindergarten and Grade 1 classroom. As postulated by Louise, this could have been because the students were from male-dominant cultures in which they had seen women and girls considered and treated as inferior in the home environment.

In other instances, it was the male teacher whose authority was questioned. In Callum's case, parents of a certain cultural background did not want their daughter to be taught by a male teacher. The specific incident Callum shared involved the issue of touch. Even though he tried to defend his placing his hand on the student's shoulder as his usual manner of encouraging students during his teaching, the situation was complex. Physical contact of any form between people of opposite genders (other than certain family members) is considered to involve sexual intentions in many cultures and is, therefore, socially unacceptable or even forbidden (Borkhetaria 2017; Shadia 2013). Moreover, in many societal contexts, the teacher is positioned as a "powerful agent of an oppressive bourgeois educational system and the children as oppressed innocents" (Phelan 1997, 79), and educational settings are singled out as possible spaces where child abuse is more likely to happen. Hence, often teachers are socially burdened with (re)defining their interactions with students to qualify certain actions as "appropriate and legitimate touching" (Johnson 1997, 109). Gendered cultural and social norms breed "moral panic" among teachers and force many teachers to adopt a "no touch" policy to avoid legal situations (p 106).

In this case, the teacher, Callum, retracted from having any one-on-one interactions with the student and decided to let her work on her math alone. Even though the student did not say anything directly to the teacher, the teacher's disconnection from the student (and the student's culture) was evident in his statement, "But this girl had a taboo. . . . I wish they had told me at the beginning of the year." The teacher's compliance with the parents' request and his subsequent abandonment of the student are problematic. One may see this strategy as the teacher's reluctance to support this student's learning in his mathematics classroom. This is unfortunate, as it may lead to differing teacher expectations, which, in turn, can negatively influence student interest and achievement in mathematics. Research suggests that students from academically stigmatized groups, including students from certain culturally diverse backgrounds, as well as girls, are more likely to be responsive to negative teacher expectations (McKown and Weinstein 2002).

Considering that, in this case, the teacher was a male teacher, one may wonder if the same concern would have been raised by the parents if the child were a boy and were tapped on the shoulder by a female teacher. This particular case also draws attention to the vulnerability and disempowerment of teachers, especially male and/or homosexual teachers, who often find themselves objects of suspicious gazes, parental distrust and threats of litigation because they are more likely to be perceived as being sexually dangerous to students (Tobin 1997). As mentioned previously, this threat of legal implications has forced teachers in many contexts to embrace a "no touch" policy (Johnson 1997). While such a policy may protect teachers from legal suits, the total absence of touch may affect the development of trusting adult–child relationships and "caring encounters" in the classroom, because tactile communication has been identified as a critical stimulation for healthy child development (Johnson 1997; Muir 2002).

Moreover, questioning the actions of male teachers indicates the social reality that the ethics of care is predominantly considered to have arisen from women's experiences (Noddings 1984), thus indicating that men in education have yet to establish their role as carers. According to Noddings (2012), care ethics is relational and evolves in the reciprocal acceptance and acknowledgement of an "act of care" between the "carer" and the "cared-for." Caring alone does not merit the role of carer, as caring relations are not established when the cared-for does not recognize and accept the caring given by the carer. Hence, in Callum's case, even though he attempted to justify his tapping a female student on the shoulder as an act of displaying his care, the absence of acknowledgement by the student and her parents of this touch as a caring attitude led to a discomfiting situation for the teacher and the student.

In the same vein, relational caring was absent in Louise's and Meera's actions. In her efforts to ensure gender equity by correcting the behaviour of her male student, Louise neglected to consider that her reprimands may have resulted in the student's disengagement. Many culturally diverse male students may not even understand how the same behaviours that are accepted and promoted in the home could put them at risk in the classroom. Similarly, while leading the discussion on prenatal testing in her Grade 9 science classroom, Meera failed to acknowledge and respond to the feelings of the female student who shared her story of being disliked by her grandparents because she was a girl. Meera considered the student's experience "interesting," but she did not use this opportunity to raise critical consciousness among her students about gender inequalities.

In such situations, should teachers just be attentive listeners, or should they do something more to support and build the self-esteem of their victimized students? Meera maintained her focus on discussing the science content and ignored the emotional experiences that were central to making the learning meaningful and relevant for students, as well as crucial for guiding their thinking toward the social injustices associated with gender inequity in many cultural contexts. The role of emotions in teaching, particularly in integrating social justice aspects, requires greater attention, as emotions influence how teachers communicate and empathize with their students in the teaching environment (Zembylas and McGlynn 2012). Discussing issues related to gender and sexual identity and to gender roles is difficult for teachers (Reygan and Francis 2015). For example, teachers are often unprepared to challenge bullying related to homophobia. They often avoid such issues because of experiencing negative emotions while discussing non-normative sexual and gender identities. Moreover, they may themselves hold gendered cultural beliefs, and unconsciously and unreflexively perpetuate heterosexism and homophobia in the classroom. By physically and pedagogically distancing themselves from students who hold non-normative identities, and by discouraging discussions about diverse sexualities and genders in their classrooms, teachers may be engaged in teaching a hidden curriculum that dehumanizes and marginalizes non-normative identities (Reygan and Francis 2015).

# Conclusion

The findings in this study indicate that while teaching science and mathematics in their cultural-diversity-rich elementary and secondary classrooms, these Canadian teachers attempted to invite students' cultural understandings and used those understandings in making these subjects comprehensible to their students. In addition, the teachers encountered many other complexities that culturally diverse students brought into their classrooms in the form of gendered cultural practices. In these situations, the teachers remained distanced and largely unresponsive in terms of their emotions, attitudes and beliefs regarding the diversity of gender roles and gendered cultural experiences of their culturally diverse students.

These findings call for promoting (trans-multi)cultural understandings among teachers (Raisinghani 2016). This could be done by supporting teachers in advancing their understandings of culturally responsive teaching, especially with regard to including social justice aspects in their science and mathematics teaching and responding to the gender (and sexual) diversity, gendered cultural identities and intersecting lived sociocultural experiences of their culturally diverse students. Further research exploring culturally diverse students' perspectives on their science and mathematics classrooms could provide another dimension in understanding the phenomena of cultural diversity and culturally responsive teaching.

While these findings are bounded by the specific contexts, temporal space and particularity of this case study, they may offer insights for teachers in other Canadian and international contexts that value multicultural and intercultural understandings. They may inform a framework for integrating (trans-multi)cultural education perspectives in teacher education and teachers' professional development programs on a consistent and strategic basis. These findings may also guide future research to further explore phenomena of cultural diversity and culturally responsive teaching in other disciplinary and socio-political-cultural contexts.

# Notes

1. All participating teachers in this study were involved in teaching science or mathematics at the elementary and secondary levels in two public schools in a large urban city in western Canada during the 2014/15 school year.

2. Following Battiste (2009), the term *Aboriginal* in this article refers to all Indigenous peoples of Canada, including First Nations, Inuit and Métis.

3. The participating teachers in this study also shared their concerns regarding inappropriate support and inadequate resources for successful integration of Aboriginal knowledges. This finding has been discussed in detail in another article.

4. The names of all participating teachers are pseudonyms.

# References


Ahlquist, R, and J Kailin. 2003. "Teaching Science from a Critical Multicultural Perspective." In *Multicultural Science Education: Theory, Practice, and Promise,* ed S M Hines, 37–53. New York: Lang.

Aikenhead, G S. 2006. "Towards Decolonizing the Pan-Canadian Science Framework." *Canadian Journal of Science, Mathematics and Technology Education* 6, no 4: 387–99.

Aikenhead, G S, and D Elliott. 2010. "An Emerging Decolonizing Science Education in Canada." *Canadian Journal of Science, Mathematics and Technology Education* 10, no 4: 321–38.

Aikenhead, G, and H Michell. 2011. *Bridging Cultures: Indigenous and Scientific Ways of Knowing Nature.* Toronto: Pearson Canada.

Allan, J. 2012. "Teacher Competences for Diversity: Becoming Ethical and Responsible." In *Interculturalism, Education and Dialogue,* ed T Besley and M A Peters, 201–11. New York: Lang.

Arnold, C. 2018. "My Question to the Minister: Is the Government Prepared to 'Go Deep Enough' in Committing to Education for Reconciliation in BC Schools?" *Teacher Magazine* 30, no 3 (January/February): 21. Also available at www.bctf.ca/publications/TeacherArticle.aspx?id=48755 (accessed July 17, 2018).

Atwater, M M, T B Freeman, M B Butler and J Draper-Morris. 2010. "A Case Study of Science Teacher Candidates' Understandings and Actions Related to the Culturally Responsive Teaching of 'Other' Students." *International Journal of Environmental and Science Education* 5, no 3: 287–318.

Banks, J A. 2010. "Multicultural Education: Characteristics and Goals." In *Multicultural Education: Issues and Perspectives,* 7th ed, ed J A Banks and C A M Banks, 3–30. Hoboken, NJ: Wiley.

Battiste, M. 2009. "Cognitive Assimilation, Culturalism, and Diversity: Evolving Educational Discourses for First Nations Students." In *The Challenges of Student Diversity in Canadian Schools: Essays on Building a Better Future for Exceptional Children,* ed J Lupart, A McKeough, M Porath, L Phillips and V Timmons, 189–222. Markham, Ont: Fitzhenry & Whiteside.

Bennett, C I. 2012. "Multicultural Teacher Education." In *Encyclopedia of Diversity in Education,* ed J A Banks, 1565–69. Thousand Oaks, Calif: SAGE.

Berry, J W. 2013. "Research on Multiculturalism in Canada." *International Journal of Intercultural Relations* 37, no 6 (November): 663–75.

Bhabha, H K. 1994. *The Location of Culture.* New York: Routledge.

Bishop, A J. 1994. "Cultural Conflicts in Mathematics Education: Developing a Research Agenda." *For the Learning of Mathematics* 14, no 2 (June): 15–18.

Borkhetaria, B. 2017. "Why Not Touch Each Other?" *Daily Princetonian,* March 28. Also available at www.dailyprincetonian.com/article/2017/03/why-not-touch-each-other (accessed July 17, 2018).

British Columbia Ministry of Education. 2016. *Aboriginal Report 2011/12–2015/16: How Are We Doing?* Victoria, BC: British Columbia Ministry of Education. Also available at www.bced.gov.bc.ca/reports/pdfs/ab_hawd/Public.pdf (accessed July 17, 2018).

British Columbia Teachers' Federation (BCTF). 2017. *2017 BCTF Curriculum Change and Implementation Survey.* Vancouver: BCTF. Also available at https://bctf.ca/uploadedFiles/Public/Issues/Curriculum/Survey/2017Survey.pdf (accessed July 17, 2018).

Brown, J C, and K J Crippen. 2017. "The Knowledge and Practices of High School Science Teachers in Pursuit of Cultural Responsiveness." *Science Education* 101, no 1 (January): 99–133.

Canadian Teachers' Federation. 2012. "National Teacher Survey Shows Diversity as a Key Challenge in Canadian Classrooms." News release. January 31. www.ctf-fce.ca/en/news/Pages/default.aspx?newsid=1983984744&year=2012 (accessed July 18, 2018).

Collier-Reed, B, and Å Ingerman. 2013. "Phenomenography: From Critical Aspects to Knowledge Claim." In *Theory and Method in Higher Education Research,* vol 9 of International Perspectives on Higher Education Research, ed J Huisman and M Tight, 243–60. Bingley, UK: Emerald.

Cornbleth, C. 2008. *Diversity and the New Teacher: Learning from Experience in Urban Schools.* New York: Teachers College Press.

Danesh, H B, ed. 2011. *Education for Peace Reader.* Education for Peace Integrative Curriculum Series 4. Victoria, BC: EFP Press. Also available at http://efpinternational.org/wp-content/uploads/2011/11/efp_reader.pdf (accessed July 17, 2018).

Daniel, S M. 2016. "Grappling with Culturally Responsive Pedagogy: A Study of Elementary-Level Teacher Candidates' Learning Across Practicum and Diversity Coursework Experiences." *The Urban Review* 48, no 4 (November): 579–600.

Darling-Hammond, L. 2017. "Teacher Education Around the World: What Can We Learn from International Practice?" *European Journal of Teacher Education* 40, no 3: 291–309.

Egbo, B. 2009. *Teaching for Diversity in Canadian Schools.* Toronto: Pearson Prentice Hall.

Else-Quest, N M, C C Mineo and A Higgins. 2013. "Math and Science Attitudes and Achievement at the Intersection of Gender and Ethnicity." *Psychology of Women Quarterly* 37, no 3 (September): 293–309.

Ezeife, A N. 2002. "Mathematics and Culture Nexus: The Interactions of Culture and Mathematics in an Aboriginal Classroom." *International Education Journal* 3, no 3: 176–87. Also available at https://ehlt.flinders.edu.au/education/iej/articles/v3n3/Ezeife/paper.pdf (accessed July 17, 2018).

———. 2003. "The Pervading Influence of Cultural Border Crossing and Collateral Learning on the Learner of Science and Mathematics." *Canadian Journal of Native Education* 27, no 2: 179–94.

Fleras, A. 2009. *The Politics of Multiculturalism: Multicultural Governance in Comparative Perspective.* New York: Palgrave Macmillan.

Freiler, C, S Hurley, R Canuel, B McGahey, B Froese-Germain and R Riel. 2012. *Teaching the Way We Aspire to Teach: Now and in the Future: Teachers' Vision for Teaching and Learning in Canada's Public Schools.* Toronto and Ottawa: Canadian Education Association (CEA) and Canadian Teachers' Federation (CTF). Also available at www.ctf-fce.ca/Research-Library/AspirationReportFullVersion_EN.pdf (accessed July 17, 2018).

Gay, G. 2002. "Preparing for Culturally Responsive Teaching." *Journal of Teacher Education* 53, no 2 (March/April): 106–16.

———, ed. 2003. *Becoming Multicultural Educators: Personal Journey Toward Professional Agency.* San Francisco: Jossey-Bass.

———. 2010a. "Acting on Beliefs in Teacher Education for Cultural Diversity." *Journal of Teacher Education* 61, nos 1–2 (January/February): 143–52.

———. 2010b. *Culturally Responsive Teaching: Theory, Research, and Practice.* 2nd ed. New York: Teachers College Press.

———. 2013. "Teaching To and Through Cultural Diversity." *Curriculum Inquiry* 43, no 1 (January): 48–70.

Ghosh, R. 2008. "Racism: A Hidden Curriculum." *Education Canada* 48, no 4 (Fall): 26–29. Also available at www.edcan.ca/wp-content/uploads/EdCan-2008-v48-n4-Ghosh.pdf (accessed July 17, 2018).

Ghosh, R, and A A Abdi. 2013. *Education and the Politics of Difference: Select Canadian Perspectives.* 2nd ed. Toronto: Canadian Scholars' Press.

Ghosh, R, and M Galczynski. 2014. *Redefining Multicultural Education: Inclusion and the Right to Be Different.* 3rd ed. Toronto: Canadian Scholars' Press.

Gill, H, and G Chalmers. 2007. "Documenting Diversity: An Early Portrait of a Collaborative Teacher Education Initiative." *International Journal of Inclusive Education* 11, nos 5–6: 551–70.

Gillborn, D. 2005. "Education Policy as an Act of White Supremacy: Whiteness, Critical Race Theory and Education Reform." *Journal of Education Policy* 20, no 4: 485–505.

Giroux, H A. 2001. *Theory and Resistance in Education: Towards a Pedagogy for the Opposition.* Rev ed. Westport, Conn: Bergin & Garvey.

———. 2005. *Border Crossings: Cultural Workers and the Politics of Education.* 2nd ed. New York: Routledge.

Goodenough, W H. 1976. "Multiculturalism as the Normal Human Experience." *Anthropology and Education Quarterly* 7, no 4 (November): 4–7.

Grant, C A, and C E Sleeter. 2010. "Race, Class, Gender, and Disability in the Classroom." In *Multicultural Education: Issues and Perspectives,* 7th ed, ed J A Banks and C A M Banks, 59–80. Hoboken, NJ: Wiley.

Henry, A. 2017. "Culturally Relevant Pedagogies: Possibilities and Challenges for African Canadian Children." *Teachers College Record* 119, no 1: 1–27.

Hodson, D. 1999. "Critical Multiculturalism in Science and Technology Education." In *Critical Multiculturalism: Rethinking Multicultural and Antiracist Education,* ed S May, 216–44. Abingdon, UK: RoutledgeFalmer.

hooks, b. 1994. *Teaching to Transgress: Education as the Practice of Freedom.* New York: Routledge.

Horowitz, F D, L Darling-Hammond and J Bransford. 2005. "Educating Teachers for Developmentally Appropriate Practice." In *Preparing Teachers for a Changing World: What Teachers Should Learn and Be Able to Do,* ed L Darling-Hammond and J Bransford, 88–125. San Francisco: Jossey-Bass.

Howe, E R. 2014. "A Narrative of Teacher Education in Canada: Multiculturalism, Technology, Bridging Theory and Practice." *Journal of Education for Teaching* 40, no 5: 588–99.

Hughes, J N, K A Gleason and D Zhang. 2005. "Relationship Influences on Teachers' Perceptions of Academic Competence in Academically At-Risk Minority and Majority First Grade Students." *Journal of School Psychology* 43, no 4: 303–20.

Johnson, R. 1997. "The 'No Touch' Policy." In *Making a Place for Pleasure in Early Childhood Education,* ed J Tobin, 101–18. New Haven, Conn: Yale University Press.

Joshee, R, C Peck, L A Thompson, O Chareka and A Sears. 2016. "Multicultural Education, Diversity, and Citizenship in Canada." In *Learning from Difference: Comparative Accounts of Multicultural Education,* ed J L Bianco and A Bal, 35–50. Cham, Switzerland: Springer.

Kahn, L G, L Lindstrom and C Murray. 2014. "Factors Contributing to Preservice Teachers' Beliefs About Diversity." *Teacher Education Quarterly* 41, no 4 (Fall): 53–70.

Kanu, Y. 2011. *Integrating Aboriginal Perspectives into the School Curriculum: Purposes, Possibilities, and Challenges.* Toronto: University of Toronto Press.

Keating, A. 2007. *Teaching Transformation: Transcultural Classroom Dialogues.* New York: Palgrave Macmillan.

Kim, M. 2017. "Indigenous Knowledge in Canadian Science Curricula: Cases from Western Canada." *Cultural Studies of Science Education* 12, no 3 (September): 605–13.

Kirova, A. 2008. "Critical and Emerging Discourses in Multicultural Education Literature: A Review." *Canadian Ethnic Studies* 40, no 1: 101–24.

Kovach, M. 2009. *Indigenous Methodologies: Characteristics, Conversations, and Contexts.* Toronto: University of Toronto Press.

Kuhn, T S. 1970. *The Structure of Scientific Revolutions.* 2nd rev ed. Chicago: University of Chicago Press.

Ladson-Billings, G. 2001. *Crossing Over to Canaan: The Journey of New Teachers in Diverse Classrooms.* San Francisco: Jossey-Bass.

Lee, O. 2001. "Culture and Language in Science Education: What Do We Know and What Do We Need to Know?" *Journal of Research in Science Teaching* 38, no 5 (May): 499–501.

Lee, S. 2010. "Reflect on Your History: An Early Childhood Education Teacher Examines Her Biases." *Multicultural Education* 17, no 4 (Summer): 25–30.

Levin, B. 2009. "The Politics of Diversity." In *The Challenges of Student Diversity in Canadian Schools: Essays on Building a Better Future for Exceptional Children,* ed J Lupart, A McKeough, M Porath, L Phillips and V Timmons, 105–27. Markham, Ont: Fitzhenry & Whiteside.

Levine-Rasky, C. 2006. "Discontinuities of Multiculturalism." *Canadian Ethnic Studies* 38, no 3 (Fall): 87–104.

Marton, F. 1981. "Phenomenography—Describing Conceptions of the World Around Us." *Instructional Science* 10, no 2 (July): 177–200.

———. 1986. "Phenomenography—A Research Approach to Investigating Different Understandings of Reality." *Journal of Thought* 21, no 3 (Fall): 28–49.

May, S, and C E Sleeter. 2010. "Introduction: Critical Multiculturalism: Theory and Praxis." In *Critical Multiculturalism: Theory and Praxis,* ed S May and C E Sleeter, 1–16. New York: Routledge.

McGee, E O. 2014. "When It Comes to the Mathematics Experiences of Black Pre-Service Teachers . . . Race Matters." *Teachers College Record* 116, no 6: 1–50.

McKown, C, and R S Weinstein. 2002. "Modeling the Role of Child Ethnicity and Gender in Children's Differential Response to Teacher Expectations." *Journal of Applied Social Psychology* 32, no 1 (January): 159–84.

Merriam, S B. 1998. *Qualitative Research and Case Study Applications in Education.* San Francisco: Jossey-Bass.

Merriam, S B, J Johnson-Bailey, M-Y Lee, Y Kee, G Ntseane and M Muhamad. 2001. "Power and Positionality: Negotiating Insider/Outsider Status Within and Across Cultures." *International Journal of Lifelong Education* 20, no 5: 405–16.

Miles, M B, and A M Huberman. 1994. *Qualitative Data Analysis: An Expanded Sourcebook.* 2nd ed. Thousand Oaks, Calif: SAGE.

Moodley, K A. 1995. "Multicultural Education in Canada: Historical Development and Current Status." In *Handbook of Research on Multicultural Education,* ed J A Banks and C A M Banks, 801–20. New York: Simon & Schuster.

———. 1999. "Antiracist Education Through Political Literacy: The Case of Canada." In *Critical Multiculturalism: Rethinking Multicultural and Antiracist Education,* ed S May, 138–52. Abingdon, UK: RoutledgeFalmer.

Morency, J-D, É C Malenfant and S MacIsaac. 2017. *Immigration and Diversity: Population Projections for Canada and Its Regions, 2011 to 2036.* Ottawa: Statistics Canada. Also available at www150.statcan.gc.ca/n1/pub/91-551-x/91-551-x2017001-eng.htm (accessed July 18, 2018).

Muir, D W. 2002. "Adult Communications with Infants Through Touch: The Forgotten Sense." *Human Development* 45, no 2: 95–99.

Nashon, S M, and D Anderson. 2013. "Interpreting Student Views of Learning Experiences in a Contextualized Science Discourse in Kenya." *Journal of Research in Science Teaching* 50, no 4 (April): 381–407.

Nicol, C, J Archibald and J Baker. 2010. *Investigating Culturally Responsive Mathematics Education.* Toronto: Canadian Council on Learning. Also available at www.researchgate.net/profile/Jeff_Baker8/publication/267954541_Investigating_Culturally_Responsive_Mathematics_Education/links/54b91f1d0cf269d8cbf7324c/Investigating-Culturally-Responsive-Mathematics-Education.pdf (accessed July 18, 2018).

———. 2013. "Designing a Model of Culturally Responsive Mathematics Education: Place, Relationships and Storywork." *Mathematics Education Research Journal* 25, no 1 (March): 73–89.

Nieto, S. 1995. "From Brown Heroes and Holidays to Assimilationist Agendas: Reconsidering the Critiques of Multicultural Education." In *Multicultural Education, Critical Pedagogy, and the Politics of Difference,* ed C E Sleeter and P L McLaren, 191–220. Albany, NY: State University of New York Press.

———. 2000. *Affirming Diversity: The Sociopolitical Context of Multicultural Education.* New York: Longman.

———. 2001. "Critical Pedagogy, Empowerment and Learning." In *Developing Pedagogy: Researching Practice,* ed J Collins, K Insley and J Soler, 39–49. London: Chapman.

———. 2003. *What Keeps Teachers Going?* New York: Teachers College Press.

———. 2005. *Why We Teach.* New York: Teachers College Press.

Nieto, S, and P Bode. 2010. "School Reform and Student Learning: A Multicultural Perspective." In *Multicultural Education: Issues and Perspectives,* 7th ed, ed J A Banks and C A M Banks, 395–415. Hoboken, NJ: Wiley.

Noddings, N. 1984. *Caring: A Feminine Approach to Ethics and Moral Education.* Berkeley, Calif: University of California Press.

———. 2012. "The Language of Care Ethics." *Knowledge Quest* 40, no 5 (May–June): 52–56.

Obidah, J E, and K M Teel. 2001. *Because of the Kids: Facing Racial and Cultural Differences in Schools.* New York: Teachers College Press.

Phelan, A M. 1997. "Classroom Management and the Erasure of Teacher Desire." In *Making a Place for Pleasure in Early Childhood Education,* ed J Tobin, 76–100. New Haven, Conn: Yale University Press.

Putnam, R D. 2007. "*E Pluribus Unum:* Diversity and Community in the Twenty-First Century: The 2006 Johan Skytte Prize Lecture." *Scandinavian Political Studies* 30, no 2 (June): 137–74.

Raisinghani, L. 2016. "(Re)searching (Trans-Multi)Culturally Responsive Curricular Conversations." *Journal of the Canadian Association for Curriculum Studies* 14, no 1: 182–98. Also available at https://jcacs.journals.yorku.ca/index.php/jcacs/article/view/40310/36172 (accessed July 17, 2018).

Rasmussen, J, and M Bayer. 2014. "Comparative Study of Teaching Content in Teacher Education Programmes in Canada, Denmark, Finland and Singapore." *Journal of Curriculum Studies* 46, no 6: 798–818.

Reygan, F, and D Francis. 2015. "Emotions and Pedagogies of Discomfort: Teachers' Responses to Sexual and Gender Diversity in the Free State, South Africa." *Education as Change* 19, no 1: 101–19.

Riley, T. 2014. "Boys Are Like Puppies, Girls Aim to Please: How Teachers' Gender Stereotypes May Influence Student Placement Decisions and Classroom Teaching." *Alberta Journal of Educational Research* 60, no 1 (Spring): 1–21. Also available at https://ajer.journalhosting.ucalgary.ca/index.php/ajer/article/view/1166/1143 (accessed July 18, 2018).

Robinson-Cimpian, J P, S T Lubienski, C M Ganley and Y Copur-Gencturk. 2014. "Teachers' Perceptions of Students' Mathematics Proficiency May Exacerbate Early Gender Gaps in Achievement." *Developmental Psychology* 50, no 4 (April): 1262–81.

Rosenthal, R, and L Jacobson. 1968. *Pygmalion in the Classroom: Teacher Expectation and Pupils' Intellectual Development.* New York: Holt, Rinehart & Winston.

———. 1992. *Pygmalion in the Classroom: Teacher Expectation and Pupils' Intellectual Development.* Exp ed. New York: Irvington.

Rubie-Davies, C, J Hattie and R Hamilton. 2006. "Expecting the Best for Students: Teacher Expectations and Academic Outcomes." *British Journal of Educational Psychology* 76, no 3 (September): 429–44.

Shadia, M. 2013. "Touching Opposite Gender May or May Not Be Improper." *Orange County Register,* April 8. www.ocregister.com/2013/04/08/shadia-touching-opposite-gender-may-or-may-not-be-improper/ (accessed July 18, 2018).

Sleeter, C E. 2001. "Preparing Teachers for Culturally Diverse Schools: Research and the Overwhelming Presence of Whiteness." *Journal of Teacher Education* 52, no 2 (March): 94–106.

———. 2008. "Learning to Become a Racially and Culturally Competent Ally." In *Building Racial and Cultural Competence* *in the Classroom: Strategies from Urban Educators,* ed K M Teel and J E Obidah, 82–96. New York: Teachers College Press.

———. 2012. "Confronting the Marginalization of Culturally Responsive Pedagogy." *Urban Education* 47, no 3 (May): 562–84.

Sleeter, C E, and C Cornbleth, eds. 2011. *Teaching with Vision: Culturally Responsive Teaching in Standards-Based Classrooms.* New York: Teachers College Press.

Smith, L T. 2012. *Decolonizing Methodologies: Research and Indigenous Peoples.* 2nd ed. New York: Zed Books.

Snively, G, and J Corsiglia. 2001. "Discovering Indigenous Science: Implications for Science Education." *Science Education* 85, no 1 (January): 6–34.

Snively, G, and L Williams. 2006. "The Aboriginal Knowledge and Science Education Research Project." *Canadian Journal of Native Education* 29, no 2: 229–44.

———. 2016. "Why Transforming the Science Curriculum Is Necessary for Aboriginal Students." In *Knowing Home: Braiding Indigenous Science with Western Science,* ed G Snively and W L Williams, 13–34. Victoria, BC: University of Victoria. Also available at https://dspace.library.uvic.ca/bitstream/handle/1828/7821/Ch%202_Knowing%20Home.pdf?sequence=5&isAllowed=y (accessed July 18, 2018).

Stake, R E. 1995. *The Art of Case Study Research.* Thousand Oaks, Calif: SAGE.

Statistics Canada. 2013. "2011 National Household Survey: Immigration, Place of Birth, Citizenship, Ethnic Origin, Visible Minorities, Language and Religion." *The Daily,* May 8. www.statcan.gc.ca/daily-quotidien/130508/dq130508b-eng.htm (accessed July 18, 2018).

Teel, K M, and J E Obidah. 2008. *Building Racial and Cultural Competence in the Classroom: Strategies from Urban Educators.* New York: Teachers College Press.

Timmermans, A C, H de Boer and M P C van der Werf. 2016. "An Investigation of the Relationship Between Teachers' Expectations and Teachers' Perceptions of Student Attributes." *Social Psychology of Education* 19, no 2 (June): 217–40.

Tobin, J. 1997. "Playing Doctor in Two Cultures: The United States and Ireland." In *Making a Place for Pleasure in Early Childhood Education,* ed J Tobin, 119–58. New Haven, Conn: Yale University Press.

Tobisch, A, and M Dresel. 2017. "Negatively or Positively Biased? Dependencies of Teachers' Judgments and Expectations Based on Students' Ethnic and Social Backgrounds." *Social Psychology of Education* 20, no 4 (December): 731–52.

van den Bergh, L, E Denessen, L Hornstra, M Voeten and R W Holland. 2010. "The Implicit Prejudiced Attitudes of Teachers: Relations to Teacher Expectations and the Ethnic Achievement Gap." *American Educational Research Journal* 47, no 2 (June): 497–527.

Van Nuland, S. 2011. "Teacher Education in Canada." *Journal of Education for Teaching* 37, no 4: 409–21.

Zembylas, M, and C McGlynn. 2012. "Discomforting Pedagogies: Emotional Tensions, Ethical Dilemmas and Transformative Possibilities." *British Educational Research Journal* 38, no 1: 41–59.

Zine, J. 2006. "Unveiled Sentiments: Gendered Islamophobia and Experiences of Veiling Among Muslim Girls in a Canadian Islamic School." *Equity and Excellence in Education* 39, no 3: 239–52.

# The DRiVe Inquiry Framework

*Erica Alexander, Richard Pardo, Susan Lindsay and Carol Rees*

### *Abstract*

This article describes the DRiVe (demonstrate, replicate, investigate, variate, evaluate) Inquiry Framework, which provides teachers with specific detailed strategies and graphic organizers to support them in developing their science inquiry practices and in shifting to more open-ended science inquiry. Designed by teachers for teachers, the DRiVe Inquiry Framework has been implemented extensively in classrooms across Canada. This article takes readers through the details of using the framework in a Grade 7/8 combined class in which students tested pop bottle water filters. The part of the activity this article focuses on used the following science practices: asking questions; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating and communicating information.

## Introduction from Ms A

In classrooms across Canada for the past decade or more, within the confines of big ideas in each content area of science, teachers have been encouraged to support their students in engaging in practices of scientific inquiry and engineering that are more open-ended (Alberta Education 1996; British Columbia Ministry of Education 2013; Ontario Ministry of Education 2007). The aim is to encourage students to work collaboratively to develop their own questions and potential solutions to problems, to conduct scientific investigations or technological trials, and to come up with answers or solutions they can defend (Council of Ministers of Education, Canada 2013).

However, it was not until 2011 that I (Ms A) began implementing opportunities for my students to engage in this more open-ended style of scientific inquiry and technological problem solving (Bybee 2011), with my Grade 7/8 combined class. We had always done lots of hands-on science and technology, but I had used a teacher-directed or confirmation style (Bell, Smetana and Binns 2005). In other words, I chose the question to be investigated or the technological problem to be solved, I gave the students the procedure to follow, and the students worked to come up with an answer or a solution that I already knew.

My concern about moving to a more open-ended style for hands-on activities was that I could not see how to implement it successfully with my students. I worked at a school where students had many problems to deal with in real life. I could see that most of them had not yet developed the kind of work skills they would need in order to make use of the opportunities for independent learning that the more open-ended style promoted. I could not see how to manage the transition to the more open-ended style without creating a free-for-all that could result in unsafe situations.

In 2011, I signed up for a series of professional development workshops offered by science curriculum coordinators in my school district. It was this workshop series that turned my classroom practice around. Workshop participants were provided with concrete guidelines, strategies and graphic organizers that we could use with our classes. We took four workshops together over a period of three months. Through a process of practice, trial and error, and discussion, we learned how to organize and guide our classes toward the more open-ended style of science investigation and technological problem solving that we were aiming for. I have written this article along with the curriculum coordinators who ran the workshops and supported me in the classroom, as well as with a researcher who observed my classes, so that I can pass along some of this learning.

In this article, we describe how teachers can use the materials from the workshops (framework, strategies and graphic organizers) to move their classes from confirmation to more open-ended science inquiry. The framework has been developed from an earlier version

(Pardo and Parker 2010) and is now called the DRiVe Inquiry Framework. Here, we share a specific example from my Grade 7/8 class in which my students constructed pop bottle water filters as part of a unit on water. The part of the activity we will focus on used the following science practices:

- asking questions;
- planning and carrying out investigations;
- analyzing and interpreting data;
- using mathematics and computational thinking;
- constructing explanations;
- engaging in argument from evidence; and
- obtaining, evaluating and communicating information.

## The DRiVe Inquiry Framework

DRiVe is an acronym that incorporates the following phases of inquiry:

- *D* stands for *demonstrate*. This phase allows the teacher to demonstrate a procedure, so that students acquire the practical skills, tools and safe practices that are important for the particular activity in the specific area of science or technology that is the focus.
- *R* stands for *replicate*. In this phase, students reproduce the teacher's demonstration in an attempt to confirm the teacher's results.
- *i* stands for *investigate*. The lowercase *i* denotes that this phase can happen anywhere in the DRiVe sequence, depending on the needs of the students. The teacher provides access to resources for students to build their background knowledge of the essential concepts and skills at just the right time.
- *V* stands for *variate*. In this phase, students develop testable questions that are the jumping-off point for their own investigations that stem from the teacher's demonstration.
- *e* stands for *evaluate*. The lowercase *e* denotes that evaluation takes place throughout with formative assessment for learning. The final product of the activities is evaluated as summative assessment of learning.

Table 1 outlines the phases of the DRiVe Inquiry Framework.

## The Inquiry Activity

### Demonstrate Phase

In the demonstrate phase, Ms A builds the pop bottle water filter. First, she takes a retort stand and fixes a ring in place. After cutting a pop bottle in half, she places the top of the bottle upside down in the ring. She then adds a coffee filter. She measures out the required amounts of clean sand and stones and adds them in order. She places a beaker beneath the

**Table 1.** Phases of the DRiVe Inquiry Framework

| | Description | Inquiry level |
|---|---|---|
| Demonstrate (D) | Teacher models investigation behaviour and the desired outcome, and specifies the task (diagnostic assessment) | |
| Replicate (R) | Students reproduce the teacher's investigation to verify skills or to accomplish the task (diagnostic—formative assessment) | Confirmation |
| Investigate (i) | Teachers and students gain further knowledge they might need (formative assessment) | |
| Variate (V) | Students investigate a testable question they developed (formative assessment) | Open |
| Evaluate (e) | Formative assessment for learning—teacher, peer and self—in all preceding activities<br>Summative assessment of learning—using criteria for success | |

open end of the bottle and pours tap water through the bottle. Finally, she pours in the pond water to be cleaned. The water passes through the filter and collects in the beaker.

During this demonstration, students take notes and ask clarification questions. Here is an example of a student's question and the teacher's response:

Student. What's one of those . . . ? What's that called again?

Ms A. What's which called? (*Points to stand.*) This part? (*Points to ring.*) Or this part?

Student. The circle part.

Ms A. This is called a ring. OK?

In the second part of the demonstrate phase, Ms A prompts the students to look at their notes and tell her what they have observed her doing and what happened to the pond water that she poured through the filter. She writes each step that students tell her on a separate sticky note—pink for what the scientist did and green for what happened to the pond water. She attaches the sticky notes to Poster 1 (see Figure 1).

Below is an example of an exchange between Ms A and a student about what she (the scientist) did:

Ms A. And then what did I do? After I touched the retort stand, what did I have to do?

Student. Put in the ring clamp. I added a ring clamp good (*writing this step on a pink sticky note and attaching it to the poster*).

As the class goes through this recounting, students make any changes they need to their notes so that by the end they have a procedure to follow for the replicate phase.

## Replicate Phase

Ms A introduces the replicate phase of the pop bottle water filter activity as follows:

Ms A. I now have a control. This is what mine looks like (*holding up the filtered water sample*). My challenge to you is to make a filter that produces this.

In the replicate phase, students work in pairs, using their notes as their procedure and replicating step by step and as closely as possible what Ms A did in the demonstrate phase when she built her pop bottle water filter. When they have their filters built, they pour in the pond water sample and collect the filtered water.

Ms A asks students to place their samples under the document reader so that everyone can see all the samples together. As a whole class, they discuss what aspect of the samples they can measure to compare

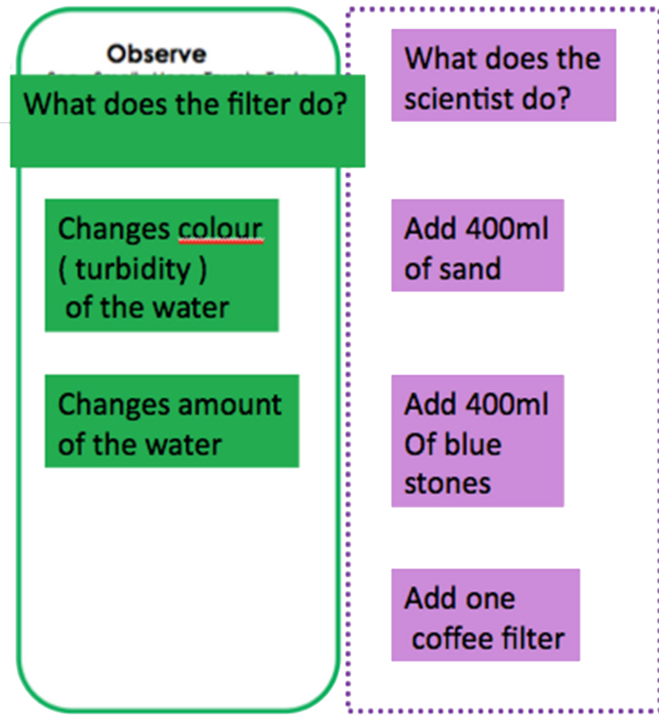


Figure 1. Poster 1, with students' observations on sticky notes.

them. A student suggests arranging the samples according to colour, and the class does so. Ms A then introduces the class to the concept of turbidity and explains that it can be measured using a turbidity probe.

## Investigate Phase

Ms A arranges for Mr P, a science curriculum coordinator, to come to her class with a turbidity probe and demonstrate how to use it. Ms A and Mr P support students in learning to use the turbidity probe to measure the turbidity of their filtered water samples. Here is an example of Mr P sharing his expertise:

Mr P. So when you handle the sample holder, handle it by the lid. OK? Now where's the . . . ? See the little arrow? See the little arrow thing? The white arrow? You have to line that arrow up with this arrow.

## Variate Phase

The class decides on turbidity of the water as the dependent variable that they will measure. On a green sticky note (colour consistent with Poster 1), Ms A writes, "What will happen to the turbidity of the water?" She places the sticky note on the brain graphic on Poster 2 (see Figure 2).

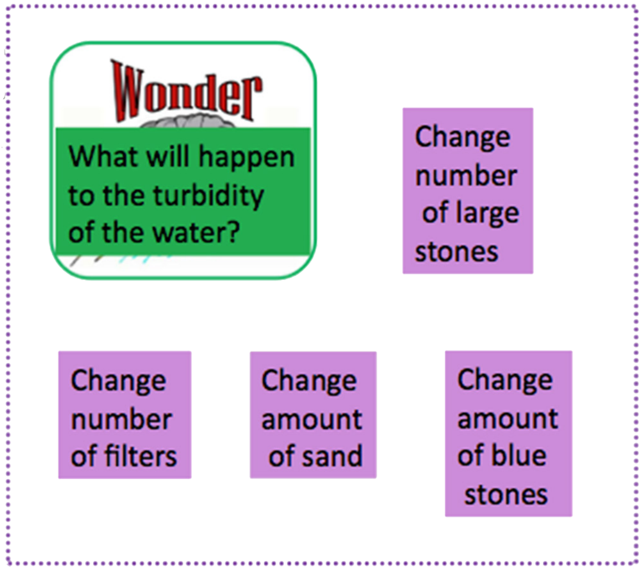


**Figure 2.** Poster 2, with students' ideas on sticky notes.

The class looks at the pink sticky notes on Poster 1 for variables in the pop bottle water filter that could affect the turbidity of the water. On pink sticky notes, Ms A writes every idea the students provide and attaches them to Poster 2.

She takes from Poster 2 the green sticky note with "Turbidity of water" and places it on Poster 3 (see Figure 3) at the head of the fishbone organizer, in the DV (dependent variable) position. Then, from Poster 2, she chooses one variable (number of coffee filters) to change and moves that pink sticky note to the IV (independent variable) position on the fishbone, to the left of the DV, on Poster 3. Then, she moves all remaining variables written on pink sticky notes to the CV

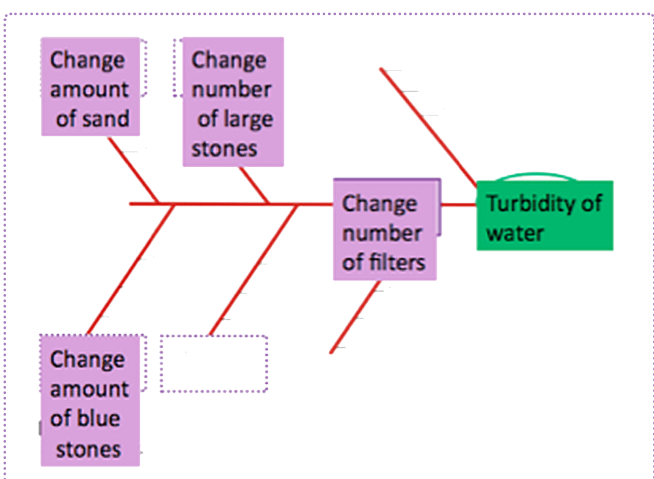


**Figure 3.** Poster 3, with students' ideas on sticky notes.

(controlled variables) positions on the spines of the fishbone. Then, she phrases the testable question: "If I change the number of coffee filters, what will happen to the turbidity of the water?"

Next, in pairs, students choose a variable to change and design their own experiment. In all cases, their DV is the turbidity of the water. After the following introduction from Ms A, the students go on to perform their experiments, collect their filtered water samples and measure the turbidity:

Ms A. Remember, what is your question, what is the one thing you are going to change? Remember, you need to keep everything else exactly the same. You know where the equipment is, so you can begin.

After they have completed their experiments, the students add their turbidity results to the class chart, and the class looks at all the results together to find out the impact of each variable on the turbidity of the water.

### Evaluate Phase

In Ms A's class, many students have writing challenges. Ms A has designed a foldable that can be used as part of the evaluation process, along with the notes she has collected. On the foldable, students can privately write their predictions, reasoning, findings and explanations. Ms A uses the success criteria shown in Appendix A to evaluate students' work on their foldables.

## Conclusion from Ms A

I have used the DRiVe Inquiry Framework in my classroom since 2011. I find that my students are more engaged, and over the school year they develop their ability to use the practices of science to conduct more open-ended science investigations. What I particularly like is how the DRiVe approach scaffolds me and the students as we gradually shift from the confirmation style they are familiar with to the more open-ended style of science inquiry we are aiming for.

This model has provided my students with a voice, they see themselves as scientists, and they have become more confident in their academic abilities all around. As they become more confident, they demand more from themselves and their peers. This model has changed the way I think about teaching and how my students feel about learning.

# Appendix A: Success Criteria for Summative Evaluation

## Success Criteria and Feedback—Lab Report

### *Success Criteria*

*What are the features of an effective lab report?*

### *Introduction*

- ☐ I have clearly stated my prediction ("If . . . , then . . . .")
- ☐ I have logical and reasonable support for my prediction.
- ☐ I have included personal connections and background knowledge to support my prediction.
- ☐ I have used research (theories, models, insights) to support my prediction.

### *Methods*

- ☐ I decided on evidence to collect and measurements to collect.
- ☐ I have outlined plans to test my prediction.
- ☐ I have outlined procedures to manipulate and control my variables.

### *Results*

- ☐ I have collected and recorded my measurements in a clear and organized way.
- ☐ I have recorded additional observations using measurements and senses.
- ☐ I have collected and displayed my observations in a clear and organized way.

### *Discussion*

- ☐ I have outlined trends shown in my data.
- ☐ I have made connections to scientific concepts in my explanations.
- ☐ I have compared my observations to my prediction.
- ☐ I have a valid conclusion based on my data.
- ☐ My conclusion relates to my question.
- ☐ I have evaluated my procedure and identified experimental errors.

### *Overall*

- ☐ I have organized my reasons in my explanations.
- ☐ I have used appropriate scientific vocabulary.
- ☐ I have used clearly labelled diagrams that clarify my thinking.

### *Self-Reflection*

*Analyze your lab report using criteria.*

Two things I did well:

________________________________________

________________________________________

________________________________________

________________________________________

Something to think about for my next inquiry:

________________________________________

________________________________________

________________________________________

________________________________________

### *Teacher Feedback*

*Use the success criteria to provide feedback about two things done well and one suggestion for improvement.*

# References


Alberta Education. 1996. *Science (Elementary).* Edmonton, Alta: Alberta Education. Also available at https://education.alberta.ca/media/159711/elemsci.pdf (accessed July 18, 2018).

Bell, R L, L Smetana and I Binns. 2005. "Simplifying Inquiry Instruction." *The Science Teacher* 72, no 7 (October): 30–33.

British Columbia Ministry of Education. 2013. BC's New Curriculum: Science. https://curriculum.gov.bc.ca/curriculum/science (accessed July 18, 2018).

Bybee, R W. 2011. "Scientific and Engineering Practices in K–12 Classrooms: Understanding *A Framework for K–12 Science Education*." *Science and Children* 49, no 4 (December): 10–16. Also available at http://nstahosted.org/pdfs/ngss/resources/201112_framework-bybee.pdf (accessed July 18, 2018).

Council of Ministers of Education, Canada (CMEC). 2013. *Pan-Canadian Assessment Program (PCAP): Science Assessment Framework*. Toronto: CMEC. Also available at www.cmec.ca/docs/pcap/pcap2013/Science-Framework-EN-April2013.pdf (accessed July 18, 2018).

Ontario Ministry of Education. 2007. *The Ontario Curriculum Grades 1–8: Science and Technology.* Toronto: Ontario Ministry of Education. Also available at www.edu.gov.on.ca/eng/curriculum/elementary/scientec18currb.pdf (accessed July 18, 2018).

Pardo, R, and J Parker. 2010. "The Inquiry Flame: Scaffolding for Scientific Inquiry Through Experimental Design." *The Science Teacher* 77, no 8 (November): 44–49.

# Development of Science Pedagogical Content Knowledge: A Model Proposed for Elementary Teacher Education in Alberta

*Saiqa Azam*


## *Abstract*

Elementary science instruction in Alberta predominantly follows a generalist model. Many elementary science teachers lack science content knowledge, as well as interest and confidence in teaching science. Current teacher education programs in Alberta focus on developing generalist elementary teachers, and preparation for science teaching is not a strong aspect of those programs. Moreover, professional development activities for elementary science teachers have less focus on science instruction. This raises serious concerns for the development of elementary teachers' pedagogical content knowledge (PCK) for teaching science. To address these concerns, this article proposes a model for preservice and inservice teacher education, which is anticipated to help preservice elementary teachers develop PCK-readiness, which will in turn lead to their accelerated acquisition of experiential science PCK as practising elementary teachers.


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Gess-Newsome (1999a) outlines five delivery models for elementary science instruction: classroom generalists, classroom science specialists, science support teams, departmentalization within grade levels and science specialists. Alberta elementary schools tend to follow a classroom generalist model for delivering science instruction, as illustrated by the report *Elementary Science Education in Alberta Schools* (Rowell and Ebbers 2004), which highlights that most elementary teachers have not studied pure science (64 per cent) or applied science (89 per cent) at the postsecondary level. This raises the possibility that many elementary teachers have limited science content knowledge. Another issue identified in the report is the fact that elementary teachers usually teach science to their homeroom class only, and just one out of five teachers teaches science to two or three classes. This indicates the possibility of a lack of confidence when teaching science. Though Alberta Education recommends five to twenty hours of professional development for elementary teachers, the report shows that most elementary teachers are not satisfied with the PD provided to them for teaching science, and this view has been consistent over the last 20 years. Alberta elementary science teachers see specific pedagogical suggestions or activities for immediate use in the classroom, especially from experienced classroom teachers, as being the most effective PD.

Effective elementary teachers need to have sufficient pedagogical content knowledge (PCK) for teaching science. Shulman (1986, 1987) identified the idea of PCK while studying development and use of teacher knowledge, and he considered PCK to be an integration of many aspects of knowledge at the intersection of content and pedagogy. Later research on PCK proved the usefulness of the idea for teacher education. Most reform documents on teacher education recommend that PCK should be a goal of any teacher preparation program.

Rowell and Ebbers's (2004) report on science education in Alberta elementary schools shows that elementary teacher education programs produce generalist elementary teachers and are, thus, not successful in achieving the goal of developing PCK in science content. This is sometimes because a single teacher education course aims to address the needs in all curriculum areas. In such a program, very little time is allotted to learning how to teach science. To fully implement the Alberta elementary science program of studies, science specialists are required in Alberta elementary schools; hence, teacher education programs for elementary science specialists need to be designed. In the absence of such programs, we must use the limited time available in existing generalist elementary teacher education programs to help teachers develop PCK for science teaching, or at least develop "PCK-readiness" (Smithey 2008, 2), so that they can develop further experiential science PCK. Moreover, as mentioned above, inservice PD activities are not contributing to the goal of developing science PCK. This provides some evidence that science instruction in Alberta elementary schools is not in very good shape.

This article aims to formulate essential processes in existing generalist elementary teacher education programs to focus on developing science PCK. To serve this purpose, I propose a model that can help develop science PCK-readiness in a short time. This model can be extended to a PD program based on the same principles, with a focus on science content and pedagogy, for helping inservice elementary teachers develop their science PCK. This article provides a conceptual framework for the design of elementary science education courses or PD workshops.

## PCK for Teaching Elementary Science

Teaching is a highly complex cognitive activity that involves deeply understanding the content and that is highly dependent on the context. To unpack this conceptual and contextual complexity, Shulman (1986) studied the phenomenon of teaching and teacher knowledge to offer a professional knowledge base for teaching. To reduce this complexity, he proposed a model to represent a knowledge base for teaching consisting of seven hypothetical domains of teacher knowledge:

- content knowledge,
- general pedagogical knowledge,
- pedagogical content knowledge,
- knowledge of students,
- knowledge of curriculum,
- knowledge of goals and
- knowledge of educational context.

His model helps not only to look into teacher cognition but also to strengthen the status of teaching as a profession by introducing a special domain of teacher knowledge—pedagogical content knowledge. Shulman defined *pedagogical content knowledge* as "the most useful forms of [content] representation . . ., the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject [matter] that make it comprehensible to others" (p 9).

After Shulman introduced the concept of professional knowledge for teachers and coined the term *pedagogical content knowledge,* PCK became a popular construct, and substantive research has been done in the last three decades to study teachers' knowledge and their pedagogical reasoning during an act of teaching. Since the introduction of the idea, the definition of *PCK* has evolved with disciplines, subject areas and grade levels. Scholars in the area of science education have expanded on the definition of *PCK* to include additional teacher knowledge categories (Abell 2008; Azam 2015; Grossman 1989; Lee and Luft 2008; Loughran et al 2001; Magnusson, Krajcik and Borko 1999; Marks 1990; Park and Oliver 2008; Tamir 1988) and offered multiple visual representations of PCK, most popularly called PCK models. In a special issue of the *International Journal of Science Education* (Berry, Loughran and van Driel 2008), Abell (2008) asserted that PCK has finally achieved some common characteristics. Researchers seem to agree that PCK includes discrete categories of knowledge that are applied synergistically to the problem of practice. It is also generally accepted that PCK is dynamic and not static, that content (science subject matter) is central to PCK, and that PCK involves the transformation of other types of knowledge. A line of research to study or measure the PCK of science teachers has focused on topic-specific PCK, but a lack of consensus still prevails as to whether PCK is topic-specific knowledge or not. The latest discussions on science PCK, as a result of the PCK Summit in 2012, are more likely to acknowledge the topic specificity of science PCK (Kind 2015).

### PCK Development and Preservice Science Teachers

The PCK construct has been used to study, measure and document teacher knowledge. Much of the research on science PCK involves studying the development of the PCK of teachers in preservice and inservice teacher education programs. There has been particular interest in knowing how science teachers develop science PCK and use it to teach certain topics in science;

thus, the research is mainly topic specific. This research shows that developing science PCK is a challenging and slow process.

Regarding the development of the science PCK of preservice teachers, divergent views exist. One view purports that it is difficult for preservice teachers to develop science PCK because they lack teaching experience, which is described as a central characteristic of PCK development (van Driel, De Jong and Verloop 2002; van Driel, Verloop and de Vos 1998), whereas the second view suggests the likelihood of preservice teachers' PCK development (Davis and Petish 2005; Zembal-Saul, Blumenfeld and Krajcik 2000).

For preservice elementary teachers, Smithey (2008, 2) introduced a new concept, "PCK-readiness," at the border of these divergent views, which "put[s] [preservice teachers] in a good position to develop rich usable PCK once they have more experience in the classroom" (p ix).

Based on this idea of PCK-readiness, this article argues that if opportunities are provided in a preservice teacher education program, specifically through science methods courses, preservice teachers can develop some PCK or PCK-readiness for further development of science PCK.

## PCK Development and Preservice Elementary Teachers

Research shows that PCK may vary for different subject areas, topic areas and grade levels. So, the PCK of an elementary science teacher may differ from that of a secondary science teacher (Appleton 2006). The process of developing the science PCK of an elementary teacher may also be different based on the fact that elementary science teachers are predominantly generalists and not specialists in science. The nature of elementary teacher education programs may also have a lot to do with the process of developing science PCK. This raises interesting questions: How can we define the PCK of elementary teachers? How do elementary teachers develop PCK? What kind of teacher education program design can help with developing better science PCK?

The scarce body of research on PCK conducted in the context of elementary science education provides some answers to these questions. Appleton (2003) identifies PCK as an important aspect of elementary teachers' professional knowledge of science teaching, which influences their confidence in teaching science. He defines science PCK for elementary teachers as

> the knowledge that the teacher uses to construct and implement a science learning experience or series of science learning experiences. . . . It includes versions of science content appropriate to the students concerned and ways of making that content understandable—not just in terms of analogies and examples to use in explanations, but also in the types of learning experiences in which students should engage and in the sequence in which these should occur. (Appleton 2006, 35)

He further describes the nature of the science PCK of elementary teachers as "a dynamic form of knowing that is constantly expanding and being transformed from other forms of teacher knowledge, and through the experiences of planning, implementing and evaluating science teaching and learning" (p 35).

# Representations of Science PCK: PCK Models

The literature on pedagogical content knowledge offers many different models for representing the PCK of teachers. These models are "proposed as conceptual tools to identify and discriminate among hypothesized constructs and represent inferred relationships among constructs" (Gess-Newsome 1999b, 3). Popular models have been developed by Magnussun, Krajcik and Borko (1999), Gess-Newsome (1999b) and Abell (2008). Appleton (2006) exclusively developed a model to represent the science PCK of experienced elementary teachers.

One aim of any science teacher education program is to help preservice teachers develop science PCK; however, this is a daunting task when it comes to elementary teachers. Therefore, I hoped to examine the development of science PCK for preservice elementary teachers, as a possible framework for elementary science teacher education programs in Alberta. This model is informed by the existing PCK models suggested by Gess-Newsome (1999b), Loughran and colleagues (Loughran, Berry and Mulhall 2006; Loughran et al 2001; Loughran, Mulhall and Berry 2004) and Appleton (2006). Here, I will describe these models briefly and discuss how they inform the current inquiry to propose a model for elementary teacher education in Alberta to develop science PCK-readiness.

## Gess-Newsome's Model: Transformative Versus Integrative PCK

Gess-Newsome (1999b, 10) offers two models for the development of PCK: an integrative model and a transformative model. These models illustrate extremes on a continuum in the development of PCK.

At one end, PCK does not exist as a discrete entity, and teacher knowledge can be most readily explained by the intersection of three constructs: subject matter, pedagogy and context. Teaching, then, is the act of integrating knowledge across these three domains, and a successful teacher is believed to have mastery in these three domains of teacher knowledge, so that they are readily available for use whenever required. Gess-Newsome calls this an integrative model.

At the other extreme, PCK is the synthesis of all the knowledge needed to be an effective teacher. In this case, PCK is the transformation of subject matter knowledge, pedagogical knowledge and contextual knowledge into a unique form—the only form of knowledge that has an impact on teaching practice. She calls this a transformative model.

Gess-Newsome uses the analogies of mixture and compound to explain the models. Integrative knowledge is like a chemical mixture, in which the individual elements are mixed but remain chemically distinct and can be separated. On the other hand, transformative PCK is like a compound, in which individual elements are combined and cannot be separated.

Gess-Newsome discusses how the integrative and transformative models of teacher knowledge differ with regard to knowledge domains, the concept of the expert teacher, and implications for teacher education and research.

She claims that, according to the integrative model, "the knowledge of subject matter, pedagogy, and context are developed separately and integrated in the act of teaching" (p 13), and each domain of knowledge should be well structured and easily accessible. On the other hand, according to the transformative model, "knowledge of subject matter, pedagogy, and context, whether developed separately or integratively, are transformed into PCK, the knowledge base used for teaching" (p 13), and PCK is well structured and easily accessible.

Gess-Newsome explains the teaching expertise for the two models, and she maintains that according to the integrative model, expert teachers are capable of integrating knowledge domains actively for each topic taught, while according to the transformative model, expert teachers possess PCK for all topics to be taught.

Regarding the implications of the two models for teacher preparation, Gess-Newsome argues that the integrative model demands that teacher preparation programs teach various knowledge domains separately, along with the required skills to integrate them. The experience of teaching and reflecting on teaching helps teachers enhance the development and use of distinct knowledge domains. On the other hand, the transformative model for teacher preparation insists that knowledge domains should be taught in an integrative manner, and the experience of teaching and reflecting on teaching supports the development and use of PCK.

The most popular implications of the integrative and transformative models proposed by Gess-Newsome for research have been comparing the PCK of experienced and beginning teachers with an assumption that novice teachers may have integrative PCK whereas experienced teachers possess PCK in a synthesized form. The transformative model recognizes the value of a synthesized knowledge base for teaching. According to the transformative model, PCK that helps students understand specific science concepts is the only knowledge used in classroom instruction. Thus, an expert teacher has well-formed PCK for all the topics commonly taught.

The integrative model is the more commonly used framework for science teacher education. Teacher knowledge in various domains is taught to preservice teachers, and it is expected that they will be able to integrate these knowledge domains for teaching science topics. The transformative model is comparatively new and not yet a popular model to follow for teacher preparation. Using a transformative model for teacher education means providing a synthesized form of science PCK to prospective teachers to help them learn how to teach science. One reason for the lack of popularity of the transformative model is the lack of examples of transformed PCK.

This article argues the usefulness of the transformative model for the current situation of elementary teacher education, because it can provide a base for understanding science PCK that may be developed in a short time for preservice teachers and is readily accessible for beginning teachers to develop more in-depth science PCK during their teaching practice and inservice PD activities. Moreover, this transformed PCK not only can help elementary teachers enhance their subject matter knowledge but may also result in greater confidence in teaching science. However, this raises the question, How do we provide transformed science PCK for elementary science? We need to have transformed science PCK for all units and topics in the elementary science curriculum.

## Loughran's Model: Examples of Transformative PCK

I turned to the literature on PCK to find examples of transformed PCK. I could find many examples of research exploring topic-specific PCK for many science topics (Cohen and Yarden 2009; De Jong, van Driel and Verloop 2005; Loughran, Berry and Mulhall 2006; Smith 1999). Most of these examples are from the junior high or senior high school level, and few examples exist at the elementary level.

Loughran, Mulhall and Berry (2004) developed a framework to document the PCK of science teachers in the form of content representation (CoRe) and professional and pedagogical experience repertoire (PaP-eR). CoRes are the big ideas and the conceptual understanding involved in teaching those concepts. PaP-eRs are the narrative accounts of teachers about their successes and challenges in implementing instructional strategies to teach certain science topics.

Loughran, Berry and Mulhall's (2006) book on the development of the PCK of science teachers provides unit plans from experienced science teachers for teaching certain science topics at the junior high and senior high school levels in the form of CoRes and PaP-eRs. These unit plans are examples of transformed science PCK. I think they could be modified for elementary science.

Ideally, through research, we will be able to develop examples of elementary science PCK in the form of CoRes and PaP-eRs. Examples of transformed science PCK can be used to help elementary teachers develop science PCK for teaching certain topics. Based on these examples, topic-specific units can then be designed for preservice or inservice elementary teachers. CoRes can also be used as an instructional strategy to help elementary science teachers develop a better understanding of science content. PaP-eRs can be used as cases to initiate discussion on various pedagogical strategies to teach science content.

## Appleton's Model: Development of Science PCK for Elementary Teachers

Appleton (2006) has developed a model to show how elementary teachers develop and use PCK for teaching science. His model is based on a generalist approach to elementary science instruction, in which elementary teachers have limited science content knowledge.

According to Appleton, the centre of science PCK for generalist elementary teachers is "science activities that work" (p 32), and these activities work as sources for teachers' subject matter knowledge and interest in science. He found that elementary teachers develop a collection of activities that work and related knowledge to teach in the classroom. Ultimately, these activities and knowledge of teaching with these activities help develop teachers' science PCK. Appleton's model is based on real situations of elementary teachers struggling to develop science PCK through a process that seems quite slow.

I think that randomly selected science activities may be limited with regard to developing teachers' subject matter knowledge of science, and, as Appleton describes, this can slow the process of attaining experiential science PCK (which is transformed science PCK, as described earlier). There is also the danger that elementary teachers may give up during the process of developing science PCK. This generates a need to consider a model that is useful for developing the science PCK of generalist teachers who have limited time, content knowledge and interest in science.

# The Proposed PCK Model for Elementary Science Teacher Education

The proposed model (shown in Figure 1) is a modified form of Appleton's (2006) model for developing the PCK of elementary science teachers. Appleton visualized this model while studying the science PCK of elementary teachers in real situations. I here propose a model that replaces Appleton's "activities that work" (p 32) with examples of transformed science PCK. As discussed above, the examples of transformed science PCK are in the form of unit plans on teaching specific science topics, with Loughran, Mulhall and Berry's (2004) Co-Res and PaP-eRs at the heart. The underlying assumption is that introducing preservice elementary teachers to

CoRes and PaP-eRs (the examples of transformed science PCK) may help them develop an in-depth conceptual understanding of elementary science topics and expose them to effective teaching ideas, which can help them develop PCK-readiness that may accelerate the process of developing their experiential science PCK. The proposed model considers elementary teachers' PCK at three levels: entering, beginning and experiential.

The proposed model is presented in two sections: preservice and inservice (PD). Elementary teachers have some prior knowledge when they enter into a teacher education program, which is called initial knowledge. During preservice teacher education, elementary teachers develop PCK for teaching specific science topics in elementary science, which is called the science PCK of beginning teachers. Then, an inservice PD program is designed based on the same principles adopted for preservice, and each PD activity is an effort to develop PCK for a single unit of elementary science, leading teachers to develop experiential science PCK.

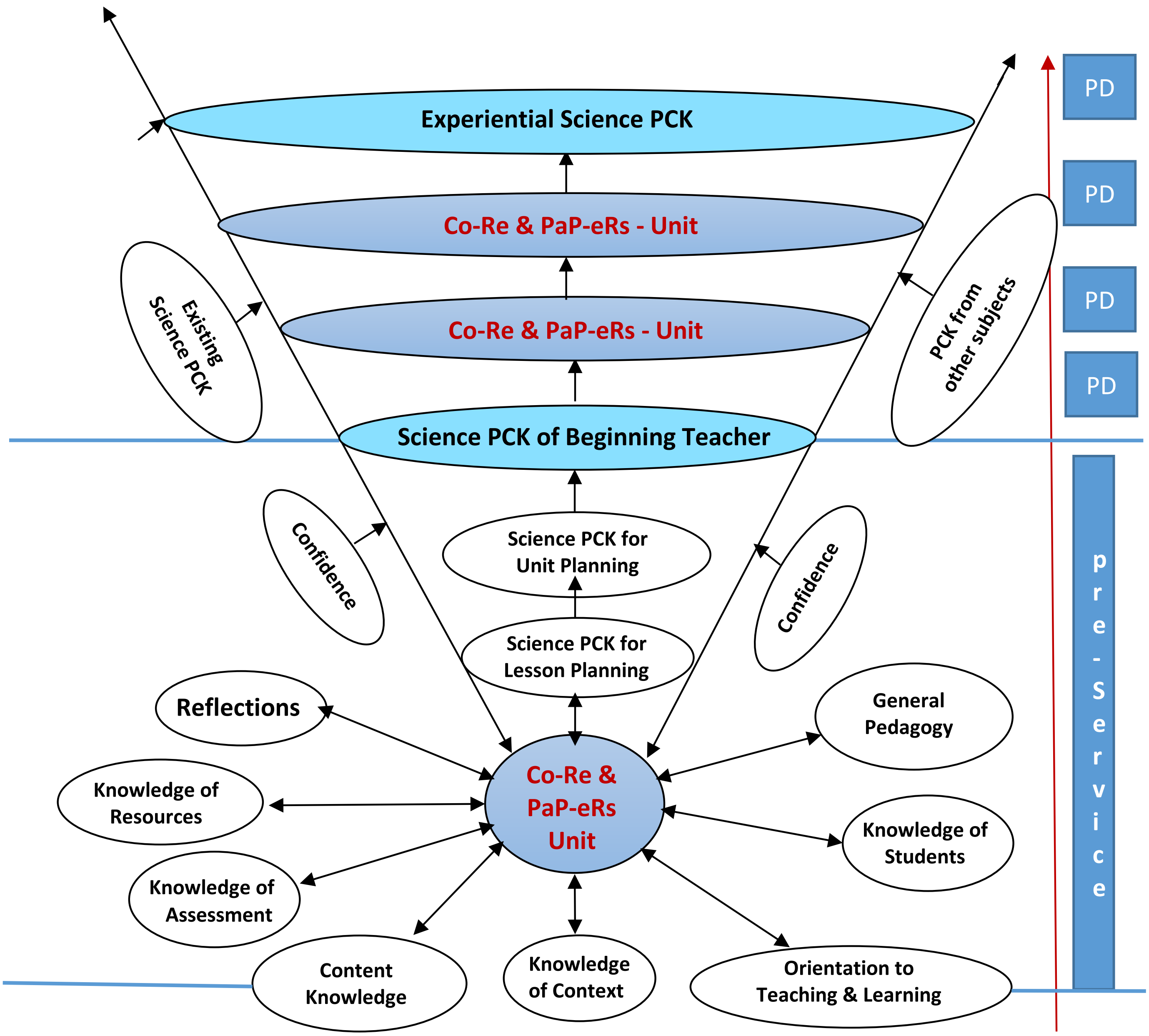


FIGURE 1. Proposed model for developing the science PCK of elementary teachers.

## Initial Knowledge

At the entering level, prospective elementary teachers have some content knowledge of science—at least knowledge of high school science (because in Alberta all students study science in high school). A few have studied more advanced science (Science 20 and 30, Biology/Chemistry/Physics 20 and 30) in Grades 11 and 12. A few have some postsecondary science. Also, regarding science content, prospective elementary teachers bring the orientations to learning and teaching science that they developed during their study of science in high school and university.

## Science PCK of Beginning Teachers

A typical generalist elementary teacher education program focuses on developing prospective elementary teachers' knowledge of student learning, assessment for learning, teaching resources and reflective practice. As observed by Appleton (2006, 32), elementary teachers start developing their science PCK from "science activities that work" in their science teaching. He proposes that preservice and inservice teacher education programs should include these science activities.

Differing from this, I suggest that prospective elementary teachers should be exposed to science PCK with the help of the CoRes and PaP-eRs developed by Loughran, Berry and Mulhall (2006) instead of science activities that are a limited form of science content and pedagogy. The underlying assumption, as described earlier, is that the research-based CoRes and PaP-eRs will accelerate the process of developing experiential science PCK.

In a generalist elementary teacher education program, the time allocated for preparing preservice teachers to teach elementary science is very limited—in some cases, only a single week in a curriculum inquiry course designed for all curriculum areas. The proposed model considers this limited time and suggests following a single unit or two, depending on the time available. The unit is named CoRes and PaP-eRs, after the title of the framework developed to document PCK by Loughran and colleagues. A brief description of a sample CoRes and PaP-eRs unit on electricity is given in Appendix A. The unit can be used with preservice or inservice elementary teachers to help them develop PCK, or at least PCK-readiness.

Appendix A outlines a Co-Res and PaP-eRs unit that introduces a theoretical framework for PCK, taking into consideration the teacher knowledge domain used for developing science PCK. Then, prospective elementary teachers are facilitated to develop their PCK for teaching electricity. Working in groups, they design, teach and improve a minilesson on electricity and develop a unit plan for teaching ideas related to electricity.

Working through a Co-Res and PaP-eRs unit, as well as other courses on general pedagogy, educational context, methods and field experiences, prospective elementary teachers gain an understanding of science content and confidence in teaching elementary science. After completing the preservice teacher education program, beginning elementary teachers will, hopefully, have some science PCK, which I call the science PCK of beginning teachers, along with readiness for developing experiential science PCK.

## Experiential Science PCK

As suggested by Northfield and Gunstone (1997), preservice teacher education is by definition incomplete and teachers need continuous PD during inservice to help them continue to develop their science PCK.

The literature shows that PD for teaching science in elementary schools should include selected science content, science PCK associated with the science content and positive personal encouragement to teach science (Appleton 2006). Shapiro and Last (2002) identify the need for addressing elementary teachers' needs to learn science content and new strategies for helping learners. According to Shapiro (2006), PD for elementary science teachers should be based on existing teacher knowledge, experiences and understandings and should bring about change in the culture of science teaching and learning. She also emphasizes encouraging teachers to take responsibility for their own PD and advises a shift away from one-shot workshops.

Therefore, once elementary teachers enter into the field as practising teachers, the proposed model suggests a continuous PD program designed using the same pattern as the preservice teacher education program: CoRes and PaP-eRs units on elementary science topics, followed by lesson and unit planning for those topics. Research states that beginning teachers need continuous PD, so I recommend recurrent PD activities for teaching science. Moreover, to make these PD activities consistent with the preservice teacher education program, I suggest (if possible) holding these PD activities in education faculties or in collaboration with education faculties. Ideally, I would suggest a PD program as an extension of a preservice elementary teacher program—a weekend program for a year or so in addition to a one- or two-year preservice program, and this extra year should be an inservice program. In any case, it is assumed that frequent PD will certainly increase elementary teachers' science PCK and help them develop experiential science PCK, which is derived from PD events, from teaching other subjects and from existing beginning science PCK.

# Conclusion

The proposed model is meant for implementation in elementary science teacher education programs. This model can help in designing curriculum for a generalist elementary teacher education program to help prospective elementary teachers develop their science PCK. This model also has implications for designing PD activities for elementary teachers to help them develop experiential science PCK. The proposed model not only has the potential to help elementary teachers develop science PCK but can also contribute to accelerating the process of developing experiential science PCK. The proposed model calls for research on documenting examples of transformed science PCK using an existing framework (CoRes and PaP-eRs) suggested by Loughran, Mulhall and Berry (2004) or developing new frameworks.

# Appendix A: Example of a CoRes and PaP-eRs Unit on Electric Circuits

## Day 1

- Discussion about PCK as a conceptual framework for planning science
- Orientation toward teaching electricity (How were you taught about electric circuits? Was that strategy helpful in learning about electric circuits?)
- Curriculum mapping and goals of teaching electricity (explore the Alberta elementary science curriculum and the goals of teaching electricity)

## Day 2

- Inquiry into electric circuits (conceptual quiz as a pretest, activities for designing electric circuits, conceptual quiz as a posttest, discussion about students' ideas about electricity and using these activities for conceptual change)

## Day 3

- CoRe on electricity used as a tool for discussion about big ideas and the conceptual understanding involved
- PaP-eRs on electricity used as cases around some pedagogical strategies

## Day 4

- Review of PCK (the knowledge aspects required for PCK for teaching electric circuits at the elementary level)
- Mini-lesson study (planning a mini-lesson and teaching for 10 minutes, followed by a group evaluation of the lesson)

## Day 5

- Mini-unit plan (final assignment)
- Development of a mini-unit plan based on the mini-lesson, including all knowledge aspects of PCK

# Bibliography


Abell, S K. 2008. "Twenty Years Later: Does Pedagogical Content Knowledge Remain a Useful Idea?" *International Journal of Science Education* 30, no 10: 1405–16.

Appleton, K. 2003. "How Do Beginning Primary School Teachers Cope with Science? Toward an Understanding of Science Teaching Practice." *Research in Science Education* 33, no 1: 1–25.

———. 2006. "Science Pedagogical Content Knowledge and Elementary School Teachers." In *Elementary Science Teacher Education: International Perspectives on Contemporary Issues and Practice,* ed K Appleton, 31–54. Mahwah, NJ: Erlbaum.

Azam, S. 2015. "Stories of Teaching Force and Motion: A Narrative Inquiry into Pedagogical Content Knowledge of Science Teachers." PhD dissertation, University of Calgary.

Berry, A, J Loughran and J H van Driel, eds. 2008. "Developments and Challenges in Researching Science Teachers' Pedagogical Content Knowledge: An International Perspective." Special issue, *International Journal of Science Education* 30, no 10.

Cohen, R, and A Yarden. 2009. "Experienced Junior-High-School Teachers' PCK in Light of a Curriculum Change: 'The Cell Is to Be Studied Longitudinally.'" *Research in Science Education* 39, no 1 (January): 131–55.

Davis, E A, and D Petish. 2005. "Real-World Applications and

Instructional Representations Among Prospective Elementary Science Teachers." *Journal of Science Teacher Education* 16, no 4 (December): 263–86.

De Jong, O, J H van Driel and N Verloop. 2005. "Preservice Teachers' Pedagogical Content Knowledge of Using Particle Models in Teaching Chemistry." *Journal of Research in Science Teaching* 42, no 8 (October): 947–64.

Gess-Newsome, J. 1999a. "Guest Editorial: Delivery Models for Elementary Instruction: A Call for Research." *Electronic Journal of Science Education* 3, no 3: 1–8.

———. 1999b. "Pedagogical Content Knowledge: An Introduction and Orientation." In *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education,* ed J Gess-Newsome and N G Lederman, 3–17. Dordrecht, Netherlands: Kluwer.

Grossman, P. 1989. "A Study in Contrast: Sources of Pedagogical Content Knowledge for Secondary English." *Journal of Teacher Education* 40, no 5 (September): 24–32.

Kind, V. 2015. "On the Beauty of Knowing Then Not Knowing: Pinning Down the Elusive Qualities of PCK." In *Re-Examining Pedagogical Content Knowledge in Science Education,* ed A Berry, P Friedrichsen and J Loughran, 178–96. New York: Routledge.

Lee, E, and J A Luft. 2008. "Experienced Secondary Science Teachers' Representation of Pedagogical Content Knowledge." *International Journal of Science Education* 30, no 10: 1343–63.

Loughran, J, A Berry and P Mulhall. 2006. *Understanding and Developing Science Teachers' Pedagogical Content Knowledge.* Rotterdam, Netherlands: Sense.

Loughran, J, P Milroy, A Berry, R Gunstone and P Mulhall. 2001. "Documenting Science Teachers' Pedagogical Content Knowledge Through PaP-eRs." *Research in Science Education* 31, no 2 (June): 289–307.

Loughran, J, P Mulhall and A Berry. 2004. "In Search of Pedagogical Content Knowledge in Science: Developing Ways of Articulating and Documenting Professional Practice." *Journal of Research in Science Teaching* 41, no 4: 370–91.

Magnusson, S, J Krajcik and H Borko. 1999. "Nature, Sources and Development of Pedagogical Content Knowledge for Science Teaching." In *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education,* ed J Gess-Newsome and N G Lederman, 95–132. Dordrecht, Netherlands: Kluwer.

Marks, R. 1990. "Pedagogical Content Knowledge: From a Mathematical Case to a Modified Conception." *Journal of Teacher Education* 41, no 3 (May): 3–11.

Northfield, J, and R Gunstone. 1997. "Teacher Education as a Process of Developing Teacher Knowledge." In *Teaching About Teaching: Purpose, Passion and Pedagogy in Teacher Education,* ed J Loughran and T Russell, 48–56. Abingdon, UK: RoutledgeFalmer.

Park, S, and J S Oliver. 2008. "Revisiting the Conceptualisation of Pedagogical Content Knowledge (PCK): PCK as a Conceptual Tool to Understand Teachers as Professionals." *Research in Science Education* 38, no 3 (May): 261–84.

Rowell, P, and M Ebbers. 2004. *Elementary Science Education in Alberta Schools: A Summary Report.* Edmonton, Alta: Centre for Mathematics, Science and Technology Education (CMASTE), University of Alberta.

Shapiro, B. 2006. "Professional Development in Elementary Science: New Conversations Guiding New Approaches in Teachers' Work and Learning." *Alberta Science Education Journal* 38, no 1 (November): 28–32.

Shapiro, B, and S Last. 2002. "Starting Points for Transformation: Resources to Craft a Philosophy to Guide Professional Development in Elementary Science." In *Professional Development of Science Teachers: Local Insights with Lessons for the Global Community,* ed P Fraser-Abder, 1–20. Abingdon, UK: RoutledgeFalmer.

Shulman, L S. 1986. "Those Who Understand: Knowledge Growth in Teaching." *Educational Researcher* 15, no 2 (February): 4–14.

———. 1987. "Knowledge and Teaching: Foundations of the New Reform." *Harvard Educational Review* 57, no 1 (Spring): 1–22.

Smith, D C. 1999. "Changing Our Teaching: The Role of Pedagogical Content Knowledge in Elementary Science." In *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education,* ed J Gess-Newsome and N G Lederman, 163–98. Dordrecht, Netherlands: Kluwer.

Smithey, J F. 2008. "Preservice Elementary Teachers' Development of PCK-Readiness About Learners' Science Ideas." PhD dissertation, University of Michigan. Also available at https://deepblue.lib.umich.edu/bitstream/handle/2027.42/58448/jsmithey_1.pdf;sequence=1 (accessed July 17, 2018).

Tamir, P. 1988. "Subject Matter and Related Pedagogical Knowledge in Teacher Education." *Teaching and Teacher Education* 4, no 2: 99–110.

van Driel, J H, O De Jong and N Verloop. 2002. "The Development of Preservice Chemistry Teachers' Pedagogical Content Knowledge." *Science Education* 86, no 4 (July): 572–90.

van Driel, J H, W R Veal and F J J M Janssen. 2001. "Pedagogical Content Knowledge: An Integrative Component Within the Knowledge Base for Teaching." *Teaching and Teacher Education* 17, no 8 (November): 979–86.

van Driel, J H, N Verloop and W de Vos. 1998. "Developing Science Teachers' Pedagogical Content Knowledge." *Journal of Research in Science Teaching* 35, no 6: 673–95.

Zembal, C, M Starr and J Krajcik. 1999. "Constructing a Framework for Elementary Science Teaching Using Pedagogical Content Knowledge." In *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education,* ed J Gess-Newsome and N G Lederman, 237–56. Dordrecht, Netherlands: Kluwer.

Zembal-Saul, C, P Blumenfeld and J Krajcik. 2000. "Influence of Guided Cycles of Planning, Teaching, and Reflection on Prospective Elementary Teachers' Science Content Representations." *Journal of Research in Science Teaching* 37, no 4 (April): 318–39.

# Book Review

## *Small Teaching: Everyday Lessons from the Science of Learning*

*by James M Lang*

*Jossey-Bass, 2016*

### *Reviewed by Kerry Rose*

James M Lang has some advice for educators: think small.

Lang is a professor at the Center for Teaching Excellence at Assumption College, in Worcester, Massachusetts, but he speaks in language that science teachers can understand as he distills educational research down to principles and practices that teachers in real science classrooms can use.

However, the best thing about Lang's book, *Small Teaching: Everyday Lessons from the Science of Learning*, is that he is a master storyteller. To illustrate why we should help students retrieve stored (or—heaven forbid—memorized) information so that they can use it to develop higher-level thinking skills, he tells a story about a coffee shop waitress who couldn't remember his order and how he fixed this problem. To explain why the simple act of predicting the outcome of an experiment can increase both engagement and concept formation, he recounts his experiences in a friendly college football pool. Then, he tells us how research has proven that his suggestions for small changes in teaching practice can make big learning differences for students.

*Small Teaching* is divided into three concise and well-organized sections: Knowledge, Understanding and Inspiration. In each section, Lang recounts what the research has to say about how people learn best and how this applies to classroom teaching practice. Although he is a postsecondary instructor and this book is targeted at others working at universities and colleges, his recommendations and experiences are as applicable to a Grade 6 science class as they are to a senior English university course. The lesson is simple—if we understand how people learn, we can design our classrooms to support learning. Unlike many of his contemporaries who publish in this area, Lang provides recommendations that do not require large amounts of time or money to implement, that work with larger class sizes, and that do not take much (if any) time away from other classroom activities and processes.

For example, one of his chapters is entitled "Motivating." Those of us who have heard much jargon and theory about how to increase student motivation in our classrooms may immediately recoil from advice on this topic. Most theorists are very good at giving recommendations in this area, and those recommendations are often easy to understand but hard to maintain over the approximately 200 days a year that we work with students. Lang is a practising educator, though, so not only does he offer suggestions that work simply and well every day, but he has tried these strategies and listened to his students when they gave him feedback.

In this chapter, he first recommends three very simple strategies:

- Get to Class Early Part 1—start class with a great image, newspaper/Internet story or quotation
- Get to Class Early Part 2—find time by the end of the semester to talk to each and every student individually, no matter how briefly
- Tell Great Stories—self-explanatory

As a long-time science teacher, through trial and error, I have also discovered these strategies—many of us have—but here Lang presents the theory behind why this approach works, how to get this done without it being too stressful for you and your students, and how it worked out for him in his own classrooms. All of this is accomplished in less than 10 pages, so you can extrapolate from that the value of the information provided in the 250-page book. And even though, as a veteran teacher, I found many of his ideas to be strategies I was already using or had used, the reminders here and the research base to support the strategies inspired me to be newly enthusiastic while planning for lessons.

You can probably borrow this book from the library, but it may be one that you want to buy and keep on your desk. I have found myself going back to it again and again to reread sections as I plan for my classes. Lang was trained as an English professor, but his writing is unexpectedly concise. He is also an astute critical observer, and he has an excellent grasp of what good evidence looks like. (In other words, he could be a science teacher!)

*Small Teaching* is about taking small steps to improve the learning environment for our students, but Lang is also concerned with the bigger picture. In his last chapter, "Expanding," Lang describes how his journey into small instructional changes eventually led him to consider larger educational reform. He began by asking more of his students and eventually started asking more of himself as an educator. He started asking his students to take their learning outside the classroom. Since he works in a postsecondary environment, he had more freedom than the average K–12 classroom teacher does, but the ideas here are interesting to ponder. How about asking students to research the sources of their food for one day? Or asking them to go to a small natural space and "interview" it to see what it may tell them? Teaching small can expand to allow you and your science students to consider the larger issues in our world. And Lang would say that this is a process that can be quite easy—as long as you start with the small.

# Publishing Under the *Personal Information Protection Act*

The Alberta Teachers' Association (ATA) requires consent to publish personal information about an individual. *Personal information* is defined as anything that identifies an individual in the context of the collection: for example, a photograph and/or captions, an audio or video file, and artwork.

Some schools obtain blanket consent under FOIP, the *Freedom of Information and Protection of Privacy Act*. However, the *Personal Information Protection Act* (PIPA) and FOIP are not interchangeable. They fulfill different legislative goals. PIPA is the private sector act that governs the Association's collection, use and disclosure of personal information.

If you can use the image or information to identify a person in context (for example, a specific school or a specific event), then it is personal information and you need consent to collect, use or disclose (publish) it.

Minors cannot provide consent and must have a parent or guardian sign a consent form. Consent forms must be provided to the Document Production editorial staff at Barnett House together with the personal information to be published.

Refer all questions regarding the ATA's collection, use and disclosure of personal information to the ATA privacy officer.

Notify the ATA privacy officer immediately of any incident that involves the loss of or unauthorized use or disclosure of personal information, by calling Barnett House at 780-447-9400 or 1-800-232-7208.

Maggie Shane, the ATA's privacy officer, is your resource for privacy compliance support.
780-447-9429 (direct)
780-699-9311 (cell, available any time)

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The Alberta Teachers' Association

## Consent for Collection, Use and Disclosure of Personal Information

Name: ______________________________________________ (Please print)

☐ I am giving consent for myself. ☐ I am giving consent for my child or ward.

Name: ______________________________________________ (Please print)

By signing below, I am consenting to The Alberta Teachers' Association collecting, using and disclosing personal information identifying me or my child or ward (identified above) in print and/or online publications and on websites available to the public, including social media. By way of example, personal information may include, but is not limited to, name, photographs, audio/video recordings, artwork, writings or quotations.

I understand that copies of digital publications may come to be housed on servers outside Canada.

I understand that I may vary or withdraw this consent at any time. I understand that the Association's privacy officer is available to answer any questions I may have regarding the collection, use and disclosure of these audiovisual records. The privacy officer can be reached at 780-447-9429 or 1-800-232-7208.

Signed: ____________________________________

Print name: ________________________________ Today's date: _______________

For more information on the ATA's privacy policy, visit www.teachers.ab.ca.

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