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Building Connections Through Contextualized Learning in an Undergraduate Course on Scientific and Mathematical Literacy

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Building Connections Through Contextualized Learning in an Undergraduate Course on Scientific and Mathematical Literacy

Abstract
With increasing demands for universities to create graduates that are numerically and scientifically literate, it is important to determine effective ways to engage students so that they can acquire these literacies. Using an undergraduate, interdisciplinary course that focused on scientific and mathematical literacy, I examined how contextualization influenced students' abilities to build connections between their learning and their lives. In their written reflections, students connected course concepts with their social lives, academic pursuits and global or societal issues without specific prompting. I suggest that contextualization combined with reflection allows students to illustrate their understanding and apply this knowledge to novel scenarios.

Keywords
contextualize, relevance, real world, learning, connections, math and science literacy

Cover Page Footnote
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Introduction

As more universities are reviewing their learning outcomes and curricula, there is worldwide attention on ensuring that university graduates are scientifically and mathematically literate. The interest in enhancing these competencies is not an attempt to increase enrollment in particular science, technology, engineering and mathematics (STEM) disciplines but rather a recognition of the need for students to be able to interpret, evaluate and draw evidence-based conclusions from scientific and numerical information, and to apply this knowledge to make importance decisions affecting society. In fact, the American Association of Universities and Colleges (AAC&U) has stated that university graduates in *all* fields of study should be able to: "use scientific reasoning to gather and evaluate evidence; understand how scientific and social science studies are designed and executed and recognize the implications of design choices; use statistical reasoning to evaluate data and use data to communicate effectively; and base decisions on analysis of evidence, logic, and ethics" (AAC&U, 2013a).

Over the past few decades, different pedagogies and methodologies have been proposed to help students create connections with their world and promote higher-order thinking: skills necessary to gain these literacies. Many of these approaches stem from constructivist theory where learning is based on experience and individuals construct their own knowledge through these experiences; this work has been developed over the years by a number of prominent scholars including John Dewey, Lev Vygotsky, Jean Piaget, Paulo Freire, David Kolb, among others. Active learning is one such methodology where students are actively engaged in their learning usually through readings, discussions, and writing. When students are actively engaged in their learning, they show increased engagement (Fechner, 2009; Hulleman & Harackiewicz, 2009) and improved performance (Hake, 1998; Deslaurier, Schelew & Wieman, 2011). There is generally broad support for using active learning techniques in science classrooms (reviewed in Prince, 2004); however, many have been advocating for a variation on active learning: authentic learning. Authentic learning can include various methodologies such as experiential learning, problem-based learning, case studies, inquiry-based learning, or undergraduate research (Lombardi, 2007), but the main aspect is that science is seen as an activity to be performed by students. This involves a shift in thinking where the student is no longer just absorbing information; rather they are engaged in the material and are constructing their own knowledge. Authentic learning is based on three main criteria: students are constructing their own knowledge, they have a deep understanding of the problem or issue from a disciplinary perspective, and there is immediate value to the learning beyond an academic setting (Newmann, Marks, & Gamoran, 1996). These three criteria form the gold standard of authentic learning, even though not all three may be happening in each situation.

These new pedagogical approaches can be difficult to implement. Many faculty are not experts in learning strategies, and many have not immersed themselves in the extensive literature on teaching and learning; faculty are experts in their disciplines, and many teach using traditional methods that reflect how they were taught. Implementation of authentic learning techniques also requires additional preparation that, in many cases, exceeds what would be needed for a traditional lecture, and the time needed to effectively introduce new learning strategies also comes at a cost of reduced coverage of specific content. However, alternatives like contextualization may provide similar learning gains.

The aim of this study is to investigate the role of contextualization and its influence on student learning. Contextualization is the practice of connecting academic skills (usually reading, writing and mathematics) to specific content that is meaningful and useful to students. Mazzeo, Rab and Alssid define it as "a diverse family of instructional strategies designed to more seamlessly link the learning of foundational skills and academic or occupational content by focusing teaching and learning squarely on concrete applications in a specific context that is of interest to the student" (2003, p. 3). It is important to note that "meaningful" is used in the context of students' past experiences, future careers or interests. Although students might consider something meaningful if it impacts grades, the theory of contextualization focuses on connections to personal and professional growth, not on assessment.

Perin (2011) reviewed terms that are commonly used to represent contextualization including: integrative curriculum, embedded instruction, work-based learning, among others. There are some minor differences among these terms but in essence, they represent similar pedagogies. For example, while contextualized instruction aims to teach academic skills for the purpose of meaningful application, integrated instruction focuses on disciplinary content, and skills are obtained in the process (Pearson, 2010). Regardless of the specific term, providing content that is relevant and meaningful to students combined with skill development seems to be important for student learning. Krajcik and Sutherland (2010) suggest five strategies to support students in developing science literacy: "(i) linking new ideas to prior knowledge and experiences, (ii) anchoring learning in questions that are meaningful in the lives of students, (iii) connecting multiple representations, (iv) providing opportunities for students to use science ideas, and (v) supporting students' engagement with the discourses of science." Each of these five strategies is embedded in the philosophy of contextualization.

Similar to Krajcik and Sutherland (2010), many have been advocating the use of relevant examples and assessments to improve student learning (Bradstreet, 1996; Bybee, 2000; Meyers, 1997). DeLott Baker, Hope, and Karandjeff suggest the use of relevant context as it "helps students recognize the purpose and value of basic skills development to their academic or career advancement – enhancing the learning process and facilitating students' mastery of material" (2009, p.3). Students themselves also report a significant preference for problems that are either relatable or intriguing (Premadasa & Bhatia, 2013). Although Premadasa and Bhatia (2013) did not link this preference to student learning, others suggest that motivation and engagement with material is an important aspect to student learning. For example, one experimental study found that activities that encouraged students to connect course materials with their lives (called a relevance intervention) increased students' interest and overall course grades for those that had low expectations of success (Hulleman & Harackiewicz, 2009). Students that already had high expectations of success did not show a similar influence of the relevance intervention. Hulleman and Harackiewicz (2009) suggest that learning that is situated in a relevant context improves performance, likely through increased motivation to engage with the materials. Similarly, Fechner (2009) investigated the effects of context-oriented learning on student interest, achievement and retention. Using a likert-scale questionnaire to assess student interest and a multiple-choice format to assess achievement, Fechner found that contextualization increased both student interest and achievement in chemistry; however, there was no effect on retention.

Although use of contextualized learning seems theoretically and pedagogically sound, evidence for its impact on student learning has been mixed. Beswick (2011) recently reviewed the literature to determine whether evidence suggests that contextualized problems enhance student engagement, participation and achievement when specifically learning about mathematics. Beswick (2011) concluded that there is very little evidence to support any specific influence of contextualized problems; however, "participation and engagement with mathematics are not unrelated to achievement but are likely to be most strongly influenced by affective factors and the development of and appreciation for mathematics". Beswick (2011) concludes with a call for more research on the effectiveness of contextualized problems to better understand the different factors influencing student learning.

Through this study, my goal is to further our understanding of the role of contextualized learning in an interdisciplinary university course for undergraduates through reflective writing. This study provides an opportunity to use these student reflections as a mechanism to assess their learning using qualitative analysis. I am not asking students about how contextualization impacts their own learning (self-assessment) but rather am using their own words to determine how contextualization influences their learning.

Methods

I conducted this study at Mount Royal University, a medium-sized Canadian public university. All undergraduate students are required to take a general education course that focuses on numeracy and scientific literacy. This study investigates student learning in one section of *Scientific and Mathematical Literacy for the Modern World*. As this is a course required by all degree programs, the composition of the class (n = 30 students) was diverse with respect to academic level (freshman, sophomore, etc.) of the students and their disciplinary majors. Thus students were starting this class with very different backgrounds and efficacies around learning math and science; some students were science majors while others were history, English or business majors, for example.

When instructing students, I approached each topic using contextualization. I used relevant, real-world examples to illustrate the approaches from different scientific disciplines along with required mathematical skills and thinking. For example, I used the Fukishima nuclear disaster to teach the physics of how nuclear power works, the geology responsible for the tsunami, the biological effects of radiation on humans along with the mathematical principles for the exponential decay of radioactive material and unit conversions among different types of energy. Although similar to teaching with case studies, not all topics were structured in a case study format that included associated questions or learning tasks; some topic were taught through a video and class discussion, a scenario where students were play out different options, or even a reading from a newspaper article to situate the upcoming content. The pedagogical intervention was based on contextualization – using real-world examples that were meaningful to students.

Students were provided with class time to reflect on their learning with a 250-word response to an instructor-generated prompt. Reflections were completed approximately every two weeks so that each student had seven reflections over the semester-long course. These reflections were part of the coursework for the class and students were awarded up to 10% of their course grade for completing all the reflections;

reflections were not graded on content but rather were assessed solely on their completion. The exact wording of the prompts varied throughout the semester, but in each case the students were asked to generally reflect on their learning. Prompts did not specifically ask students to connect course content to any other aspect of their lives but rather they were generic prompts to get students to reflect broadly on the course content. For example, the first prompt (given after the first week of classes) asked students to consider how their thinking about the importance and value of numeracy and scientific literacy may have changed. In their second journal prompt, I asked students "How has this course/class material helped inform your ideas about numeracy?" and in the fourth prompt (midway through the course), I asked students to reflect broadly by asking them to "Reflect on the numeracy portion of the course. Was there a particular aspect of the course (activity, discussion, exercise, etc.) that influenced your views, feelings or opinions about numeracy?" Similarly, the sixth prompt asked students to reflect on the scientific portion of the course, while the final prompt asked students to reflect back on the entire course.

Students were informed this research project in the first class of the semester, and they had the option to consent to participate. A colleague administered this consent form; I was not aware of who agreed to participate in the study until the course was completed and all grades were submitted. The protocols, forms and procedures of this study were reviewed and approved by the Mount Royal University Human Research Ethics Board.

Results

Over the semester, I collected 142 journal entries from 21 individuals who agreed to participate in the study (70% participation rate). After reading through their journal entries, I outlined categories and relationships among their reflections. Using categorizing strategies (Maxwell, 2012), I identified patterns in the data through coding and thematic analysis. One very obvious pattern that emerged in their journals was that students were generating connections between the content knowledge from the course with aspects of their everyday lives. In their reflections, students would relate information from a specific class topic, problem, or example to their everyday lives. Students were building these connections spontaneously, as the journal prompts were generic and were not asking students to relate this material to the greater world. Students were consistently bringing in examples that were not discussed in class as a tool to illustrate their learning. I would expect for students to use examples that we discussed in class within their journals but students also applied the concepts to novel scenarios that related to other aspects of their lives. After seeing this pattern, I categorized these connections into three main groups: students integrated the concepts from the course within a social context (friends, family, employment), integration with other academic pursuits, and finally integration with larger global or societal issues. Every student integrated content from their lives into their discussion about their learning. Excluding any discussion of specific examples from the course, 15 of 21 students connected material within a social context at least once in their journal and of these students most integrated course material with their social lives repeatedly in their reflections. Thirteen students wrote about the course material as it related to other academic coursework, 19 students brought global or societal issues into their reflections, and 10 students connected all three within their reflections. Thus, students were building connections and constructing new meaning by applying the concepts to situations outside the classroom.

Social Context

This course used real world, relevant examples to explain the content, and in their journals, students regularly connected their learning with aspects of their social lives. Students discussed everything from tuition, car payments, and mortgages to health to employment. One student actually used her journal to weigh the pros and cons of accepting a new part-time job. This student calculated the difference in salaries, the cost of additional gasoline (the new job was farther out of town) and time lost due to increased travel time. Other students connected course content with very personal family issues in their journals. When asked to reflect on percentages, one student wrote about her high risk for type I diabetes and reflected

> If I consider the significance percentages have imposed on me without realizing it, I can only imagine what other math lessons I have obtained that cause the same reaction. Percentages are used in my everyday life, whether I realize it or not and therefore it is important that I learn how to use them and understand how they work (Student E).

The comments from this student were not an isolated phenomenon. Most students were regularly making connections with some aspect of their social network or personal issues. Although these connections may just indicate an egocentricity of students, there were many instances where students' reflections would challenge this idea: "We are living in a universe where everyone can be in danger due to different kinds of diseases. After learning this, I know that I should do more to protect the environment and specifically water resources. I shouldn't be as naïve as I am in taking every day for granted and the services which provide my basic needs" (Student L). This student comments specifically on how she, personally, is responsible for implementing change. Not only does this illustrate her understanding of the content but also indicates an understanding of her own role in society from a personal perspective. Thus, contextualizing content through social contexts seemed to help students build connections and integrate the content leading to increased understanding.

Academic Context

Students could see connections with courses they had taken in the past, were currently taking, or courses they knew they would have to take in the future. Some students compared this course to previous classes, and although this course is very different from a traditional disciplinary course since its focus is on numeracy and scientific literacy, their comments help us understand the importance of using relevant examples to stimulate learning. For example, Student S commented specifically on her enjoyment of the content and how relevant examples motivated her to engage with the material: "…the math I enjoy learning about the most is math that applies to the real world – it is easy to understand. By relating math to everyday situations, I was able to actually look at math in a positive light and not assume it's useless" (Student S). The term "useless" seemed to come up repeatedly in the context of previous math courses and many students commented on how examples within a real-world context made them aware of the importance of the content.

> What they don't teach you in high school is how it [math] can be applied to the real world. The numeracy part of the course taught me to make good use of my mathematical knowledge and take advantage of what I know. No more does math seem like 'useless knowledge' or 'stuff' I will never use in life after school (Student R).

Students were able to recognize the importance of the information they were learning and were able to illustrate their gains in knowledge by connecting the content to other academic pursuits. "This course has prepared me for future classes. Especially statistics, logic and probability will be very helpful for my psychology major" (Student C). Not only did students relate the course content to other courses but many also commented on its role in their entire academic career. "My favourite part of the course was the statistics unit because I feel like it applies to my major and my day to day life" (Student F). This student was able to clearly see connections among courses and topics that she expected to learn in her major and aspects of the content being learned in this class, but she also recognizes the importance of the material to her everyday life. Student G related the content directly to a business course that he was taking at the same time:

> My international business course has been lecturing largely on the pros and cons of globalization… This article offered the opposite as a thesis and its delivery used percentages from a survey as a rhetorical device for establishing its point…I thought (the authors) reinforced the message most effectively and backed up normative statements thrown around in my business class. (Student G)

This example illustrates not only how students integrate course content with other courses but also how they can use their knowledge to interpret and evaluate data to support arguments. If our goal for students is to see their education as a whole rather than a series of individual courses, this student is illustrating the integration and transfer of knowledge that we hope out of a university education.

Global and societal issues

The majority of students (19 of 21), at one point or another, related their learning to larger global issues. I would expect for students to comment on specific content after dramatic examples that might inspire such thoughts (such as the cholera outbreak in Haiti), but students commented on global issues throughout their journals. In the last journal entry for the course, student D wrote

> It is so easy to waste in our culture, our society because we live in this pocket of over abundance and sometimes we don’t even see how this kind of lifestyle can have consequences. The fact is, it does. There is no unlimited resources of anything really, this world is sustainable, yes, but not infinite and we could save so much by taking and using what is necessary, not just what the greedy side of us wants.

This student has taken information from topics such as land use changes and their relation to natural disasters, and increased energy use and the potential for alternative energies, and applied it to the larger societal issue of waste and overuse of resources. He has recognized connections between the course content and the larger world and is reflecting on his own role in society. Another student who had never engaged in politics reported a newfound interest: “I was never into politics and voting or even hearing about polls and percentages. But now because I’ve learned some more about it, I’ve been really interested in knowing who has the highest percent in the polls and who is winning so far” (Student O). This student’s comment illustrates how the specific content of one class has made him more aware of politics, and his statement also implies that he might take a more active role in society. In the natural disasters section of the course, Student I commented: “I am more aware and conscious of what’s happening around me, rather than at me. If I could I would help go somewhere in need and help them with their devastation and destruction, but I guess I actually have to go instead of just saying it." The use of reflections in this course seemed to stimulate students' thinking about social engagement and made students think broadly about how they are part of the global world.

Discussion

This study highlights the importance of contextualization in the classroom. Engaging students in a reflective activity combined with the use of relevant and meaningful content enabled students to build connections between new knowledge and familiar scenarios. Content that was contextualized helped students understand and build connections, even when these connections were not solicited through directed prompts.

Other studies have found that contextualization results in increased interest and participation among students (reviews in Bennett, 2003 and Nentwig, 2005). However, interest or enjoyment in a course doesn't necessarily correlate with student learning or achievement, although interest might influence motivation through intrinsic measures or by increasing self-efficacy (Glynn & Koballa, 2006). Numerous studies have shown the positive relationship between motivation and student success, but in this study, I was primarily interested in assessing how students approach the course concepts rather than assessing how contextualization influences interest or motivation. As this study examined students taking a course in scientific and mathematical literacy, it is important to consider what "learning" means in this context. If the goal for creating scientific and mathematically literate students is for individuals to interpret, evaluate and draw evidence-based conclusions from scientific and numerical information and then to apply this knowledge, these are the learning outcomes that should be assessed.

The amount of integration that students exhibited between their learning and social, academic, and global issues was unexpected. In their reflections, students were not just repeating examples provided in class, they were making inferences and evaluations of the content: they were illustrating their learning. Reflection has been defined as "an active and deliberate process of exploration and discovery, involving a periodic stepping back to consider meaning and the connection between experience and learning" (Mackay & Tymon, 2013). This definition exactly describes what the students did: they stepped back from the content, considered its meaning and made social, academic, and global connections with their learning. Students seemed to be constructing their own relevance, making connections between their experiences and their learning, and they seemed to making these connections without the class time many active learning techniques require.

In recent years, educators, especially in science and mathematics, have been advocating for pedagogies that are centered on learning by doing. Research shows that active learning techniques are an effective way to increase engagement and performance, but Nelson and Moscovici (1998) refer to this as "activitymania" where the completion of an activity results in understanding and any lack of understanding just requires another activity. One drawback to this approach is that students are just completing an activity and are not necessarily thinking about their learning; they are not engaged in metacognition.

Flavell (1979) and later Brown (1987), describe metacognition as a process consisting of both metacognitive knowledge and metacognitive experiences. Metacognitive knowledge consists of two components: an individual's knowledge of their own learning process, and the knowledge of how parameters and processing requirements of a task might influence an individual's ability to be successful at the undertaking. Metacognitive experience refers to the strategies that an individual undertakes to control their own learning. Metacognition is an important aspect of learning, especially academic learning, and numerous studies have found that when students have knowledge and control of their own cognitive processes, learning is enhanced (reviewed in Hacker, Dunlosky, & Graesser, 2009). Blank's (2000) research highlights the importance of including a metacognitive component to student learning. Blank (2000) found that by providing students with the opportunity to discuss and evaluate findings (a metacognitive activity), students exhibited significantly higher knowledge retention and test scores compared to the activity-based group. The addition of the metacognitive activity improved student learning.

In this study, students were creating connections between the course content and multiple aspects of their lives, and were building these connections even when reflections were not prompting them to do so. It would be surprising for students to not be trying to relate new knowledge to a familiar situation. It is likely that students had previously been building connections in their own minds, but the addition of a reflection on their learning provided students with an opportunity to document how they process new content, develop an understanding of new information, and to illustrate their learning. In fact, the act of writing about their thinking can help students better comprehend and clarify their thinking: the fundamental basis of the writing to learn movement (Britton et al., 1975). Based on research coming out of the writing to learn literature, which shows the promise of writing to promote integration (Rivards, 1994, Bean, 2011), some may argue that it was the act of writing that was responsible for the widespread integration that students exhibited; however, students in previous classes that included reflection without the contextualization intervention didn’t exhibit the same patterns or levels of integration. This could be an important avenue for future research but in this study it is impossible to separate the influence of contextualization from their learning through writing. Regardless, one of the best ways to uncover student learning is to assess their understanding through reflections of their own thinking.

Although students were writing about their thinking, this writing doesn’t necessarily indicate that students were engaging in metacognition. In fact, none of the students’ journal entries specifically discussed how they learned or strategies they used to approach their learning about the course content. Thus, there was no evidence that they were thinking about the process of their learning but the combination of both contextualization and reflection may have provided an opportunity to make the students’ learning visible. To promote further metacognition, it could be useful for faculty to scaffold metacognitive activities in courses that use contextualization as an instructional strategy in order to elevate student learning.

The integration of content was promoted by contextualization but other factors might also have contributed to the spontaneous connections that students were exhibiting. By using examples in the classroom that were meaningful and relevant to students to teach particular scientific and mathematical concepts, contextualization was modeled for the students during class. Students frequently learn about faculty expectations of student work through class activities. Thus, students were likely using contextualization as a response to the prompts in an effort to meet these expectations. In university, students are exposed to a wide diversity of instructors, each having their own set of expectations and requirements. Good students are those that are able to negotiate the system and comprehend faculty expectations. Students may have interpreted my instructional use of contextualization as an expectation for their learning and incorporated this technique into their journals. Finally, providing students with an opportunity to reflect on their learning also authorizes students to discuss their experiences. In a traditional math or science class, there is little opportunity for personal opinion and reflection; in many cases personal opinions have negative academic consequences as they are biased and based on anecdotal accounts instead of evidence. By allowing students the freedom to express their thoughts and ideas, students have a new opportunity to approach their learning from new perspectives.

The contextualization of content along with reflection is an effective methodology when authentic learning may not be feasible due to time, budget, or other constraints. Providing relevant, meaningful content and allowing students the opportunity to reflect on their learning enables students to build connections at various levels and to integrate their learning within a larger context. A minor pedagogical change can have a substantial influence on student learning.

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