

Using Ethnomathematics Principles in the Classroom:

A Handbook for Mathematics Educators

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## **Abstract**

The alarming underperformance in mathematics of many students worldwide and the economic implication for a global society have taken residence in the highest offices across nations. This has pressed researchers, administrators, and educators to seek better pedagogical practices that fit the description of diverse classrooms and equip students with the requisite skills to advance in the global marketplace. Recent research unveiled that traditional approaches to teaching mathematics do not convey meaning making and exclude students from many cultural groups. However, such approaches still prevail in many classrooms and have proven to be perennially challenging to dismiss. Many mathematics educators, therefore, advocate for more meaningful and inclusive practices using ethnomathematics principles. Ethnomathematics, expresses the relationship between mathematics and culture (D'Ambrosio, 2001). Acknowledging the need for better practices in classrooms worldwide, this project extracted the major themes of ethnomathematics from an extensive literature review and used them to compile a teaching and learning handbook with culturally sensitive teaching strategies. The handbook was designed to provide mathematics educators with research-based information to help them to develop curriculum, activities, tasks, and instructions so that mathematics may be meaningful to all students. Since the literature reveals that tasks bridge the between teaching and learning, the handbook culminates by exemplifying how its content can be applied to create culturally rich mathematics tasks, using the backward design planning process.

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## CHAPTER ONE: INTRODUCTION TO THE STUDY

Mathematics is viewed as important for economic growth (Yıldırım & Sidekli, 2018), however, many students worldwide struggle at the discipline, registering low scores on standardized tests. Consequently, within mathematics education, what constitutes good pedagogical practices is highly controversial and has long been the focus of much research worldwide (Bell, 1993; Ben-Chaim, Keret, & Ilany, 2007; Boaler, 2002, 2016; D’Amboisio, 1985; Hiebert & Wearne, 1993). Adding to the body of research, this developmental study investigates literature relating to ethnomathematics as a means to provide culturally appropriate pedagogy. Findings from the detailed literature review were presented in the form of a handbook, comprising of suggested teaching strategies, specifically focusing on rich mathematical tasks, which bridge the gap between teaching and learning. The handbook can be utilized by mathematics educators at all levels, however, the tasks exemplified, using the backward design planning process, are suited for middle school learners.

In general, while the handbook keys in on task development, the main objective of the developmental studies is to help teachers orchestrate a learning environment that will immerse students in meaningful and impactful learning experiences. Additionally, in tandem with ethnomathematics perspectives, this project focused on equitable strategies, addressing the current climate of growing diversity in the classroom.

### **Background of the Problem**

In many classroom mathematics, teaching and learning is dominated by repetitive procedural tasks that duplicate solution methods, which do not support deep understanding and consequently dissuade students—especially female students—from

the STEM field (Boaler, 2016). Boaler (2016) contends that although students, in general, have a need for meaningful learning, female students have a greater desire for deep understanding. In addition, the increasing diversity of the classroom, stemming from globalization (Merriam & Kim, 2008; Spring, 2015), necessitates pedagogical practices that promote inclusion and diversity. Observing the increase in immigrant population in Canada, the Ontario Ministry of Education (2016) noted that the already sensitive issue of diversity and inclusion in the classroom is becoming more complex. The Ontario Ministry of Education (2016) notes various qualities and attributes that account for diversity, which include but are not limited to “ancestry, culture, ethnicity, gender, gender identity, language, physical and intellectual ability, race, religion, sex, sexual orientation, and socioeconomic status” (p. 2). Consequently, the Ministry urges educators to be aware of these differences and to provide adequate resources to meet each student’s needs within an inclusive setting. However, McCrimmon (2015) contends that although teachers are expected to meet diverse needs amidst mounting challenges in the classroom, investigation of programs offered by Canadian universities for pre-service teachers reveals that educators are not adequately prepared to provide modified curriculums to meet the current climate of diversity within Canadian classrooms. Thus, it is necessary for researchers to consistently investigate practices that will support mathematics educators at all levels to develop strategies that will promote inclusion amidst the varied needs among students.

Barton (1997) asserts that inclusion is not merely about placing students in an unmodified classroom with their peers of similar age, but also involves attending to all aspects of learning that are necessary to orchestrate learning environments where all

students can benefit. Furthermore, maintaining such an environment, in which students feel safe regardless of individual differences, requires constant awareness and exploration combined with an understanding that students' personalities are developed within a school setting (Vasiliki, 2018). In relation to the teaching and learning of mathematics, many researchers connect students' feeling of exclusion in the mathematics classroom, and subsequent underperformance and low representation within math-related fields to the mentally stultifying effects of poor pedagogical practices within the classroom (Boaler, 2016; D'Ambrosio, 1985). As a result, a significant aspect of the reform movement within mathematics is geared towards providing more inclusive practices whereby all students have the opportunity to excel in an innocuous setting.

Also, Bell (1993) posits that pedagogical practices should reflect mathematics curricula, which transmit mathematical ideas that equipped students with the requisite skills to systematically interpret and represent everyday experiences by using the language of mathematics in such a way that they will carry forward these skills in their adult life. As it stands, there is a general concern that many individuals are incapable of using the mathematics they learn in the classroom in everyday life situations (Boaler, 2002). Additionally, in the U.S. and other parts of the world mathematics has a deep history of being promoted as a difficult discipline that can only be learned by those who are specially endowed with the gift of doing it. Therefore, students often give up because they perceive themselves as not being a "math person" (Boaler, Dieckmann, Perez Núñez, Liu Sun, & Williams, 2018). Further, the traumatic effect experienced by some students while learning mathematics by traditional methods often prevents them from excelling, thus contributing to low achievement and feeling of exclusion (Boaler, 2016).

Subsequently, mathematics education has been a source of major concern in many countries, including Canada. Anna Stokke (2017), professor of mathematics at the University of Winnipeg, noted that an early solid foundation in mathematics situates students for future academic and career success. However, assessments by professional institutions like the Caribbean Education Council (CXC) and Canada's Education Quality and Accountability Office (EQAO) highlight the continual underachievement of students in the subject. In 2016, the Canadian Press revealed that the Ontario EQAO results over the last 10 years have shown a steady decrease for students and has also shown an alarming deterioration while progressing from grade 3 to grade 6 ("Only 50%," 2016). In addition, although Canada is among the top-ranking countries in the Programme for International Student Assessment (PISA), there are still countries that outperform Canada in mathematics (OECD, 2018). These results have called for new and innovative research-based approaches to respond to the outcry of students and teachers who are suffering amidst such dismal reports.

Research suggests mathematics tasks are critical learning resources that can help to deal with issues of diversity and inclusion and encourage all students to learn mathematics (Boaler, 2016; Grootenboer, 2009) since tasks are conduits that mediate between the teaching and learning of mathematics (Margolinas, 2013). A mathematical task refers to whatever a teacher uses to demonstrate mathematical concepts, engage students in interaction, or request students to do something, such as homework problems and classroom activities on their own or in a group (Breen & O'Shea, 2010; Margolinas, 2013). Tasks may also include any students-initiated action in response to a given situation (Margolinas, 2013). Mathematical tasks, carefully orchestrated, may spark



students' curiosity and interest, inform students of what it means to do mathematics, and thus shape their mathematics identity and determine their future progression in related pathways (Boaler, 2016; Grootenboer, 2009; Schoenfeld, 1994). Further, in a study titled "Impact of Teaching Approaches on Students' Mathematical Proficiency in Sweden," Samuelsson (2010) states, "it is obvious that different teaching approaches have different impacts on different aspects of students' mathematical proficiency" (p. 71).

Mathematical proficiency involves five strands: conceptual understanding; procedural fluency; strategic competence (ability to communicate mathematical ideas to solve problem); adaptive reasoning (capacity for to reason rationally through reflection, clarification, and justification); and productive disposition (seeing mathematics as making sense in that it can be utilize in everyday life coupled with an individual's confidence to apply it (Kilpatrick, Swafford, & Findell, 2001). Given that there is overwhelming evidence supporting that task design is fundamental to effective mathematics teaching, many researchers put forward theories to help mathematics educators design and implement rich mathematics tasks (Margolinas, 2013). However, research shows that many teachers still struggle with creating rich mathematical tasks that are authentic (Suurtamm, 2004).

Breen and O'Shea (2010), and Boaler (2016) maintain that pedagogical practices should scaffold mathematical thinking and should reflect the work that professional mathematicians do. Though a precise definition of mathematical thinking may be hard to coin, most authors agree that important aspects involve in-depth knowledge through conjecturing, reasoning and proving, abstraction, and generalization (Bell, 1993; Breen & O'Shea, 2010). These crucial aspects of mathematical thinking, in turn, support the cycle

of how mathematics is most often used—mathematization, manipulation, and interpretation. This involves recognizing the significance of some mathematical relationship in an arising situation, communicating the relation mathematically through symbol, and further manipulating the symbolic representation to deduce new meaning and insight into the arising situation (Bell, 1993). One way that mathematics education could help students to scaffold mathematical thinking skills is to assign tasks designed for this purpose (Breen & O’Shea, 2010). Furthermore, well thought out tasks may support students’ understanding of mathematics, as well as establish how it is applicable in the classroom and wider society (Sullivan, Mousley, & Zevenbergen, 2006).

In addition, Grootenboer (2009) maintains that it is imperative that rich mathematical tasks cater for a wide cross-section of students, having multiple access points relating to interest and ways of knowing that result in various pathways and representations of mathematical ideas. Conversely, Breen and O’Shea (2010) also point out that often times classroom practices emphasize content with the assumption that mathematical thinking and understanding are natural byproducts of teaching. Moreover, Boaler (2016) argues that procedural tasks, which are still common in many classrooms, focus on content rather than meaningful learning, promote a fixed mindset (ability is not changeable) instead of a growth mindset (ability changes as one learns).

Despite the many benefits of rich mathematics task and the many studies (Boaler, 1998, 2002, 2016; Breen & O’Shea, 2010; Stein & Lane, 1996; Sullivan et al., 2006) that indicate traditional teaching approaches do not sufficiently allow students to maximize their learning, it has proven perennially challenging to replace tasks that are dominant in

the classroom with those of alternate design, that are non-routine and support meaningful and deep learning (Doorman et al., 2007; Kool & Keijzer, 2018; Lithner, 2017).

Therefore, there is a need for continued research to provide educators with alternative strategies to mitigate against the myriad of challenges that persist in mathematics education; strategies that are inclusive, applicable to students' everyday lives, facilitate high cognitive level, and provide meaningful and impactful learning that will increase student achievement in mathematics.

### **Purpose of the Study**

Amidst mounting challenges in classrooms, teachers are expected to employ practices that will equip students with the requisite skills and knowledge for the 21st century (Ontario Ministry of Education, 2016). The purpose of the developmental study is to provide mathematics educators, particularly intermediate teachers, with added resources to improve their practice. The resulting handbook from this study will support mathematics educators to employ inclusive strategies and approaches that are culturally sensitive to promote engaging and meaningful learning. In particular, the handbook will assist educators to create rich mathematical tasks that will engender the skills of a mathematician within students so that they may utilize mathematics in everyday situations to solve problems. In general, this study encourages educators to reflect on their practice in relation to using equitable strategies that will promote deep learning of all students, regardless of qualities and attributes the accounts for diversity.

### **Guiding Questions**

In order to provide a focus for this study, the following questions were developed. The questions were also used to summarize the extensive body of literature in the field of

ethnomathematics to provide direction for developing the handbook:

1. What role does culture play in mathematics?
2. How can ethnomathematics methods be incorporated into the teaching and learning of mathematics to create rich mathematics tasks?
3. Can ethnomathematics strategies promote equity within the mathematics classroom?
4. How can mathematics curriculum be interpreted using culturally appropriate pedagogy in order to generate and promote meaningful learning?
5. What are different ethnomathematics practices that can be integrated in teaching-learning of mathematics to help students to understand and better appreciate mathematics?

### **Rationale for the Study**

Mathematics education has been perennially challenging in many parts of the world, including Ontario Canada, the U.S., and Great Britain, thereby impacting parents, teachers, mathematicians, and others for decades (Bedford, 2017; Boaler, 2003, 2016). The challenges are deep-rooted and are woven within the foundations perspective of education: historical, philosophical, political, and sociological. One major challenge is the procedural approach that mainly involve providing students with previously prescribed repetitive questions that do enhance deep-connected understanding and meaningful learning (Boaler, 2016). Moreover, the increasing diversity of the classroom, stemming from globalization (Merriam & Kim, 2008; Spring, 2015), further adds new dynamics to the classroom thereby requiring inclusive practices that cater for such need. Failure to address this issues within mathematics education contributes to traumatic

effects for students such that many view mathematics as a difficult subject that cannot be deciphered. Therefore, researchers in mathematics education contend that pedagogical practices within mathematics education should incorporate real-life situations and the work that professional mathematicians do (Boaler, 2016; Breen & O'Shea, 2010). Boaler (2003) contends that “researchers in mathematics education need to study the practices of classrooms in order to understand relationships between teaching and learning and they need to capture the practices of classrooms in order to cross divides between research and practice” (p. 15). Kuhn and Dean (2004) further maintain that education practitioners, theorists, and researchers, though most often differ in views about pedagogical practices, should better collaborate in the interest of developing critical thinking in students, enabling them to function in a democratic society. Consequently, there is a need for a study that not only critically investigates current practices in mathematics education, and the theories that govern them, but one that merges both theory and practice, as this study seeks to accomplish.

### **Significant of the Study**

This study, with an embedded handbook containing instructional strategies and guidance for task designing emerging from an in-depth literature review, is one step closer to help mathematics educators cross the divides between theory and practice, particularly because teachers find it difficult to design tasks (Bridge, Day, & Hurrell, 2012; Suurtamm, 2004), which is crucial for effective teaching (Boaler, 2016; Breen & O'Shea, 2010; Grootenboer, 2009). This handbook will not only afford teachers the convenience of research-based information on technique to create tasks but also provide actual examples based on the research.

Additionally, this study may provide information to parents or anyone who may be puzzled or anxious about appropriate teaching approaches in mathematics. Research shows that while many parents are involved in their children mathematics learning, they often express feeling of defeat and insufficiency when assisting their children with mathematics (Hoover-Dempsey, Bassler, & Burow, 1995). Further studies indicate that when they have an idea of how their children understanding mathematics their attitudes and beliefs about mathematics change (Westenskow, Boyer-Thurgood, & Moyer-Packenham, 2015).

This study serves to benefit the educational community as a whole since the information presented, although targeting mathematics education, can also inform educators at all levels on issues such as inclusive education practices, which is a point of consideration in many classrooms, given the effect of globalization on education. (Spring, 2015).

### **Scope and Limitations of the Study**

While the information presented in this handbook may be applicable for all levels of mathematics teaching, the activities and tasks specifically target years 7 and 8. This decision was made to target this level since years 7 and 8 bridge the gap between high school mathematics and primary mathematics. Also, it is advantageous to the researcher to utilize years of teaching experience at these levels.

Even though this handbook was created after an in-depth and comprehensive literature review, the information presented by no means exhausted the extensive body of literature relating to ethnomathematics and culturally related mathematics pedagogy. Additionally, because of the limited time frame to complete this study, the handbook was not evaluated by experts in the field on mathematics.

## Theoretical Framework

This project was influenced by leading scholars in education reform such as psychologist Lev Vygotsky (1978) and philosopher John Dewey (1916); however the main theory that forms the theoretical foundation of this project is “Firsthand Learning Through Intent Participation” by Rogoff, Paradise, Arauz, Correa-Cavez, and Angelillo (2003), which has similar components to the work by the aforementioned theorists. The schools of thought of both Dewey (1916) and Vygotsky (1978) support the constructivist view of education, which states that learning is socially constructed, in which the learner is the key actor (Ornstein & Hunkins, 2017). Dewey (1916) maintains that knowledge is formed when humans actively interact with their environment. Similarly, Vygotsky (1978) believes that a children’s thoughts and actions evolve from interacting with their sociocultural background. Therefore, socializing fosters cognitive development with a more knowledgeable other (MKO) within their environment, which may include parents, teachers, or peers. The formation of these acquired skills negotiates further learning. Vygotsky described the zone where learning takes places as the Zone of Proximal Development (ZPD), the bridge that separates a student’s ability to independently complete a task and his/her ability to complete the task with an MKO—a scaffold (Vygotsky, 1978). Both theorists favour the pragmatist perspective of education that view learning as what works.

Rogoff et al.’s (2003) *learning through intent participation* theory examines the informal way children learn by intently listening in and observing, and then voluntarily participating in the communal activities based on expectation. Rogoff et al. further explained that such learning is common among indigenous communities and charitable

institutions depending on voluntary work, and in middle-class schools in U.S. communities, which foster learning by engagement in a shared task; each person is held accountable for the success of the other. Rogoff et al.'s theory is rooted in Dewey's (1916) naturalistic view of knowledge and share similarities with Vygotsky's (1978) social developmental theory.

Rogoff et al.'s (2003) theory involves the learner participating in a particular task by interacting with a more experienced person which can be parallel with the MKO that scaffold learning in Vygotsky's theory. Rogoff et al.'s theory of intent participation and Vygotsky's (1978) theory both emphasize that social interaction with an MKO is critical for cognitive development in children. According to Daniel, Lafortune, Pallasio, Spitter, Shade, and de la Garza (2005), while thinking may develop in adults, most research presupposed that critical thinking does not develop in children. However, they also pointed out that research supports that aspects of critical thinking do appear but critical thinking, which is more complex, needs to be simulated. This is enabled by a teacher or an MKO aided by the social environment within which learning is facilitated.

Like Dewey's (1916) theory, the natural environment in Rogoff et al.'s (2003) theory is an important part of how learning takes place. The environment in *intent participation* facilitates a communal inclusive opportunity for the learner to participate. Rogoff et al. state that within the environment the learner is on the outskirts keenly observing without initial participation and, although expected, is given the choice to contribute within a reasonable time frame that is transmitted by cultural understanding; there is a common understanding, socially implied, that is not based on any specific criteria upon which the child initiates participation in common tasks.



All three theories posited by Rogoff et al. (2003), Dewey (1916), and Vygotsky (1978) are rooted in everyday life experiences in that the learner's experiences extend outside the perimeter of schools to the sociocultural environment; that is, such theories account for how a child is socialized by the various aspects of life such as school, home, culture, religion, and many other groups, which guide our beliefs, mores, and the way we perceive things (Sadovnik, Cookson, & Semel, 2004).

### **Outline of Remainder of the Document**

The remainder of this document includes: an extensive review of literature in chapter 2; a description of the methodology used to compile and present information for the handbook in chapter 3; the presentation of findings in the form of the handbook in chapter 4; and lastly a summary of the entire study in chapter 5.

The comprehensive literature review, the foundation of this study on Ethnomathematics, first provides a brief history of pedagogical practices which leads to the procedural approach that prevails in many classrooms worldwide. It then looks at the role of cultural pedagogy and indigenous mathematics in the classroom. Further, chapter 2 explores the meaning of ethnomathematics (cultural related mathematics pedagogy), and examines how an ethnomathematics approach lends itself to provide meaningful and inclusive mathematics. The chapter ends by looking at criticism of ethnomathematics and application of ethnomathematics in the classroom.

Chapter 3 specifically outlines the research procedures used to compile the information in the handbook. It describes the main themes arising from the literature that was used to develop the handbook, and also subthemes used to accomplish the objectives

of the study. It also discusses the need for the handbook, implementation of the handbook, and a chapter summary.

The handbook in chapter 4 develops on two major themes of the literature review: meaningful learning and inclusive practices in mathematics education. The ideas were streamline into tips, suggestions, and instructions to improve practice.

The overall summary of the study in chapter 5 includes a summary of the handbook and implications for theory, practice, and future research. Finally, chapter 5 culminates with a brief conclusive statement of the developmental study.

## **CHAPTER TWO: LITERATURE REVIEW**

This chapter is a synthesis of current literature relevant to this developmental study. It begins by outlining the brief history of mathematics education leading to the procedural approach to teaching mathematics that endures in many classrooms. The sections that follow explore how cultural pedagogy improve creativity and provide the medium for meaningful and inclusive practice in mathematics education. This chapter also examines critiques of ethnomathematics principles and applications of these principles in the classroom.

### **Brief History of Procedural Approaches to Mathematics**

The 20th century gave birth to mass education, but academic mathematics and pedagogical practices remained in alignment with Western historical perspectives of maintaining economic and social dominance of the elite (D'Ambrosio, 1985). Within North America, the Western worldview regards mathematical knowledge as being absolute, objective, and void of experience, history, and cultures (Stavrou & Miller, 2017). This perception is documented as far back as the Greek philosopher Plato, who believes that mathematical objects are eternal and exist outside of matter (Allan, 1988). Hence by this object, mathematics can only be understood for their properties, using a dialectic approach (Allan, 1988; Sadovnik et al., 2003). Thus, there is a perpetual notion, grounded only in tradition, that mathematical concepts are inherently difficult to grasp (Ju, Moon, & Song, 2016). Even though at some points the historical trajectory of mathematics shifted, such that some appreciate it for its universal applicability, the view that mathematics is abstract, incomprehensible, and irrelevant is still prevalent and permeates academic mathematics (Allan, 1988; Barjaktarovic, 2012).

Therefore, in many mathematics classrooms emphasis is placed on manipulation of numbers and operations rather than encouraging conjectures, hypotheses, and interpretation (Boaler, 2016; D'Ambrosio & D'Ambrosio, 2013). Thus, Boaler (2016) points out that students distinguish mathematics as a subject of procedures and rules, without relevance to the real world, which is contrary to the way mathematicians perceive it and embrace it for its exploratory potential. Barjaktarovic (2012) asserts that contrary to the pervading Eurocentric views that leads to this perception of mathematics, the discipline has been practiced by the rest of the world since ancient times. Thus, the wealth of contribution made by other culture can be utilize to improve practice (Barjaktarovic, 2012).

### **Cultural Related Teaching Pedagogy and Indigenous Mathematics**

Many studies connect the way mathematics is historically perceived and taught to the low achievement in mathematics, thereby proposing reform approach to mathematics teaching and learning. For example, the low achievement of indigenous (native, Aboriginal) students in comparison to their non-native counterparts within Canada and other countries such as Australia, America, and New Zealand is associated with a disconnection between indigenous and Western ways of knowing (Barta, Jetté, & Wiseman, 2003; Owens, 2013; Sterenberg, 2013). Therefore, many researchers seek to identify culturally situated pedagogical approaches to spark the interest of all students (Barta et al., 2003; Brandt & Chernoff, 2015; D'Ambrosio & D'Ambrosio, 2013). In particular, research in indigenous mathematics education explores connections between Western mathematical curriculum and mathematics knowledge within indigenous cultures, with the aim of engaging indigenous students in mathematics that is more

consistent with their life experiences (Barta et al., 2003; Beatty & Blair, 2015; Owens, 2013; Sterenberg, 2013).

In a study by Perry and Howard (2008) aimed at developing “mathematics curricula to enhance the knowledge and capacity of Aboriginal students, community and schools” (p. 4), it was noted that learning opportunities increase when Aboriginal people feel that their knowledge is appreciated and there is greater involvement of Aboriginal people within a school curriculum. In another study focused on the practice of an Aboriginal teacher in response to a Western mathematics curriculum, Sterenberg (2013) noted that for the teacher, teaching from an indigenous perspective requires interpretation of the curriculum with an understanding of what is important and meaningful to the students that pay homage to their ancestors and the land. Moreover, Sterenberg also posits that a deep understanding of indigenous knowledge is necessary in order to respectfully and appropriately represent indigenous knowledge within mathematics curricula. Indigenous mathematics is often confused with ethnomathematics (Pais, 2011); however, indigenous mathematics is just one component of ethnomathematics (Haryanto, Nusantara, Subanji, & Rhardjo, 2017).

### **Ethnomathematics**

Ethnomathematics was originally developed as a means to express mathematics that were practiced outside the perimeter of scholarly settings: the mathematics found in primitive culture (Powell & Frankenstein, 1997). As studies in the area expanded as it relates to education, culture, and politics, evolving ideas produced a broader view of ethnomathematics (Powell & Frankenstein, 1997). Hence, there is no simple definition of

the term, but collective perspectives from many writers on the subject provide an adequate understanding of its scope and purpose (Weldeana, 2016).

Generally speaking, ethnomathematics expresses the relationship between mathematics and culture (D'Ambrosio, 2001). Culture transcends boundaries and includes “arts, history, languages, literature, medicine, music, philosophy, religion, and science” (D'Ambrosio & D'Ambrosio, 2013, p. 23). Ethnomathematics, therefore acknowledge mathematical practices within these expressions of culture, which collectively and uniquely form cultural groups such as “urban or rural communities, working groups, professional grade, students in groups, indigenous peoples, and other specific groups” (Haryanto et al., 2017, p. 325).

Subsequently, ethnomathematics seeks to make use of cultural anthropology and cognitive theory to expropriate ad hoc mathematical practices of these identifiable cultural groups in an effort to emancipate mathematics education of the procedural rigor that is notorious in academic mathematics (D'Ambrosio, 1985).

### **Creativity in Mathematics**

Boaler (2016) believes that the procedural rigour of mathematics robs it of its creativity and beauty, thus resulting it being thought of as a “performance subject” in which drilling and testing dominate mathematics teaching and teach (Mann, 2006). Furthermore, D'Ambrosio, and D'Ambrosio (2013) contends that the testing culture that is dominant in mathematics education detracts educators form preparing students to attend to the needs of society. Additionally, Caine and Caine (1990) asserts that “overemphasis on such procedures leaves the learner impoverished, does not facilitate the transfer of learning, and probably interferes with the development of understanding” (p.

68). Caine and Caine (1990) suggest employing brain-based learning strategies to designing classroom environment that will inspire students' creativity and meaning making. Brain-based learning approaches focus on designing engaging learning strategies based how the brain processes and comprehends information (Gözüyeşil & Dikici, 2014). Caine and Caine (1990) contend that by overlooking the learner's personal world, educators actually impede the effective working of the brain.

Likewise, Aikpitanyi and Eraikhuemen (2017) posit that a deeper understanding of how mathematics occur and is utilized in existing cultures will promote better teaching practices that will improve student achievement in the discipline. Monasterio Astobiza (2017) agrees, adding that understanding of culture is a crucial component in understanding us as humans and for explaining cultural concepts correctly. Furthermore, Sánchez (2018) points out that culture takes root in practically all aspects of human living. Thus, whether knowingly or unknowingly, humans work out all their daily activities using suitable calculations based on how nature dictates the condition in which they live. Similarly, Boaler (2016) contends that mathematics not only manifests itself in culture but exists all around us, in the way animals naturally use mathematics, in art, and in the world in general. Boaler (2016) states:

Mathematics is a cultural phenomenon; a set of ideas, connections, and relationships that we can use to make sense of the world. At the core, mathematics is about patterns. We can lay a mathematics lens upon the world, and when we do, we will see patterns everywhere; and it is our understanding of patterns, developed through mathematics study, that new and powerful knowledge is created. (p. 23)

Upon that premise, Boaler (2016) argues that these ideas should be integrated into mathematics teaching and learning to help students see the creativity and beauty in the subject. Furthermore, Allan (1988), Mann (2006), and Boaler (2016) posit that lasting progress will only be achieved in mathematics teaching and learning when pedagogical practices extract the aesthetic and creativity of mathematics. Additionally, D'Ambrosio and D'Ambrosio (2013) suggest that creativity is essential for the "emergence of new concepts of humanness" (p. 20), whereby students can devise strategies for attaining world peace.

### **Ethnomathematics in the Classroom**

It is believed by many researchers in ethnomathematics (Brandt & Chernoff, 2015; D'Ambrosio & D'Ambrosio, 2013; Naresh, 2015; Powell & Frankenstein, 1997) that the Eurocentric views of mathematics suppress other expressions of mathematics knowledge, thereby stifling creativity in the classroom. Consequently, Powell and Frankenstein (1997) and Brandt and Chernoff (2015) propose ethnomathematics as a powerful tool to challenge hegemonic Eurocentric approaches to mathematics in regards to the history and elitist construct of academic mathematics, which limits individuals to understand the interconnectedness of mathematics to our everyday lives and all other disciplines. D'Ambrosio, and D'Ambrosio (2013) noted that the transcultural and transdisciplinary nature of ethnomathematics provides the necessary theoretical framework that gives rise to innovative methodological approaches that can tackle complex issues relating to adequate resources necessary for the survival of humanity. Similarly, Brandt and Chernoff (2015) proposed that mathematics educators should



integrate components of ethnomathematics within lesson planning, to take advantage of a culture that is dominated by technology.

Furthermore, Boaler (2016) and Brandt and Chernoff, (2015) contend that approaches that are entrenched in real-world applications generate mathematics excitement, thus helping to overcome the fear and loathing that students in the Western world associate with mathematics. Moreover, Pais (2011) contends that ethnomathematical study has the potential to provide individuals with a more in-depth understanding of the history and philosophy of mathematics.

Additionally, since ethnomathematics seeks to include informal educational setting (the knowledge and cultural practices of other groups that are innately mathematics), study in ethnomathematics is seen as a multicultural approach, driven by the current climate of diversity in the society (Pais, 2011). Therefore, ethnomathematics is also seen by many writers (Aikpitanyi & Eraikhuemen, 2017; Brandt & Chertoff, 2015; D'Ambrosio & D'Ambrosio, 2013) as a powerful tool to promote inclusion and diversity in the classroom as it transcends sexual orientation, gender, ethnicity, race, and socioeconomic status (Aikpitanyi & Eraikhuemen, 2017). Brandt and Chertoff (2015) noted that the theme of social justice supported by ethnomathematics is possibly its most impactful benefit. D'Ambrosio and D'Ambrosio (2013) contend that ethnomathematics by its very nature promotes the dignified existence of humanity through the ethics of diversity, which is "respect for, solidarity with, and cooperation with the other (the different)" (p. 22).

Furthermore, Merriam and Kim (2008) point out that more inclusive practice can expand educators' understanding of learners, thus promoting meaningful learning

experiences. While support for inclusive practices is etched in human rights acts and educational policies worldwide, pedagogical practices within mathematics education, in particular, demonstrate a slow interpretation of epistemic understanding of inclusion, such that instructional strategies often promote division and inequality (Dalene, Hong-Lin, & Stella, 2017). These divisive measures are often centered on ability grouping, which Boaler (2016) believes send a message to students that only a selected group of individuals, endowed with the mathematics genes, can do mathematics; this propagates the elitist construction of mathematics.

Furthermore, Boaler (2016) maintains that this discriminatory idea of who can and cannot do mathematics extends to areas such as gender and ethnicity, promotes a fixed mindset instead of a growth mindset in all students (not just students who are labeled as incapable), and consequently determines a student's future in mathematics. The influence of the social construction of ability can be so irrepressible that often resulting practices within mainstream classrooms may inadvertently exclude students who are "included" (Dalene et al., 2017). This, therefore, alerts many writers (Boaler, 2016; Brandt & Chernoff, 2015; Dalene et al., 2017; Tan, 2017) in mathematics education to advocate for inclusive strategies that are not inimical to the self-worth of individuals. Therefore, Brandt and Chernoff (2015) state that by including ethnomathematics into the classroom, educators are heralding the voices and ideas to those who have been traditionally suppressed. Thus, Daniel and Milton (2007) assert that the focal objectives of the ethnomathematics perspective in mathematics curriculum development should be:

The inclusion of moral consequences to mathematical-scientific thinking,  
mathematical ideas and experiences from different cultures around the world, the

acknowledgment of contributions that individuals from diverse cultural groups make to mathematical understanding, the recognition and identification of diverse practices of a mathematical nature in varied cultural procedural contexts, and the link between academic mathematics and student experiences. (p. 59)

Stinson (2016) asserts that, within a diversified setting, there is tremendous potential in dispelling traditional views of mathematics, in favour of acknowledging and extracting mathematical ideas and ingenuity of all students, regardless of qualities and attributes such as ethnicity and gender that account for diversity.

Agreeably, Brandt and Chernoff (2015) argue that pedagogical practices in mathematics classroom should represent the diversity displayed in the mathematics classroom and further address the interconnectedness of a world, which as Spring (2015) noted, is rapidly changing by globalization. Merriam and Kim (2008) further add that globalization brings people together in such a way that the world is connected economically, culturally, technologically, and educationally. Furthermore, Kahn and Agnew (2017) maintain that in this 21st century, no one source remains the scholar of profound knowledge; instead, knowledge is diversified by international influences, various discourse communities, multiple disciplines, and worldviews. Thus, Bartell and Meyer (2008) suggest that teachers should explore and openly identify their conceptual understanding of equity, in order to address related issues within areas of teaching and learning to which they have control, such as curriculum and classroom. Boaler (2016) contends that by using the curriculum to which they are provided, teachers who “are that most important resource for students” (p. 57) have the opportunity and the responsibility to employ equitable strategies that enable all students to achieve their maximum.

Among these strategies, teachers can use the curriculum to which they are provided to design rich mathematical tasks that are highly engaging to students, providing meaningful learning, thus helping them develop a mathematical mindset (Boaler, 2016). Further, Yankelewitz, Mueller and Maher (2010) noted, in relation to a study conducted, that “carefully designed tasks can enable students to reason effectively and in targeted ways, and can assist them in learning to use varied arguments as they engage in mathematics, meeting a primary goal of mathematics education” (p. 84). Rich mathematical tasks: (a) are open in that they can be attempted in various ways and have multiple representations (Boaler, 2009, 2016); (b) cater to a wide cross-section of students in terms of supporting previous mathematical achievement, attracting interest, as well scaffolding of informal mathematics knowledge (Grootenboer, 2009, Knowles, 2009); (c) are challenging but attainable (low floor high ceiling), learner centered, tactile and exploratory in nature (Boaler, 2016; Knowles, 2009); (d) portray the use of mathematical knowledge in the community (Hawera & Taylor, 2011); and (e) engender skills that mathematicians would use to do their work such as conjecturing, hypothesizing, justifying, and representing mathematics in a meaningful way (Breen & O’Shea, 2010; Grootenboer, 2009).

Moreover, studies suggest that rich mathematical task should be extended to develop deep understanding through substantive conversation among peers, which can be promoted through cooperative learning (Boaler, 2016; Grootenboer, 2009). Cooperative learning is pedagogical practice, whereby students work together in small groups with various abilities, each having an equal chance to optimize their learning (Loeser, 2018). While cooperative learning has the potential to maximize learning outcome, merely

telling students to work together in groups does not mean that they will cooperate towards achieving the desired learning outcome (Boaler, 2016). Ideally, cooperative learning promotes interaction, positive interdependence, individual accountability, interpersonal and personal skills, and facilitates group evaluation (Gillies, 2003). Further, studies indicate that the students show greater achievements and have a more positive attitude when tasks are accomplished cooperatively rather than using traditional methods (Capar & Tarim, 2015).

Furthermore, the students develop their perception and understanding predominantly by how they engage with mathematics in the classroom. For this reason, mathematics tasks are posited as being fundamental to the teaching and learning of mathematics (Boaler, 2016; Hiebert & Wearne, 1993; Schoenfeld, 1994). In response to a research study, Hiebert and Wearne (1993) noted that instruction relates teaching and learning, and possibly influencing the level of thinking that students are engaged in.

In regards to a project aimed at enhancing the mathematical learning for indigenous students in remote communities, Grootenboer (2009) reported that central to the pedagogical approaches to develop the project is the design of mathematical tasks. Thus, it is imperative that mathematics classroom activities are orchestrated in such a way that they foster an appreciation of what mathematics is and what doing mathematics means (Schoenfeld, 1994). However, Bridge et al. (2012) posit that within classrooms where the culture of mathematics is driven by prescribed textbooks, and where lessons are critiqued against mandated curriculums, teachers often find it difficult to design rich tasks that are engaging to students. Naresh (2015) suggests that integrating ethnomathematics components into mainstream classrooms as opposed to using it as an

alternative for academic mathematics may provide meaningful learning for students, since an ethnomathematics approach covers all aspect of the mathematics teaching and learning, including content and the process of curriculum (Aikpitanyi & Eraikhuemen, 2017). Additionally, Wiggins and McTighe (2005) propose that a backward design approach to planning tasks, which first considers the end result, may help task designers to focus on the understanding that is worthwhile.

### **Criticism of Ethnomathematics**

Despite the many benefits outlined by proponents of ethnomathematics, many believe that mathematics should be taught in homogenous curricula and pedagogy (Brandt & Chernoff, 2015) and therefore critique and ethnomathematics approach. Rowlands and Carson (2002) maintain that the “bottom-up” curriculum offered by ethnomathematics and other related approaches, whereby children initiate and solve problems based on interpretation garnered from the group to which they belong, minimize mathematics as a discipline with an abstract body of knowledge. Furthermore, Pais (2011) asserts that critics acknowledge the manifestation of knowledge from different cultures; however, they believe that Western knowledge is superior because it gives people the potential to fully access modern society. Therefore, school and school mathematics should afford this opportunity to everyone by giving them access to this universal knowledge, learned without context. Furthermore, Rowlands and Carson (2002) argue that if mathematics is understood and utilized based on cultural perception, as proposed by ethnomathematics, then such an approach would ironically maintain the status quo instead of promoting equity as advocated by proponents of ethnomathematics. Pais (2011) also argues that if the theoretical framework of a divergent educational model

of equity and diversity inadequately representing individual culture, then such multicultural approach becomes racist. That is, the “Other is squeezed from its otherness”; a willingness “to accept the Other as long as it is deprived of all the vicissitudes that characterize the otherness” (Pais, 2011, p. 210).

Likewise, Horsthemke and Schäfer (2007) maintain that while application of mathematics concept may characterize a particular culture, the concept sole proprietorship of mathematics to a unique cultural is misinformed and simply strengthens disunity and marginalization. Horsthemke and Schäfer (2007) further argues that since research suggests that ethnomathematics may only be meaningful in a localized setting, where the related context is identifiable to the learners, it has limited scope to qualify as a pedagogical or epistemological paradigm; therefore, it may only be relevant to expand a contextual, cultural, and historical understanding of the underlining mathematics.

### **Application of Ethnomathematics**

Notwithstanding criticism, Naresh (2015), in a research presentation, developed and implemented mathematics content course for preservice teachers using the principles of a critical ethnomathematics curriculum, which seek balances culturally responsive pedagogy with traditional mathematics. Likewise, results from another study reported by Achor, Imoko, and Uloko (2009) revealed that students who were taught using an ethnomathematics teaching approach showed superior attainment than students taught using traditional approach, in terms so academic achievement and retention of knowledge. The study was conducted with Nigerian school children after noting the tremendously alarming failure and that the Eurocentric mode of teaching, had no bearing on their cultural understanding. Moreover, Naresh (2015) argues that such curriculum is

necessary not only to empower all learners and widen the pedagogical understanding of both teachers and students but also to dispel the notion shared by some educators that an ethnomathematics approach compromises the legacy of academic or school mathematics.

Furthermore, Lewis, Manouchehri, and Gorsuch (2017) recommend proposing ethnomathematics strategies within the curriculum to scaffold modeling cognition, noting that modeling is deeply embedded in students' cultural experience. Stohlmann, Maiorca, and Olson (2015) indicate that even though modeling is an innovative teaching approach that can immerse students into a meaningful learning experience, research suggests that teachers find it difficult to incorporate task relating to mathematical modeling into teaching and learning of mathematics. Lesh and Doerr (2003) noted that mathematical modeling refers to how conjectures and inquiries about real-life events are expressed using new or existing mathematical ideas. Agreeably, Daniel and Milton (2007) noted that ethnomathematics uses mathematical modeling to solve real-world problems and translate them into modern mathematical language systems.

### **Summary of Literature Review**

A long history of mathematics being perceived as an elitist subject has resulted in traditional teacher-centered pedagogical practices that are still dominant in many classrooms (Boaler, 2016; D'Ambrosio & D'Ambrosio, 2013). This approach, also called the Eurocentric view of mathematics, mainly focuses on transmitting procedures and rules to students; therefore, many perceive mathematics as an irrelevant subject, void of meaning. Consequently, many researchers (D'Ambrosio & D'Ambrosio, 2013; Lewis et al., 2017; Naresh, 2015) contend that a cultural approach to teaching mathematics, in which students used their sociocultural background to scaffold mathematical concepts,



will help them to see the applicability of mathematics to everyday life situation, thus extracting students' creativity and critical thinking skills.

Moreover, ethnomathematics, which broadly speaking relates mathematics with culture, is valued as a means to promote inclusion and equality in the classroom, since from this point of views mathematics is an expressions of mathematics practices within cultural groups (Haryanto et al., 2017, p. 325). This idea is central to encourage all students to include their cultural understand of mathematics in the classroom, thereby challenging the hegemonic Eurocentric perception of mathematics (Brandt & Chernoff, 2015; Powell & Frankenstein, 1997). Furthermore, ethnomathematics principles can be applied to all aspects of the curriculum to enhance teaching and learning (Aikpitanyi & Eraikhuemen, 2017), including mathematical tasks, which is valued as a crucial area of the curriculum that bridges the gap between teaching and learning.

In sum, while many writers critique an ethnomathematics approach to teaching and learning (Brandt & Chernoff, 2015), ethnomathematics principles are applied successfully in classrooms.

### **CHAPTER THREE: METHODOLOGY**

This chapter details the research process used to develop the handbook, *Using Ethnomathematics Principles to Create Rich Mathematical Tasks: A Handbook for Intermediate Math Teachers*. The process of developing the handbook as it relates to the theme extracted from the literature review is first discussed, followed by the need for the handbook, implementation of the handbook, and a chapter summary. The complete handbook is presented in chapter 4 of this developmental study.

#### **Process of Development of the Handbook**

The primary objective of this handbook is to guide teachers to design rich mathematics tasks that are inclusive of all students, given the diverse needs in the classroom. The handbook was developed using ethnomathematics principles, which broadly speaking is how culture relates to mathematics (D'Ambrosio, 2001).

Ethnomathematics principles were considered for the development of this handbook because everyone can identify with a culture, giving all students an access point to learning. An extensive literature review uncovered several focuses of ethnomathematics as well as several components of rich mathematical tasks that were utilized in the compilation of this handbook.

#### **Themes of Ethnomathematics**

Ethnomathematics' primary objective is to incorporate mathematics found in identifiable cultural groups into the mainstream classroom. The two major themes that emerge from the literature review under which the purposes of ethnomathematics can be captured are:

1. **Making Mathematics More Meaningful**—Ethnomathematics seeks to use culturally focused pedagogy to help students connect the practical aspect of everyday life with the abstraction of mathematics. In other words, ethnomathematics sees mathematics as a human activity, embedded in culture. The objective of such a curriculum is to demystify the false connotation of mathematics as a procedural subject that is void of meaning and, therefore, is irrelevant. It is believed that this approach to curriculum design will help to prepare students to attend to the needs of society.
2. **Encouraging More Inclusive Practices in the Classroom**—Ethnomathematics include other ways of knowing by highlighting the contribution of different cultures to mathematics over time, opposing the Eurocentric view of mathematics as an elitist subject. The idea is to break down the social divides that pedagogical practices based on this perspective promote among diverse cultures. This aspect of ethnomathematics is concerned with including diverse cultures so that no student will feel alienated. In addition, ethnomathematics presupposes that the multiple perspectives will encourage aesthetic and creativity in problem-solving within the classroom.

### **Rich Mathematical Tasks**

Rich mathematical tasks are vital for effective teaching (Hawera & Taylor, 2011).

The literature review reveals several components of rich mathematical tasks that are summarized below:

1. **Open**—Rich mathematical tasks are open in that they can be attempted and represented in multiple ways, with varying solution pathways (Boaler, 2016).

2. Inclusive—Rich mathematical tasks cater to a wide cross-section of students in terms of supporting previous mathematical achievement, attracting interest, as well as scaffolding informal mathematics knowledge (Grootenboer, 2009; Hawera & Taylor, 2011; Knowles, 2009).
3. Challenging but Attainable: Low Floor, High Ceiling (Boaler, 2017; Knowles, 2009)—Rich mathematical tasks should be accessible by all students but have the potential to extend to high cognitive levels. The exploratory potential of such tasks may also lead students to unexpected insights.
4. Learner-Centered—Rich mathematical tasks are learner-centered by their very nature. Since tasks are based on a constructivist approach to learning in that they encourage a unique solution pathway instead of a prescribed method (Boaler, 2016), the teacher’s role is mostly supervisory. Such an approach opposes the traditional teacher-centered approach, which focuses on routine algorithm and calculation (Bell, 1993; Ben-Chaim et al., 2007).
5. Engender Skills of Mathematicians—Rich mathematical tasks are exploratory in nature and require the skills mathematicians use to solve problems such as conjecturing, hypothesizing, justifying, proving, explaining, reflecting, and reporting (Bell, 1993; Boaler, 2016; Breen & O’Shea, 2010; Grootenboer, 2009; Knowles, 2009).
6. Encourages Collaboration Among Students—Rich mathematics promotes discussion and collaboration among students in order to develop deep conceptual understanding (Boaler, 2016; Knowles, 2009).
7. Authentic—Rich mathematical tasks may be authentic in that they “are genuine,

trustworthy and usually present problems with relation to everyday life” (Ben-Chaim et al., 2007, p. 335); rich in that they reflect the use of mathematical knowledge in the community (Knowles, 2009).

### **Task Design**

Another salient point derived from the literature is the importance of task design to transform the mathematics experience of learners, foster meaningful learning, and to determine their future progress in mathematics. Consequently, mathematics teachers should consistently reflect upon their approach to teaching and learning and the resulting effect on students’ outcome. Wiggins and McTighe (2005) state:

Teachers are designers. An essential act of our profession is the design of curriculum and learning experiences to meet the specific purposes. We are also designers of assessments to diagnose student needs to guide our teaching and to enable us, our students, and others (parent and administrators) to determine whether our goals have been achieved; that is, did the students learn and understand the desired knowledge? (p. 13)

There are many approaches to curriculum design that subsequently determine the tasks and experiences of the teaching and learning process (Ornstein & Hunkins, 2017). The handbook takes advantage of the backward design approach to curriculum planning by Wiggins and McTighe (2005) because the focus of this approach is to provide meaningful learning through authentic task development, which is also a key aim of ethnomathematics. The backward design approach to curriculum planning first considers the end result (knowledge, skills, goal, standard or value, and attitude) essential for students to know or do before designing of the activity. Wiggins and McTighe (2005)

believe that this is the most effective approach to curriculum planning because, unlike the subject design approach, which aligns curriculum content to textbooks (Ornstein & Hunkins, 2017), this approach focuses on the end performance of students and the teaching required to give all students an equal chance to get there. The inclusive theme of this approach is also shared with ethnomathematics through the ethics of diversity, which is “respect for, solidarity with, and cooperation with the other (the different)” (D’Ambrosio & D’Ambrosio, 2013, p. 22).

Additionally, by the very nature of backward design approach, designers are required to put into operation their goals based on assessment evidence at the beginning of planning as opposed to considering the assessment at the end or toward the completion of an assessment period (Wiggins & McTighe, 2005). Assessment is not only critical to the teaching-learning process of different subjects (Ortega & Minchala, 2017) but is also vital to provide suitable evaluations in the curriculum process (Ornstein & Hunkins, 2017). The backward design planning can be summarized into three stages (Wiggins & McTighe, 2005):

1. Stage 1: Identifying Desired Results—At this stage, the aim is to formulate a clear perspective of what students should know, understand, and be able to do. It is determining what knowledge is worthwhile and what enduring understanding is required.
2. Stage 2: Assessment Evidence—This stage involves thoughtful consideration of what assessments are acceptable evidence of student understanding and proficiency in relation to Stage 1.

3. Stage 3: Plan Learning Experiences and Instruction—This stage focuses on designing the task, or activities, and considering the teaching method and resources necessary to “hook” students into a rich learning experience.

### **Need for the Handbook**

The importance of teachers to the teaching and learning process should never be overlooked. They are the “most important resource for students” (Boaler, 2016, p. 58). It is by their vision and interpretation of the curriculum that students are immersed in rich learning experiences that provide meaningful learning. The literature review reveals that mathematical tasks play a vital role in bridging that gap between teaching and learning. Rich mathematical tasks scaffold critical thinking skills, which according to Lipman (2014) is skillful meta-cognition that facilitates good judgment within a specified context. On the other hand, the literature also reveals that teachers often find it difficult to design these rich mathematical tasks to help students attain essential learning outcomes relating to critical thinking. Therefore, there is a need for universities and colleges to provide adequate support to help pre-service teachers develop rich mathematical tasks that support deep, connected understanding in students.

Additionally, the literature points out that many mathematics classrooms are dominated by procedural approaches to mathematics, which give students a false impression of what it means to do mathematics. The literature points to what Kuhn and Dean (2004) refer to as “activities that have value” (p. 273) to counteract traditional teaching methods, which is diagnosed as inadequate.

Another salient point of the literature review is the importance of tasks to promote diversity and inclusion in the classroom. The issue of diversity and inclusion is a point of

interest in many countries and is supported by human rights acts and educational policies. Thus, this should be of major consideration in curriculum planning, particularly in mathematics education since there is a slow transition from traditional approaches to teaching (Dalene et al., 2017).

Given the power of rich mathematical tasks to aid in the teaching and learning process, both pre-service and in-service teachers should be furnished with as many resources as possible to assist them with the mandate of educating the nation's children. As is well known, the future of the society rest in hands of the children, therefore it is incumbent on educators to find ways to make the classroom experience count, thereby helping them to be global citizens who are critical thinkers capable of negotiating world peace (Kuhn & Dean, 2004). Therefore, amidst the mounting challenges in the classroom, such as time constraint and disciplinary problems, this handbook aims to provide teachers with information to aid in designing tasks.

### **Implementation of the Handbook**

Since culture and the use of mathematics (formally or informally) is common in every society, this handbook, which underscores cultural pedagogy in mathematics education, has universal application. However, this handbook was designed using the Ontario Mathematics Curriculum for years 7 and 8 to be applicable to said levels across schools in Ontario, Canada. The handbook can be used by curriculum designers, teachers, and parents or by anyone who is involved in the teaching and learning process. It can also be utilized by colleges or universities to assist in instruction on task design.

### **Summary**

Pedagogical practices relating to mathematics education have generated much interest in the Western world. Designing tasks that provide worthwhile classroom



experiences for students is among the areas that are heavily debated. There are many descriptions and designs made available by researchers to aid in creating these tasks. While there is a wide body of available information, it is the responsibility of mathematics educators to carefully assess the learning needs of students in planning tasks and activities to meet these learning need. Also, teachers need to continually reflect upon their practice in light of emerging research, which may point to alternative ways of teaching. In general, mathematics educators should not be static recipients of curriculums but rather creators of meaningful learning so that their teaching experience may also be a process of growth and development.

## **CHAPTER FOUR: THE HANDBOOK**

The following handbook was developed as a resource for mathematics teachers of all levels to help them provide more meaningful and inclusive mathematics. The handbook has three chapters: (a) Ethnomathematics: Making Mathematics Meaningful; (b) Ethnomathematics: Promoting Inclusive Practices in the Classroom; and (c) Ethnomathematics: Designing Culturally Rich Mathematics Task.

Brock University Department of Graduate and Undergraduate  
Studies in Education

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# Using Ethnomathematics Principles to Create Rich Mathematical Tasks

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A Handbook for Intermediate Math Teachers  
Wendy Ann Forbes



2018

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# Introduction

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As globalization heavily influences social, economic and political changes in society, preparing students to positively respond to those changes is of utmost importance (Ontario Ministry of Education, 2018; Spring, 2015). According to Spring (2015), nothing remains constant in the global education hierarchy that affects national and local school policies and practices. Further, Spring (2015) noted that the global economy has become the steering wheel of mass migration of worker, resulting in worldwide conversations about multicultural education. These and other realities have clearly communicated to educators and researchers that traditional teaching approaches cannot sufficiently contend with ensuing issues of diversity and inclusion while providing meaningful learning that will equip students with the necessary skill-set to function in a global society. Therefore, classroom teachers and curriculum planners are pressed to utilize innovative teaching approaches to facilitate a multicultural setting in classrooms. Given that inclusive practices play a pivotal role in the dynamics of these classrooms, ethnomathematics, which focuses on cultural sensitive pedagogy is quite applicable in these contemporary classrooms.

This handbook provides useful information on how ethnomathematics can be used to enhance pedagogical practice by providing meaningful and inclusive strategies. Therefore, the first chapter of this handbook explores meaningful mathematics, while conveying the understanding that ethnomathematics provides meaningful brain-based learning. The second chapter of the handbook covers key aspects that inclusion through ethnomathematics naturally addresses. In the third chapter, the handbook looks at components of rich mathematics task, which bridge the gap between teaching and learning. Further, it looks at how ethnomathematics



principles can be used to create rich tasks that are both inclusive and meaningful based on criteria in the first two chapters. The task was designed using the backward design approach, which is designing for understanding.

# How to Use the Handbook

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An ethnomathematics approach encompasses all aspect of the curriculum (Aikpitanyi & Eraikhuemen, 2017). Therefore, the information presented in this handbook can be utilized by administrators, curriculum planners, and teachers. The principles in the handbook can be both applied to the overt or hidden curriculum. While all the information in this handbook is important, suggestions in this handbook are highlighted as “Meaningful Tips”, and focal information is highlighted as “Important to Note.” Users of this handbook are encouraged to carefully read through this it and applied the information to applicable areas of the curriculum, whether direct instructions or development of rich mathematical task, as in this handbook.

The last chapter of this handbook outline how to use the backward design planning process to create culturally rich mathematics tasks based on ethnomathematics principles. In general, the information in this handbook can be utilized alongside other theories and practices to promote meaningful and inclusive pedagogical practices.

# Ethnomathematics:

## Making Mathematics Meaningful

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### Key Terms

**Ethnomathematics** - The relationship between mathematics and culture (D'Ambrosio, 2001).

**Ethnomathematics pedagogy** – Pedagogical practices that incorporate diverse cultural practices into the teaching and learning of mathematics. (D'Ambrosio, 1985).

**Culture** – culture refers to the identifiable groups that a person is a part of which include urban or rural communities, working groups, students in groups, social groups, and other specific groups (Haryanto, Nusantara, Subanji, & Rhardjo, 2017).

Designing meaningful mathematics experiences to meet the learning needs of diverse students, can be a daunting task for teachers. However, by focusing on key elements when creating instructional activities, teachers can help all students to experience growth in mathematics (Megan, 2010).

### Meaningful Tips



To make mathematics meaningful, ensure that your lessons, activities or tasks:

- ✓ are personally relevant
- ✓ facilitate deep connected understanding
- ✓ enhance reasoning
- ✓ give students opportunities to collaboration
- ✓ are engaging and inspiring

### Important to Note





Importantly, mathematics lessons should lead students to make their own meaning, rather than teachers aiming to transmit what they discern as meaningful to students. Students mathematical perceptiveness is determined by the mental structures or frames that they have constructed. These further dictate how they negotiate mathematical problems and situations, thus, building their mathematical experiences (Battista, 2010).

Students will come to the classroom with mental structures that are influenced by mathematics experiences based on their background, whether they are assimilated formally from prior classroom experiences, or informally constructed from sociocultural experiences.

The diagram below illustrates how students form new experiences. The circle for sociocultural experiences is bigger because it is suggested that instructional strategies use sociocultural experiences to scaffold classroom experiences.

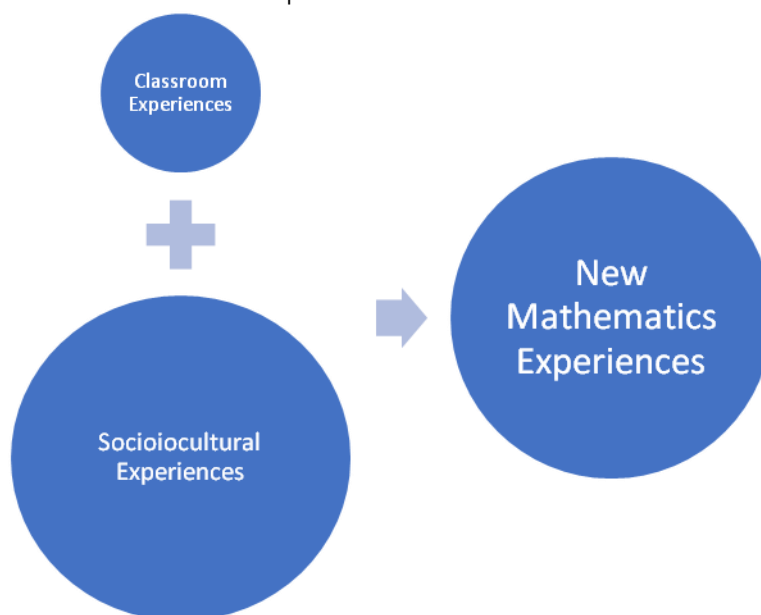


Figure 1

In many cases, mathematical experiences within the classroom are negative and traumatic (Boaler, 2016), therefore, focusing on the sociocultural experiences may

prove to be more positive for students. Sociocultural experiences are acquired naturally and are not traumatic to students (Caine & Caine, 1990).

### Meaningful Tips



- ✓ Use sociocultural experiences to scaffold classroom experiences in order to make mathematics meaningful to students (Caine & Caine, 1990).
- ✓ Do not restrict yourself by the curriculums- Often times, teachers restrict themselves by curriculum, thus their initial approach inhibit students' full engagement (Edwards, Harper, & Cox, 2013).

Students can construct their sociocultural experience in many different ways. Battista (2010) notes the following as ways which students naturally acquire their sociocultural experiences.

- Cultural artifacts such as language and symbol/representation systems
- Social norms, interaction patterns, and mathematical practices of the various communities in which students participate
- Direct interactions with other people (including teachers)
- Cultural backgrounds and contexts

The following sections will explore each aspect of meaningful mathematics in relation to sociocultural experiences.

## Meaningful Mathematics



Figure 2

## Personally Relevant Mathematics

There is overwhelming research indicating that making mathematics meaningful is making mathematics relevant to students' experiences. Brough and Calder (2014) suggest that in reflecting on their practice, teachers of mathematics must ask themselves if the way they teach replicates the experiences that students will encounter on a daily basis.

Although it is important for teachers to orchestrate the learning environment for students to be immersed in the learning experience, educators should value that meaning-making and the experiences that prove relevant to the learners are ultimately dependent upon them.



### Meaningful Tips

- ✓ Do not make the mistake of designing tasks and activities that are so specific such that there is no room for learners to connect learning to prior experiences.
- ✓ A task or activity can be embedded in real-life based on a teacher's perception but may still not be personally relevant to students because

there is no opportunity given for them to connect new knowledge with their prior knowledge (required by brain-based learning).

- ✓ Students should be given the opportunity to make conjectures that are relevant to their personal experiences. Cultural pedagogy offers the platform whereby this can be accomplished.

### Important to Note



Ethnomathematics principles do not offer a static learning experience as suggested by challengers of cultural pedagogy, but instead, provide a framework where students can consistently link ongoing experiences outside of the classroom with new knowledge experienced in the classroom. When this is done, mathematics will remain personally relevant to students. The path to solving complex problems begins with challenges that students are presently facing as a result of their sociocultural experiences, and further develops based on student interest and the new experiences they encountered. As posited by Clark and Rossiter (2008), human beings are constantly storying or constructing narratives to make sense of the myriad experiences they encountered.

“Coherence creates sense out of chaos by establishing connections between and among these experiences” (Clark & Rossiter, 2008; p. 62).

The above quotation is also true for mathematics education. As students experience mathematics in and out of the classroom they will need to connect both experiences in order for mathematics to be meaningful or relevant to them. As indicated by Caine and Caine (1989), meaning making is inherent to human beings. Cultural pedagogy provides the means for students to link both knowledges

Therefore, activities and tasks should not be so specific such that learners cannot incorporate their unique experiences to make meaning of the mathematics they experienced in classrooms. Moreover, in designing activities teachers should be mindful that each student's narrative or story is different and the way they restory there narrative will also be different (Caine & Caine, 1990; Clark & Rossiter, 2008).

## Deep Connected Understanding

### Key Terms

**Mathematizing** When students mathematize, they describe a situation or problem using symbols which may include diagrams or graphs. They further manipulate the symbolic mathematical problem to understand the existing relationships or answer questions about the particular situations.

Mathematizing is different from solving routine procedural problems.

(Galileo Educational Network Association, 2014; Jupri & Drijvers, 2016).

**Skills of a Mathematician** Hypothesizing, justifying, proving, explaining, reflecting, reporting etc. (Bell, 1993; Boaler, 2016; Breen & O'Shea, 2010; Grootenboer, 2009; Knowles, 2009).

Teaching for deep connected understanding surpass traditional approach of preparing students to solve prescribed mathematics problem; rather, it requires a more student-centered curriculum where mathematics knowledge is constructed by teachers and students. This approach places emphasis on the learning and problem-solving that is relevant to students' immediate environment or those that result from conjectures posed by students from interaction with the learning environment (Brough & Calder, 2014).

Students should be given the opportunity to mathematize. Students mathematize to make sense of something or to solve a problem, by using mathematical language to express a situation (Galileo Educational Network Association, 2014). Naturally, the problems and situations that would provide deep connected understanding are those that are directly related to student sociocultural experiences.

## Meaningful Tips



- ✓ Students should be encouraged to make inquiries relating to their interest and background in order to develop their mathematical thinking.
- ✓ Since students are expected to use mathematics to solve complex problems that they will encounter in their future careers, a practical starting point is to solve problems that arise from their natural environment using the mathematical they are exposed to.
- ✓ The focus of teaching and learning should be to engender skills that mathematician used to solve problems, focusing on the problems students encounter in their everyday life; problems from their sociocultural experience.
- ✓ The classroom should be a place where these problems are expressed and investigated through mathematizing.

## Reasoning

**Mathematical Reasoning** is seen as a high-level cognitive process, which involves interrogating a problem or phenomenon to arrive at a reasonable result (Erdem & Gürbüz, 2015).

The focus of 21-century learning is students as constructors of knowledge; rather than merely consumers of information (Bada & Olusegun, 2015). This shift from the traditional teacher-centered approach to learning has redefined the meaning of mathematical proficiency; thus, affecting pedagogical practices within

mathematics classrooms. Therefore, educators and researchers alike are pressed to develop teaching approaches that facilitate skill that will that fulfill the mandate of new mathematics curriculums. One important skill that seem as indispensable to doing mathematics is mathematical reasoning (Gürbüz, Erdem, & Gülburnu, 2018). Mathematical reasoning is seen as a high-level cognitive process, which involves interrogating a problem or phenomenon to arrive at a reasonable result (Erdem & Gürbüz, 2015). Mathematical reasoning can be developed using carefully designed tasks (Mueller, Yankelewitz & Maher, 2015). Therefore, Stacey (2012) recommends that age-appropriate reasoning tasks, which are progressively sophisticated should be methodically included throughout a student's mathematics experience. However, Cheeseman, Clarke, Roche, and Walker (2016) points out that teachers often find it challenging to present these tasks to students in a way that is not daunting, but instead sustain engagement and exploration while maintaining an appropriate level of challenge.

### Important to note

A plausible way to attract students to mathematical reasoning activities is to give them the avenue to incorporate their cultural experiences. In that way, tasks will be open, having low floor and high ceiling, as Boaler (2016) required for learning tasks that are accessible to all students. Low floor in that all students will have an access point and high ceiling in that the tasks will provide opportunities for challenge. The access point of the task would be culturally relevant problems that are initiated by students with guidance from teachers, and then develop through mathematizing and mathematical reasoning skills. Mathematical reasoning skills involve “generalizing/abstraction/modeling, ratiocination, development and creative thinking skills and the relationships among these skills” (Mumcu & Aktürk, 2017, p. 225).

## Meaningful Tips



- ✓ Put reasoning in the hands of the students by allowing them to make decisions on how to initiate problem-solving. Cheeseman et al. (2016)
- ✓ Encourage students to develop reasoning by initiating a task using the following steps by Cheeseman et al. (2016):
  1. Understanding the requirement of the task.
  2. Access relevant mathematical knowledge.
  3. Design a plan.
  4. Put the plan into effect.

## Important to Note



Students should be encouraged to understand the task in relation to sociocultural experiences. This will add relevance to the task and help engage students into the learning experience. Properly guided by the teacher, the learning experience can remain challenging for students.

## Collaboration

Collaborative skills are seen as critical in today's technological and scientific society. As a result, various techniques have been employed to facilitate collaboration through learning in contemporary education (Capar & Tarim, 2015; Wu, 2018). Furthermore, collaborative learning is valued by many educators as a means to increase interest among students, as well as to promote critical thinking (Gokhale, 1995). Two approaches that are commonly employed to increase collaboration are cooperative learning and collaborative learning. Though similar, they differ in how tasks are assigned and evaluated. Both techniques involve



students working in groups or teams to accomplish tasks. However, they differ in that cooperative learning emphasizes team-work while collaborative learning focuses on individual performance within a team (Wu, 2018). Though some educators may value one approach over the other, from a cultural standpoint both are relevant in extending cultural practices to the classroom. Within a communal setting, individuals work together to achieve a common goal, as well as to achieve individual goals. It is also true that individuals work independently within a communal setting. Thus, the method employed by a teacher should be dependent on the learning objective.

### Important to Note

Students should be given the option to choose their mode of learning (group work or individually) appropriate to their sociocultural background or based on the approach they choose to express their mathematical thinking. Within a classroom setting, there will be students of similar culture who may want to work together to accomplish a common task, while there may be others who choose to work independently because of how they choose to express the requirement of the task. The idea is that teachers should not merely place students in groups and assign roles to accomplish a preset task in a bid to increase collaboration. Such a method is a teacher-directed approach to collaborative or cooperative learning. Instead, teachers should encourage collaboration among students, whether within groups or across groups. Students should be encouraged to ask each other questions and make suggestions to each other.

## Engaging and Inspiring Mathematics

Student engagement and inspiration is hinged on how successfully teachers design the learning environment. Here, the learning environment is referring to anything (task, activities, direct instruction, hidden curriculum, etc.) that affects

the overall atmosphere. Research indicates that teachers who are mindful of maintaining a positive classroom environment are more likely to scaffold deep understanding by capturing students' engagement (Merritt, 2013). Boaler (2016) noted that the zenith of students' engagement is mathematics excitement, which this is highly dependent on teachers. Research indicates that focusing on how the brain works can help educators to design curricula, lesson plans, or classroom tasks and activities that engage and inspire students (Ambrus, 2014; Busso & Pollack, 2015; Gözüyeşil & Dikici, 2014; Moghaddam & Araghi, 2013). We will now look at brain-based learning and how ethnomathematics pedagogy supports this type of learning.

### **Brain-Based Learning**

Traditionally, people were perceived as having a fixed brain and potential. This belief has influenced the teaching and learning process such that there was not much variation in the learning environment and strategies used in the classroom. However, with the development of neuroscience in recent years, there are myriad of research in the field of education on pedagogical practices with respect to how the brain works. This information has unearthed many innovative teaching approaches. Brain-based learning associates learning with the structure and function of the brain by using neuroscience techniques to examine the connection between the brain, the neural system and our cognitive behavior learning (Gözüyeşil & Dikici, 2014; Moghaddam & Araghi, 2013). Therefore, designing lessons with brain-based learning techniques can help mathematics educator to facilitate improved learning.

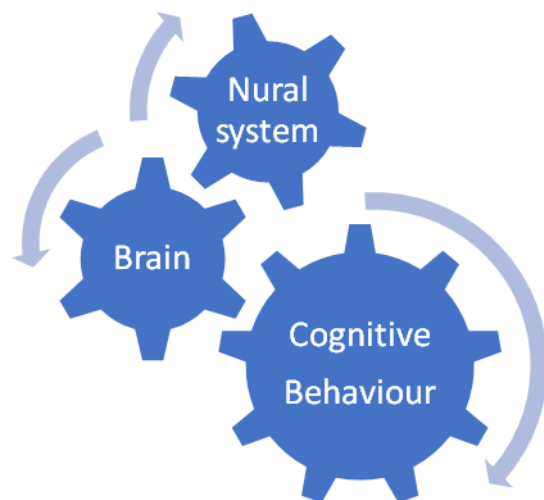


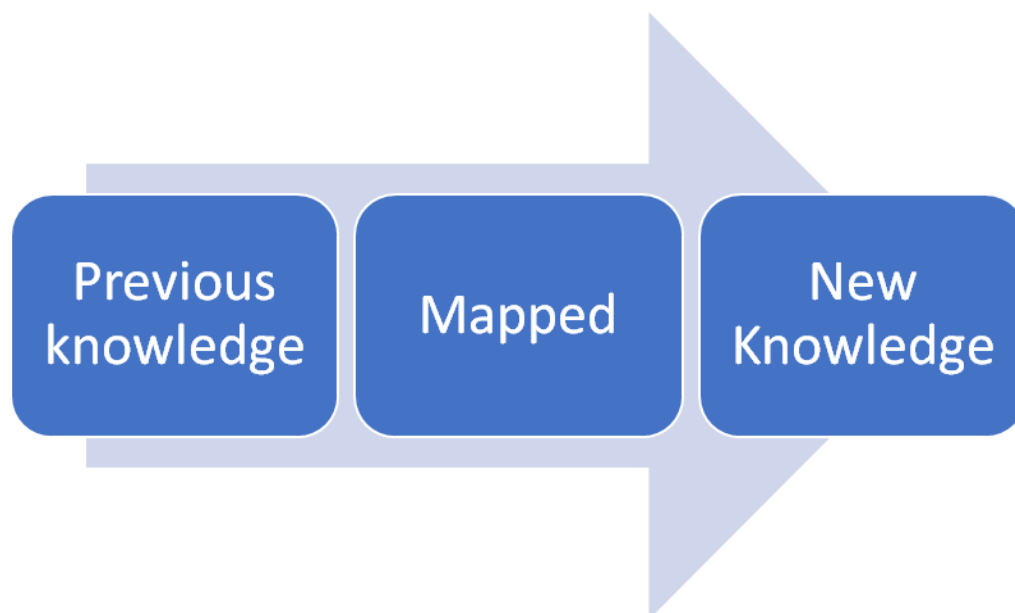
Figure 2

### Important to Note

Brain-based learning:

- Facilitate natural learning by using strategies to organize lessons.
- Identify ways of maximizing learning and enhancing performance.
- Improve the learning of students by recognizing the individual differences.
- Develop instructional strategies to help students assimilate, think and remember.

The main idea of brain-based learning is meaningful learning, which is maintained when new knowledge is mapped to previous knowledge. (Gözüyeşil & Dikici, 2014). This is also at the core of ethnomathematics. Teachers using an ethnomathematics approach to planning should focus on scaffolding new mathematics knowledge with cultural understanding. This can be done in many innovative ways using mathematics history, community mathematics or inviting students to use their cultural perception to mathematize.



*Figure 3: Mapping means that new knowledge is connected to previous knowledge and the new knowledge becomes a part of the current learning system. (Keleş & Çepni, 2006, as cited in Gözüyeşil & Dikici, 2014)*

Brain-based learning is theoretically established on twelve principles of the brain. Educators who use ethnomathematics pedagogy may also use these principles by Caine and Caine (1990) as a frame of reference to guide their practice. The following table outline these twelve principles. There are three columns. The first two column summarizes Caine and Caine (1990) work on the twelve brain principles and their implication to education, respectively. The third column, cultural connection, explores how an ethnomathematics approach to teaching and learning measures up to brain-based learning.

## Twelve Principles of Brain-Based Learning

Principle of Brain Based Learning	Implication for Education	Cultural Connection
<p><b>Principle One: The Brain is a Parallel Processor.</b></p> <p>Brain processes involve multiple modes. Thoughts, emotions, imagination and predispositions happen simultaneously.</p>	<p><b>Implications for education:</b></p> <p>Good teaching incorporates a wide range of methods and techniques to fully engage students, taking advantage of the brain's potential. Addressing multiple modes increases the students' retention and understanding of concepts.</p>	<p>Students learn in a variety of ways, which is attached to their cultural experiences (Green, 1999). Thoughts, emotions, imagination and predispositions interact with cultural understanding (Caine &amp; Caine 1990).</p> <p>Furthermore, studies show that when multiple mental codes - verbal (symbolic), iconic (visual) and motor- are used to represent information, students are more likely to remember information (Ambrus, 2014). Cultural activities normally involve more than one mental codes. These findings imply that allowing students to incorporate their cultural experiences increases learning.</p>

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<p><b>Principle Two: Learning Engages the Entire Physiology.</b></p> <p>Learning occur naturally, similarly to how breathing, takes place; but it can either be inhibited or facilitated. Whatever affects our physiological operations affects our learning capacity.</p>	<p><b>Implications for education:</b> Brain-based teaching must fully incorporate the whole being e.g. stress management, nutrition, exercise, drug education, or anything that affects our physiology should be factored into the learning process.</p>	<p>An ethnomathematics approach involves students constructing their mathematics knowledge from their cultural understanding. This is a constructivist approach to education, which is noted as less stressful to students (Bada &amp; Olusegun, 2015). Thus, using an ethnomathematics promotes a healthy learning environment</p>
<p><b>Principle Three: The Search for Meaning Is Innate.</b></p> <p>The quest for meaning or making sense is inborn. The brain innately desires and recognize the familiar while responding to stimuli that are foreign. This search for meaning can only be focused and directed but not stopped.</p>	<p><b>Implications for education:</b> The learning should be an environment should facilitate stability and familiarity. It should simultaneously facilitate innovation, exploration, and challenge.</p>	<p>Culture is a stable and familiar context. Culture takes root in practically all aspects of human living Sánchez (2018). Teachers can use the familiar to bridge the unfamiliar (previous knowledge is mapped on to new knowledge).</p>

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<p><b>Principle Four: The Search for Meaning Occurs Through "Patterning"</b></p> <p>Meaning making occur through patterning, naturally. Therefore, the brain resists meaningless information. Meaningless information refers to isolated pieces of information that is not related to what make sense to the learner. "When the brain's natural capacity to integrate information is acknowledged and invoked in teaching, vast amounts of initially unrelated or seemingly random information and activities can be presented and assimilated." (p. 67)</p>	<p><b>Implications for education:</b> Patterning is a constant process for the learner, even when they are not involved in formal learning activity. This cannot be stopped but can be influenced using different approaches.</p>	<p>Everyone has a unique culture that is familiar. Therefore, teachers can use ethnomathematics to help students make connections. Mathematical expression is derived from natural pattern of the real-world. Teachers can help students to use similar patterns that are a part of their cultural experiences to make connections.</p>
<p><b>Principle Five: Emotions Are Critical to Patterning</b></p>	<p><b>Implications for education:</b> It is important for teachers to</p>	<p>Cultural is all-encompassing and includes activities that are</p>

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<p>Learning is influenced and organized by emotions, the perception of our abilities and our desire for social interactions.</p>	<p>understand that students' feelings and general disposition is involved and will determine present and future learning. Thus, teachers should make the classroom climate emotionally conducive for learning.</p>	<p>linked to emotions such as arts, history, music, philosophy and religion. (D'Ambrosio &amp; D'Ambrosio, 2013). Teachers, can therefore use these expressions of culture to help students map prior learning to new learning</p>
<p><b>Principle Six: Every Brain Simultaneously Perceives and Creates Parts and Wholes</b></p> <p>The brain has two hemispheres, the left and the right, which are separate but work simultaneously as a whole. One hemisphere reduces information into parts and the other perceive and works at it as a whole. That is, on each of our daily task, both hemisphere work together even though each part is responsible for different activities.</p>	<p><b>Implications for education:</b></p> <p>Students experience difficulties if any of the two parts of the brain is neglected. Teaching should focus on both side hemispheres because they derive meaning from each other.</p>	<p>Cultural learning facilitates the both sides of the brain. According to Caine and Caine (1990), effective teaching should scaffold both understanding and skills over a period of time as learning is a developmental process where new concepts are built on old concepts to form new learning. Likewise, Green (1999) posits that the brain best engages with and organizes information within context. Giving example, Caine and Caine (1990) note that, equations and scientific principles are best dealt</p>



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with in the context of everyday science.

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<p><b>Principle Seven: Learning Involves Both Focused Attention and Peripheral Perception</b></p>	<p><b>Implications for education:</b> All aspects of the educational environment are important. Teachers need to engage the interest and enthusiasm of students by organizing material that is not within direct focus. This include charts, artworks, music designs, and art. Also, a teacher's overall disposition and innermost attitude, impact learning significantly.</p>	<p>Ethnomathematics promotes inclusion of all culture. Teachers can use a variety of materials that culturally represent all students. Additionally, in promoting inclusion and diversity, the attitude of both teachers and students may be more tolerant, thereby improving students overall focus.</p>
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<p><b>Principle Eight: Learning Always Involves Conscious and Unconscious Processes</b> Learned information is not only what we consciously understand but also includes</p>	<p><b>Implications for education.</b> Understanding may not occur immediately but at a later time when students are given time to process information. Therefore, reflection and</p>	<p>Since students also remember their learning experience, it is important for teachers to use strategies that convey enjoyment and meaning. Teachers can encourage students to</p>
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<p>information that unconsciously enters the brain. Most information enters the brain peripherally. Our experiences become part of our understanding.</p>	<p>processing time are significant to the learning environment. This is called active processing. Teachers may enable active processing by creatively using conceptual metaphor. That is the means by which abstract concepts are assimilated by using concrete concepts.</p>	<p>use conceptual metaphors of their cultural experiences to reorganize information in a way that is personally meaningful and enjoying. Further, if learning is grounded in cultural experiences, overtime students can continue to make connection and associate it with their natural environment.</p>
<p><b>Principle Nine: We Have Two Types of Memory: A Spatial Memory System and a Set of Systems for Rote Learning</b>          We have natural spatial memory; memory that is not dependent on rehearsal but remember experiences instantaneously. This memory is unlimited and is enriched as our experiences are catalogued overtime. It is motivated by innovation and drives the quest for</p>	<p><b>Implications for education:</b> Rote memorization of fact like multiplication is a common practice in mathematics education. "However, an overemphasis on such procedures leaves the learner impoverished, does not facilitate the transfer of learning, and probably interferes with the development of understanding. By ignoring the personal world of the learner,</p>	<p>Mathematics exists in its spatial form in the personal world of students. Teacher should guide students to incorporate relatable elements of their unique cultural setting in the mathematics classroom. Practice should scaffold using brain- based techniques (Ambrus, 2014). "The more information and skills are separated from prior knowledge and actual experience,</p>

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<p>meaning.</p> <p>Correspondingly, there is the rote memory that remembers unrelated information. It deals with isolated fact and skills, which require more drilling and practice.</p>	<p>educators actually inhibit the effective functioning of the brain" (p. 68)</p>	<p>the more we depend on rote memory and repetition. These systems operate according to the information processing model of memory which suggests that all new information must be worked on before it is stored. However, concentrating too heavily on the storage and recall of unconnected facts is a very inefficient use of the brain" (Caine &amp; Caine, 1990, p. 68).</p>
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<p><b>Principle Ten: The Brain Understands and Remembers Best When Facts and Skills Are Embedded in Natural Spatial Memory</b></p> <p>Generally, experiential learning best invokes spatial memory. This is exemplified in how we learn our native language through numerous interactive</p>	<p><b>Implications for education:</b></p> <p>Embedding learning into real-life ordinary experiences adds meaning to learning.</p> <p>This process of learning is complex because it relies on the all the aforementioned principles.</p>	<p>Teachers should embed learning in a great deal of real-life activities (Caine &amp; Caine, 1990). A reservoir of experiences lies within students' cultural. Pedagogical practices should tap into this source.</p> <p>Ethnomathematics provides the means by which that source can be tapped into. "Success</p>
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experiences with vocabulary and grammar. That is an example of how specific items are given meaning when embedded in ordinary experiences. Education is enhanced when this type of embedding is adopted.

depends on making use of all the senses by immersing the learner in a multitude of complex and interactive experiences. Teachers should not exclude lectures and analysis, but they should make them part of a larger experience (Caine & Caine, 1990, p. 69).

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**Principle Eleven: Learning Is Enhanced by Challenge and Inhibited by Threat**

Learning is maximized when the brain is appropriately challenge; however, it slows down when it is threatened.

**Implications for education:**

This mean that teaches should provide an atmosphere that is low in threat and high in challenge; a state of relax alertness. Every strategy or method that teachers use to orchestrate the environment influence learning.

Cultural pedagogy offers teachers an additional learning approach to achieve relaxed alertness in the classroom. Encouraging learners to use their cultural understanding in the classroom may reduce stress as indicated earlier.

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**Principle Twelve: Each Brain Is Unique**

Although we all have identical systems such as our senses and

**Implications for**

**education:** All learners are different and learn differently; therefore, they should be allowed

Ethnomathematics provides the means by which students can use their unique experience,

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fundamental emotions, they are wired differently in every brain. As we learn, this wiring is change significantly. to use their unique experiences to scaffold learning. not void of culture, into the classroom.

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## Important to Note

Meaningful learning shifts learning from memorizing information to deep-connected learning (Boaler, 2016; Caine & Caine, 1990). In order to apply brain-based learning, teachers should apply these three interactive instructional elements or techniques by (Caine & Caine 1989, 1990): 1) Orchestrated immersion 2) Relaxed alertness 3) Active processing.

**Relaxed alertness:** Relaxed alertness means that teachers should aim for an environment that is of low threat and high challenge. In other words, an environment that eliminates fear but also is highly challenging to sustain engagement and inspiration within learners.

Many may reason that educators should aim to understand the background of students, but, how likely is this within a diverse classroom of the 21st century where diversity is ubiquitous and has ever-changing factors? Therefore, since it is not at all possible for educators to understand the background of all their students, it is more practical that tasks and activities are open. That is, facilitate an environment where all sociocultural backgrounds can be expressed, explored and developed while fulfilling the criteria of the curriculum.

Cultural pedagogy requires that the activities and tasks be open such that students can extend the learning of their cultural background to the classroom. In that way, the learning environment is low in threat and high in challenge, in that it gives students that security of a safe environment within which they are not

limited by procedural knowledge but have the leverage to be innovative in exploring and conjecturing according to their cultural understanding of situations.

**Orchestrated immersion:** As the term suggests, orchestrated immersion requires teachers to orchestrate or design or create an environment where students can be fully immersed in the learning experience. As Caine and Caine (1989) state, "immersion as an educational process refer to the intentional envelopment of a learner in multiple, interactive, lifelike context" (p. 70). In short, it is bringing learning to life.

As it relates to designing a learning experience with culture in mind, it is imperative that teachers do not make the mistake of trying to express their own interpretation of a student's culture because in doing so they run the risk of undermining the student's culture. Each student's culture is unique, even within a particular culture, and can only be understood based on individual experiences. Consequently, teachers should design the learning experience in such a way that students can express the ideas from the curriculum using their own cultural understanding, thus creating a learning discourse which merges multiple life experiences into a rich and dynamic learning environment, relevant to all students.

**Active processing:** Active processing refers to how the learner makes meaning of information by reflecting on their learning. This phase of brain-based learning allows learners to synthesize information in a way that is personally meaningful, providing conceptual understanding rather than merely memorizing of information. It is helping learners to think about their thinking (metacognition). Additionally, learning involves an emotional component, whereby in seeking to consolidate information, modification of knowledge can be disturbing. Active processing provides learners with the opportunity to deal with this aspect of learning. Another critical aspect of active processing that Caine and Caine (1989) points out is "the use of processes and procedures that avoid judgement, leaving the way open for the brain to see things in a new light" (p. 72). While, an

important part of learning is helping students to acquire and make meaning of new knowledge, giving students the opportunity to map new information to previous information that is embedded in their culture, is non-threatening and provide a useful foundation in assisting students to make connections.

Traditional approach to teaching mathematics tends to ignore that knowledge is embedded the culture of individuals. However, an ethnomathematics approach gives students the platform to use the related cultural knowledge to acquire new knowledge.

The diagram below summarizes the three interactive elements to apply brain-based learning.

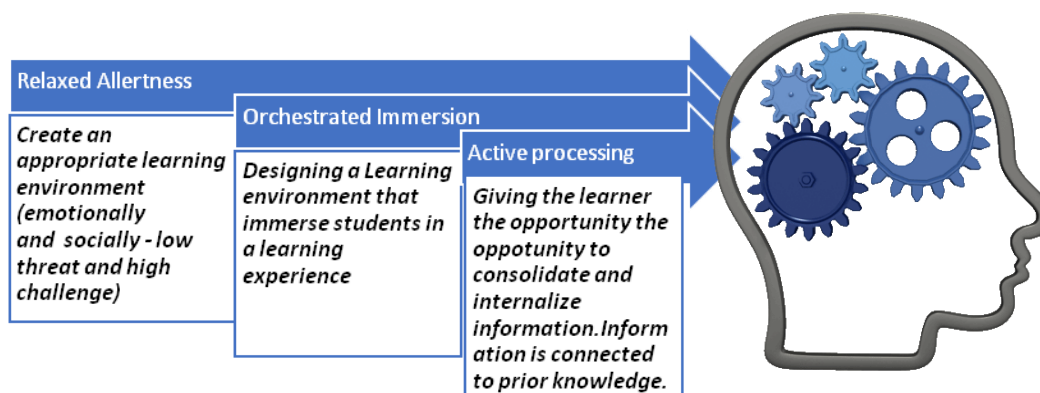


Figure 4

# Ethnomathematics:

## Promoting Inclusive Practices in the Classroom

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In today's multicultural classroom, inclusive practice is not an option but is necessary in order for classroom experiences to be beneficial to all learners, given the diversity. Furthermore, human rights acts and educational policies mandate inclusive practices in the classroom to ensure that each student is given an equal opportunity to learn. Diversity is an all-encompassing term, which accounts for qualities and attributes that accounts for differences within individuals such as "ancestry, culture, ethnicity, gender, gender identity, language, physical and intellectual ability, race, religion, sex, sexual orientation, and socio- economic status" (Ontario Ministry of Education, 2016, p. 2). Inclusion within education refers to the act of including, accepting all students within mainstream classrooms with their peers of similar age despite any notable uniqueness (Sokal & Katz, 2015).

### Important to Note



Ethnomathematics principles, with its theme of social justice, provides a worthwhile way for teachers to fulfill their learning objectives, while simultaneously promoting inclusion and diversity. In promoting inclusion and diversity in the classroom ethnomathematics, by its very nature helps to:

1. Bridge the gap between formal and informal learning.
2. Expand educators understanding of learners, thus promoting meaningful learning.
3. Promotes a growth mindset instead of a fixed mindset.
4. Extracting mathematical ideas and ingenuity of all students.
5. Helps to address issues of globalization.
6. Promotes equity in the classroom.



## Informal Mathematics in the Classroom

Many researchers and writers (Carpenter, Fennema, & Franke, 1996; Carraher, Carraher, & Schliemann, 1985; Gravemeijer & Doorman, 1999; Greer, 1997; Knowles, 2009) have for decades noted the role informal mathematics plays in scaffolding formal learning of mathematics, therefore, advocating for contextual pedagogy to teach mathematics. A contextual approach, which is noted to boost student motivation, uses context problems that are experientially real to the students to help them mathematize (Gravemeijer & Doorman, 1999). Agreeably, Greer (1997) believes that learning mathematics should relate to the experimental backgrounds of the students so that they can make sense of what they learn. Specifically, Greer (1997) posited that problem-solving should be modeled based on physical and social phenomena.

Accordingly, in a study conducted by Carraher et al. (1985), investigating the mathematics of children who sell in the street markets in Brazil, it was observed that these children solve mathematics problems relating to their context much easier than non-contextual problems, in a formal setting. The account of these writers indicates that an ethnomathematics approach offers the potential to bridge the gap between informal mathematics knowledge, from a sociocultural context, and formal mathematics knowledge from the classroom. Moreover, Gravemeijer and Doorman (1999) proposed using Realistic Mathematics Education (RME) to not just bridging the gap between informal and formal mathematics but to provide an opportunity where students are guided to reinvent formal mathematics; that is, formal mathematics emerges from the informal mathematics experience of students.

The informal mathematics found in culture may be the starting point of RME. Children learn many things informally, through *intent participation*, as pointed out by Rogoff et al. (2003). Likewise, Carlsson-Paige and Lantieri (2005) note that

“real learning is holistic and real understanding emerges from active experiences that make sense to learners (p. 100). Therefore, it is prudent for mathematics educators to capitalize on such mode of learning by applying cultural pedagogy to improve classroom instruction and students’ achievement.

## Meaningful Tips



Gravemeijer and Doorman (1999) applied the RME approach to teaching calculus and noted the following characteristics as opposed to a traditional approach. This is summarized in the table below.

Traditional Approach	Alternative Approach
Providing students with a general approach to complex problems by dissecting the problem into smaller parts, that may be ordered in a logical mathematical sequence from the point of view of the instructor.	Students and teacher work to design an insightful pedagogical sequence that emerges from a context that is familiar to the student
Learning is not grounded into students informal understanding	Provide students with opportunities to use their own informal knowledge to support their understanding
Prescribed instructional sequence	Based instruction on the students’ own contributions to the teaching-learning environment

## Meaningful Tips



Gravemeijer and Doorman (1999) also outline three different orientations that can be derived from the alternative approach that teacher may apply in teaching mathematics:

1. Helping the students qualify their experiences as the foundation of their understanding
2. Design a learning environment where the students synthesize ideas by developing and testing hypotheses
3. Fostering the (re)invention of mathematics.

Gravemeijer and Doorman (1999) point out that the first two orientations help students to bridge the gap between their informal knowledge and the formal mathematics, while the third seeks to dispel this divide by facilitating a process where formal mathematics emerges from the mathematical activities of the students. The ultimate goal of the ethnomathematics approach is to help students to reinvent mathematics; however, teachers can start by using informal mathematics to scaffold formal mathematics concept, as is done in the tasks at the end of section 3.

## Expand Educators' Understanding of Learners

The impact of globalization on classroom has progressively diversified student thinking. On one hand, this can be daunting for educators to negotiate the new dynamics and complexities of the classroom; but on the other, this new thing can lead to new learning opportunities for educators.

### Important to Note

Carpenter et al. (1996) contend that an understanding of these thought processes “can provide coherence to teachers' pedagogical content knowledge and their knowledge of subject matter, curriculum, and pedagogy” (p. 3). Thus, there are tremendous benefits for teachers to understand different ways of knowing. Accordingly, Merriam and Kim (2008) note, with regard to adult education, that an exposure to other ways of knowing can help educators to

understand the holistic nature of learning, value learning that is within the fabric of everyday life and help them to be vigilant in attending to the learning needs of learners from other culture. This is also true for learning at different levels because the same diversity is representative at any cross-section of age.

Further, Merriam and Kim (2008) assert that idea that epistemological understanding is fundamentally different for different worldviews has pedagogical implications in the constructions of knowledge by different groups, how people acquire learning, and the best instructional methods to support learning.

## Important to Note

Miriam and Kim (2008) point to three themes that may help teachers better understand knowledge that is different (termed non-Western) from a traditional perspective of knowledge. These are:

1. Learning is communal
2. Learning is lifelong and informal
3. Learning is holistic

The following table summarizes the difference between Western and Non-Western knowledge:

**Western Vs. Non-Western Knowledge**

Non- Western Knowledge	Western Knowledge
<p><b>Learning is communal</b></p> <ul style="list-style-type: none"> <li>• Learning and the construction of one's identity is communal</li> <li>• Learning is the responsibility of the entire community</li> </ul>	<ul style="list-style-type: none"> <li>• Learning is individualistic (self-centered)</li> <li>• Learning is to gain personal independence</li> </ul>

<ul style="list-style-type: none"> <li>• The individual learns for the development of the whole as opposed to the development of oneself.</li> <li>• Individual within the community has the responsibility to both teach and learn</li> </ul>	
<p><b>Learning is lifelong and informal</b></p> <ul style="list-style-type: none"> <li>• Learning is embedded in the rest of life's activities.</li> <li>• Its purpose of learning is to empower the individual to be a participating member of the community.</li> <li>• Very little learning is lodged in formal institution.</li> <li>• Learning is community based and informal</li> </ul>	<ul style="list-style-type: none"> <li>• Lifelong learning is usually for the individual to obtain skills</li> <li>• Learning is in a formal setting</li> <li>• Learning is for the workplace, with little consideration for the public good.</li> <li>• Learning that is embed in everyday like is not valued.</li> </ul>
<p><b>Learning is holistic</b></p> <ul style="list-style-type: none"> <li>• Learning involves the body, spirit, and emotions</li> <li>• Learning is more than the perusal or a certain course of study; it develops the moral, good, and spiritual person</li> </ul>	<ul style="list-style-type: none"> <li>• Learning is primarily focused on developing the mind.</li> <li>• Learning is to help the individual advance professionally.</li> </ul>

## Fixed Mindset and Growth Mindset

Mindset is a critical factor in determining students' attitude towards learning and their learning achievement (Boaler, 2016; Dweck, 2015). Carol Dweck and her colleagues have researched mindset for more than a decade and describe mindset as the general way that people perceive their abilities and use two terms to categorize how individuals view intelligence, fixed mindset, and growth mindset (Dweck, 2010, 2015). Further, Dweck (2010) states, "Individuals with a fixed mindset believe that their intelligence is simply an inborn trait - they have a certain amount and that's that. In contrast, individuals with a growth mindset believe that they can develop their intelligence over time" (p. 16).

### Important to Note



The two different mindsets result in different school behaviors outlined below (Dweck, 2010):

#### *Students with a fixed mindset:*

1. Looking smart is a priority – Sacrifice valued opportunities to learn if they believe that those opportunities put them at risk of looking deficient or not smart. Opportunities may require them to admit deficiencies.
2. Do not value effort – exerting effort means that they are not smart; with ability, everything comes naturally
3. Do not handle setback well- they are discouraged or make excuses for setback; they may resort to unpleasing behavior like lying about their score or cheating.
4. Find learning tasks that require risk threatening.

#### *Students with a growth mindset:*

1. View challenges as opportunities to learn, grow and improve. They persist at difficult problems, value mistake as a learning opportunity and feel tremendous satisfaction in persevering to solve a problem.
2. Value effort, and believe that even geniuses have to exert effort; believe that ability can be improved upon
3. Persevere through setback; find new strategies and take full advantage of available resources.
4. Tackle work with excitement.

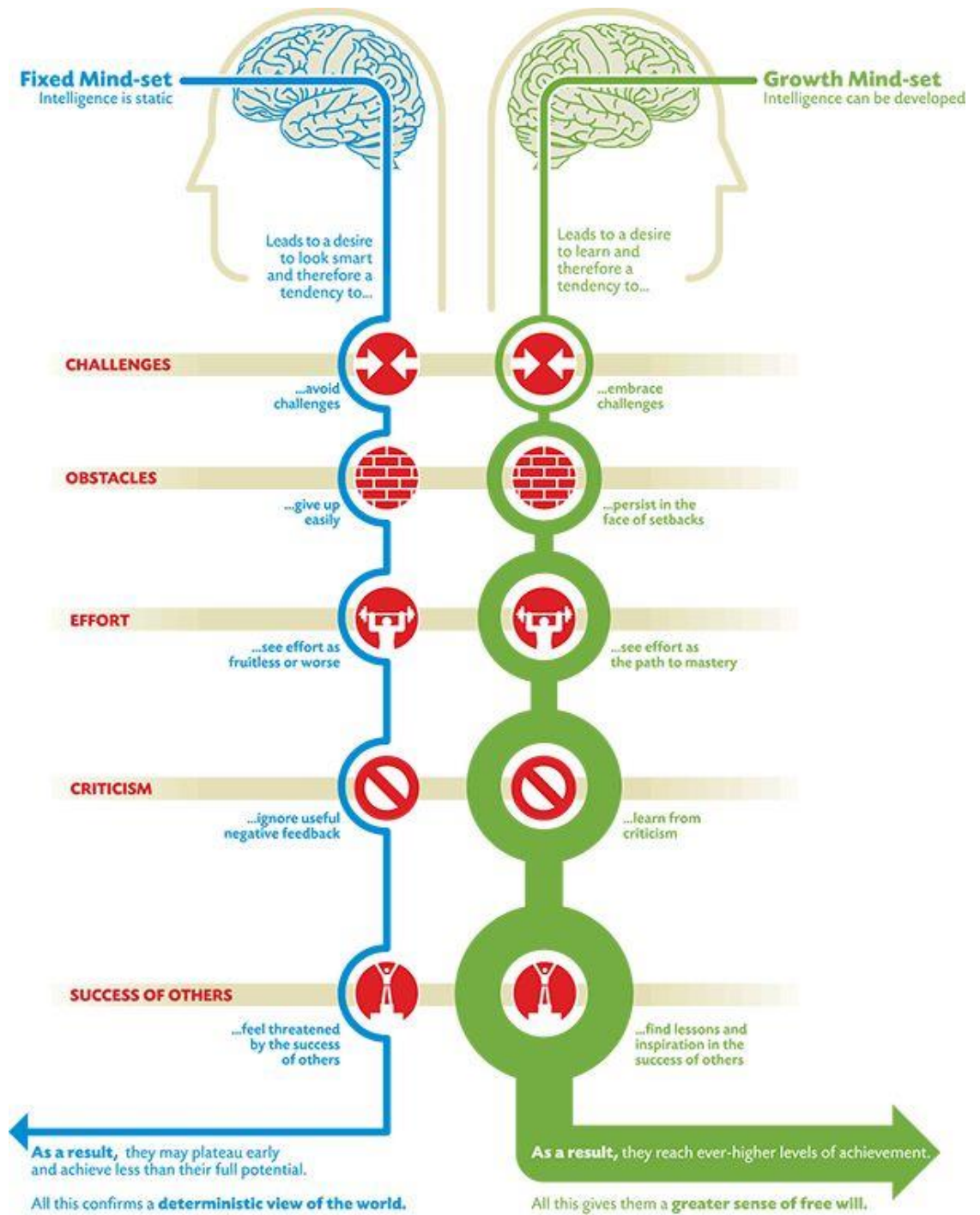


Diagram on mindset (Dweck, 2009, p. 7)



## Important to Note



Boaler (2016) point out that mathematical mindset is not only important for students in learning mathematical concepts but is also important for teachers, to inspire all students to learn and develop confidence in the subject. Boaler (2016) further asserts that students often develop trauma during the experience of learning mathematics, which prevents them from wanting further interaction with the subject. However, teachers can employ strategies to change students' mindset and boost their performance (Dweck, 2015). Dweck (2015) states:

...students who believed their intelligence could be developed (a growth mindset) outperformed those who believed their intelligence was fixed (a fixed mindset). And when students learned through a structured program that they could "grow their brains" and increase their intellectual abilities, they did better... having children focus on the process that leads to learning (like hard work or trying new strategies) could foster a growth mindset and its benefits. (p. 20)

Consequently, teachers aim at all times to promote a growth mindset in students, whether in designing major task or merely giving instructions. Moreover, Dweck (2010) asserts that teacher should aim to create a culture of a growth mindset in the classroom.

An ethnomathematics approach to mathematics teaching and learning inherently promotes a growth mindset. One of the key objectives of ethnomathematics is to dispel the hegemonic Eurocentric view that confined mathematics to a Western culture (Brandt & Chernoff, 2015; Powell & Frankenstein, 1997). This view, which is rooted deep in history, and contributes to what Boaler (2016) describes as "the elitist construction of mathematics" affects how students of certain

race and gender (female students) perceive their ability to do mathematics. In promoting that mathematics is not restricted to any culture, an ethnomathematics approach to mathematics education will essentially promote a growth mindset.

With the debilitating elitist belief aside, teachers can focus on promoting a culture of a growth mindset in students, rather than a culture of cultural ingenuity.

## Meaningful Tips



Teachers can use the following ways to create a culture of a growth mindset in the classroom.

- ✓ Provide appropriate kind of praise and encouragement - Praise students for the process they were involved in (their effort, the method, and strategies they choose, the value they displayed etc.), instead of conveying the idea of smartness. This is proven by research to yield more lasting benefits (Boaler, 2016; Dweck, 2010).
- ✓ Emphasize deep learning rather than fast learning- Impress upon students to take time to think about their learning. Fast learning does not necessarily mean deep learning. Students who take more time often understand and experience more sustained learning (Boaler, 2016; Dweck, 2010). From a cultural perspective, teachers could highlight individuals from diverse cultures who experience success in mathematics despite not being “fast”.
- ✓ Teach students about growth mindset directly. Consistently impress upon students that the human brain has the ability to grow despite race or gender or any other factor (Dweck, 2010).
- ✓

- ✓ Impress upon students that it is OK to make mistake. Let students know that based on brain research mistake allow their brain sparks and grow. In Chapter 2 of her book *Mathematical Mindset*, Jo Boaler (2016) describe some creative ways to teach students that it is OK to make mistake.
- ✓ Ask students to identify one area that they would like to improve upon, and then to commit to a personal goal that would be a stretch for them (Dweck, 2010). Dweck (2015) gave the following example: an algebra student having challenges understanding absolute values could make a decision to understand the process and teach it to a peer. As students see themselves improve and help others to improve they will be less inclined to think that they are born with a fixed brain)
- ✓ Ask students to write a letter to a student who is struggling and explain the concept of a growth mindset, encouraging and give tips to the student on how he or she could change their mindset.

## HOW TO ENCOURAGE STUDENTS

<b>Growth Mindset</b>	<b>Fixed Mindset</b>
What to say:	What not to say:
<p>"When you learn how to do a new kind of problem, it grows your math brain!"</p>	<p>"Not everybody is good at math. Just do your best."</p>
<p>"If you catch yourself saying, 'I'm not a math person,' just add the word 'yet' to the end of the sentence."</p>	<p>"That's OK, maybe math is not one of your strengths."</p>
<p>"That feeling of math being hard is the feeling of your brain growing."</p>	<p>"Don't worry, you'll get it if you keep trying."*</p> <p><small>*If students are using the wrong strategies, their efforts might not work. Plus they may feel particularly inept if their efforts are fruitless.</small></p>
<p>"The point isn't to get it all right away. The point is to grow your understanding step by step. What can you try next?"</p>	<p>"Great effort! You tried your best!"*</p> <p><small>*Don't accept less than optimal performance from your students.</small></p>
	
<p><small>SOURCE: Carol Dweck</small></p>	

Figure 6: How to Encourage Students (Dweck, 2015, p.4)

## Extracting Mathematical Ideas and Ingenuity of All Students

“Mathematics was created by people who needed to solve problems; it was not ordained from on high” (Katz, 1994, p. 26).

Mathematics ideas emerged from many different cultures, by peoples' need to solve problems (Katz, 1994; Sánchez, 2018). Still today, mathematical concepts of the classroom are present in people's everyday activities through varying cultural understandings (Katz, 1994). Employing strategies for students to see this through ethnomathematics principles can help teachers to extract the ingenuity of all students. Aikpitanyi and Eraikhuemen (2017) posit that a deeper understanding of how mathematics occurs and is utilized in existing cultures will promote better teaching practices that improves student achievement in the discipline. In applying ethnomathematics principles in the classroom by demonstrating that mathematical ideas are not restricted to any dominant culture, teachers help students to see themselves as mathematicians.

### Meaningful Tips



The following are some cultural practices that teachers can use to promote creativity in students:

- ✓ Include Mathematics history in lesson planning – Teacher can give a brief history of the contribution of different culture or gender to mathematics in relation to the topic. This can be done for 1-3 minutes at the beginning of the lesson. This will help students to appreciate different cultures. In particular, this will help to dispel the elitist construct of mathematics that gives the perception that mathematics ability is restricted to certain people based on ethnicity, social class or gender.

- ✓ Consistently remind students that mathematics is not constant and can emerge from anyone or any culture based on their need to solve a problem. – This will help to develop a growth mindset within students as they identify themselves among people who can make contributions to mathematics. This will also help to dispel the elitist construct of mathematics.
- ✓ Where possible express to students how similar mathematics idea can be expressed in different ways based on cultural understanding. For example, show students how measure and numbering are expressed in different ways by different cultures. Also, teachers can demonstrate to the class how two different students express the same concept in different ways based on cultural experiences.

This will help students to see mathematics as open, having multiple solutions and solution pathways. Likewise, this will help to create a growth mindset as this contradicts the procedural approach to mathematics.

A very helpful paper, that teachers can read for examples on important mathematical contributions of different cultures to mathematics is *Ethnomathematics in the Classroom* by Katz (1994). This paper provides examples of combinatorics, arithmetic, and geometry. The following passage was extracted from that paper:

A careful reading of the history of mathematics generates numerous pedagogical ideas which can and should be used in today's classrooms. In particular, since many important mathematical ideas grew out of the needs of various cultures around the world, it is vitally important that students in Western nations be exposed to the fact that mathematics is a universal phenomenon. What we call mathematics was-and is-present in many civilizations, although not always in explicit form. In particular, various

mathematical ideas which arise in today's courses were considered by other peoples in the context of their own experiences and values. We can and should use these ideas out of ethnomathematics whenever possible to illuminate the concepts discussed as well as to demonstrate the universality of mathematical ideas (Katz, 1994, p. 26).

## Promotes Equality and Equity and in the Classroom

Ethnomathematics by its very nature promotes equality since each student has the opportunity to express their culture in the classroom. Ideally, no culture is given dominance in the ethnomathematics classroom. Also, ethnomathematics promotes equity. Given that mathematics ideas are express in different ways, each student is provided with the necessary guidance and resources to achieve.

## Addressing Issues of Globalization in the Mathematics Classroom

“The reality of our shrinking planet and its impact on young people has implications for how and what we teach them in school” (Carlsson-Paige & Lantieri, 2005, p. 97).

The interconnectedness of the world, resulting from globalization, demands that education prepare students to function in a global society. Carlsson-Paige and Lantieri (2005) states, “the reality of our shrinking planet and its impact on young people has implications for how and what we teach them in school” (p. 97). Consequently, mathematics education plays a critical role in helping to equip students with the requisite skills to manage the negotiate the undercurrent of the world in which they live.

## Important to Note



D'Ambrosio and D'Ambrosio (2013) assert that mathematics education should enable students to become global citizen, actively maintain world peace. This means that the knowledge that students possess must extend beyond the boundaries of their own culture. This also means that student must learn to appreciate the contribution and the role other cultures play in creating a global society. D'Ambrosio and D'Ambrosio (2013) point out that this is possible through the ethics of diversity which is promoted by ethnomathematics, "respect for, solidarity with, and cooperation with the other (the different)" (p. 22).

D'Ambrosio and D'Ambrosio (2013) further assert that the classroom is a fitting place to begin to create a collaborative environment where teachers and students can work together to apply problem-solving strategies and critical thinking for the obliteration of inequality and social bias, as well as preserving the world resources. Thus, teachers should create classroom opportunities for this, whether explicitly or through the hidden curriculum. Quite appropriately, Carlsson-Paige and Lantieri (2005) add that "children develop an understanding of the social world not by lightning strikes but through a long, slow process of construction in which they learn how people treat each other (p 98).

"Children develop an understanding of the social world not by lightning strikes but through a long, slow process of construction in which they learn how people treat each other" (Carlsson-Paige & Lantieri, 2005, p 98).



# Ethnomathematics:

## Designing Culturally Rich Mathematics Tasks

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### What is a Mathematical Task?

A mathematical task refers to whatever a teacher uses to demonstrate mathematical concepts, engage students in interaction or request students to do something, such as homework problems and classroom activities on their own or in a group (Breen & O'Shea, 2010; Margolinas, 2013). Tasks may also include any student-initiated action in response to a given situation (Margolinas, 2013).

### What Makes a Task Culturally Rich?

Based on the definition above, anything assigned to students in the classroom with the intention to transmit mathematical concepts can be considered as a task. It could be activities or questions found in the textbook, online worksheets, activities found within the curriculum or teacher generated activities. However, tasks are not necessarily rich in and of themselves. Yes, a particular student may find a random task chosen from a textbook engaging, but a good teacher will not want to leave anything to chance; instead, he/she will want to make the effort to design tasks to provide meaningful learning.

“Teachers are the most important resource for students. They are the ones who can create exciting mathematics environment, give students the positive messages they need and take any math task and make it one that piques students’ curiosity and interest” (Boaler, 2016; p. 57)

## Meaningful Tips



It is also true that a teacher may plan an activity that he/she perceived will engage students but has the opposite effect. Therefore, it is necessary to have guidelines when creating a task. Here are some questions that teachers can ask themselves when designing a rich task.

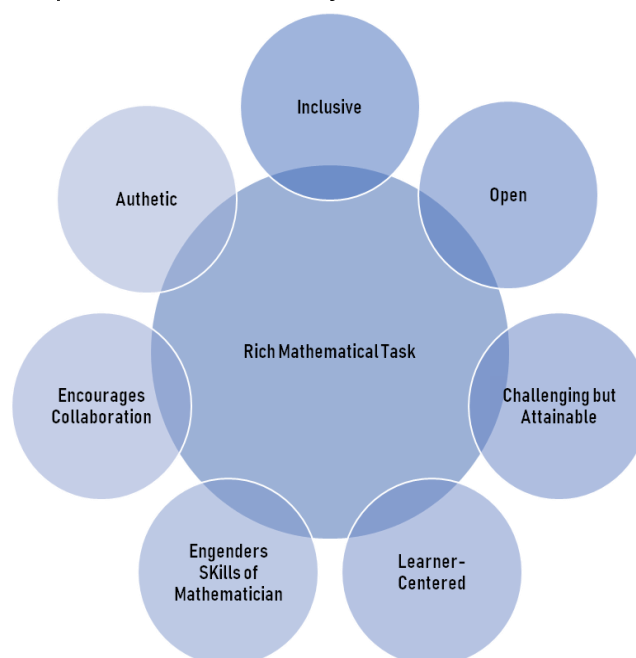
1. How can I make the task open such that it has multiple pathways and representations?
2. Does my task cater to a wide range of students with varied experiences, culture and interest?
3. Is the task challenging but attainable (low floor high ceiling)?
4. Is my task learner centered?
5. Does the task have exploratory potential?
6. Will this task help students to use skills that mathematicians use?
7. Will this task be relevant to students?
8. Will this task facilitate collaboration among students?
9. Did I consider brain-based learning?
10. Can this task lead to mathematics excitement?

The teacher should aim to have an affirmative answer to as many of these questions as possible. The table below shows the components of rich mathematics tasks.

<b>Components of Rich Mathematics Tasks</b>	
<b>Open</b>	Rich mathematical tasks are open in that they can be attempted and represented in multiple ways, with varying solution pathways (Boaler, 2016)
<b>Inclusive</b>	Rich mathematical tasks cater to a wide cross-section of students in terms of supporting previous mathematical achievement, attracting interest, as well scaffolding of informal mathematics knowledge (Grootenboer, 2009; Hawera & Taylor, 2011; Knowles, 2009)
<b>Challenging but Attainable</b>	Rich mathematical tasks should be accessible by all students but also extend to high cognitive level - low floor high ceiling (Boaler, 2016; Knowles, 2009). The exploratory potential of such tasks may also lead students to unexpected insight.
<b>Learner-centered</b>	Rich mathematical tasks are learner-centered by their very nature. Since tasks are based on a constructivist approach to learning in that they encourage a unique solution pathway, instead of a prescribed method (Boaler, 2016), the teacher's role is mostly supervisory. The approach opposes the tradition teacher-centered approach, which focus on routine algorithm and calculation (Bell, 1993; Ben-Chaim, Keret, & Ilany, 2000)

<p><b>Engender Skills of Mathematician</b></p>	<p>Rich mathematical tasks are exploratory in nature and requires the skills mathematicians use to solve problems such as conjecturing, hypothesizing, justifying, proving, explaining, reflecting and reporting (Bell, 1993; Boaler, 2017; Breen &amp; O'Shea, 2010; Grootenboer, 2009; Knowles, 2009)</p>
<p><b>Encourages Collaboration Among Students</b></p>	<p>Rich mathematics promotes discussion and collaboration among students in order to develop deep conceptual understanding. (Boaler, 2016, Knowles, 2009)</p>
<p><b>Authentic</b></p>	<p>Rich mathematical may be authentic in that they “are genuine, trustworthy and usually present problems with relation to everyday life” (Ben-Chaim et al., 2007, p. 335) Rich in that they reflect the use of mathematical knowledge in the community (Knowles, 2009).</p>

### Components of Culturally Rich Mathematic Tasks



## Task Design

Instructional tasks are critical to students learning. They are the channel through which content and skills are transmitted as well as the medium to engage students in meaningful learning experiences. Different tasks provide different learning opportunities for students. Procedural tasks that focus on rote memorization lead to limited opportunities for student thinking; tasks that require synthesis concepts through active engagement provide more opportunity to stimulate deep thinking (Stein & Lane, 1996). Thus, it is of utmost importance that teachers carefully design task to meet the learning needs of students.

“Carefully designed tasks can enable students to reason effectively and in targeted ways, and can assist them in learning to use varied arguments as they engage in mathematics, meeting a primary goal of mathematics education” (Yankelewitz, Mueller and Maher, 2010; p. 84).

### Important to Note



## The Backward Design Planning Process

There are varied methods that educators may use to plan how to design a learning task. This handbook takes advantage of the backward design planning process by designing culturally meaningful tasks. The backward design planning process is built on the premise that you can plan for understanding. Wiggins and McTighe (2005) maintain that when understanding is planned for the likelihood will increase. This process offers a three-step guide for planning curriculum, assessment, and instruction. Using this process, the designer or the planner

considers the end result (knowledge, skills, goal, standard or value and attitude) essential for students to know or do before designing.

Wiggins and McTighe (2005) believe that this is the most effective approach to designing activities because designers are required to put into operation their goals based on assessment evidence at the beginning of planning as opposed to considering the assessment at that end or toward the completion of an assessment period (Wiggins & McTighe, 2005). The backward design planning can be summarized into three stages (Wiggins & McTighe, 2005):

**Stage 1: Identifying Desired Results** - At this stage, the aim is to formulate a clear perspective of what students should know, understand, and be able to do. It is determining what knowledge is worthwhile and what enduring understanding is required; ultimately, what needs to be transferred. That is the planner look at the objectives or expectations that need to be covered from the standard (provincial, state or national) document and decide what big idea students need to understand and demonstrate in the long run, since in most instances it is impossible to cover all the content in the required time period. This stage is necessary to help students to find meaning in what they learn.

Within a cultural context, and in this case, planning tasks, we not only think about the enduring understanding but also of how the task can be opened to unique cultural experiences.

**Stage 2: Assessment Evidence** – this stage involves thoughtful consideration of what assessments is acceptable evidence of student understanding and proficiency in relation to Stage 1. The focus is on how we will know that students understand and is able to transfer their learning to actual situations. It is also considering how evaluation can be fairly done. This stage affords the planner the opportunity to align the assessment or the task to the desired result since the assessment is based on the enduring understanding in Stage 1.

In this handbook, the focus is mainly on the development of culturally rich task. The culturally rich tasks invite the students to use knowledge from their sociocultural setting to scaffold their understanding of mathematics concepts. Wiggins and McTighe (2005) outline six facets to ascertain understand. Students validate their understanding by their ability to:

- i. **Explain** learning in their own words so that others can understand, make justifications for their answers, and show their reasoning.
- ii. **Interpret** by making sense of data in varied forms, and also represent the information in different ways.
- iii. **Apply** by effectively transferring their learning to different situation and complex contexts.
- iv. **Demonstrate** the big idea from their viewpoint while recognizing different perspectives.
- v. **Display** empathy by observing sensitively and sharing in someone else's experiences.
- vi. Show **self-knowledge** by reflecting on their own thoughts and actions resulting from their learning and experiences.

Wiggins and McTighe (2005) point out that all six facets of understanding may not be necessary criteria for every assessment; noting also that explanation, interpretation and application are most natural for mathematics.

**Stage 3: Plan Learning Experiences and Instruction** – This stage focuses on designing the tasks, or activities, and considering the teaching method and resources necessary to 'hook' students into a rich learning experience. The tasks or activities that are designed at this stage is meant to reinforce the main ideas and processes so that students will be able to show understanding based on some or all of the six facets noted above. Thus, at this stage, the planner will also focus the necessary resources and material to accomplish the desired result. In the

case of this handbook, it is important for the designers to focus on the key objectives of culturally rich tasks, which is to bridge the gap between informal knowledge from sociocultural experiences and formal knowledge from the classroom.

Mathematical tasks, carefully orchestrated may spark students' curiosity and interest, inform students of what it means to do mathematics, and thus shaping their mathematics identity and determining their future progression in related pathways (Boaler, 2016; Schoenfeld, 1994, Grootenboer, 2009).

## Designing the Culturally Rich Task Using the Backward Design Planning Process

### Stage 1: Identifying Desired Results

In this section, we will design two culturally rich tasks using the backward design planning process. The tasks are based on the unit Number Sense and Numeration using three specific expectations taken from the Ontario Grade 7 Curriculum. The tasks were not intended to be used as a full lesson plan, Instead, they can be used for culminating activities for a lesson within a unit plan.

#### Task 1

Specific Expectation: Represent, compare and order decimals to hundredths and fractions using a variety of tools (e.g., number lines, Cuisenaire, rods, base ten material, calculators).

Using the above specific expectations as the starting point consider:

- ✓ What are the enduring understandings that students should take away from the task?



**Possible Consideration:** How do students use decimals/fractions in their cultural experiences? How could they use this understanding to help them develop a number sense of fraction and decimal? How could they, then transfer that developed understanding to other areas in their everyday situations to solve problems?

Most students like sport or do some kind of shopping, so the task can be centered around those areas. This understanding is enduring because students will relate decimals/fractions to their experience or interest, and also know how it can be applied to everyday life situations.

### Important to Note

As best as possible, the task need to

1. Be open, having multiple pathways and representations?
2. Cater to a wide range of students with varied experiences, cultural and interest.
3. Be challenging but attainable (low floor high ceiling).
4. Be learner-centered.
5. Have exploratory potential.
6. Help students to use skills of mathematicians.
7. Be relevant to students.
8. Facilitate collaboration among students.
9. Be brain-based learning

**Stage 2: Assessment Evidence** – this stage involves thoughtful consideration of what assessments is acceptable evidence of student understanding proficiency in relation to Stage 1.

At this stage we ask the question:

- ✓ What would be acceptable evidence for students to show that they can use their understanding of decimals/fraction in their everyday cultural experience?
- Or
- ✓ How can students use their informal understanding of fractions and decimals to scaffold their learning?

**Possible Consideration:**

**Examples of situation that students choose.**

Grocery shopping: Comparing the price of similar items with different brands online. The students could write down the most expensive and the least expensive item or just compare the price of two brands, and then report the finding in a news clipping.

Some students that are interested in sport could compare the time of their favorite athletes, or some students could even have a competition with few of his/her friend, using the stopwatch to take the time. They could then make comparisons and report their finding in a news clipping.

Also, culturally rich tasks foster collaboration an inclusiveness.

**Stage 3: Plan Learning Experiences and Instruction** – This stage focuses on designing the task, or activities, and considering the teaching method and resources necessary to ‘hook’ students into a rich learning experience.

Remember The tasks or activities that are designed at this stage is meant to reinforce the main ideas of decimals or fractions, using students’ cultural experiences so that they can show understand based some or all of the six facets of understanding.

**Task: Decimal (a similar task can be done for fractions)**

1. Find a situation where you use decimals in your daily life (for example, shopping or some sporting activity) or think about something of interest that require the use of decimals. (Students may work in pairs)
2. Write down the situations.
3. Generate decimal numbers from the situation.
4. Order the number in ascending or descending order. What does that tell you? Write sentences to talk about the situation.
5. Represent your decimal number on the number line or using a graph or any other means that you can think of.
6. Do at least five comparisons using the lesser than or greater than sign. What does that tell you? Write sentences to talk about fact from the situation.
7. Works in groups to prepare a five-minute news clipping about your finding from the situation.
  - a. Your news clipping should contain visual representations and written mathematical expressions using the greater than and lesser than sign

**Possible consideration:** Students may need computers to research information. Material and resources to create charts and graph if that choose to use the computer to generate visuals.

## Task Evaluation Form

Important questions	Answers
1. Is the task open such that it has multiple pathways and representations?	Yes. This task is open. Students are not limited in how they approach it or how they choose to represent the solution in visual form. Also, by asking them to make sense of their answers, the task is open to boundless possibilities
2. Does my task cater to a wide range of students with varied experiences, cultural and interest (inclusive)? In other words, is the task inclusive?	Yes. The task gives all students the opportunity to use their cultural experiences to scaffold their formal learning. Additionally, teachers could learn about their students through the cultural activity that they associate the task with.
3. Is the task challenging but attainable (low floor high ceiling)?	Yes. The task is low floor in that it is accessible to all students because of the cultural approach and also because students were given a prompt as to the possible choices they could make; most students could associate with shopping or sport. The task is high ceiling in that the method of presentation provides boundless possibilities.
4. Is my task learner- centered?	Yes. The task is learner-centered. The students have control over the process of the task. The teacher responsibility is to facilitate students by prompting, asking questions and making suggestions

<p>5. Does the task have exploratory potential?</p>	<p>Yes. The task has exploratory potentials. In reporting, students have the opportunity to make observe and think deeply about data to come up with ideas to put in the news clipping. The students have the opportunity to be creative in how they work together. If it is a sporting activity they may want to make comparisons which may include subtraction of decimals or some other concepts of decimals. The reporting also invites them to make inquiries.</p>
<p>6. Will this task help students to use the skills that mathematicians use?</p>	<p>Yes. This task is exploratory in nature and requires some skills mathematician use such as justifying, proving, explaining, reflecting and reporting. Students may need to convince their peers about ideas for the news clipping.</p>
<p>7. Will this task be relevant to students?</p>	<p>Yes. Students can see how decimals relate to what they do in their sociocultural activities.</p>
<p>8. Will this task facilitate collaboration among students</p>	<p>Yes. Students have to work together, to explain, justify, and make decisions before reporting their result. They also have the opportunity to learn from each other and learn about each other culture.</p>
<p>9. Did I consider brain-based learning?</p>	<p>Yes. The task is embedded in real-life. This makes it brain-based; it gives students the opportunity to make meaning of what they learn, the main focus of brain-based learning.</p>

10. Is the task engaging?	Yes. The task can engage students as they work together to bring their results to life.
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In evaluating the task, you do not have to write down answers; you can simply check the answer column (and empty form is at the end of this chapter). The questions are simply for you to reflect on your task.

## Task 2

### Stage 1: Identifying Desired Results

By the end of this task, students will:

1. generate multiples and factors, using a variety of tools and strategies (e.g., identify multiples on a hundred chart; create rectangles on a geoboard)  
(Sample problem: List all the rectangles that have an area of  $36 \text{ cm}^2$  and have whole number dimension)

Using the above specific expectations as the starting point consider:

- ✓ What are the enduring understandings that students should take away from learning about factors and multiples? What should they know and understand about factors and multiples?

### Possible Enduring Understanding

1. Students should see that they use multiples and factors in a variety of everyday life situation e.g. sharing items, making decisions, arranging or stacking items on a shelf or in container etc.
2. They should see the relationship between factors and multiples.

### Possible Consideration:

The understandings are enduring because students will appreciate that factors, multiples, and the relation between them are not abstract concepts

but are applied in everyday life situations; concepts they used and can use in real life situation.

**Stage 2: Assessment Evidence** – this stage involves thoughtful consideration of what is acceptable evidence for students to show the enduring understanding outlined in Stage 1. How will we know that the students can use their informal knowledge of multiples and factors to help them generate factors and multiples in abstract situations.

**Possible Consideration:** Students may use factors and multiples when sharing items or when making decisions about buying items with their allowances or maybe when stacking items at home. We want them to identify from their own sociocultural experiences (not from our perspective) how they use factors and multiple and use it to scaffold their understanding of the concepts in a formal setting (generate multiples and factors, using a variety of tools and strategies). Also, culturally rich tasks foster collaboration an inclusiveness.

**Stage 3: Plan Learning Experiences and Instruction** – This stage focuses on designing the task, or activities, and considering the teaching method and resources necessary to 'hook' students into a rich learning experience. Remember, the tasks or activities that are designed at this stage is meant to reinforce the main ideas of multiples and factors, using students' cultural experiences so that they can show understand based some or all of the six facets of understanding

### **Culturally rich mathematics task. (Think- Peer-Share**

Ask students to:

1. identify as many situations as possible in which you use factors and multiples in your everyday life situation e.g. sharing items, making decisions, arranging or stacking items on a shelf or in containers etc. (Try to find examples for both factors and multiples)

2. Share your answers with a peer and explain and justify how the situation demonstrates the use of factors and multiples by (for large classes students could share in groups of four).
3. In your pairs, write down a mathematical expression to represent your finding. For e.g., if the student share items equally between friend, say 20 plums between 5 people, the student would write down  $20 \div 5 = 4$
4. Using the word factors or multiple, Justifying your response

Students could say 5 is factor of 20 because when you divide 20 by 4 we get an integer. Or 20 is a multiple of 5 and 4 because you can multiply either 5 or 4 by an integer to get 20.

Also, students could explain a situation where a number is not a factor or multiple of another.

5. Do you observe any relationship between factors and multiple? Explain to your peers.
6. Could you identify any other situations where factors and multiples are used or could be used?
7. Report your finding of your collective experiences to the class.

**You are now invited to evaluate this task using the form below.**



## Task Evaluation Form

Important questions	Answers (Check)
1. Is the task open such that it has multiple pathways and representations?	
2. Does my task cater to a wide range of students with varied experiences, cultural and interest (inclusive)? In other words, is the task inclusive?	
3. Is the task challenging but attainable (low floor high ceiling)?	
4. Is my task learner-centered?	
5. Does the task have exploratory potential?	
6. Will this task help students to use the skills that mathematicians use?	
7. Will this task be relevant to students?	
8. Will this task facilitate collaboration among students	
9. Did I consider brain-based learning?	
10. Is the task engaging?	

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## **CHAPTER FIVE: SUMMARY, IMPLICATIONS, AND CONCLUSIONS**

This chapter begins with a summary of the handbook and then discusses the implications of this study to pedagogical practices and theory within mathematics education, as well as to future research. Finally, the chapter concludes with a summary of the overall study.

### **Summary of the Handbook**

The handbook was compiled based on themes extracted from a comprehensive literature review of ethnomathematics. The major themes of ethnomathematics are meaningful learning, and diversity and inclusion. Accordingly, the handbook investigated those two themes in relation to culture. The handbook commenced by looking at characteristics of meaningful learning, namely: engaging and inspiring learning; personally relevant; deep connected understanding; enhanced reasoning; opportunity for learners to collaborate. Additionally, the handbook discusses how a cultural approach practice expresses and, in many cases, enhance those aspects of meaningful learning. The book also detailed how a cultural approach to learning is brain based, linking previous knowledge to new knowledge, which is the foundation of brain-based learning. Secondly, the handbook explored how ethnomathematics principles promote inclusion and diversity while simultaneously:

1. Bridging the gap between formal and informal learning;
2. Expanding educators understanding of learners, thus promoting meaningful learning;
3. Promoting a growth mindset instead of a fixed mindset;
4. Extracting mathematical ideas and ingenuity of all students;

5. Helping to address issues of globalization; and
6. Promoting equity in the classroom.

Finally, the handbook looks at components of rich mathematics tasks, which bridge the gap between teaching and learning. Further, it looked at how ethnomathematics principles can be used to create rich tasks, using the backward design approach, which is designing for understanding. Rich mathematics tasks as revealed by literature: are inclusive and open; are challenging but attainable; are learner-centered; engender skills of a mathematician; encourage collaboration; and may be authentic.

### **Implications for Theory**

Though there are many studies conducted on ethnomathematics from a purely theoretical standpoint, there seem not to be enough studies on the practical use of ethnomathematics validating those theories. Ethnomathematics principles are in line with the leading sociocultural theories that are now practiced in many Western classrooms; however, the application of such principles seems not to be similarly popular in this classroom. Many of these theories, like Lave and Wenger's (1991) situated learning theory and Bronfenbrenner's (1977, 1978) ecological systems theory stemmed from Vygotsky's (1978) and Dewey's (1916) work which is rooted in the belief that learning is socially constructed. Lave and Wenger (1991) situated learning contends that learning takes place relative to the context in which it is learned through legitimate peripheral participation whereby "newcomers become oldtimers" (p. 68) by authentically taking part in a seamless process of gradually increasing responsibilities. Bronfenbrenner (1977, 1978) believed that a child's development is affected by everything in his/her surrounding environment. These theories are widely supported by educators and applied in practice



using a constructivist approach. From a constructivist perspective, the teacher is not the transmitter of knowledge but a facilitator of a learning experience in which the learner is actively involved in learning. Central to the constructivist approach is that new knowledge is scaffolded by prior knowledge. Ethnomathematics views of applying cultural understanding and experiences to teach mathematics supports this worldview, yet the application of ethnomathematics principles are rarely implemented in the classroom. Mathematics is still taught widely using conventional methods with routine questions from worksheet and textbooks or generated from computer software. Consequently, more studies should focus on how ethnomathematics principles are applied to practice. In that way, sound theories on ethnomathematics can be built on logical explanation supported by data and not just ideologies.

Educational theory can be described as a set of principles that guides educational practices based on evidence, or at the minimum, by experience of continual successful experience (Kaufman, 2003). Thus, in order for ethnomathematics to gain clout, more research in ethnomathematics needs to focus on the testing stage, rather than on the hypothesis phase, where writings are focused on the potential benefits of ethnomathematics. The successful use of ethnomathematics principles will undoubtedly silence many critics. This handbook is thereby a step in that direction of applying ethnomathematics to mainstream classrooms. According to Davids and Waghid (2017), the relationship between theory and practice is a nexus, in that one informs the other. Hopefully, the tasks in this handbook, as well as the method of creating these tasks, can be applied in classrooms where research is focused on the impact of ethnomathematics principles on teaching and learning; thus, evidence from the classroom may provide the platform for sound educational theories.

### Implications for Practice

The development of this handbook was motivated by two things: (a) the low Education Quality and Accountability Office (EQAO) mathematics test score of Ontario students, recently published by *CBC News* (“Only 50%,” 2016); and (b) to demystify the false notion that mathematics is a difficult subject that can only be learned by people who has been endowed with a special ability (Boaler et al., 2018). The fact that everyone has cultural experience that they can relate to, coupled with the perspective by many researchers (Boaler, 2016; Grootenboer, 2009; Schoenfeld, 1994; Stein & Lane, 1996; Yankelewitz et al., 2010) that task bridges the gap between teaching and learning, further laid the groundwork for developing strategies that mathematics educators apply to improve their practice and ultimately student achievement.

Although the ethnomathematics instructional approach is not all-encompassing, it covers some key aspects of modern educational approaches that have attracted much research corresponding to brain-based learning and sociocultural approaches to learning. This suggests that an ethnomathematics approach is quite valid and warrants not only investigation by researchers but also educators who are reflective practitioners. As a reflective practitioner, Tanner (2004) notes, “Changing the way we teach is a journey, one of our own learning reflection, and growth” (p. 4). Tanner (2004) acknowledged weaknesses as a nurse educator and challenges herself to improve her practice in light of numerous emerging studies which point to alternative ways of more meaningful experience. Likewise, mathematics educators need to consistently reflect upon their practice, especially since mathematics education is notorious for producing low academic achievement. Additionally, Tanner suggests that embarking on or considering new approaches could better allow educators to better interpret the curriculum.

Ethnomathematics views challenge mathematics educators not to be static recipients of curriculums but to view them through the lens of research that will make learning more meaningful for students and teaching an experience of growth and development.

### **Future Research**

This research has the potential to impact further research in ethnomathematics and task development. The comprehensive literature review brought several views on the subjects under one umbrella, which can be of tremendous support to researchers in these areas. Furthermore, the two major themes of ethnomathematics that were uncovered can provide a foundation for anyone wanting to compile a mathematics teaching and learning handbook.

Additionally, the two themes, meaningful learning, and diversity and inclusion, are critical and may prove insightful for any research focusing on pedagogical practices in mathematics education, given that: (a) meaning-making is central to both theory and practice relating to innovative teaching (Caine and Caine (1990); and (2) inclusive education is supported by educational human rights acts (Dalene, Hong-Lin, & Stella, 2017). Research on teaching and learning strategies could explore the two themes against the parameters outlined in both the handbook and the literature review. This handbook explored and discussed the theme of ethnomathematics and used them to create culturally rich mathematical tasks based on components of rich mathematical tasks that were revealed by the literature. Similarly, other research could focus on applying those themes to other pedagogical practices in mathematics—namely, curriculum, unit, and lesson planning.

### **Concluding Statement**

Mathematics education is important for economic growth (Yıldırım & Sidekli,

2018); however, many students across nations underperform in state or provincial exams, as in the case of Ontario's EQAO mathematics result. The research and many others (Boaler, 2002, 2016; Bell, 1993; Ben-Chaim et al., 2007; D'Ambrosio, 1985; Hiebert & Wearne, 1993), is a response to the clear signals for better pedagogical practices, given by these results, and the responses from students and parents (Abeles, 2010). This research addressed the issue in the form of a handbook, using a cultural approach based on the principles of ethnomathematics: meaning making and inclusion and diversity. The handbook explored the two themes of ethnomathematics with the intention of helping mathematics educators at all levels to provide better teaching practices. Culminating, the handbook applied the principles of ethnomathematics to design culturally rich tasks using the backward design planning process. Importantly, ethnomathematics principles are not limited to task development but can be applied across the curriculum to enhance learning. "Ethnomathematics deals with both content and the process of curriculum, classroom, teacher expectations, professional development and relationship among teachers, administrators, students and community" (Aikpitanyi & Eraikhuemen, 2017, p. 35).

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