BRIDGING THE GAP BETWEEN STUDENTS’ CULTURAL NORMS AND THE CULTURAL NORMS OF SCIENCE: A SELF-STUDY ON STUDENTS’ PERCEPTIONS OF INQUIRY ACTIVITIES AND CULTURALLY RELEVANT LESSONS

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Pamela Anne Spock, candidate for the degree of Master of Education in Curriculum and Instruction, has presented a thesis titled, *Bridging the Gap Between Students’ Cultural Norms and the Cultural Norms of Science: A Self-Study on Students’ Perceptions of Inquiry Activities and Culturally Relevant Lessons*, in an oral examination held on June 14, 2015. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

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Abstract

Relevant literature recommends good teaching practices to help students bridge the gap between their personal cultural norms and the cultural norms of secondary science teaching. Some students’ cultural practices encourage developing a strong ability to memorize and students use their strong ability to maintain good grades in their secondary science courses. However, good teaching practices may not effectively enable students to move from rote learning to meaningful knowledge construction. The purpose of the self-study is to critically examine the use of inquiry and culturally relevant lessons to enable students to meaningfully construct knowledge in their secondary physics and chemistry classes.

I worked with the 8 students in my Physics 20 class and the 10 students in my Chemistry 30 class for one semester using inquiry laboratory practices, student-developed analogies, advance organizers, student inquiry, and lessons using Muslim scientists and Islamic practices. Data gathering methods included daily exit slips, student journal entries, and end-of-semester interviews as well as interviews with a former student and a student’s mother.

Participants in the study confirmed the importance of finding ways to help teachers develop effective ways to bridge the gap between students’ cultural norms and the cultural norms of science. Many students found that developing their own analogies and using inquiry helped them to avoid rote memorization. Some students found that culturally relevant lessons interested them and promoted further inquiry. The results suggest that using inquiry and culturally relevant lessons may be effective teaching
strategies to help secondary science teachers in their increasingly culturally diverse classrooms.
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Chapter 1: Introduction

As the end of each semester draws near, my colleagues and I discuss how to design meaningful final assessment items for the high school students at the Islamic school where we teach. Each semester, we find that our students memorize content without demonstrating the development of skills or knowledge in a meaningful way. Our students demonstrate their remarkable ability to memorize content by rewriting entire paragraphs, or calculation sequences from their notes or textbooks onto an exam paper. Although it is remarkable that students have memorized adequate content to complete multiple questions on multiple evaluation items by memorizing and rewriting, their inability to realize that such memorized information fails to answer the question indicates little or no understanding of the content.

Context

My frustration with students’ tendency to memorize everything but understand little seems to peak in the late stages of the semester as I reflect on my pedagogy and the differences between my personal and my students’ demonstrated epistemologies. For the past eight years, I have been teaching at an associate school for Muslim students. I am a non-Muslim teacher at a school where the guiding principle is “Gaining the best of Canadian culture while preserving the Islamic identity” (School Policy Manual1). As a high school mathematics and science teacher in a small school, I am often disappointed by my students’ inability to apply content to word problems and novel applications, and

1 The name of the school has been omitted here and in the reference section to maintain anonymity of my school and students.
to advance their understanding to higher level thinking. I often begin my lessons by reminding students about past lessons that will contribute relevant knowledge to the current topic; students often comment that they do not remember the past discussions. Application questions on assignments, quizzes, and exams are poorly completed by my students because they seem unable to relate information to any new application. Although high school students receive many benefits by attending the school, including small class sizes, the benefits do not seem to transfer to learning secondary science in a deep and meaningful way.

The Pre-Kindergarten to Grade 12 school where I teach has approximately 320 students, 60 of whom are in high school. Our school has 22 teachers who hold Saskatchewan teaching certificates issued by the Saskatchewan Ministry of Education and teach Saskatchewan curricula. As well there are six who do not hold Saskatchewan teaching certificates who teach Islamic Studies, Arabic language, and Qur’an memorization classes. The school is classified as an associate school, meaning it is part of the public school division, but also has its own Board, ideals, and procedures. English is the language of instruction in all courses except Arabic. Students’ first languages are as diverse as their countries of origin; I estimate that there are as many as 10 different students’ first languages. The school building is a converted elementary school with no science laboratory facilities.

Throughout my thesis, as I refer to students’ Islamic culture, I am referring solely to the students I teach in my school. Cited literature supports my ideas and practices, but I am not attempting to generalize my findings to all Muslim students in all classrooms. I would like other secondary science teachers to consider the work I have done when
planning effective teaching in their classrooms, but my findings cannot be generalized to include all Muslim students in all situations.

My students share many cultural similarities because they are all Muslim, but they come from many different countries of origin including Pakistan, Saudi Arabia, Libya, Egypt, and Somalia. As a result there are also broad cultural variations. My students discuss the differences in their cultural norms such as how they dress, celebrate birthdays and other events, and cook. While my students’ diverse countries of origins create differences in their cultural norms, there are similarities. The most pronounced common cultural norms I have observed in my students are the value they place on memorization and their strong ability to memorize content. The value and ability of memorization for my students impacts how they learn secondary science.

Memorization is common for young Muslims since “a child interested in studying Islam will learn to read the entire Qur’an in Arabic and to memorize its more significant verses. [Islamic teachers] stress proper memorization … [while] understanding the contents of the Qur’an is not taught” (Horvatich, 1994, p. 812). Memorization is a cultural norm for my students and a very important part of their religion. They were taught memorization skills at a young age and use and improve their rote memorization skills continuously. All Grade 1 to Grade 12 students at my school have Qur’an classes each week to teach them how to memorize hadiths. I currently teach two Grade 11 students who have memorized the entire Qur’an, and I teach several more students who are close to completion. Although many of my students do not speak, write, or understand Arabic, they have memorized long hadiths in Arabic, which
demonstrates that they are able to memorize large amounts of information while stating they have little or no understanding of its meaning.

During the past eight years, I have noticed how effectively my students memorize content and that they do not limit their memorization skills to hadiths from the Qur’an. I have also noticed that my students struggle with problem solving and application of knowledge. My students think primarily using the lowest level of Bloom’s revised taxonomy, remembering, while very rarely accessing higher levels including applying or analyzing (Anderson & Krathwohl, 2001, p. 67). I have observed this pattern repeatedly; students are able to complete questions similar to those they have seen before, but struggle with questions that require additional analysis, application, or synthesis of ideas. In several situations, when I have asked a question on a quiz or exam that is similar to one we have studied in class, students have recorded the exact class notes from memory on the exam, although the question has different numbers or context. I have observed many similar situations to show that while my students are able to memorize content and numbers very effectively, they struggle with understanding and applying mathematics and science skills and concepts.

For example, I often use a dish-washing analogy to introduce the ideas of reaction mechanisms and rate-determining step to my Chemistry 30 students. The analogy helps me to think about a single process occurring in a series of steps, and that the slowest step will be the one that determines the overall speed of the process. I tell my students to think about washing dishes after a large family meal: one person brings dishes from the table to the counter, another person washes dishes, another dries, and a fourth person returns dishes to the cupboard. A couple times, students have stopped me
at this point, in disbelief that I allow my guests to wash dishes at my house; already a few students find my analogy unhelpful because their cultural practices do not fit the situation I have described. I continue to talk about the speed of each person: the person carrying the dishes does so at a rate of 15 dishes per minute, the washer washes at a rate of 3 dishes per minute, the dryer at a rate of 5 dishes per minute, and the dishes are returned to the cupboard at a rate of 8 dishes per minute. I then ask students which person determines the overall rate, how later steps are affected by the rate of earlier steps, and which step we must speed up in order to make the entire process faster.

The dish-washing analogy is a way for me to use a concrete, well-known process to explain somewhat abstract, difficult to observe chemical reactions. However, the analogy is not very useful for my students. I recently held a hot dog sale with my grade 12 students as a fundraiser for their upcoming graduation ceremony. While we were washing dishes after the sale, I noticed that they washed dishes in a very different way than I have ever observed. There was not a single person to complete each step; students moved in and out from the sink, each one collecting a dish, washing it, drying it, and then handing it to me. I began to realize just how ineffective my analogy is for this group of students because it is not how they wash dishes. During two different semesters, I have overheard students preparing for their reaction rates exam using last-minute memorization. I have heard my students say, “Okay, there are four people. The first person’s rate is 15 dishes per minute, the second 3 dishes per minute…” The analogy that I have been using as a great way for students to understand a chemistry concept is as abstract to them as the chemistry concept itself, another thing to memorize in preparation for the test.
In another example, Nidhal Guessoum (2011) discusses a science fair held at his sons’ Islamic school in United Arab Emirates. He notes that students failed to use the processes of science because their “experiments” were demonstrations that they did not understand. Only a handful of parents attended, few students participated, and no school administration or board members attended. A few days later, a Qur’an memorization contest was held; for this event, all students took part, 200 parents attended, and school officials and media were involved. I have noticed a similar focus at my school. While parents want a science fair, fewer parents encourage their children to take part in science fair than in the Qur’an competition, and prizes for students in the Qur’an competition are much more valuable than prizes in the science fair. Guessoum (2011) is discouraged that the money invested each year in the Qur’an competition is 20 times that of the science fair. He also notes that “the whole competition, which lasted for a couple of months (and is repeated year after year), consists solely of rote memorization” (p. 9). None of the students are ever asked to explain any of what they have memorized. The description of the science fair at Guessoum’s sons’ school resonates with me. I could tell almost the same story with science fairs at my school. My concern is not that a greater value is placed on religious activities than science, but because the emphasis and reward given for each activity is inequitable, students learn that memorizing Qur’an hadiths is more valuable than posing questions and thinking critically about how to answer their questions.

During science fairs as well as in my classroom, I have noticed that while my students’ ability to memorize large amounts of content is remarkable, problem solving and application of knowledge is a weakness they frequently exhibit. The two are related;
because my students memorize content so effectively and have learned rote memorization as a central skill, their default strategy is memorization rather than knowledge construction that should lead to deeper understanding. The difficulty they experience applying content to new situations and remembering content in future situations are indicators they lack sufficient depth of understanding according to the constructivist view of learning.

I have chosen to use a constructivist theory of learning because it complies with the observations I have made during my own learning experiences and during my work with students more than behaviourist or cognitivist theories. My constructivist view of learning extends to all classes I teach. I currently teach Science 10, Physics 20 and 30, Chemistry 20 and 30, Pre-calculus 30, Foundations of Mathematics 30, and Calculus 30. All the courses I teach require prior learning and sufficient depth of understanding to be successfully learned. I know the Grade 11 and 12 students well because I teach them seven courses over two years. Our class sizes are small with seven Grade 11 and eleven Grade 12 students during the 2012-2013 school year. I work a lot with my students in an attempt to develop higher thinking skills, and to develop their problem-solving abilities. I model strategies, have students play games and activities, and practice problem solving. I use graphic organizers to encourage metacognitive processes when applying knowledge. However, despite the time and effort I have spent developing my students’ problem solving skills, I have seen very little evidence of stronger abilities on assignments and exams. I think that my students do not struggle with the process of application, but they lack a meaningful understanding to do so.
Many of my students perform well on assignments and exams while understanding little. Although I include at least one task on each assessment item that requires some additional application or synthesis to complete, students seem content to perform very well on the other tasks and lose some marks on the ones that memorization will not allow them to successfully complete. While my students have shown that they have not gained a deep understanding of the content, they do well enough on simple tasks that they complete the course with satisfactory grades.

In September 2012, two students who completed my courses with excellent grades visited from university for assistance in their first-semester chemistry course. They asked me to help them with limiting reagent, titration, and oxidation-reduction questions. I did a few examples and questions with them, and they seemed to have a good grasp of the skills. As my former students were packing their books and preparing to leave, one asked me, “Since we learn these things in our first university chemistry course, why don’t you introduce them to us in high school?” I was perplexed with the question. I reminded them that we had discussed limiting reagent in both Chemistry 20 and Chemistry 30, and we had discussed titrations and redox in Chemistry 30. I reminded them of ways I introduce the concepts, the laboratory experiments they had performed, analogies and jokes I used, and the many questions they had done to practice. They still had no recollection; while I was taking the traditional steps and using good teaching practices to ensure deep understanding in science courses, my students did not remember any of it a few months later, demonstrating their temporary use of the lowest level of Bloom’s revised taxonomy, remembering (Anderson & Krathwohl, 2001, p. 67), in order to perform well on my assessments but not retain information further.
The situation with my two former students was not new for me. I often begin my lessons by attempting to access prior knowledge; I remind students about lessons from yesterday, last semester, and even the last few years. My approach is an attempt to ensure that students are accessing their prior knowledge to enable them to construct new knowledge I am teaching. While I thought I was accessing students’ prior knowledge, I was really discussing content they had previously memorized and forgotten. I provide students with models that deepen understanding for me, but not for them. If the model or explanation I use does not fit with my students’ understanding, I have not helped them construct meaning. Rather, I have given them one more abstract piece of information to memorize for the upcoming test. To help my students construct new knowledge, I must first have them access concepts and ideas they truly understand. Effective knowledge construction will lead to meaningful learning for my students.

Many of my students complete their secondary science courses with very high grades. According to my students and their parents, they have successfully learned what they need to. However, since my students do not retain information, I think that they have not successfully learned the scientific content; rather, they have played the necessary school games to complete the course with a good grade. Science is highly regarded in my school community, so many of my students enter science degrees in postsecondary education. After talking to graduates from my school, I estimate that about half of my students who begin a science degree switch to a non-science program within their first year of study. Since they really struggle in their future science courses, I realize that I am not effectively teaching them to understand science concepts at the secondary level. Partially because I use primarily traditional assessment strategies,
students may be successful in my courses without true understanding of scientific concepts. Until I show my students the importance of developing deep understanding and making connections to their cultural understanding of the world, many may continue to be unsuccessful in future science courses.

**Cultural Concerns**

There are huge complexities as I consider culture. Many factors contribute to a person’s culture and their cultural norms. For my students, significant factors include religion, country of origin, language, and the amount of time they have spent in Canada. While I cannot pretend that I have a deep understanding of culture and I do not want to oversimplify the complex nature of a person’s culture, I notice daily how my students’ cultural norms and practices affect their ability to learn science in a meaningful way.

I observe two aspects of my students’ culture that affect my ability to effectively teach secondary science. Most noticeably, there is a gap between the accepted cultural norms of science (knowledge construction and application) and my students’ cultural norms (memorization). The gap can be observed through examples of students’ tendency to memorize content. The second aspect, cultural relevance, is not as readily noticeable for a casual observer, but I think it is equally important for meaningful knowledge construction. The importance of using culturally relevant ideas is demonstrated in the dishwashing analogy I use. Without using lessons and ideas that are culturally relevant to my students, they have no way to construct an understanding of new ideas because they have no relevant prior knowledge to access and link. My research attempts to attend to both aspects of culture my teaching practices have failed to address.
Before beginning research with my students, I interviewed a parent and a former student who have both experienced success in science. Both identified memorization as an important part of the Muslim religion. My former student also discussed educational practices in her home country, where teachers value and encourage memorization and rarely ask students to apply, analyze, or create. Talking to my former student and a student’s mother confirmed the importance of completing research into how to more effectively assist my students to move beyond memorization and helped me to clearly define the issue in my science classroom and to develop a clear purpose for research.

The purpose of my research was to learn more about how to assist my students construct a deeper understanding of scientific concepts by moving away from rote memorization, and to enable them to construct a deeper understanding of chemistry and physics concepts. My research question is How can I work with my students to learn to reconstruct my teaching so that it is meaningful to students who maintain their Islamic cultural norms? More specifically, a.) Do my attempts at culturally relevant lessons enable students to apply and analyze knowledge? and b.) Do my attempts to use inquiry-based instruction enable students to bridge the gap between their cultural norms and the cultural norms of science?
Chapter 2: Literature Review

Related literature recognizes the importance of teachers’ work to bridge the gap between scientific and students’ cultural norms. The purpose of this review is to critically examine literature related to students’ and science’s cultural norms, multicultural education, and cultural relevance and relate each to inquiry learning and knowledge construction rather than rote learning.

Rote Learning versus Knowledge Construction

Rote learning is “the acquisition of new information without specific association with existing elements in an individual’s conceptual structure (i.e., memorization)” (Edmondson & Novak, 1993, p. 548) while meaningful knowledge construction “occurs when new information is linked with existing concepts, and integrated into what the learner already understands” (Edmondson & Novak, 1993, p. 548). My students admit that they have used memorized information to successfully move through their science courses; in consecutive lessons and courses, when I remind students of past discussions, they rarely remember the lesson I reference. I think my students resort to rote learning each day because they do not remember past lessons and cannot therefore link new information to any previous knowledge.

Cobern (1991) found that “contextual constructivism is about understanding the fundamental, culturally based beliefs that both students and teachers bring to class, and how these beliefs are supported by culture” (p. 18). Therefore, constructivist theory dictates that students’ culture must be considered when secondary science teachers plan lessons for their students. By doing so, “a constructivist teacher works at the interface of
curriculum and student to bring them together in a way that is meaningful for the learner” (Cobern, 1991, p. 25). Science teachers, therefore, must give primary consideration for students’ cultural understanding and norms as part of a constructivist learning model.

A constructivist model of learning identifies the need for students to bridge the gap between scientific and their own cultural norms. Yore (2001) notes that “constructivism recognizes that contemporary science is based on a hybrid worldview of knowing that stresses the importance of interactions with the physical world and the sociocultural context in which interpretations of these experiences reflect the lived experiences and cultural beliefs of the knowers” (Science Teaching section, paragraph 5). A corollary of constructivist theory is that to construct new knowledge, students must have the ability to connect new ideas to prior knowledge. If the content is culturally irrelevant, students may not have any pertinent prior knowledge to link to new information.

Because my students often do not connect science to their cultural worldview, they have been unable to construct meaningful knowledge in past courses. Therefore, any attempt to relate new lessons to previous knowledge fails; I cannot relate content to knowledge that does not exist for my students. I have been engaging my students in a continuous cycle of rote learning: students are unable to make meaningful links so they memorize content; therefore they fail to remember content when I bring it up in subsequent lessons, and must consequently resort to rote learning again. Until I find a way to interrupt this cycle of rote learning, my students will be unable to construct a
meaningful understanding of physics and chemistry concepts and will not reach higher, more advanced levels of learning and thinking.

**Bloom’s Taxonomy**

Bloom’s revised taxonomy organizes rote learning, or remembering, and more meaningful learning processes into a hierarchy (Figure 1). Bloom’s Taxonomy has been used for more than 50 years, and “it continues to be widely used today in the disciplines of teaching, curriculum writing, and learning theory, as well as content development, instruction, and assessment” (Seaman, 2001, p. 30). Bloom’s Taxonomy is useful to my research because my goal is to move students past the first level of the hierarchy, remembering, into higher levels such as applying and analyzing.

**Figure 1: Revised Bloom’s Taxonomy**

![Revised Bloom's Taxonomy Diagram]

Adapted from Anderson and Krathwohl
The Presentation of Western Science

To help students move their learning strategies into higher levels of Bloom’s taxonomy, I must first examine how we present information to secondary science students. Research regarding effective strategies for teaching science to all students is important for secondary science teachers because “teachers and students have interacting and interconnected epistemological perspectives, and … identifying students’ epistemological positions is an important part of understanding the teaching and learning processes” (Edmondson & Novak, 1993, p. 549). Teachers may focus on their own epistemology to form their pedagogy, but students’ epistemology must also work inform an effective teacher’s practice.

Considering students’ cultural norms when teaching science is critical because “effective science instruction incorporates students’ prior cultural and linguistic knowledge in relation to science disciplines” (Lee & Luykx, 2006, p. 26). Jegede and Aikenhead (1999) take the idea a step further by stating

From the viewpoint of cultural anthropology, to learn science is to acquire the culture of science. To acquire the culture of science, pupils must travel from their everyday life-world to the world of science found in their science classroom (p. 47).

Teachers’ current practice of not providing students with opportunities to acquire the cultural norms of science may interfere with them learning science in a meaningful way.

Loo (2001) states that “undeniably, current practice falls short of the … ideal. As science is a branch of knowledge generated by human beings, scientific inquiry is a humanistic process that is not founded solely on the cornerstone of reason. There are no doubts that culture and religion have contributed much to science” (p. 71). Scientists’
cultural worldviews have defined scientific theories and advances. For example, many scientists “maintain that Darwin formulated his theory of biological evolution in terms of individual competition in the struggle for existence because the society in which he lived was so individualistic and competitive” (Hull, 2010, p. 2). As science has developed, it has become more narrowly focused on Western ideals as universally accepted knowledge and practices.

The view that science is universal, a Universalist view of science, upheld by many western-educated science teachers forces students to attempt to find their own methods for reconciling their own culture with the culture of science. Since “the scientific worldview is uniquely Western, and is characterized by a mechanistic, reductionist view of the world where machine-type analogies are used to explain natural phenomena” (Lynch, 2000, p. 69), students may struggle with fitting the nature of science into their own worldview without the assistance of their science teachers to decolonize science education. Science has been claimed as Western because

… one of the major distinctive characteristics of modern Western culture … (is) its scientific character and the prestige it attached to ‘the scientific’. Other world cultures developed empirical knowledge, but this is not the same thing as theoretically organized science (Bocock, 1996, p. 170).

Students are perhaps more aware of the cultural gap than their teachers are because:

… whenever pupils enter the world of school science, it soon becomes evident that science too is another culture with which s/he has to interact, bringing with him/her the other baggage of cultures s/he already carries. It does not take too long for the pupil to recognize that the science being taught at school has been influenced by the culture of the scientific community itself (Jegede & Aikenhead, 1999, p. 52).
Science teachers must recognize that for an increasing number of students, there is a cultural gap between the presentation of science in secondary classrooms and students’ worldviews.

Teachers must create opportunities for students to bridge cultural gaps because “different cultural processes are involved in the acquisition of science culture. When the culture of science generally harmonizes with a pupil’s life-world culture, science instruction will tend to support the pupils’ view of the world” (Jegede & Aikenhead, 1999, p. 3). Science teachers must change their approach because,

…it does not make sense for scientists, mathematicians, science teachers, and science educators to talk about an absolute reality independent of community members. The character of the scientists’ reality of the external world is only known to them through their meaning-making (Atwater, 1996, p. 828).

Without a cultural context, students have no way to make connections to prior knowledge. To provide a cultural context for students, the cultural gap between students’ cultural practices and norms and the culture of science as presented by teachers must be bridged.

The cultural gap is widened when teachers expect students to assimilate to the culture of science. Jegede and Aikenhead (1999) state that “attempts at assimilation can alienate pupils from science, thereby causing them to develop clever ways (school games) to pass their science courses without learning the content in a meaningful way assumed by the school and community” (p. 49). My students appear to have resorted to developing clever ways to successfully complete my courses without abandoning their cultural practice of memorization while I assume an opinion that rote learning is not
meaningful learning. I believe that without meaningful learning opportunities in science, students will not achieve their full potential in science courses.

Students from non-Western cultures may underachieve in science because “learning is mediated by cultural, linguistic, and social factors. Learning is enhanced – indeed, made possible – when it occurs in contexts that are culturally, linguistically, and cognitively meaningful and relevant to students” (Lee & Luykx, 2006, p. 26). Most elementary and secondary science content is presented as Western science (Jegede & Aikenhead, 1999; Robottom & Norhaidah, 2008). Aikenhead and Michell (2012) argue that a major concern for non-Western students in science classes is that scientists and science teachers may contend that science is universal, “that scientific knowledge transcends culture because it has no cultural content – it is culture-free” (p. 29). Conventional “school science usually attempts to enculturate all students into the culture of academic Eurocentric science, replete with its canonical knowledge, techniques, and values” (Aikenhead & Elliott, 2010, p. 322). A student whose own cultural norms do not align well with Western science norms will struggle with scientific knowledge construction because the construction may seem to negate their knowledge and beliefs. Since “scientific entities and ideas … are constructed, validated, and communicated through the cultural institutions of science” (Driver et al, 1994, p. 6), students attempting to construct meaning of scientific principles using their own cultural institution may be unsuccessful and may resort to rote learning. Additionally, “the Western science taught at school is often shown to be more superior to knowledge within the local culture” (Jegede & Aikenhead, 1999, p. 58). A student whose knowledge system is made to seem inferior to their teacher’s knowledge system will complete necessary tasks to complete a
secondary science course, but will not learn in a meaningful way. I regard my students’
ability to memorize as strength rather than weakness. However, when students do not
construct knowledge, the memorized content is not enough to allow them to successfully
demonstrate understanding of science content.

I do not want to suggest that Western science is more legitimate or more
dominant than another cultural way of knowing or learning. However, we are currently
teaching secondary science as if it is the only way of knowing some aspects of nature,
and we must address the cultural needs of each student in the class rather than pretending
that science is culture-free. Aikenhead (2001) suggests that the first step secondary
science teachers must take to overcome cultural differences is to “recognize Western
science as being a cultural entity itself” (2001, p. 183). When teachers fail to recognize
Western science as a culture with its own set of norms, “Western science attempts to fix
a position for the dominant knowledge, arguing for validation and recognition as it
(re)asserts and defends its borders” (Carter, 2006, p. 687). In order for all students to
learn science, science teachers must stop perpetuating a solely Western science.

Postcolonialism stresses the importance of avoiding the creation of a false binary.
“Postcolonial analysis usually proceeds around a critique of embedded binary
representations of the Other, the hegemony of some forms of knowledge and
deligitimation of others” (Carter, 2006, p. 680). I think we currently have a bleak
situation in secondary science classrooms of students who benefit from our current
science pedagogy and students who struggle because of their teachers’ inability to
present science in a more culturally relevant, accessible manner. When I refer to non-
Western students, I am referring to any student whose personal understanding of the
world does not coincide with the way we currently teach science, which can include students from any cultural background, including Canadian students who are attempting to learn science.

Edward Said (1978) stresses the negative impacts when we generalize an entire group of people. He discusses the problems with Orientalism, a term he has used to refer to the West's misrepresentations and misunderstanding of Eastern societies, including Middle Eastern cultures, and the belief that the West is stronger and more rational in comparison to the Eastern societies. Perhaps the most troubling result is “an assumption … that the Orient and everything in it was, if not patently inferior to, then in need of corrective study by the West” (p. 41). The purpose of my work is not to demean or belittle my students’ cultural norms, and not to suggest that my students’ cultural practices are in need of corrective study. Instead, I consider this research to be a corrective study of my own teaching practices and how it impacts my students’ learning.

**International Trends in Science Education**

Since “learning is a generative process requiring effort in which learners actively construct their own meanings that are consistent with their prior ideas rather than passively acquire knowledge transmitted to them” (Chin & Osborne, 2008, p. 3), it is important that students are able to find ways to think of science as consistent with their cultural ideas. My students are similar to other Muslim students around the world who struggle with the application of science content. The failure of science teachers to bridge the culture of science and Islamic cultures is not a dilemma unique to my classroom. Segal (1996) notes that,
...by any index, the Muslim world produces a disproportionately small amount of scientific output, and much of it is relatively low in quality... forty-one predominantly Muslim countries with about 20 percent of the world’s total population generate less than 5 percent of its science (p. 61).

Results from the 2007 Trends in International Mathematics and Science Study (TIMSS) show that students from Muslim countries do not score as high on science assessments as students from other countries. Reported data “show Arab/Muslim pupils perform at the very lowest levels compared to international standards” (Guessoum, 2009, p. 2). PISA 2012 creative problem solving results (OECD, 2014, p. 15) show students from United Arab Emirates and Turkey, the two participating countries that represent my students’ home countries, demonstrated poor relative performance in problem solving. Compared to students around the world with similar performance in mathematics, reading and science, students from Turkey achieved a relative score of -14 and students from United Arab Emirates achieved a relative score of -43. A contribution to the causes of Muslim students’ apparent weakness in applying science and mathematics at comparable levels with the rest of the world is that science is not presented in a culturally relevant manner to Muslim students (Segal, 1996). Iqbal’s (2011) major concern is that “in the case of Muslims, there is not even a theoretical framework for the teaching of science from an Islamic perspective” (p. 2). Without a framework, teachers lack the experience and knowledge to effectively present science that is relevant to Muslim students. Using a more inquiry-based approach to teaching science may give students an opportunity to construct meaningful knowledge in the absence of a framework for teaching science to Muslim students.

Robottom and Norhaidah (2008) discuss the importance of an Islamic science framework as well. They argue that,
…culture and religion are important factors shaping (and potentially constraining) the ways Islamic-background learners make meaning of their science education experiences – in short, a manifestation of the constructivist idea that biography shapes meaning construction – provision of an appropriate conceptual (epistemological) frame for reconciling encountered discord would seem to be crucial for non-western learners of (western) science (p. 162).

Muslim students face greater challenges compared to other non-Western learners of Western science because,

…discourses experienced by Islamic learners in science education contexts exceed the kinds of factors usually referred to in constructivist explanations of the formation of alternative conceptions of western science subject matters: they are of a far more fundamental, personal and philosophical nature, entailing issues of epistemology, ontology, and religious commitment (Robottom & Norhaidah, 2008, p. 160).

The resulting implication is that teachers must develop some effective strategies for connecting the cultures of science and Islam or help students make the connections.

**National Trends in Science Education**

As the immigrant population in Canada increases (Figure 2), secondary science teachers will likely teach more Muslim students than they have in the past. According to the 2011 Statistics Canada National Household Survey, “Canada had a total of about 6,775,800 foreign-born individuals who arrived as immigrants. They represented 20.6% of the total population, compared with 19.8% in the 2006 Census” (p. 4). Additionally, the Muslim population is steadily increasing (Figure 3). Census data show that “slightly over 1 million individuals identified themselves as Muslim, representing 3.2% of the nation's total population” (Statistics Canada, 2011, p. 5). Therefore, it is becoming progressively important for research into effectively bridging the gap between the cultural practices of Islam and science. Research with specific classroom examples of bridging the gap between students’ cultural norms and the cultural norms of science may
assist secondary science teachers to support their non-Western students’ learning of science.

**Figure 2: Foreign Born Individuals in Canada**

![Figure 2: Foreign Born Individuals in Canada](source)

Source: Statistics Canada, 2011

**Figure 3: Major Religious Affiliation in Recent Immigrants to Canada**

<table>
<thead>
<tr>
<th>MAJOR RELIGIOUS AFFILIATIONS IN IMMIGRANTS</th>
<th>MAJOR RELIGIOUS AFFILIATIONS IN RECENT IMMIGRANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PERCENTAGE IN THOSE WHO ARRIVED BEFORE 1971</strong></td>
<td><strong>PERCENTAGE IN THOSE WHO ARRIVED BETWEEN 2006-2011</strong></td>
</tr>
<tr>
<td>Christian: 78.4%</td>
<td>Christian: 47.5%</td>
</tr>
<tr>
<td>No religious affiliation: 16%</td>
<td>No religious affiliation: 19.5%</td>
</tr>
<tr>
<td>Other religions: 0.5%</td>
<td>Other religions: 0.6%</td>
</tr>
<tr>
<td>Sikh: 0.8%</td>
<td>Sikh: 4.8%</td>
</tr>
<tr>
<td>Hindu: 0.9%</td>
<td>Hindu: 6.6%</td>
</tr>
<tr>
<td>Buddhist: 0.7%</td>
<td>Buddhist: 2.8%</td>
</tr>
<tr>
<td>Muslim: 0.7%</td>
<td>Muslim: 17.4%</td>
</tr>
<tr>
<td>Jewish: 2.2%</td>
<td>Jewish: 0.9%</td>
</tr>
</tbody>
</table>

Source: The National Post, 2013
**Provincial Trends in Science Education**

A look at Saskatchewan’s immigrant landing data shows that both the number of immigrants to Saskatchewan and the percent of total Canadian immigrants coming to Saskatchewan have shown a steady increase (Figure 4). As a result of the increased immigration to the province, Saskatchewan teachers have an increasing number of non-Western students in their science classrooms. As the number of non-Western students in science classrooms increases, a framework must be developed to bridge the gap between students’ cultural practices and the cultural of science.

**Figure 4: Saskatchewan Immigrant Landings, 1998 – 2007**

Source: Saskatchewan Ministry of Advanced Education, Employment and Labour, 2009

As secondary science courses are being renewed in Saskatchewan and teachers are developing new instructional strategies and approaches to learning science, cultural relevance and inquiry are areas of primary focus. Renewed secondary science curricula encourage teachers to take a student inquiry approach to instruction, specifically adding a student-directed study outcome in each of the renewed secondary science courses.
Renewed curricula include an updated Saskatchewan Scientific Literacy Framework to outline the importance of learning contexts such as inquiry, technological problem solving, cultural perspectives, and STSE decision making. My research into inquiry and cultural relevance aligns with the renewed curriculum documents with one key distinction. The framework states that “the K-12 aim of Saskatchewan science curricula is to enable students to develop scientific literacy within the context of Euro-Canadian and Indigenous heritages, both of which have developed an empirical and rational knowledge of nature” (Saskatchewan Ministry of Education, 2013, p. 1). Saskatchewan science curriculum documents highlight the importance of incorporating First Nations and Métis ways of knowing while I want to study the importance of incorporating Islamic ways of knowing and learning.

Michell and Aikenhead’s (2012) important work is becoming a foundation for Saskatchewan science curriculum documents. However, as curriculum documents are highlighting the importance of Indigenous ways of knowing, other non-Western cultural perspectives are not being addressed. Saskatchewan Ministry of Education science curriculum documents highlight the importance of scientific knowledge construction as one of four foundations of scientific literacy. Renewed science curricula create opportunities for students to “construct an understanding of concepts, principles, laws, and theories in life science, in physical science, in earth and space science, and in Indigenous knowledge of nature; and then apply these understandings to interpret, integrate, and extend their knowledge” (Saskatchewan Ministry of Education, 2013, p. 2). I would like to provide opportunities for my students to construct an understanding in their own non-Western knowledge of nature, perhaps using their Islamic perspective.
Iqbal (2011) argues that if science is presented to Muslim students with an Islamic perspective, “chemistry, physics, biology, and other branches of the natural sciences would then not float in a vacuous and disconnected isolation, but would be integral parts of a greater whole embracing all branches of knowledge” (p. 3). Such an outcome would be exciting for Saskatchewan secondary science classrooms with increasing Muslim student populations. However, because Muslim students are still a small percentage of Saskatchewan learners, Iqbal’s vision of science education for Muslims in Saskatchewan may be impossible.

A systematic effort aimed at developing content, methods, and pedagogies for teaching science from an Islamic perspective [to] develop the framework into which this content can be absorbed and link it to the Qur’anic worldview at several levels of production, distribution, and delivery (Iqbal, 2011, p. 5) is unrealistic for non-Muslim teachers like me because I do not share the Qur’anic worldview with my students. I think that a framework to link science and Islamic practices like memorization would be valuable, but a framework that links science content to specific hadiths from the Qur’an does not help non-Muslim science teachers. I do not think it would be a useful framework in multicultural science classrooms, where many students do not share the Qur’anic worldview. While Iqbal’s dream of Islamic science education may be practical in Islamic countries, it is likely not as practical in Saskatchewan as other teaching strategies, such as inquiry.

**Trends in Science Teaching in My Classroom**

Like other Saskatchewan science teachers, I am improving my focus on students’ cultural backgrounds in order to improve students’ learning. My observations follow Sousa’s (2008) findings that “students may diligently follow the teacher’s instructions to
perform a task repeatedly, and may even get the correct answers, but if they have not
found meaning after the learning episode, there is little likelihood of long-term storage”
(p. 58). Without creating meaningful opportunities to construct knowledge in terms of
their own cultural understanding, students resort to memorizing how to perform a task
rather than learning the meaning of the task. Sousa raises concern with the way we
present information to students because “information is often taught in such a way that it
lacks meaning for the student. Mathematics, for example, is presented as a series of
equations and figures, but why these numbers and symbols are important is not
explained. Yet the brain needs to attach significance to information in order to store it in
long-term memory” (p. 50). Since my lessons do not carry meaning or significance for
my students, they often cannot scaffold to prior knowledge or remember content long-
term.

Sousa (2008) also thinks that teachers are not adequately meeting their students’
need for context. He has found “teachers spend about 90 percent of their planning time
devising lessons so that students will make sense of the learning objective. But teachers
need to spend more time helping students establish meaning” (p. 56). Sousa raises
concerns with students’ default learning tactic of memorization. He states that:

… when students attempt to carry out simple arithmetic computations using
memorized facts, they often jump to conclusions without considering the relevant
conditions of the problem. They become so skilled at the mechanics of
computation that they arrive at answers that do not make sense (Sousa, 2008, p.
57).

My students struggle with determining the validity of their answers since they do not
construct knowledge of the theory behind the calculations; and, therefore, cannot
determine what a reasonable answer would be.
In order to allow for better knowledge construction, Johnson (2011) argues that valid culturally relevant science teaching must include three propositions including “academic success, cultural competence, and critical consciousness” (p. 172). I think the three propositions are an appropriate starting point for secondary science teachers. However, once teachers have expressed high academic expectations for their students, helped students to develop positive cultural identities, and taught students to think critically about societal and scientific issues, there is still work to be done. Johnson recommends supporting student success through a variety of instructional strategies. I think that my school and more specifically, my own teaching practices currently address the first and second culturally relevant pedagogy propositions more effectively than the third. I want to study the effects of culturally relevant lessons and inquiry learning in an effort to more effectively incorporate critical scientific thinking into my classroom.

Cultural Relevance

Culture is a very complex concept. Erickson (2010) notes there are “more than 250 different uses of the term culture” (p. 35), so it is easy to use the term, but difficult to ensure we are considering a common idea. When I talk about my students’ cultures, I refer to Bocock’s (1996) fourth definition of culture as “the distinctive ways of life, the shared values and meaning” (p. 152) my students have. When I consider their culture, I must consider all “components of a culture, from language to rituals, from cooking and types of foods eaten, to fundamental categories of thought” (Bocock, 1996, p. 162). Many of the components of their culture are diverse, so I cannot consider all my students to be from the same culture. Instead, I am considering cultural norms and practices that I have noticed are common and follow Bocock’s thinking that to analyze cultures, “we
should analyze the beliefs, values, and meanings – the powerful symbols – shared by a particular group” (Bocock, 1996, p. 154) rather than individual components like food, celebrations, and clothing. As a teacher, my analysis of my students’ culture is primarily focused on the value and meaning they give to memorization, which is a powerful symbol of wisdom and accomplishment in their cultures, and impacts their learning of secondary science concepts.

To construct knowledge that will lead to critical scientific thinking, students must be able to link what they are learning to what they already know. Since culture contributes to a person’s worldview, it plays a large role in how students construct new knowledge. I teach using the cultural norms of Western science like posing questions, experimenting, and drawing conclusions, while my students learn using their Islamic cultural norms; since the two cultures do not consistently correspond, there is a gap between my teaching and students’ learning. When my students are unable to construct an understanding, they go to one of their greatest strengths: rote learning. For me to teach science more effectively to Muslim students, I need to find a way to bridge the gap between the cultural practices of science and Islam.

To do so, I must address students’ cultures. “Culturally relevant science instruction harnessing knowledge, experiences, and cultures of diverse populations is a crucial component of reforming science education” (Johnson, 2011, p. 172). Therefore, to reform science education, educators must consider how culture impacts behaviour and learning.
Malcolm Gladwell (2008) outlines the impact culture has on the way people perform and behave through the poor safety history of Korean Air. Korean culture dictates that copilots and ground crew members show complete respect to pilots who outrank them and may not question or offer suggestions. A study of cockpit communication during the last five minutes before several crashes shows that copilots had concerns, attempted to address the pilot very respectfully according to cultural norms, and their concerns were not heard. Because Korean pilots behaved and communicated in a way defined by their culture, they are unable to perform effectively. Similarly, students whose cultural norms define their behaviour and the way they interact with language and ideas may prevent them from performing effectively according to Western ideals. For example, memorization is an important, renowned skill for young Muslims to develop, but memorization is considered the lowest level of learning in Western educational settings and is criticized by many secondary science teachers.

**Inquiry Learning**

Inquiry learning may be a way to move students beyond memorization in a Western science classroom. The continuum of student inquiry ranges from confirmation inquiry to open inquiry (Banchi & Bell, 2008, p.26). My traditional teaching style uses some confirmation inquiry where students confirm a concept I have taught them by completing an activity I have designed. I also use a lot of structured inquiry where students discover the answer to a question I present by completing a procedure I provide. I rarely use guided inquiry, where students investigate a question I give them by designing and carrying out their own procedure, and I never use open inquiry, where
students design their own questions and develop their own strategies and procedures to answer them.

Structured or guided inquiry activities may assist students because “to make meaning out of their experiences in science classrooms, pupils need to negotiate a cultural transition from their life-world into the world of school science” (Jegede & Aikenhead, 1999, p. 24). Open inquiry may provide students with the opportunity and the tools necessary to begin the transition as they form an understanding concordant with their own cultural contexts. It is important for me to reflect critically and that “instructional efforts directed only at teaching the “right” concepts will not be sufficient to modify the conceptual frameworks on most students in a positive way” (Edmondson & Novak, 1993, p. 549). In order for my students to develop new frameworks, I must provide them with opportunities to ask questions, make observations or complete research, and to draw conclusions, despite the possibility of students drawing incorrect or incomplete conclusions.

Teaching science using unguided inquiry is different than using scientific inquiry in the science classroom. Scientific inquiry, which is similar to structured inquiry, is what science teachers typically use during laboratory work and “is generally defined as a process of asking questions, generating data through systematic observation or experimentation, interpreting data, and drawing conclusions” (Sandoval and Reiser, 2004, p. 345). Teaching science using guided or open inquiry is similar in each step except that students may not generate data solely through systematic observation or experimentation; they may generate data in additional ways including additional reading or discussion. For the purpose of my research, guided and open inquiry encompass
scientific inquiry during experimentation, students asking questions to deepen their understanding of content, and students developing analogies or models to explain content in a meaningful way.

Lee et al. (2006) use open inquiry to teach science to students with diverse cultural backgrounds. They recognize

...a need for teachers to recognize the intellectual resources that these students bring to school science, to incorporate linguistic and cultural funds of knowledge that diverse student groups bring to the classroom, and to examine how students’ everyday knowledge and language intersect with scientific practices (p. 609). When students guide the inquiry process, cultural and scientific intersections may be discovered by students as they are learning.

Students will be more likely to make meaning out of their experiences if they are asking questions and developing answers rather than teachers asking questions then providing answers. For teachers, “questions from students indicate that they have been thinking about the ideas presented and have been trying to link them with other things they know” (Chin & Osborne, 2008, p. 2). Guided and open inquiry may start to provide students with the opportunity and the tools necessary to begin the transition as they form an understanding according to their own cultural contexts.

Research into inquiry demonstrates positive results for “cognitive achievement ... scientific literacy, science processes, vocabulary knowledge, conceptual understanding, critical thinking, and attitudes towards science” (Anderson, 2002, p. 4 – 5). Open inquiry is an effective teaching strategy because student “learning may occur through the formation and rearrangement of cognitive networks or schemata as students progressively construct explanations and answers to each question that they pose” (Chin
& Osborne, 2008, p. 3). In addition, “the generalizations … discovered by students through their own inquiries [will] be remembered longer” (Deboer, 2006, p. 23). Using inquiry learning may therefore help my students construct long-term knowledge as they ask and answer questions. Asking and answering good questions is one step in a meaningful learning process I would like to see my students develop through my research.

**Self-Study Action Research**

I value the process and nature of action research. Because I am teaching in a unique situation, and I want to focus specifically on improving my own teaching practices, the collaborative nature of true action research is not practical. However, I can use the process of action research through self-study research. Samaras & Roberts (2011) explain self-study teacher research as “designed to encourage teachers to be agents of their own reform initiatives… In self-study, teachers critically examine their actions and the context of those actions as a way of developing a more consciously driven mode of professional activity, as contrasted with action based on habit, tradition, or impulse” (p. 43). Chiu-Ching and Chan (2009) explain that

… for teacher-researchers, self-study encapsulates a wealth of experience embodied by teachers and their understanding of what teaching is. It is through inquiry that teachers examine the self within the teaching environment and their practices in terms of roles, actions, and beliefs, in order to consider making changes for improvement (p. 20).

McNiff & Whitehead (2011) identify self-study action researchers as the second group of action researchers characterized by their internal approach to data collection and their ability to “offer their own explanations for what they are doing” (p. 11). Because I am studying challenges I face in my own classroom, and describe personal observations as
the foundation and purpose for my research, self-study action research is an ideal methodology for me to utilize to reach my objectives.

**The Goal of my Research**

Through my self-study action research, my objective is to provide students with more meaningful learning opportunities through inquiry and cultural relevance. With a better understanding of science content and the nature of science, I think students will be less likely to resort to school games such as rote memorization and may be more likely to retain information for longer periods of time which will aid my students in being better problem solvers. Kirschner, Sweller, and Clark (2010) cite studies whose “results suggest that expert problem solvers derive their skill by drawing on the extensive experience stored in their long-term memory and then quickly select and apply the best procedures for solving problems” (p. 76). In order for my students to become more effective problem solvers, they must first construct knowledge in a meaningful, culturally relevant way, so that it may be stored in their long-term memory.

My students all share their Islamic culture. Zine (2008) discusses the ideal learning environment in Islamic schools. “Islamic studies is meant to be a seamless strand of knowledge that connects all subjects as they are taught from an Islamic perspective” (p. 18). She argues that “the primary goal of [Islamic] schools – Islamic immersion – is far from being reached” (p. 19). As a non-Muslim Canadian teacher working in an Islamic school, I do not have the cultural background or beliefs to enable me to develop an Islamization of scientific knowledge. Islamization of science is not my goal. Zine (2008) feels that “the Islamization of knowledge involves more than simply remaking Western knowledge with a different spin and inserting Islamic referents” (p.
My goal is for my students to reconcile their understanding of scientific content with their own cultural understanding. By developing more meaningful analogies and models, my students are likely making different connections to Western science, and therefore have not Islamized the content. However, a sufficiently deep, culturally meaningful understanding of scientific ideas may be more useful to my students as they continue to study science in their postsecondary endeavors. My students and their parents often tell me that science-based careers are regarded highly in Islamic culture. In particular, high school students work to study pre-medicine and engineering in their post-secondary endeavours because Muslims consider both to be significant careers.

Much of the literature I have discussed has a focus for First Nations students and Muslim students. While I am not arguing that First Nations and Islamic cultures are the same, parallel questions may be raised by teachers attempting to bridge the gap between the presentation of Western science and students’ cultures for both groups of students because both groups may experience a similar gap. First Nations and Muslim populations are both increasing in Saskatchewan, so it is becoming increasingly important to research ways to bridge cultural gaps.

I have chosen to use the metaphor bridging the gap between students’ and scientific cultures. Giroux (1992) and Aikenhead (1996) talk about crossing the borders between cultures, but I prefer the bridge metaphor. A border crossing implies students may only comply with the culture of science or with their own culture at a given time, but never both. We cannot be in two countries at the same time; once we cross the border, we remain there until we cross back into domestic territory. Similarly, students may move from one to the other as necessary but they may struggle to comply with both
at the same time. I also prefer the bridge comparison over Jordan’s (1985) translation from a student’s culture to the culture of science; while people who speak two languages may easily translate words from one language to another, they will think and understand in one language in some situations and in another language in other situations without combining the two. Jegede and Aikenhead (1999) regard science teachers as “travel agents” for their students to cross the borders between science and their own worldview. An effective travel agent is knowledgeable about clients’ destinations; while I know about the destination I want for my students, I cannot simply give them a set of instructions to move from where they currently are to where I want them to be. I like to view my students as bridging a gap with me. The harder we work, the closer we get to building an effective bridge so there is no longer a gap between the two cultures, but a permanent link between them.
Chapter 3: Methods

I implemented a self-study action research cycle to learn how to help my students construct scientific knowledge more effectively. Because my research is primarily self-serving and is not collaborative or community-oriented, I cannot call it action research. However, I value the process of action research, so I have used a process similar to an action research cycle to complete my self-study. In education, action research typically begins with a teacher identifying an issue in her classroom before developing and implementing an action research plan (Figure 5).

Figure 5: The Action Research Cycle

Identify an Issue for Investigation

Action research is “a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives” (Stringer,
2007, p. 1), so it is an ideal process for my self-study because the challenges I want to address through research in my classroom are daily concerns. As discussed, the struggle I face in modifying my students’ tendency to use memorization as their primary learning strategy is an issue I would like to investigate to become a more effective secondary science teacher. The potential benefits of implementing an action research cycle are worthwhile for me since “it assists [researchers] in working through the sometimes puzzling complexity of the issues they confront to make their work more meaningful and fulfilling” (Stringer, 2007, p. 1). Overcoming differences in cultural norms and the norms of knowledge construction in science is a complex issue, but an important one for me to study.

Stringer (2007) notes that “unlike traditional experimental/scientific research that looks for generalizable explanations that might be applied to all contexts, action research focuses on specific situations and localized solutions” (p. 1). My primary goal is to help students consider how they may adjust their approach to learning by changing my teaching practices. However, I also hope that some of my methods, findings, and conclusions may be utilized by other secondary science teachers who face similar challenges in their classrooms.

**Develop and Implement an Action Plan**

The president of my school’s private board approved my research in September 2012 without requesting changes (appendix I). I received approval to work with my students as research participants from the University of Regina Research Ethics Board in October 2012 (appendix A). I submitted a request for approval to changes to my research to include interviews with a student’s mother and a former student. The changes were
approved in January 2013 (appendix B). The Research Ethics Board agreed that because I did not know which students chose to participate in my research until the semester was complete; there was not a conflict of interest.

I taught Physics 20 and Chemistry 30 from September 2012 through January 2013 using a combination of traditional teaching methods, inquiry lessons, and lessons used to make science relevant to my students’ Islamic cultural norms. After I received approval to complete my data collection, the principal of the school and I explained my research to students in my Physics 20 and Chemistry 30 courses. We told students that returning their consent forms to the school office indicated that they wanted to take part in my research. All data collection was part of the instructional strategies I used in the courses; all students participated in each activity and data collection whether participating in my research or not. The only difference between participants and non-participants is that participants in my research allowed their work produced in the class to be data included in my research. Participating students did not receive any benefits by participating in my self-study action research cycle and non-participating students were not disadvantaged. Of the eighteen students in the two courses, eight gave consent to take part in my research. Participants’ identities remained hidden from me until semester marks had been finalized. Once data had been collected and disseminated, the principal of the school and I spoke to all students about the results of my research.

I used lessons I deemed to be culturally relevant based on my experiences with my students and inquiry activities throughout the semester with my seven Physics 20 students and eleven Chemistry 30 students. After each lesson, I evaluated its effectiveness through students’ answers from exit slips and journal entries. Exit slips
(appendix D) typically required students to respond to one content-related question about the day’s lesson so that I could assess how well students understood topics of discussion while journal entries asked students to reflect on the effectiveness of the lesson. The journals and exit slips informed my action research cycle and guided how quickly to move from teacher-guided inquiry to less guided inquiry activities. I also used the responses from students’ journal entries to inform me of students’ attitudes toward types of lessons and the content and processes presenting the greatest challenges for my students. I continued a cycle of implementing a lesson or activity, assessing effectiveness in terms of motivation and understanding, and adapting future lessons as necessary.

**Culturally Relevant Lessons**

Culturally relevant lessons are those I developed to incorporate Muslim scientists or Islamic practices into my teaching. Because relevant literature suggests that allowing students to construct knowledge in terms of what is already part of their culture will increase understanding, I designed the lessons to enable students to use people or events from Islamic culture to construct knowledge of physics and chemistry content. While I found many interesting resources available to assist me in implementing science that is relevant to Islamic culture, some resources revolve around how science is present in the Qur’an and other religious beliefs of Muslim people. My students have told me about scientific miracles present in the Qur’an. For example, in the Qur’an, exactly 86 letters into a verse, the letters “Rn” appear for the first time. My students believe that since the atomic number of radon is 86, the Qur’an predicts both the number of protons in the element and its chemical symbol centuries before its discovery. I do not share my
students’ belief, and their use of the term prediction in such situations does not correspond to the use of the term prediction in scientific practices.

Because I am not Muslim, I avoided these resources and approaches because I think using beliefs I do not share with my students, and do not fully understand would be disingenuous. Therefore, my culturally relevant lessons focused on cultural practices and Muslim people rather than on specific religious beliefs. Students were able to use religion through inquiry and analogies as they saw appropriate. I mentioned the Qur’an and science resources to my students several times throughout the semester, and two of them chose to use the resources as part of their Student-Directed Study at the end of the course.

Students may be able to gain a deeper understanding of the cultural norms of science if they are able to bridge the cultural gap because “culturally diverse knowledge systems are resolved by idiosyncratically making sense of how they are related, according to a person’s worldview” (Aikenhead and Michell, 2012, p. 114). A student who constructs her own scientific knowledge connected to prior understanding will likely have a greater ability to address new problems and situations more successfully. Perhaps culturally relevant lessons will enable students to resolve the differences between diverse scientific and students’ cultural practices and worldviews.

**Physics 20 Culturally Relevant Lessons**

I developed a number of lessons and activities that combined Islamic cultures with physics content. Students read about contributions of Islam to areas of science including medicine, biology, physics, and chemistry. Students chose one physics topic
we had studied, and researched how Muslim scientists have contributed to the field. They read about the Golden Age of Islam and how some of their home countries’ production of science has decreased dramatically and discussed possible causes and effects. Students constructed pinhole cameras to make the same observations of light that Ibn Al-Haytham used to conclude that light travels in straight lines. Since students were given background information about Al-Haytham’s process but not his findings, my intention for the pinhole camera activity was to combine cultural relevance and guided inquiry in a single activity.

**Chemistry 30 Culturally Relevant Lessons**

I repeated many of the culturally relevant lessons in Chemistry 30. Additionally, students completed a case study to learn about ways in which science has helped Muslims in their religious practices; students examined experimental data regarding the movement of crowds in small spaces to develop conclusions about safe and effective crowd movement including introducing barriers or more people, alternating direction of motion, wave movement in crowds, and the effect of bottlenecking. Students then studied how the experimental data has been used to alter the Jamarat bridge to make the annual pilgrimage to Hajj safer for the millions of Muslim people who participate each year.

**Inquiry Activities**

Inquiry-based activities are activities where students are required to ask questions, to develop strategies to answer their questions, and to draw conclusions based on their research or procedures. I worked with my students to study the impact that teaching inquiry-based science has on their ability to construct an understanding of
scientific concepts based on their own cultural experiences rather than lessons presented entirely using cultural norms of science. I also worked with my students to study the impact teaching inquiry-based science has for students to develop learning beyond rote memorization. Additionally, I was interested to observe whether students begin to use inquiry more frequently and memorization less frequently as their inquiry skills improve. Typically my students struggle with inquiry activities, so I primarily used guided inquiry activities rather than open inquiry activities.

Keys and Bryan (2000) discuss the positive effects that studies reveal when inquiry involves “incorporating rich inquiry-based instruction based on student generated questioning, experimentation with technological and real-life tools, model formulation, and metacognitive reflection” (p. 641). When developing inquiry lessons in my classroom, I followed their suggestions in combination with my students’ feedback in an attempt to incorporate each of the suggested features. Students developed questions and found answers, performed laboratory experiments and virtual experiments, articulated their own analogies and models, and reflected on their thought processes while moving through the inquiry process.

**Physics 20 Inquiry Activities**

I used a number of inquiry laboratory procedures in my Physics 20 course. Students investigated waves on a spiral spring, water waves in a ripple tank, images in plane mirrors, images in converging mirrors, images in converging lenses, and calorimetry. Each procedure required varying levels of student inquiry; some were primarily teacher-guided while others required more student-centered inquiry than I typically expect through the development of their own method for collecting data. In all
activities, students followed a procedure, made observations, and drew conclusions. At the end of the semester, I gave students an assignment to go through their notes and develop at least one question for each unit of study to look deeper into the science content we had discussed. Students then developed a procedure or performed research to answer their questions.

**Chemistry 30 Inquiry Activities**

I used several inquiry laboratory procedures in Chemistry 30. Students investigated the moles of chalk required to print their name and their personal preferred concentration of powdered drink. For both of these activities, I gave students a question to answer and they developed their own procedure and data collection methods to answer the question. After students’ data collection was complete, they submitted a formal laboratory write-up. At the end of the solutions and solubility unit, I gave students an assignment to go through their notes and develop at least four questions to look deeper into the chemistry content we had discussed. Students then developed a procedure or performed research to answer their questions and submitted a detailed summary of their question, procedure, and answer.

I used analogies in Chemistry 30 as a tool to help my students inquire into ways to connect new content knowledge to previous understanding. Primarily “analogies are used in science to develop insights into, hypotheses and questions about, and explanations of phenomena that are usually unobservable: they must be understood” (Brown & Salter, 2010, p. 167). Typically my students seem to memorize unobservable scientific phenomena rather than constructing knowledge. If students are able to develop a reasonable analogy using a base they understand to explain an unobservable target,
they have constructed a working understanding of the scientific phenomena. Another
benefit of analogies is that “the exploration of an analogy compared with the results of
experimental exploration of the phenomenon it models helps to identify misconceptions.
Analogy is a tool of science, and its use is, in effect, a model of professional behavior”
(Brown & Salter, 2010, p. 169). Analogies can be a very effective, multifaceted inquiry
tool in science when used appropriately.

In Chemistry 30, I provided my students with a car collision analogy to explain
factors affecting rates of a chemical reaction in terms of collision theory. For example,
we talked about driving at a higher speed to model the effect of increasing temperature,
and increasing the number of vehicles in a given area to model the effect of increasing
concentration. I then asked students to develop their own analogy for the same set of
ideas. I used a children’s see saw analogy to explain Le Chatelier’s Principle and the
effect of adding or removing substances involved in a chemical reaction.

Kirschner et al. (2010) argue that inquiry-based learning is ineffective partially
because students do not have the background knowledge students need to effectively
inquire into science content. I tried beginning two units with student questions, but found
the questions shallow and ineffective in motivating students. Students asked “what are
solutions?” and “what is solubility?” to begin the solutions and solubility unit. I
encouraged my students to think about their interests and curiosity, and they were still
unable to suggest meaningful questions to guide the unit of study. I thought that students
should have known the answers to both questions they posed, and the simplicity of their
questions discouraged us from looking deeply at any content. My teaching experience
seems consistent with Kirschner et al. so I began to use advance organizers at the
beginning of each unit. Advance organizers provide “information that is presented prior to learning that can be used by the learner to organize and interpret new incoming information” (Mayer, 2003, p. 14), which is what I wanted to provide for my students. Typically

these organizers are introduced in advance of learning itself, and are also presented at a higher level of abstraction, generality, and inclusiveness; and since the substantive content of a given organizer or series of organizers is selected on the basis of its suitability for explaining, integrating, and interrelating the material they precede, this strategy simultaneously satisfies the substantive as well as the programming criteria for enhancing the organization strength of cognitive structure (Ausubel, 1960, p. 270).

Therefore, the use of advance organizers seem to fit my students’ need to develop questions at a deeper, higher cognitive level and to organize their thoughts during the course of the unit of study.

**Reflect on Effectiveness of Action Plan**

At the end of each inquiry activity or culturally relevant lesson, I asked students to complete exit slips (appendix D), which are written by students in the last few minutes of class in response to my specific questions. Students handed them to me immediately. I used exit slips to check for students’ understanding of concepts and I asked students to explain what concepts or tasks they found challenging, what they found interesting, and questions they had. I often asked students an additional calculation question, or I asked them to apply what they had learned in class to another situation. My primary goal for the exit slips was to inform my self-study action research cycle. For example, after the first inquiry activity I used in Chemistry 30, many students responded that they found the lack of teacher guidance very challenging and confusing; they felt lost. In response, I
moved from teacher guided to more open inquiry more slowly than I had initially planned.

At the end of each unit of study, students completed journal entries (appendix E) with similar questions; I asked students what they found challenging, interesting, thought-provoking, and motivating, and how they had prepared for the unit exam. Students were given more time to complete the journal entry, and were expected to write more and explain their comments fully. I used all students’ journal entries to inform my action research cycle. For example, after the first unit in Chemistry 30, students’ shallow questions in their journal entries made me rethink how I was using inquiry. I began to use advance organizers to help students develop deeper questions. In this thesis, I have used data only from students who consented to participate in my research.

Three weeks before the end of the semester, I gave my Chemistry 30 students six questions from topics we had discussed early in the semester (Appendix F). Students had not yet started studying for their final exam, so they relied on their memory from a few months earlier to answer the six questions. The first two questions were related to factors affecting the rate of a chemical reaction; when I taught students about reaction rates, students developed their own analogy, and I gave them an analogy I find useful. The next two questions required students to use Le Chatelier’s Principle; when I taught Le Chatelier’s Principle, I gave the students an analogy but did not ask them to develop their own. The last two questions were calculation-based; students were not given an analogy to access. Each of the three sections was marked out of 4. I compared students’ ability to answer each type of question, whether they chose to use an analogy to respond to the questions, and whether they preferred the analogies I gave them, or the analogies they
developed independently. The president of the school board has allowed me to use the Chemistry 30 class-wide data because it is anonymous, contains no direct quotations, and uses average marks to demonstrate trends. I used this short assessment to learn how effectively analogies enable students to remember content before beginning to memorize content for their final exam. I consider how well my students remember content to be very important because,

…the aim of all instruction is to alter long-term memory. If nothing has changed in long-term memory, nothing has been learned. Any instructional recommendation that does not or cannot specify what has been changed in long-term memory, or that does not increase the efficiency with which relevant information is stored in or retrieved from long-term memory, is likely to be ineffective (Kirschner et al., 2010, p. 77).

I retained a journal of my observations throughout the semester to supplement students’ exit slips and journal entries.

I used an unstructured style to interview a former student and a student’s mother to learn more about culture and science and to refine my research purpose and philosophy. While “no interview can truly be considered unstructured … some are relatively unstructured and are more or less equivalent to guided conversations” (DiCicco-Bloom & Crabtree, 2006, p. 316), which characterizes the interviews I conducted. I selected the interviewees based on their success in applied science and the positive rapport I have developed with each of them. In qualitative interviews “rapport involves trust and a respect for the interviewee and the information he or she shares. It is also the means of establishing a safe and comfortable environment for sharing interviewee’s personal experiences and attitudes as they actually occurred” (DiCicco-Bloom & Crabtree, 2006, p. 316). I chose the times and locations for the interviews to
ensure both interviewees were comfortable. I interviewed my former student after school in my classroom at her convenience. I interviewed my student’s mother in her home on a Sunday evening while having coffee with her. Both interviewees seemed relaxed and comfortable during our discussions.

I interviewed participating students to gauge their reaction to particular lessons and strategies I used in the classroom as the chief data collection method for my research. I used semi-structured interviews with my students that were “generally organized around a set of predetermined open-ended questions, with other questions emerging” (DiCicco-Bloom & Crabtree, 2006, p. 314) as I considered students’ responses. My purpose for interviewing students was “to derive interpretations, not facts or laws, from respondent talk” (Gubrium & Holstein, 2002, p. 83), which fits with the role of qualitative interviews that typically “contribute to a body of knowledge that is conceptual and theoretical and is based on the meanings that life experiences hold for the interviewees” (DiCicco-Bloom & Crabtree, 2006, p. 314). I used qualitative interviews to gain some insight into my students’ perspectives because “perspective is especially significant in qualitative interviewing, where meaning making is center stage in the interpretive process” (Gubrium & Holstein, 2002, p. 84) and students’ perspectives demonstrate their motivation and interest in meaningful learning.

My initial plan was to complete five-minute interviews with each student in Physics 20 and Chemistry 30 at the end of the semester. The first interview I conducted seemed to make my student uncomfortable; I asked her to recall effective versus ineffective, and stimulating versus mundane lessons. She struggled to recall some of the activities from the semester, and seemed to be frustrated as she looked through her book
and I waited for a response. I decided to give students the interview questions in advance to enable them to recall and evaluate the lessons more effectively. The second interview I conducted was more effective because my student seemed more confident in his responses, but he indicated that he had reviewed activities and considered what to say, but had forgotten some of the comments he wanted to make. I decided to conduct written interviews with my students (Appendices G and H) to give them the opportunity to review the lessons and activities from the semester and to take their time to compare how effective they were in terms of interest and developing understanding. Students completed the interviews independently. After students submitted their responses, I asked students to expand or clarify their answers as necessary.

I think that I worked primarily in the co-operative phase of qualitative interviewing with the interviewees in both my unstructured and semi-structured interviews. The phase “is characterized by a comfort level in which the participants are not afraid of offending one another and find satisfaction in the interview process” (DiCicco-Bloom & Crabtree, 2006, p. 317). Since I have known the interviewees for years, a level of trust and comfort had been established before I began interviewing and I was able to use the interviews to assess how effectively I had reached my objective.

**Evaluate and Share Findings**

This thesis is the method I am choosing to evaluate and share my results with others. Additionally, I have shared my findings with my colleagues so that they may learn from my work with our students and perhaps extend the results to work with our students in their classrooms. We often discuss our teaching practices in our biweekly high school staff meetings and the use of guided inquiry, analogies, and culturally
relevant lessons have become frequent conversation topics. Some of my colleagues have also experienced minor success in their classrooms when they implement inquiry learning, culturally relevant lessons, and analogies.
Chapter 4: Findings

To begin to evaluate my data collection methods, I interviewed a former student’s mother, Hafsah. She has a master’s degree in engineering and has worked professionally in her field for the past twenty years. She is an intelligent, outspoken woman who is highly regarded in her community. I have taught her two children science, mathematics, chemistry, physics, and biology classes. I asked Hafsah if she had experienced gaps between Islamic and scientific cultures. She believes that when the culture of school content conflicts with students’ culture, “the conflict will get them to create a screen to block the information from passing into their brain.” Some of my students seem to generate this “screen”, but to succeed in secondary science courses, they must demonstrate knowledge of the content on exams and assignments. The result is my students memorize words, phrases, and processes rather than attempt to gain understanding of the information and skills I teach. Some of my students are quite candid about their intent to memorize content when they do not understand. I have had students tell me, “I don’t understand so I am just going to memorize it.” My students are following their own version of “Fatima’s Rules” (Larson, 1995), (Aikenhead & Jegede, 1999) named after a chemistry student who failed to construct knowledge by linking it to previous knowledge but was very successful in her secondary chemistry courses as a result of her ability to memorize words and concepts without developing any meaningful understanding of chemistry. Fatima, similar to my students, was able to memorize important concepts and processes to score well on exams without understanding many concepts. When secondary science teachers use typical assessment practices, as I do, students are able to perform well on assessment items because only one or two of the
tasks require higher level thinking than what was specifically done in class, and subsequently memorized by students.

I also interviewed one of my former students, Lamia, who has been working towards a bachelor of engineering degree with an environmental major and petroleum minor since graduating in 2008. She recognizes now that throughout her secondary education she used her remarkable ability to memorize content without understanding many of the mathematics, biology, chemistry, or physics concepts I had taught. She remembers memorizing all the possible combinations of operations used to perform dimensional analysis rather than learning the process. As a university student, she recognizes the irony of memorizing the steps of a process designed to allow scientists to perform calculations without relying on memorized processes. Lamia memorized every possible combination of steps to perform stoichiometric calculations while admitting that she had no understanding of why she was dividing by Avogadro’s number in some situations and multiplying in others. She commented that an important part of Muslim religion is memorizing the Qur’an, so memorization is taught and practiced extensively beginning at a young age. She thinks “that is why we work our brain that way.” Since Muslim students have developed and refined their memorization skills so thoroughly, they default to using memorization when they are unable to construct knowledge effectively. I asked her about the plausibility of bridging the gap between science and Islam, and she remarked “science is in Islam and in the Qur’an. There are all these agreements with science.” Because Lamia recognizes many connections between science and her culture, and is able to link science to her religious beliefs, cultural practices, and worldview, she has been successful at constructing meaningful knowledge in applied
science. She explained how different her learning process in university is when compared to high school using words such as intuitive, comprehend, and apply. Because she had classmates model the behavior for her, she began the process. Lamia explained that out of necessity, her study group taught her to make connections to prior learning and to construct knowledge continuously through the semester. I would like to help my current students make the connections she has made.

Lamia recalled a trip to her native country during Grade 10 when she studied science with her cousins. She remembered “literally, the girls were taking their textbooks and memorizing, word for word. There was no understanding at all. The teacher asked them to recite entire pages. They looked at my science book [with coloured pictures and questions] and they loved it. It was exciting for them.” Her description of mathematics is similar since “it’s the same math [as Saskatchewan students study], but there is no problem solving at all. It is just all questions with numbers.” Because many of my students are recent immigrants to Canada, they may have developed memorization skills thoroughly in their home countries in situations similar to the ones my former student described. In my experience, students who have developed memorization abilities so comprehensively will default to that skill when cultural gaps prevent them from constructing meaningful knowledge. As a result of those experiences, the ideal data collection was to work directly with students in my classroom.

Hafsah’s and Lamia’s comments helped confirm for me that my students’ difficulty with effectively constructing knowledge of science is not because their culture disagrees with science, but because there is a gap between their cultural norms and
practices and the cultural norms of science presentation. Their culture highly values memorization while the culture of science highly values application of knowledge.

The group of three boys and five girls who agreed to participate in my research is diverse in terms of gender, country of origin, socioeconomic status, family size, language proficiency, number of years in Canada, and academic ability. All quotations I have used in this thesis were taken from interviews with students at the end of the semester except the comments made about specific lessons which were taken from journal entries. I have used pseudonyms for students so that their comments may remain anonymous.

Ali is a 16-year old student in my Physics 20 class. He is reserved and quiet, and does not often give his opinion. Ali’s family originates from Somalia but he was born in Canada. He is the oldest of three children, and has a lot of educational support from his parents but struggles in mathematics and science courses.

Mohammed is a bright student in my Physics 20 class. He was born in Pakistan and moved to Canada with his family when he was in grade 6. He is inquisitive and loves technology. Mohammed’s family expects him to be successful in his education and future career.

Daniyal is an intelligent student in my Physics 20 class. Daniyal was born in Pakistan. He is outspoken and the most inquisitive student I have taught; learning through inquiry seems to be a natural process for him. He often comments that he prefers science courses that do not require memorization. He has completed exceptional science fair projects during the past two school years, demonstrating his ability to inquire and investigate.
Bisma is the top student in my Physics 20 class and is originally from Pakistan. She is very bright but also works very hard to maintain near-perfect grades. She asks a lot of questions and attempts to help her classmates when they have questions. She plans to pursue a degree in medicine after high school.

Aisha is a bright student from Libya in my Chemistry 30 class. She works hard to achieve high marks and often looks for ways to improve her grades in mathematics and science courses. Her affluent family fully supports her drive to achieve high grades and pushes her to do better.

Farheen had lived in Canada for seven months when I began my research. She emigrated from Pakistan with her mother and two older siblings. Farheen is very modest, devout, and traditional. She often talks about the many differences in the educational systems in Saskatchewan and Pakistan. She is intelligent and hard-working; Farheen is independent, and tells me that she does not receive a lot of support from her family.

Afsana is an Algerian student in my Chemistry 30 class. She is intelligent, highly motivated, and very confident. Her family does not own a television set; they want to focus on schoolwork and helping others above entertainment. She seems to want to understand concepts at a much deeper level than her classmates demonstrate. She has many friends, but her mother tells me that she often chooses to stay home to be productive rather than going out to be social.

Arfa is a female student from Syria in my Chemistry 30 class. Although her large family encourages her and provides her a lot of support, she does not study or do much homework. She identifies herself as an underachiever due to lack of effort. Arfa
maintains excellent relationships with her peers and teachers. Arfa’s father is involved in the school’s daily procedures.

My Physics 20 and Chemistry 30 students and I collaborated throughout the semester by observing and evaluating the effectiveness of culturally relevant and student inquiry activities. Although I used students’ daily exit slips to guide my teaching, I have not included students’ exit slip responses as part of the research data because they demonstrate more short-term results than my overall goals require. I used journal entries and written interview responses from students who agreed to participate in my research and categorized their comments based on the topic of discussion. I included class-wide data to assess students’ application of knowledge.

**Culturally Relevant Lessons**

During my self-study, I often struggled teaching culturally relevant lessons because I felt uncomfortable without the level of background knowledge I typically have while teaching science. I found that I spent more time planning and assessing culturally relevant lessons than I usually spend. I also found I was more tired after using culturally relevant lessons, perhaps because I felt more on edge and less comfortable. I have continued to use culturally relevant lessons in my science classes, and I still find that I am somewhat uncomfortable and that planning, assessing, and teaching the lessons are more tiring and time-consuming than traditional teaching.

I asked students to independently reflect on their experiences in my course during the semester. I asked them to consider assignments or activities that helped them to develop a deeper understanding of a scientific concept, made them more interested in
what we studied, or made them more interested in looking deeper into what we studied.

Four students talked specifically about culturally relevant lessons.

Afsana: We learned how the Islamic Golden Era contributed to what we learned in the classroom not only in chemistry class, but in math, biology and physics. We are always learning about how the American, Canadian and British contributed to science and we hardly know anything about the scientists in our own countries and the magnanimous contributions the Muslims made during the Islamic Golden Era.

Afsana’s remarks show me that the culturally relevant activity interested her.

However, I find that Afsana is a student who is easily interested and motivated in science content. After students researched Islamic scientists, Afsana made the comment that “I asked my mom and she said that she learned about Al-Kindi when she studied chemistry in high school. He was one of the first chemists. It would be equivalent to how we study Dimitri Mendeleev in Western science.” Her comment demonstrates that she was beginning to make connections between scientists from her culture and Western science early in the semester.

Arfa: Having to research about the Muslim scientists and what they discovered has made me interested in how all this science developed and who really began with the thinking. The research made it easy for us to work with. Not only that, but I learned step by step how it developed and who developed the ideas.

Arfa began her statement showing that the activity was my choice rather than hers; having to research shows she feels forced to do the work. However, her response after completing the activity seems to be more positive than her initial feelings.

Bisma: Assignments that made me more interested in what we were learning was when we studied Ibn Al- Haytham. This made me relate to the scientist and made me want to know more about his discoveries. Also, the pinhole camera was fun to make and I really enjoyed seeing how a scientist made such a large discovery in science and the fact that it was made with such an easy instrument was really exciting. The fact that we learned about Muslim scientists was really inspiring since we could relate to them and it made us work harder.
Bisma used the word interested, which is a simple repetition of the term I used in my interview with her. On the other hand, I think her use of words like relate, fun, enjoyed, and exciting, demonstrate the positive effects of culturally relevant lessons in science for her.

Mohammed: The assignment we did regarding the Islamic Golden Age really made me interested in science and how it connects to Islam and why specifically we have come to a point at present where the Islamic world produces such a low number of inventions and scientific discoveries. This is the most research I have ever done that relates to a topic connecting to a class.

I was cautious using the Islamic Golden Age information with my students because it is critical of how poor science production currently is from Muslim scientists. As a non-Muslim, I did not want students to feel as though I was attacking their culture and presenting my own as superior, as continued Orientalism (Said, 1978), so I attempted to present the topics as a celebration of Muslim scientists’ contributions rather than a criticism of a shortage of current work. As far as I can tell, my students were not offended, but I am still cautious when I discuss the Islamic Golden Age with my students.

Most of my students claimed to find cultural lessons interesting and motivating. Several mentioned that they felt better able to relate to scientific content when it was connected to their Islamic culture. Although none of my students stated that looking into the Islamic contributions to our current areas of scientific study increased their understanding of scientific content, their increased interest and inspiration made the activities worthwhile. Some of my students who have lived in Canada for a long time commented that this experience learning about Muslim contributions to science was their first. The experience was beneficial for them as their first opportunity to read about
scientists from their own countries of origin. Other students who have moved to Canada recently commented that they had many opportunities to learn about Muslim scientists while studying in their home countries and were glad to bring some of their experience into class.

Perhaps discussing Muslim scientists will assist students who are recent immigrants make links between their previous science courses and their current learning. One student discussed how proud she was to learn that someone from her religion and her home country had contributed so much to modern science; I was pleased that a student who does not have regular opportunities to experience proud moments in chemistry was able to experience pride. I am also satisfied that relevant instruction was more engaging for her.

During three-way conferences in November, one mother told me that she was excited to see her daughter doing research into scientists that she had studied in her high school science courses in the Middle East, because she was able to share some of her knowledge with her daughter. Her excitement came from the situation that she does not often have such opportunities. When planning my culturally relevant lessons, I did not anticipate that parents would be interested and excited about the effects. While I had not considered the effect culturally relevant lessons in my classroom would have on my students’ parents, I consider it to be one of the most substantial effects I noticed. I have learned that incorporating Muslim scientists into my teaching engages some parents, who are mostly first generation Canadians, as well as many students. I think that using culturally relevant lessons in my classroom showed some students that maintaining Islamic culture and learning science in a meaningful way are not mutually exclusive; the
practice of asking questions and finding innovative ways to answer them is not at odds with Islam and its practices.

I have talked to my colleagues about the lessons I was using to bring Islam into my science classroom. A teacher who has been at the school two years longer than I have commented that in her first two years at the school, the Board required teachers to bring Islam into their Saskatchewan curriculum at least twice each year. The practice was abandoned by the time I began teaching because teachers and the Board found that teachers who have a limited understanding incorporated Islam superficially. For example, teachers would do an Islamic art project, but would not bring any Islamic content into English, mathematics, or science courses. At our biweekly high school staff meetings, I encourage my colleagues to consider finding some meaningful connections, sharing the success I have experienced. With the help of our English Language Arts teacher who self-identifies as Muslim, we have been able to do so more regularly. We continue to discuss ways we have incorporated Islamic culture into our teaching at our staff meetings and we have experienced minor success with increasing student interest. I now decorate my science classroom using contributions of Muslim scientists as well as European contributions.

**Structured and Guided Inquiry Activities**

Before beginning this self-study, my attempts to use inquiry learning in my classroom were largely unsuccessful. When I began to use inquiry activities with my students on a more regular basis, many students’ questions grew more insightful and meaningful; several students began asking questions linking topics together while others asked questions to look deeper into content we had studied. During their written
interviews, four students wrote about their experiences with structured and guided inquiry activities.

Arfa: Having to do experiments and applying the knowledge to our real world made me more interested in how science is applied to our life. For example, the lab that we did to figure out the concentration of juice and how concentrated we like it made me think about the drinks that I drink and wonder about their concentration.

Arfa uses the words interested and wonder in her comments, which show me that using inquiry laboratory work increased motivation for her. Arfa’s increased motivation is very important, because she self-identifies as an unmotivated, underachieving student, particularly in mathematics and science courses. I struggled to motivate her during Chemistry 20 and Physics 20, but I found success when using inquiry activities with her in Chemistry 30. She began to think of concentration in relationship to her everyday practices, which demonstrates the beginning stage of knowledge construction. Arfa also refers to applying, signifying a higher level of thinking according to Bloom’s revised taxonomy.

Bisma: The light and optics presentations made me interested in looking deeper into what we were studying since they were all real life applications and I wanted to know more. The fiber optics presentation was one I didn’t understand until we did the lab on total internal reflection. However, I did go online and learn more about them since they are important in our lives in this modern era, and learned about the critical angle even before we learned about it in class.

Bisma talks about interests and real-life applications, demonstrating increased motivation. She told me that her inquiry led to independent learning rather than memorizing information; when I discussed her written interview responses with her, she remembered and talked about critical angles and total internal reflection in more detail than I would have expected, which indicates more meaningful understanding than rote memorization.
Mohammed: The water tank activity to study waves was really confusing and sometimes downright weird to do because it was really hard to observe what was going on and even harder to know whether it was supposed to happen or not. I like to study a topic and then see the visual evidence and see whether it conforms with what we have studied.

Mohammed’s comments that he prefers a more traditional style of laboratory work to inquiry work conformed to what I expected most of my students to say. Although he is naturally inquisitive, his common use of inquiry does not translate to laboratory work. He was very honest by stating that he would rather learn a concept from his teacher and then confirm it in the laboratory. Part of Mohammed’s preference may come from discomfort; my colleagues and I rarely use inquiry laboratory work, so students are accustomed to knowing exactly what to expect rather than using a procedure to develop conclusions. I plan to continue inquiry laboratory work with students and hope that they will be more comfortable with more experience. I will encourage my colleagues to do the same in other science courses as well.

Aisha: Although the assignments did not require a lot of detail, I still spent a lot of time learning new information for the sake of satisfying my curiosity. Generally speaking, the work we do together as a class really helps me develop a deeper understanding of a topic. The way you teach us a new unit and give us a chance to ask you questions regarding the topic is a great way to learn. I love chemistry and I find it quite interesting. Asking questions really helps me understand the concepts we are taught and the reason why we use them.

Aisha’s comments demonstrate that when she was encouraged to use inquiry in class, it made her curious, which I consider a type of motivation. She also refers to a deeper understanding, showing that she is aware that her understanding of ideas is sometimes shallow. Aisha is a strong, hard-working student and her comments are not demonstrative of all my students, but allowed me to see that my increased use of inquiry in my science classroom helped a strong, motivated student to be more successful.
I worked a lot with my students to develop activities they would find interesting and would therefore begin to ask deeper questions and look for more meaningful answers. I noticed in students’ written interviews and during daily activities that many of my students remembered the content they learned through inquiry more fully than content I delivered directly. Arfa, Bisma, and Aisha found that they were interested in the content and began using inquiry on their own. However, not all students enjoyed the inquiry activities; Mohammed commented that he much preferred more traditional teaching styles and has more confidence in the knowledge when his teachers use traditional teaching.

During the plane mirror investigation, one group of students made inaccurate measurements and another group made incorrect observations when using ripple tanks to investigate waves. The two groups of students therefore developed incorrect conclusions and tended to hang on to their incorrect conclusions. However, the errors provided us with an opportunity to discuss scientific error less superficially than I typically do.

Throughout the years I have been teaching, I have noticed my students often struggle with inquiry activities. My colleagues tell me they also struggle with effective inquiry in their classrooms. My students tell me they are far more comfortable performing tasks when I have provided step-by-step instructions. When I ask them for further explanation, students have expressed concerns that they will do things incorrectly and their grades will suffer. As the semester progressed, many of the eighteen students in my Physics 20 and Chemistry 30 courses seemed more comfortable and confident with inquiry activities after I reassured them that I did not formally assess inquiry activity
results. With greater confidence, the depth of their questions and ability to find meaningful answers improved.

In the second half of the semester, I noticed that Mohammed, Daniyal, and Bisma had more prior knowledge than I expected about some concepts. When I asked them where they had learned about critical angles or total internal reflection, they talked about previous activities or discussions from class and how they had further questions and completed research to satisfy their curiosity. They had considered what we discussed in class, asked questions, and found answers. I think that the three students remembering content they had read as part of their inquiry so well, demonstrates that inquiry had a positive result for promoting higher level thinking skills for Mohammed, Daniyal, and Bisma.

I have continued using guided inquiry in my classes. Some of my students often tell me that they prefer doing lab work after they have learned a concept, and I have learned to accept their preference rather than fight it. I use a combination of inquiry laboratory work and completing procedures to confirm what we have discussed in class. I continue to find that at the beginning of a unit of study, most students ask simple questions which often show me they have little interest in what we will be studying. I have experienced mixed success with inquiry after I have taught some content; some students ask deep questions and find interesting ways to answer them. However, many students continue to ask questions that I have already answered for them and demonstrate little motivation to look further into any concepts.
My colleagues and I discuss inquiry learning in our classrooms on a regular basis. I have shared my findings with other high school teachers and we are currently developing consistent expectations for students to share what they have learned. We have found that when we encourage students to use inquiry, some students will memorize a fifteen minutes speech using researched information without providing any analysis, critique or insight. Some students use their same memorization strategy though we are calling it inquiry; we are currently trying to find ways that will help students move beyond memorizing not just for exams, but also for other forms of evaluation.

**Structured Inquiry: Advance Organizers**

In their written interviews, I asked Chemistry 30 students if the advance organizers helped them to understand new concepts. I was interested to hear about my students’ experiences with advance organizers because I had never required my students to learn so independently. Three of my Chemistry 30 students made comments about my use of advance organizers.

Afsana: Information I gained from the organizers helped me understand what was being said, kind of like walking into a building after having a quick look at the directory as opposed to walking into a building with a blind-fold over your eyes.

Afsana’s comparison to a building directory shows me that she was able to gain more from my lessons after an initial investigation and encouragement to form questions. Afsana is very intelligent, so I can understand that having an advance organization of the unit would be beneficial for her.

Aisha: The advance organizers did help me to understand the overall concept before we studied things further in class. Doing them brought up a lot of questions that were later answered during class.
Aisha’s comment demonstrates that having adequate knowledge enabled her to ask questions more effectively. Her comment exemplifies my personal observations that some of my students were more prone to using inquiry when I used advance organizers with them.

Arfa: Something that did not really increase my interest was going through extra work about what we were learning. I like how the teacher taught us in class and I did not really enjoy trying to learn it on my own by going through extra reading. The organizer was basically to get me thinking about the new unit that we were going to learn, but it looked more confusing than the actual work. This could be because I am the type of person who does not like to read and look for information myself; I like to hear someone talk and tell me all the important things that have to be studied and learned.

Again, Arfa’s lack of understanding of knowledge construction is shown by her comments. She identifies, using her own language, that she prefers passive over active learning. Advance organizers failed to help her to connect active learning with meaningful understanding or to promote inquiry later as we discussed ideas together.

I used advance organizers to help my students construct some knowledge so that they could ask deeper questions. Generally, I observed that both the quality and the quantity of student questions during subsequent lessons improved. I think the practice helped to make my classroom environment more open to inquiry, and provided students with the necessary tools to form insightful questions, and moved students away from relying solely on their teacher for information. However, the practice was not universally effective, as demonstrated by Arfa’s comments.

Most of my students reacted negatively each time I used the first three advance organizers in Chemistry 30. As students became more accustomed to the practice, there were fewer negative reactions, and more student interest in the benefits of having greater
prior knowledge entering each unit of study. Some students who participated in my research return from university and tell me that they have continued the practice of reading about a topic in advance of a lecture to help them understand more of what their professors are teaching.

I have continued to use advance organizers in my science classes. Many students demonstrate the little value they place on the practice by asking if the information from the advance organizer will be on the test; they do not see any benefit to increasing their background knowledge in preparation of classroom discussions and have not found that the content from the advance organizers directly relates to our class discussions. I have learned that advance organizers help strong, curious students ask deeper questions throughout my teaching, but for many unmotivated students, using advance organizers is not an effective use of time because they read and answer the questions without thinking; they merely wait until I teach them more directly to begin memorizing content that seems important.

As I encourage student inquiry in my classroom, I have found that group dynamics play a large role in how often and how well students inquire. Group dynamics have a great effect in my school because groups of students remain relatively static from pre-Kindergarten through grade 12. I have found that students who have developed confidence in the classroom and respect from their peers are far more likely to inquire while other students are less willing to inquire, especially out loud. The cautious students are often unwilling to use an inquiry approach in my classroom so I continue to encourage all my students to approach science with questions they would like to answer.
Guided Inquiry: Analogies

During their written interview, I asked Chemistry 30 students about their experience with analogies. Developing analogies is a practice valued in science, so I consider it important that students began to approach science in a way that is part of the cultural norms of science because “to learn science is to acquire the culture of science” (Jegede & Aikenhead, 1999, p. 47). I think that a student who is able to develop a strong analogy demonstrates movement through Bloom’s revised taxonomy, from the second level of understanding a scientific concept to the highest level, creating a new model for explanation (Anderson and Krathwohl, 2001, p.67). Afsana specifically notes that learning is made easier by relating to prior knowledge; she is demonstrating her effective construction of knowledge.

Afsana: I have always found [analogies] helpful, and why wouldn’t they be, when you’re comparing something new to something you are already familiar with? I liked listening to other students’ analogies, though, since some were better than my own. I think analogy-making is a study technique that every student should use.

Arfa: By doing analogies, it helped me remember information my own way and not really always make it deal with science. Using analogies, I connected things to science so I can remember some concepts. It was easy to remember concepts that way.

Afsana and Arfa’s comments demonstrate that they found analogies effective for constructing knowledge. Without knowing the term or its implications, they have established that they are constructing knowledge because “new information is linked with existing concepts, and integrated into what the learner already understands” (Edmondson & Novak, 1993, p. 548). For Afsana and Arfa, my goal of using analogies to promote knowledge construction has been achieved.

Aisha: Analogies are an excellent way to remember a concept. I still remember analogies regarding chemistry from way back. Because analogies are something that one
can usually relate to, they are easy to recall. If the analogy is attached to a picture or some sort of visual, I find that very helpful.

Farheen: Analogies helped a lot because sometimes it was very hard to remember the effect of each factor on something but with analogies, I did not have to memorize and it became very easy to understand a new concept and I always remember analogies and I think that they will help me in future.

Aisha and Farheen noticed that when using analogies, they did not resort to memorization, which is very important. Although remembering information is not conclusive evidence that Farheen and Aisha have constructed a deep understanding, I think that recalling rather than memorizing and quickly forgetting, is an indication of a higher level of thinking.

I often provide analogies for my students but encouraging them to develop their own was a new strategy for me. I was surprised to learn that several stronger students seemed to form analogies independently; I did not anticipate that any of my students were using a scientific learning process such as modeling. Students’ chosen analogies also surprised me; some girls chose to use sports analogies such as boxing which I would not have considered. I asked Afsana why she chose to use a boxing analogy to help her understand Le Chatelier’s Principle. She explained that although she knew nothing about the sport, she had played Wii Sports with a friend one time and she immediately thought of her playing strategy as I explained how stresses placed on a system at equilibrium result in a predictable response. Afsana told me that when she hit her opponent, she would react immediately in a predictable way, just as a system regaining a state of equilibrium does. I would not describe boxing as relevant to my students’ Islamic culture, but it was relevant to Afsana because she had some experience with the activity.
With my students’ use of analogies, I noticed many found application questions on corresponding unit exams less challenging.

**Scientific Inquiry in Laboratory Work**

As a small high school, we do not have adequate safety equipment to store and use chemicals, so we are limited in the laboratory work we are able to do. The school has plans to expand over the next several years, so little money has been spent on the current building to enable more laboratory work. We currently do chemistry laboratory work using a combination of experiments with household chemicals and virtual experiments when possible. Students discussed their experiences with laboratory work during the semester in journal entries and written interviews.

Afsana: I found that when doing the extra research section of lab reports, I learned a lot of new information about the concept that we were studying. The information didn’t help me develop a deeper understanding of a scientific concept as such, but it made me more interested in what we were learning and in science as a whole.

Daniyal: The lab reports have made me think deeper into the subject and ask why some things happen the way they happen. This has been one of the largest contributors to my curiosity.

As I was encouraging my students to use inquiry in laboratory work, Afsana and Daniyal also found the inquiry component of the lab report motivating.

Arfa: Doing some labs helped me understand things in a faster and more exciting way. I am not really the type of person that likes to do work on paper and sit down and study, so having to do some labs was a good way for me to learn because it made us apply what we learned to many things. For the most part, our school provides excellent education and because of the small classes and the availability of our teachers, it makes learning easy. However, I do wish we had an equipped science lab where we would be able to actually see more of the things we learn. I am a visual learner and it would be very interesting and exciting if we got to do more hands-on experiments.

Aisha: There are many concepts that we learned in class that I still think about. A lot of the laws we learn, or the concepts we apply to certain chemical equations still stir
up some thinking. I would like to be able to see these concepts applied in a lab or something where I can understand the concept further.

Both Arfa and Aisha identify laboratory work as interesting and exciting; experiments serve as both a motivator and an aid for deeper understanding. They also note that doing laboratory work makes them curious and creates inquiry opportunities for them. However, as a small school, they recognize that we are unable to do a lot of laboratory work, and see that as a weakness in the program we offer.

Bisma: The refraction of light and total internal reflection lab was one of my favourite labs because I really understood how it applied to the boys’ fiber optics presentation earlier in the unit. It was really easy to do and it cleared up any questions I might have had.

Bisma found that laboratory work helped her to solidify her understanding of some concepts and used it as a way to answer some of the questions she had formed throughout the semester.

Most students I interviewed recognize that laboratory work helps them develop a better understanding of the theoretical concepts we study. Because my past experiences indicate that my students rarely remember or apply their laboratory work to theory, I have described my students’ use of laboratory work as ineffective. However, many students view it as meaningful to them, so I have continued to use laboratory work whenever I can, but I have shifted the focus of the analysis of the data to try to have students apply their work to other situations and their daily experiences.

Remarks about Specific Lessons or Activities

Some students referred to specific lessons or activities in their unit end journal entries. Some had a lot to say about how interesting it was to learn about Islamic contributions to modern science.
Afsana: Honestly, if we didn’t have this assignment, it’s very unlikely I would ever hear these names at all.

Arfa: It related to my culture and religion so it was interesting. It is something I can relate to.

Bisma: Now I know that Muslim scientists were able to balance their religion and science and make it work, which fascinates me.

Farheen: I will never forget some concepts because I have read again and again and [made] some connections to Muslim scientists. It makes me feel proud.

Ali: The fact that Muslims are usually the first people named when talking about the history of the major sciences like chemistry, physics, and biology… is thought-provoking.

Many students were interested in reading about and discussing Muslim scientists and relating their contributions to what we were studying. Students I interviewed found the research and discussions interesting, motivating, and thought-provoking. Late in the semester, I used a cartoon quiz as a simple fun activity with my students. The cartoon contained images of famous scientists with notable features about their discovery. For example, the cartoon of Isaac Newton showed an apple falling and the cartoon of Marie Curie showed her glowing. I asked students to look at the ten cartoon images and give the name of each scientist. I was surprised with the results of the activity; few students recognized Isaac Newton, Albert Einstein, or Marie Curie, each of whom we discuss in secondary science courses. However, nearly all students recognized Ibn Al-Haytham who we had discussed in Physics 20 and Chemistry 30. I did not plan the activity as a data collection tool for my research so I have no direct data to demonstrate the activity, but I observed a difference between my students’ ability to recognize major Western and Muslim scientists we had discussed. The activity demonstrated the effectiveness of engaging students through culturally relevant discussions. I have learned the importance for students to learn about scientists from their own culture, and I bring Muslim
scientists into my teaching whenever I find a relevant connection and encourage students to find relevant connections of their own.

Most of my Physics 20 students mentioned the guided inquiry and culturally relevant activity we completed using Ibn Al-Haytham’s pinhole camera in their journals.

Bisma: The most interesting day was learning about Ibn Al-Haytham since he’s a very important Muslim scientist and brought a lot to the field of physics. The thing that made it challenging was that I was confused about why the image was inverted and had to do further research.

Mohammed: The fact that someone living that long ago came up with this is thought-provoking. The fact that someone had such a thought process to come up with such a simple yet effective device is so interesting.

Ali: The background of Al-Haytham taught me his motives and ideas which helped make the learning easier.

Bisma, Mohammed, and Ali seemed to enjoy both the cultural relevance and the inquiry component of this activity. Bisma stated that she found the cultural relevance of the activity interesting and that the activity promoted curiosity. She completed additional research to answer her question, a good example of inquiry learning. Ali found learning easier because of connection through cultural relevance. Cultural relevance provided opportunities for some students to build connections and relate what we were learning to concrete prior knowledge, demonstrating the construction of knowledge.

After studying the science of crowds and its application to Hajj, some Chemistry 30 students remarked that the results of the experiments were interesting, but no students responded that the application to the annual Muslim trek to Hajj was interesting or thought-provoking to them. I was really surprised because my students will likely all make the trip within their lifetime, and some of their parents were attending Hajj at the time we did the activity. The lack of a positive response from my students shows me that
not all culturally relevant lessons are beneficial to every group of students and that a
teacher from a different culture may not be able to predict which lessons students will
find culturally relevant. I continue to use a similar lesson in my physics course, and some
groups of students find it interesting, while other groups do not.

Rather than giving my students an analogy to explain factors that will speed up or
slow down a chemical reaction, students developed their own factors affecting reaction
rates analogy and three of the Chemistry 30 students commented specifically about the
analogies they established.

Afsana: Because we are thinking of the analogies ourselves, they are actually helpful
instead of having to memorize an analogy like plum pudding that makes sense to
one person but not to another.

Arfa: Now we can remember these factors because we related to something we know
really well.

Aisha: It is a lot easier to understand the information and a lot easier to remember and
visualize.

The three students recognize that the use of analogies is helpful and will help
them to remember ideas rather than memorizing words and phrases before an exam.

Afsana and Arfa both seemed to find their own analogies more helpful than the analogies
I provide. They demonstrated evidence more consistent with meaningful learning rather
than rote learning; I observed signals that they learned a way to construct knowledge. I
encouraged students to share their analogies in class, and the practice helped me to
recognize misconceptions my students held.

I have discussed my use of analogies with the other high school teachers at my
school and have encouraged them to bring them into their classes where possible. My
colleagues have had mixed success; one social studies teacher asked students to explain
amounts of money spent by federal and provincial governments on social programs by making a comparison to something else that costs money. For example, they could calculate how many cups of coffee they could buy, or how many houses they could build with the same funds. She found that the comparison did not really help students because they were discussing an amount of money they did not really understand in terms of another amount they did not really understand, similar to the ineffectiveness of my dishwashing analogy. My colleagues’ dissatisfaction shows that not all ideas lend themselves well to analogies and not every group of students will find the practice helpful and has confirmed for me that our students must be given freedom to develop their own analogies so that they are more likely to make meaningful connections.

Physics 20 students had a few comments about the reflection in a plane mirror inquiry activity.

Bisma: The fact that we did the experiment and were able to observe the reflected rays off the mirror first-hand made learning easy.

As well as Bisma’s comment, Mohammed identified questions that arose during their procedure and he did some experimentation to find the answer. Daniyal identified new questions that he was interested in exploring. The students recognized that they asked further questions and completed extra experimentation or research to find answers. The interest in this activity promoted scientific inquiry in my classroom.

Three students made remarks about the solutions and solubility inquiry activity in their unit-end journal entries.

Afsana: It was interesting because we got to ask questions instead of just being handed them.
Arfa: I have a better understanding because I had to research and saw lots of results. Aisha: My question 4\(^2\) gave me an “ah ha” moment. Everything made more sense.

Many students seemed to appreciate using open inquiry at the end of a unit to further their study by developing their own questions and finding their own answers. I think of this as an open inquiry activity because my students investigated questions they developed themselves. I am now more comfortable with using open inquiry with my students in some situations and have experienced success. I continue to use open inquiry with some groups of students. For example, I am currently teaching a group of students who are less motivated by grades than any students I have taught. They seem to thrive with opportunities to complete open inquiry and require little motivation than other groups of students to make connections to their own experiences.

**How Islamic Culture Affects Learning Science**

In my semester-end interviews with students, I asked them specifically whether they think that their Islamic culture affects how they learn and understand science.

Afsana: I don’t think culture plays a role as much as religion does. Religion plays a huge role, I think, in the way we – or at least I – understand science… In fact, I did some research and found that there were certain verses in the Qur’an which parallel the ideas behind the Big Bang Theory. What I am trying to communicate is that as a Muslim, I think I appreciate science more than the average teenager would since it strengthens my conviction in my faith instead of being ‘just another class I have to take’ or ‘just some other thing I have to learn’.

Afsana demonstrated her ability to construct knowledge on her own again in her comments and that she has found ways to “harmonize with [her own] life-world culture”

\(^2\) Aisha’s question 4 was about how 1 mole of a compound can dissociate into more than one mole of product. For example, 1 mole of calcium phosphate dissociates into 5 moles of ions. Her inquiry led her to discover a helpful analogy – breaking an egg into 2 pieces of shell, 1 yolk, and 1 white (1 egg breaks into 4 parts).
(Jegede & Aikenhead, 1999, p. 3). She also reveals more about her motivation for learning science beyond achieving exceptional grades.

Bisma: Our culture influences how we learn and understand science since we have a lot of pressure to do well in this subject. The reason for this is that science is essential in every career and therefore to be successful in your field of work you need to understand how the world around you works. Therefore, parents in our culture are so adamant that we get good grades in science of all subjects, and this makes us pay attention and focus on what we are learning in class.

Mohammed: I think my culture encourages me to understand why certain things are the way they are and to learn more about the basic functions of things in life. I do believe culturally it is a lot of help especially the way [our culture] encourages us to be successful in life which can only be done through learning.

Farheen: Our cultural beliefs also affect learning science, scientists that belong to our culture help us more in understanding their theories, some cultures give more importance in studying science, some not, some think that it is against religion to learn science. Our culture gives importance to learning science, people who learn science or have understanding of science are appreciated in our culture and that encourages me also to learn and understand science and to do something in the field of science.

Daniyal: I think my culture affects how I learn and understand science because we are promoted to get good grades and work hard at academics. This kind of helps you keep on going when you don’t feel like doing something or you don’t really understand something.

Bisma, Mohammed, Farheen, and Daniyal recognize that their Islamic culture places great value on science and careers involving science. Due to cultural expectations and expectations from their parents and their school, students are motivated to earn high grades in science courses. However, while the four students cite great value placed on performance in science courses, they do not mention the importance of developing an understanding of scientific concepts or proficiency with scientific skills. I think that if they are able to perform well without really understanding, they are still considered to have achieved their goal and to have met the expectations placed on them by their culture, their parents, and their school.
The value many students and their parents place on science makes my school an ideal environment for a science teacher. Some students asked me how I fit my Christian religious beliefs with my scientific understanding. I often give the example of temperature inversion in lakes as a scientific principle that confirms my faith. Many of my students are motivated to find ways to merge their cultural and religious ways of knowing and science.

**Additional Comments**

Several students had additional comments to make about their experiences with my research, and some experiences they had while we contemplated and discussed how they learn science.

Afsana: What I enjoyed most was when I was able to make connections to the real world or in my own experiences, or to other subjects. For example, I remember learning in biology that the electron carrier NAD+ was ‘reduced’ into NADH and I couldn’t for the life of me figure out why it was ‘reduced’ if something was being added to it – that is, not until we did our Reduction & Oxidation unit. This was one among many other instances when the light bulb above my head flicked on and I thought, ‘So that’s why…’

Afsana’s comment confirmed again that she was making connections far more effectively than I had expected, even before I began my self-study.

Aisha: Studying for chemistry is very different in comparison to studying for biology. Chemistry isn’t an overwhelming subject and there isn’t a lot of memorizing to do either.

Farheen: For chemistry unit exams, I had to just study for fifteen minutes maximum and it is very different from preparation of unit exams for other sciences because I had to study three to four hours but for chemistry, it was very easy because of my teacher’s style of teaching… Because due to her analogies, practice questions, applications of concept, I did not face any trouble in understanding some difficult concepts.

Farheen: [Teachers are] helping students in understanding concepts by giving examples, applications of concept, articles, analogies and advance organizers. [This] is the
way I want to learn science. By showing videos, research, labs, analogies in a creative way [and] no memorization (cramming).

Aisha and Farheen recognize that if they have learned a concept well, and understand its applications, they spend less time memorizing. Both girls identify differences between chemistry and other areas of study where they consider memorization a more suitable studying strategy. They identify analogies, research, and experiments as aids to avoid memorization.

**Long-Term Memory With and Without the Use of Analogies**

**Table 1: Average Marks and Trends by Question Type**

During the first week of January, I gave my students six questions to complete from discussions we had in November. Two questions asked about factors affecting the rate of a chemical reaction, two asked about Le Chatelier’s Principle, and two were calculation-based. All questions could have been answered equally well using memory and thought process alone; students had analogies to help understand the first four questions, and the calculation questions used dimensional analysis, a process I use nearly every day with my students and to me, uses logic rather than memorization.

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Average Mark (out of 4)</th>
<th>Trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors Affecting the Rate of a Chemical Reaction</td>
<td>3.3</td>
<td>36 % of students explained their reasoning using an analogy</td>
</tr>
<tr>
<td>Le Chatelier’s Principle</td>
<td>3.5</td>
<td>45 % of students explained their reasoning using an analogy</td>
</tr>
<tr>
<td>Calculation-Based</td>
<td>0.9</td>
<td>Students did not have an analogy to access for these questions</td>
</tr>
</tbody>
</table>

When students had the opportunity to use an analogy to remember concepts, the average mark for the questions with an available analogy was higher than the average mark for
the question without. Roughly half of the students chose to use an analogy when explaining the thought process behind their responses.

**Table 2: Average Marks of Students Who Used and Did Not Use Analogies**

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Average Mark of Students who Used an Analogy (out of 4)</th>
<th>Average Mark of Students who Did not Use an Analogy (out of 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors Affecting the Rate of a Chemical Reaction</td>
<td>4.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Le Chatelier’s Principle</td>
<td>4.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

All students who chose to use an analogy answered these questions correctly, while the average mark where students chose not to use an analogy is approximately 75%.

**Table 3: Average Marks of Students Who Used an Analogy for One of Two Questions**

<table>
<thead>
<tr>
<th>Use of Analogy</th>
<th>Average Mark (out of 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question where students used an analogy</td>
<td>4.0</td>
</tr>
<tr>
<td>Question where students did not use an analogy</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Some students chose to use an analogy to answer one of the two questions but did not use an analogy to answer the other. Students scored higher on the question they used analogous reasoning than on the question they did not use analogous reasoning. Every student scored perfectly on the question they used analogous reasoning while their average score for the question answered without the use of an analogy was 50%.

Students who used analogies to reason through the questions scored better, on average, than students who chose not to use an analogy. Students really struggled with
simple calculation questions that they had not seen for several months but did well on application and reasoning questions. Although only a small group, the data is still indicative that the use of analogies, whether students developed their own or used one I provided, helps with long-term memory of concepts. My students all scored very well on similar calculation questions on their final exam, after they had prepared adequately.

My work with analogies during this research has changed the way I teach. I use analogies whenever I can, although I am cautious to avoid oversimplifying science by forcing analogies where I should not. I limit the number of analogies I deliver and provide opportunities for my students to use their own. When I discuss students’ analogies with them one-on-one, I learn a lot more about my students’ personal experiences and how they think. I have an opportunity to correct misconceptions and answer questions. Some students refuse to develop meaningful analogies, but the more I incorporate the practice into my teaching, the more students begin to use them.

Through my research, I began to realize that my students were more effectively constructing meaningful knowledge than I thought. Many strong students were making analogies and using inquiry at a level that surprised me, even before I began to encourage such practices. I have found that by completing research in my classroom, I have become better at assessing students’ understanding of science concepts by asking questions and observing their laboratory work rather than merely marking their assignments, lab reports, and exams. I am continuing to work to strengthen students’ ability to inquire and construct knowledge.
Chapter 5: Concluding Thoughts and Recommendations

I completed a self-study action research cycle guided by a constructivist learning model to learn how to better assist my students in moving from rote memorization of chemistry and physics concepts to more meaningful learning while maintaining their cultural practices. Relevant literature recommends good teaching practices, but I wanted to look more closely at two specific teaching strategies. My purpose was to learn how well instructional strategies change students’ level of thinking according to Bloom’s taxonomy. More specifically, I studied a.) Do my attempts at culturally relevant lessons enable students to apply and analyze knowledge? and b.) Do my attempts to use inquiry-based instruction begin to enable students to bridge the gap between their cultural norms and the cultural norms of science?

Many students found science lessons relevant to their Islamic culture motivating and interesting. Bisma stated that “the fact that we learned about Muslim scientists was really inspiring since we could relate to them and it made us work harder.” Students found lessons linking Muslim scientists’ contributions to specific science content we discussed in class encouraged them to ask more questions. Aisha found she “spent a lot of time learning new information for the sake of satisfying my curiosity.” Arfa said that learning about Muslim scientists “related to my culture and religion so it was interesting. It is something I can relate to,” which demonstrates how important culturally relevant teaching is. Farheen agreed by saying “I will never forget some concepts because I have read again and again and [made] some connections to Muslim scientists. It makes me feel proud.” One important advantage I experienced by teaching students about Muslim scientists was that students remembered the ideas because they were interested and
motivated by cultural relevance. I had not anticipated the second advantage I experienced by incorporating Muslim scientists into my lessons; my students’ parents got more involved in their child’s learning in ways that they had not previously been able to. I recommend teachers who have non-Western students in their secondary science classrooms have students discuss non-Western contributors to science and how the contributions link to specific content in the curriculum.

While my students have typically struggled with inquiry-based learning, they began to ask more meaningful questions and design more effective methods to explore their questions as the semester progressed. When I began a unit with an advance organizer, students’ questions were much deeper and more meaningful. Aisha noticed “the advance organizers did help me to understand the overall concept before we studied things further in class. Doing them brought up a lot of questions that were later answered during class.” Many students resisted my use of the organizers, but the background information helped to create a more effective environment for inquiry for many students in my classroom.

I learned that my students have not yet developed an understanding of the constructivist nature of learning. I plan to spend more time with my students developing their understanding of knowledge construction. I have worked with students in the past on metacognition, encouraging them to think about how they think, but I have not discussed knowledge construction with them. I think that having a working understanding of how to effectively build knowledge will encourage students to use prior knowledge to build meaningful knowledge rather than rely on rote memorization.
I have found that my students do not learn content in a meaningful way through experimentation when I provide them with a defined procedure; they merely continue to follow steps, memorize, and forget soon after the procedure. During my research, I changed the laboratory work I typically do with students to require more student inquiry and found that some students learned content in a more meaningful way than memorizing. Several students were also motivated to look deeper into the ideas we had discussed in class. My students recognize the importance of laboratory work, and identify a small school’s inability to provide more laboratory experimentation as a weakness. I recommend secondary science teachers use scientific inquiry in their experimental work with students; students are motivated to think through content rather than mindlessly following a set procedure. I think that increasing the student inquiry component of experimentation will help students when it is appropriate to do so. I experienced a number of challenges with more inquiry-based experimentation; some students did not enjoy the work and felt lost without a descriptive procedure designed for them. Some students misinterpreted their observations and held onto misconceptions throughout the unit. Although students may have misconceptions after an inquiry laboratory procedure, more learning opportunities may be created as a result. For example, we were able to have more meaningful discussions about scientific error. Arfa says “our school provides excellent education and because of the small classes and the availability of our teachers, it makes learning easy. However, I do wish we had an equipped science lab where we would be able to actually see more of the things we learn.” Aisha recognizes the importance of learning in a practical setting by stating “I would like to be able to see these concepts applied in a lab or something where I can
understand the concept further.” In order to continue to use effective inquiry laboratory techniques, our school needs a laboratory facility.

Through my research, I found that strong science students, such as Afsana, were already making their own connections; weaker students will begin to use analogies with encouragement and assistance from their science teachers. I did not realize before reading my students’ exit slips and journal entries that the top two students in each of my classes made connections on their own, even without my guidance. I read very interesting connections and comparisons they made and how they related the lesson to prior learning; my four strongest students constructed meaningful knowledge much more effectively than I had expected. In my interviews with students, I heard that some students prefer developing their own analogies while other students prefer using mine. Discussing students’ analogies with them gave me an opportunity to find what misconceptions and challenges they had. For example, when students shared their factors affecting reaction rates analogies with me, some students shared that they did not understand how temperature affects collision frequency. We were able to meaningfully discuss the concepts of temperature and thermal energy to a deeper level than I would have thought necessary in Chemistry 30. I recommend that secondary science teachers use a combination of providing students with models or analogies and having them develop their own when appropriate. Students may be able to use their own cultural experiences to develop a model in terms of an idea they understand well.

Completing an action research cycle in my classroom enabled me to create a much more open environment for me to discuss my goals for my own teaching and my students’ learning. Although I have often discussed problem solving with my students,
through research in my classroom, I was able to share my purpose with students more regularly. Throughout the semester, students often asked at the beginning of a lesson if the lesson was being used as part of my research or if I was teaching the way I traditionally would. My students wanted to know more about why I had chosen to teach and present information in a given way. Because I became more open about my goals and purpose, students were better able to understand the expectations I had for them during and at the conclusion of a lesson or unit of study. My students excelled with better knowledge of my expectations; they began to assess their own understanding in terms of what I wanted to achieve. For the first time, my students asked questions about further applications of concepts and how calculations we were completing could be used in laboratories and industry.

Jegede and Aikenhead (1999) identify the importance of science teachers’ consideration of culture. It is important because “different cultural processes are involved in the acquisition of science culture. When the culture of science generally harmonizes with a pupil’s life-world culture, science instruction will tend to support the pupils’ view of the world” (p. 3). There are gaps between students’ cultures and the culture of science as teachers present it, and teachers must use effective teaching strategies to work to bridge the gap.

I faced a difficult challenge through my experience implementing self-study action research in my classroom. While I am comfortable teaching science concepts, I found that I was often nervous about discussing what I do not know. I did not attempt to teach my students about their Islamic culture, but questions about Islam often came up that I had not anticipated and could not answer. I relied on my students to answer such
questions when they were able. I found some of my culturally relevant lessons unsuccessful because I did not have the knowledge to help my students make some of the connections they wanted to. I encouraged my students to use resources in their Muslim community. I suppose the opportunities that were created were ideal – students could not simply look to me to answer their questions but had to look elsewhere. However, I found it difficult not knowing the answer to questions they posed in my classroom. I still struggle with not knowing, and I am trying to accept that a student answering questions using her own resources is a more effective method for knowledge construction than I have ever used.

After going through a self-study process, there are a number of things I would do differently if I were to begin again. There were several critical incidents including three-way conferences and the scientist cartoons that I had not anticipated, so I did not collect direct quotes or specific data to support my anecdotal remarks about the incidents. I think that my data would be strengthened with specific evidence from the critical incidents.

My data would also be strengthened with better interviews with my students. Starting this process again, I would plan verbal interviews with my students multiple times throughout the semester. I think I would get stronger comments if I were to ask about recent lessons and activities rather than asking about activities we completed four months before the interview. I think using written interviews weakened my results; I thought that it was the best solution for the challenges my students and I were facing, but the comments my students wrote were not as strong as the verbal comments they made in my follow-up interviews with them.
The literature review and data collected in preparation of this thesis provide two effective teaching strategies for helping students to bridge the gap between the cultural norms of science and their own cultural norms. Linking culturally relevant lessons to specific curriculum content interested and motivated my students. Teaching using student inquiry supported my students in constructing knowledge in terms of their prior understanding; with the support to construct knowledge in a meaningful way; my students no longer relied solely on rote memorization. I teach in a unique situation; my students all share common cultural norms. While most Saskatchewan secondary science classrooms are multicultural, my findings can be transferred to other situations. Teaching using student inquiry and creating opportunities for students to link their own culture to specific science content they are learning may be used to help students construct knowledge without resorting to clever school games. The use of inquiry-based instruction and culturally relevant lessons linked to specific science content motivates students and enables them to bridge the gap between their cultural norms and the norms of science.
References


doi: 10.1525/aeq.1985.16.2.04x0631g


doi: 10.1002/tea.20141


OECD, PISA 2012 Database, Tables V.2.1, V.2.2, V.2.6, V.3.1, V.3.6 and V.4.7.


Appendix A: Research Ethics Board Letter of Approval

University of Regina

OFFICE FOR RESEARCH, INNOVATION AND PARTNERSHIP
MEMORANDUM

DATE: October 11, 2012
TO: Pamela Anne Spock

FROM: Dr. Larena Hoeber
Chair, Research Ethics Board

Re: Bridging the Gap between Students’ Cultures and the Culture of Science: The Effectiveness of Inquiry Activities and Culturally Relevant Lessons to Promote Interest and Understanding (File # 15S1213)

Please be advised that the University of Regina Research Ethics Board has reviewed your proposal and found it to be:

☐ 1. APPROVED AS SUBMITTED. Only applicants with this designation have ethical approval to proceed with their research as described in their applications. For research lasting more than one year (Section 1F), ETHICAL APPROVAL MUST BE RENEWED BY SUBMITTING A BRIEF STATUS REPORT EVERY TWELVE MONTHS. Approval will be revoked unless a satisfactory status report is received. Any substantive changes in methodology or instrumentation must also be approved prior to their implementation.

☐ 2. ACCEPTABLE SUBJECT TO MINOR CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB.* Do not submit a new application. Once changes are deemed acceptable, ethical approval will be granted.

☐ 3. ACCEPTABLE SUBJECT TO CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB.* Do not submit a new application. Once changes are deemed acceptable, ethical approval will be granted.

☐ 4. UNACCEPTABLE AS SUBMITTED. The proposal requires substantial additions or redesign. Please contact the Chair of the REB for advice on how the project proposal might be revised.

Dr. Larena Hoeber

cc: Dr. Warren Wessel - Education

*supplementary memo should be forwarded to the Chair of the Research Ethics Board at the Office for Research, Innovation and Partnership (Research and Innovation Centre, Room 109) or by e-mail to research.ethics@uregina.ca.

Phone: (306) 585-4775
Appendix B: Research Ethics Board Memo to Approve Changes

OFFICE FOR RESEARCH, INNOVATION AND PARTNERSHIP
MEMORANDUM

DATE: January 31, 2013

TO: Pamela Ann Spock

FROM: Dr. Larena Hoeber,
Chair, Research Ethics Board

Re: Bridging the Gap between Students' Cultures and the Culture of Science: The Effectiveness of Inquiry Activities and Culturally Relevant Lessons to Promote Interest and Understanding
File # 1551213

This memo confirms approval of the changes outlined in your e-mail memo dated January 29, 2013.

Please contact us if you have any further questions.

Sincerely,

[Signature]
Dr. Larena Hoeber,
Chair, Research Ethics Board

cc: Dr. Warren Wessel – Faculty of Education
Appendix C: Letter of Consent

Participant Consent Form

**Project Title:** Bridging the Gap between Students’ Cultures and the Culture of Science: The Effectiveness of Inquiry Activities and Culturally Relevant Lessons to Promote Interest and Understanding

**Researcher(s):** Pamela Spock, Master of Education Student, University of Regina
Contact: (Phone) [redacted] or (Email) [redacted]

**Supervisor:** Dr. Warren Wessel, Associate Professor, University of Regina
Contact: (Phone) [redacted] or (Email) [redacted]

**Purpose(s) and Objective(s) of the Research:**

- Through first-hand teaching experiences and a review of relevant literature, I have found that students from non-western cultures may struggle with science because secondary schools teach science primarily with western culture. I would like to research some effective ways to assist students bridge the gap between their culture and the culture of science as it is taught. I would like to study two different strategies; I want to research and evaluate the effectiveness of culturally relevant science lessons and teaching science through inquiry.

**Procedures:**

- I taught physics 20 and chemistry 30 using traditional, inquiry, and culturally relevant lessons during the semester. All were asked to discuss the effectiveness of each type of lesson to their interest and understanding of scientific concepts. As part of my assessment of all students at the end of the semester, I interviewed students and had them show me how effectively they were able to apply the information I taught.
- I will interview past students and parents to learn about their experiences with learning science and non-western culture.
- I will record the interviews with a digital audio recorder.
  - I will interview past students and parents at a location and time of their convenience.
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.
Potential Risks:
- There are no known or anticipated risks to you by participating in this research.

Potential Benefits:
- This research will enable me and other secondary science teachers to have a better understanding for effectively teaching science to non-western students.

Confidentiality:
- The data from this research project will be published in a thesis; however, your identity will be kept confidential. Although I will report direct quotations from your interview, you will be given a pseudonym, and all identifying information will be removed from my report.
- Because the participants for this research project have been selected from a small group of people, all of whom are known to each other, it is possible that you may be identifiable to other people on the basis of what you have said.
- After your interview, and prior to the data being included in the final thesis, you will be given the opportunity to review the transcript of your interview, and to add, alter, or delete information from the transcripts as you see fit.
- Participation in the study is voluntary.
- Participants are free to withdraw from the research project, and this withdrawal will not affect the participants’ access to, or continuation of, services provided by Regina Huda School (see further information below).
- When a participant withdraws, his/her data will be deleted from the research project and destroyed, if desired.

Storage of Data:
- Pamela Spock will keep all data (including hard copy documents and audio tapes of interviews) in a locked filing cabinet with her thesis supervisor for five years.
- When the data is no longer required, the documents will be shredded and audio tapes will be deleted.

Right to Withdraw:
- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Your right to withdraw data from the study will apply until February 15, 2013. After this it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.
- Should you withdraw, you may ask Pamela Spock to return this consent form to you.

Follow up:
- Mrs. Spock will discuss results with students in physics 20 and chemistry 30 and other participants once the research is complete.
- To obtain results from the study, please email Pamela.Spock@rbe.sk.ca.
Questions or Concerns:
• Contact the researcher(s) using the information at the top of page 1;
• This project has been approved on ethical grounds by the U of R Research Ethics Board on October 11, 2012. Any questions regarding your rights as a participant may be addressed to the committee at (585-4775 or research.ethics@uregina.ca). Out of town participants may call collect.

Consent

SIGNED CONSENT
Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

______________________________      _______________________
Name of Participant                  Participant’s Signature                  Date

______________________________  _______________________
Researcher’s Signature              Date

A copy of this consent will be left with you, and a copy will be kept by the researcher.
Appendix D: Sample Student Exit Slip

Student: _________________________  Date: _________________________

Give a summary of what you learned today in your own words.

What did you find most interesting or thought-provoking today? Why?

What made learning challenging or easy today? Why?

How can you apply what you learned today to your daily life?

How will you remember the important concepts from today?
Appendix E: Sample Journal Entry Questionnaire

1. What was your favorite activity or lesson we did in this unit? Why did you enjoy it more than others?

2. What was your least favorite activity or lesson we did in this unit? Why did you enjoy it less than others?

3. How did you prepare for your unit exam? In what ways is this similar to or different from ways you typically study for science exams?

4. Think back to lessons from this unit. Are there any ideas you used continuously throughout the unit after you had initially learned them?

5. Is there something we did in this unit that helped you to understand something better than you did in chemistry 20?
Appendix F: Questions to Check Students’ Use of Analogies

Answer each of the following questions. Fully explain the thought process behind your response.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer and Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Explain what happens to the rate of a chemical reaction when temperature is increased.</td>
<td></td>
</tr>
<tr>
<td>2. Explain what happens to the rate of a chemical reaction when surface area of reactants is decreased.</td>
<td></td>
</tr>
<tr>
<td>3. The following equation shows the industrial production of nitric acid. 4NH₃(g) + 5O₂(g) ⇌ 4NO(g) + 6H₂O(g) + energy</td>
<td></td>
</tr>
<tr>
<td>a.) Predict the direction of equilibrium shift if the temperature is increased.</td>
<td></td>
</tr>
<tr>
<td>b.) In the above reaction, predict the direction of equilibrium shift when the volume of the reaction vessel is decreased.</td>
<td></td>
</tr>
<tr>
<td>4. Calculate the molarity of a 28 ppm sample of water containing NaF.</td>
<td></td>
</tr>
<tr>
<td>5. Calculate the heat of combustion of acetylene, C₂H₂.</td>
<td></td>
</tr>
</tbody>
</table>

Reaction Rates /4
Le Chatelier’s Principle /4
Calculations /4
Appendix G: Physics 20 Written Interview Questions

1. What assignment(s) or activity(ies) have we done this semester that have helped you to develop a deeper understanding of a scientific concept?

2. What assignment(s) or activity(ies) have we done this semester that have made you more interested in what we are studying?

3. What assignment(s) or activity(ies) have we done this semester that have made you more interested in looking deeper into what we are studying?

4. Do any assignments stick out in your mind that were not helpful to your understanding of science?

5. Do any assignments stick out in your mind that really did not increase your interest in science?

6. How did prepare for your unit exams? In what ways is this similar to or different from ways you typically study for science exams?

7. Think back to lessons from this course. Are there any ideas you used continuously throughout the semester after you had initially learned them?

8. How do you think your culture affects the way you learn and understand science?

9. How is science taught differently at Regina Huda School than in other schools you have attended?

10. How do you think attending Regina Huda School helps or hinders the way you learn science?
Appendix H: Chemistry 30 Written Interview Questions

1. What assignment(s) or activity(ies) have we done this semester that have helped you to develop a deeper understanding of a scientific concept?

2. What assignment(s) or activity(ies) have we done this semester that have made you more interested in what we are studying?

3. What assignment(s) or activity(ies) have we done this semester that have made you more interested in looking deeper into what we are studying?

4. Do any assignments stick out in your mind that were not helpful to your understanding of science?

5. Do any assignments stick out in your mind that really did not increase your interest in science?

6. How did the advance organizers help you understand new concepts this semester?

7. How did developing analogies help you understand new concepts this semester?

8. How did prepare for your unit exams? In what ways is this similar to or different from ways you typically study for science exams?

9. Think back to lessons from this semester. Are there any ideas you used continuously throughout the course after you had initially learned them?

10. How do you think your culture affects the way you learn and understand science?

11. How is science taught differently at Regina Huda School than in other schools you have attended?

12. How do you think attending Regina Huda School helps or hinders the way you learn science?
Appendix I: Private School Board President Approval

August 29, 2012

To Whom It May Concern;

I support Pamela Spock’s Master of Education research project at Regina Huda School. I have given her permission to use inquiry methods and culturally relevant lessons combined with more traditional teaching practices to study how effective each teaching style is to help students bridge the gap between their own personal cultures and the culture of science.

Her research will take place during the first semester of the 2012-2013 school year.

Thank you,

Dr. Ayman Aboguddah
President, Regina Huda School Board